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POLITECHNIKI LUBELSKIEJ
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UNIWERSYTETU IM. WOŁODYMYRA DALA W ŁUGAŃSKU

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AND POWER INDUSTRY IN AGRICULTURE
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THE APPLICATION REVIEW ON THE ROLLING STOCK OF DEVICES FOR TURN OF WHEEL PAIRS IN THE HORIZONTAL PLANE

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Summary. The application review on a rolling stock of devices for turn of wheel pairs in the horizontal plane is presented in this article. Parameters of movement of single wheel pair in a direct way and radius of curvature of a way, in which radial self-installation usual colpar is possible, are defined. The expediency of use of each kind of rotary devices is shown.

Key words: roller bench, experimental carriage, wheel pair, measuring, wheel-rail contact.

INTRODUCTION

For the purpose of the systematised review of the big variety of devices for turn of wheel pairs in the plan, we will divide into three kinds:

1. The device for turn of wheel pairs usual type with a rotating axis, but with various conical shape of bandages and a profile outline (are considered above).
2. The device for turn of wheel pairs of usual type, but with application of special directing and rotary in respect of devices [Kokorev, 1993].
3. The device for turn of wheel pairs with an unrotative axis (with a free nozzle of the right and left wheels on pins of an axial beam) and with directing and rotary devices in the plan.

Wheel pair of usual type, i.e. with a rotating axis and bandages of the conic form, possesses property to move on a twisting trajectory concerning average position in a rail track. [Vol'pert, 1990]. Therefore usual wheel pair can be considered as the elementary rotary device providing self-installation in the plan in the event that movement of colpar it is not constrained by other communications in system of rail crew, and preventing constant contact to rails and intensive deterioration of crests of bandages [Bogdanov, 1992, Byinosov, 1995, Byinosov, 1994].

THE FORMULATION OT THE TASK

The increase in diameter of wheels leads to improvement of characteristics of fluctuations of wagging in a direct way (the length of a wave "L" grows and frequency of fluctuations f decreases), conditions of passage of curve sites (the radius of curvature $R_{кр}$ increases, see tab. 1) however worsen.

Usual wheel pair has a bias of bandages i = 1/20, high-speed electric trains on railway road "New - Tokaido" in Japan have a working profile with twice smaller bias i = 1/40 for a high-speed domestic electric train “Neva express train” with constructional speed of 200 km/h a bias of a working profile of wheels is accepted still smaller i = 1/100 [Works ,1978]. It is made that frequency of fluctuations at speed of movement V = 200 km/h would be less, than at V = 100 ÷120 km/h at usual locomotives and cars.

The biaxial cart with crosswise cross-section communications (Sheffelja cart [Priests, 1979]) addressing on sites with a considerable quantity of curves, is equipped by bandages with conical shape 0,2, i.e. with the big bias i=1/10.

According to the researches conducted by Golubenko’s school [Golubenko, 1999] (see tab. 1), at i=1:10 wheel steams can self-center in a radial direction in curves R≥280 m and more that corresponds to all often meeting curve sites R. The constructive scheme of Sheffelja cart however worsens characteristics of twisting movement in a direct way (the length of a wave decreases, frequency of fluctuations grows).

Table 1. **Parameters of movement of single wheel pair in a direct way and radius of curvature of a way in which radial self-installation of usual colpar is possible**

№№ п/п	Initial data			Movement parametres in a direct way					At what value of radius of curvature of a way radial installation колпары is possible	
	D, м	*i*	y_0, *м*	*L, м*	*f [Гц]*	β_{max}	Δ	*R*	y_{max}	*Rкр≥R [м]*
1	*1,05*	*1:20*	*0,007*	*18,1*	*1,53*	*±0,00244 (8,4’)*	*±2.6*	*1190*	*0.007*	$R_{кр}$≥*1190*
2	*1,25*	*1:20*	*0,007*	*19,8*	*1,4*	*±0,00222 (7.6’)*	*±2,37*	*1420*	*0,007*	$R_{кр}$≥*1420*
3	*1,05*	*1:10*	*0,007*	*12,8*	*2,16*	*±0,00343 (11.8’)*	*±3.65*	*800*	*0.015*	$R_{кр}$≥*280*
4	*1,25*	*1:10*	*0,007*	*13,95*	*1,99*	*±0,00244 (10.8’)*	*±3.36*	*710*	*0.015*	$R_{кр}$≥*330*

where: D - diameter of wheels; i – a bias; L - length of a wave;
y_0 - the greatest displacement of colpar in a direct way
β_{max} - the greatest corner of a deviation of colpar in the plan;
Δ - longitudinal moving of axle boxes at l δ = 2134 mm;
R - curvature of a trajectory; R = (r*lk)/2yi
$y_{max}=y0 + \delta$ with the account of widening

A lot of attention was given and is given nowadays to researches for choice an optimum profile of a bandage [Golutvina, 1978, Gus'kova, 2000, Ivanov, 1974, Pan'kin, 1991, Kurasov, 1981, Stacenko, 2003], however this way of improvement of horizontal dynamics and reduction of deterioration of crests and as a whole bandages is not always effective, how in process of deterioration of bandages the initial (new) profile is deformed: dynamic qualities and obsolete characteristics, as a rule, worsen. To keep under operating conditions invariable a profile of a bandage at the expense of more frequent turnings not always expediently as it leads to price increase of repair of running gears. Deterioration of rails and as consequence the distortion of profile of rail heads leads also to instability of dynamic characteristics of a rolling stock [Byinosov, Stacenko 2002, Byinosov, Stacenko 2003].

Deep theoretical researches of system movement of crew with a rigid frame or bogie taking into account the elastic sliding of wheel pairs and limiting backlashes in axle equipment show that as a whole this system is unstable [Golubenko, 1999]. Operating experience shows that at speed of movement to 70 km/h in a direct way and in curves $R \geq 1500$ m bandages with a bias of a surface of driving 1:20 practically provide contactless movement of crests of bandages and their minimum deterioration; it does not occur at speeds above 70 km/h and in a curve way of [Golytvina, 1978]. It is almost impossible to fulfil requirements of good self-installation of usual wheel pairs in a direct way and in operational curves.

In conclusion of consideration of the elementary of "the rotary device", i.e. usual wheel pairs, it is necessary to tell what to counteract it and to carry out other direction of movement of usual wheel pair not so easily: for this purpose it is necessary to overcome a twisting moment created by forces of a friction between wheels and rails on a shoulder, equal to distance between planes of circles of driving of wheel pair $l_к$ = 1,58m:

Thus, the device of radial installation of wheel pairs of usual type, at all its simplicity, absence of feedback is automatic, creating twisting periodic movement in a rail track, but not steady and rather powerful.

Passing to consideration of rotary devices of the second kind we will tell that they are systems, in which simultaneously operate (and two independent rotary devices confront): wheel pair of usual type and the directing device which should overcome action of the first.

In this sense application of wheel pairs with an unrotative axis in the presence of a directing rail is the most radical decision of questions of horizontal dynamics as in this case the trajectory of movement of wheel pair does not depend neither on a bandage profile, nor from a difference of diameters of wheels of wheel pair. Therefore lateral static pressure upon a directing rail in curve sites of a way can be received equal to zero; it can arise only in transitive curves from inertial forces, the gyroscopic moment and damping efforts at turn of wheel pair in an input and an exit from curve sites of a way.

Passing to consideration of rotary directing devices of the third kind, i.e. with wheel steams with an unrotative axis, it is necessary to tell that they on a rolling stock of railway transport are not applied, however they are the basis for engines of all modern cars and other wheel transport cars [Boronenko, Orlova ,2006, Kaley, Semyuels, 2003].

Operational tests within a year of eight-whelled electrosection with skilled biaxial cart of type K - 68 with differential on a driving axis and an unrotative axis on a supporting axis have shown the following:

a) The Car has been less subject to cross-section fluctuations at low and high speeds of movement; amplitudes of fluctuations of wagging have decreased on 60 - 80 %, lateral pressure upon rails – for 50 %.

b) Sinusoidal fluctuations of wagging of wheel pair have been completely eliminated, the tendency to preservation of constant contact is observed between one of crests and a lateral surface of a rail.

c) It has not been noted the essential reduction of intensity of deterioration of wheel pairs bandages of new design in comparison with the usual.

d) The size of resistance to movement in curves has decreased on 20 % the electric power expense in curves has decreased on 10÷15 %.

Results of researches of the cart K - 68 in Japan show that advantages from application of wheel pairs with independent rotation of the right and left wheels (with an unrotative axis) can be received considerably more if we will apply directing device to 1st wheel pair of the cart and to provide contactless movement of bandages crests [Kobayashi, 2000]. Besides, differential, as the knot that is not peculiar for locomotive building factories, it is expedient to replace with a separate drive of the right and left wheels of wheel pair from two feasibility reports through two traction reducers. In this case each wheel with the drive rotates irrespective of other wheel.

THE DECISION OF THE TASK

Recently in patent materials appear more often the messages on patents for rotary devices separate wheel gift in carts and as a whole carts concerning a body in the plan with application of systems of automatic stabilisation of position wheel gift or frames of the cart concerning a rail track.

The considerable quantity of patents is protected by constructive schemes for realisation of turn in respect of wheel pairs of railway crew; however does not make a reservation thus, what type of wheel pairs is expedient for using. At the same time, as it follows from the aforesaid, the type of wheel pairs has the most direct relation to the scheme of the rotary device.

CONCLUSIONS

In conclusion of the review of rotary devices we will consider properties, best of them (3 kinds (fig. 1,2,3)):

a) The Minimum twisting moment for overcoming of forces of a friction, inertial and returning forces is required for turn in a horizontal plane (in the plan) wheel pair with an unrotative axis, therefore rotary devices of the third kind are the most expedient for using on a rolling stock of railways.

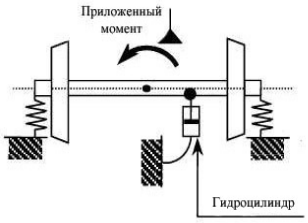

Fig. 1 Use of hydrocylinders for turn wheel parf

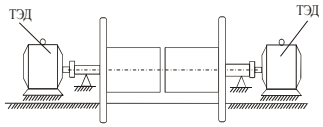

Fig. 2 Application of feasibility reports on each wheel

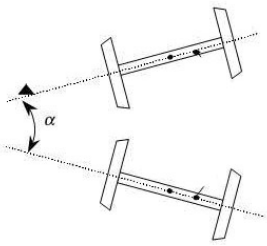

Fig. 3 Mechanical self-installation

b) Wheel steams with unrotative axes cannot be used without directing rotary devices or a compulsory steering with a drive from watching system (depending on size of a lateral backlash of wheel pair in a rail track).

c) Application for a rolling stock of railways of wheel pairs with an unrotative axis and with the rotary device is the complex action allowing considerably to improve horizontal dynamics in a direct way and in curve sites to receive economy traction and energy expenses at the expense of reduction of resistance to movement of rail crews in a direct way and especially in curves, to provide economy of metal and means at the expense of considerable decrease of intensity of bandages and rails deterioration, to raise durability of all elements of a design of wheel-motor blocks at the expense of division of a drive of the right and left wheels of wheel pair and realization thus statically - the definable scheme of a traction drive on locomotives.

d) The directing complete set consisting of wheel pair with an unrotative axis also drove with a directing roller, in the dynamic relation the deviation of a directing roller “Δ” - an entrance signal is nonperiodic link in which the cross-section deviation “y” wheel pair in a rail track from average position is in target parameter. Therefore the deviation of wheel pair at absolutely rigid rails and drive cannot be on size more = 1,5 ÷ 2 mm, and transient of cross-section moving of wheel pair in a track after moving of a directing roller is nonperiodic, i.e. is made without hesitation. The constant of time of this link is equal to the relation of length drove to linear speed of movement. This directing device is recommended to be used for cargo locomotives.

e) The ideal rotary device for wheel pairs with unrotative axes is the contactless system of automatic control of turn in respect of directing wheels of the cart (fig. 4). In this case the electric drive of the rotary device operates from the strengthened electric signal proportional to the sum of signals: a cross-section deviation of wheel pair in a rail track, “y” its the first and the second derivatives. At all advantages of this system, its lack consists in necessity of application of the difficult electronic equipment. This system of automatic stabilization of a lateral backlash of wheel pairs in a rail track is recommended for use on high-speed passenger transport with constructional speed more than 200 km/h.

$$R = \frac{rl_k}{2yi} \tag{1}$$

where: r - nominal radius of right and left wheels of wheelpair;; l_k - distance between the planes of circles of rolling; y - current transversal displacement of wheelpair is in railway track; i – slope of working surface of bracer.

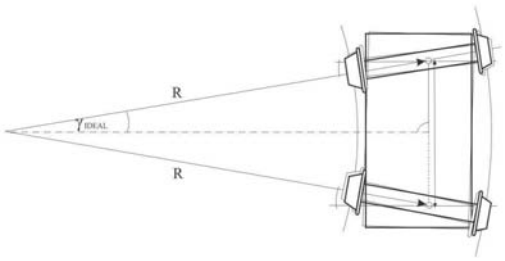

Fig. 4. Contactless system of automatic control of wheel pairs turn

In conclusion of the review of rotary devices of wheel pairs it is necessary to note the greatest expediency on railway transport of the devices of the third kind, with the automatic electric drive of turn which can be used on a rolling stock of high-speed service.

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АНАЛИЗ УСТРОЙСТВ ПОВОРОТА КОЛЕСНЫХ ПАР В ГОРИЗОНТАЛЬНОЙ ПЛОСКОСТИ

Александр Голубенко, Андрей Малохатко, Сергей Клюев, Александр Клюев

Аннотация. В статье приведен анализ устройств поворота колесных пар в горизонтальной плоскости и выбор конструктивной схемы. Определены параметры движения одиночной колесной пары в прямом пути и радиус кривизны пути, в котором возможна радиальная самоустановка обычной колесной пары. Показана целесообразность использования каждого вида поворотных устройств.

Ключевые слова: поворотное устройство, колесная пара, бандаж, невращающаяся ось, износ, рельсовое транспортное средство.

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DEFINITION OF SUFFICIENCY OF SPARE PARTS AT SERVICE OF DIESEL LOCOMOTIVES

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Summary. The technique of definition of sufficiency of spare parts is considered at service of diesel locomotives. Situations are classified and the basic structures of maintenance of service are offered by spare parts which most often are used in practice. Methods of quantitative definition of spare parts on each structure which include the nomenclature, intensity of a stream of applications, average time of restoration, and also separate price factors are offered. Sufficiency of spare parts for service maintenance service of diesel locomotives 2ТЭ116 is calculated.

Key words: sufficiency, spare parts, complete set, exchange collection, updating, repair body, service, supply, structure, diesel locomotive.

INTRODUCTION

During deep system transformations to a locomotive facilities of railways of Ukraine structural and functional interdependence promptly develop and go deep. It, on the one hand complicates, and with another strengthens economic relations without which modern locomotive depots which carry out service and repair of a traction rolling stock, cannot function and develop. In particular it concerns to material support when in conditions of transition to market attitudes{relations} development of modern methods of increase of efficiency of communications{connections} between suppliers and consumers is necessary at the organization of service of locomotives.

ANALYSIS OF LAST RESEARCHES AND PUBLICATIONS

Formation of the theory of storekeeping as scientific discipline has begun in the middle of 1950th years. Detailed development of this stage it is resulted in works [5,10,16]. There is a number of manuals [1,4,6,7,9,11,13,14,15,19] where from the mathematical point of view the essence of formation of volume of stocks reveals, and also the basic laws apply to various industries. In one of last works [16], on the basis of

generalization as the main parameter the condition of maintenance of set reliability of supply is used. Algorithms offered in given work are developed by means of the device of the classical theory of management: modern methods of the theory of adaptation, mathematical programming, stochastic optimization, a principle of a maximum. At the same time it is necessary to note, that the majority of these development have the limited applicability because of impossibility in definition of costs as a result of loss of preference, strong-willed purpose of norms of stocks, and also absence of the complex approach to components of cumulative stocks on all way of their movement and to their distribution between parts of investigated systems. Proceeding from it, in given clause the complex technique of formation and an estimation of sufficiency of stocks of spare parts in view of the basic industrial parts is offered at the organization of service in a locomotive facilities.

MATERIALS AND RESULTS OF RESEARCHES

As is known updating of any stocks $Z_{s.p}$ always happens to some delay concerning the moment of delivery on it requirements [16]. These updating can be subdivided on:

- instant (delay in delivery is very small);
- with a delay for the fixed term;
- with a delay on a casual interval of time with known or unknown likelihood distribution;
- emergency updating.

Accepting, on features of a design, a diesel locomotive as the big difficult object, it is possible to allocate in him three basic structural subsystems of the organization of supply with spare elements:

- the single complete set $Z_{s.p}^{O}$ representing amount of spare elements which are given to directly given locomotive for maintenance of his working capacity;
- the complete set of spare elements of the repair body $Z_{s.p}^{RO}$, representing amount of spare elements which are given only to him, with the purpose of maintenance of his working capacity. Functioning of repair body (*RO*) consists in elimination of refusals in faulty sites or details of the locomotive which to him act for their restoration. Thus, the repair body is intended for restoration of the objects which have acted to them and should be provided by the stock $Z_{s.p}^{RO}$;
- the exchange collection of repair body $Z_{s.p}^{EC-RO}$ representing amount of finer spare elements which are given to repair body which can serve both the single complete set $Z_{s.p}^{O}$, and sites acting in repair body.

These structural subsystems can be combined among themselves in various variants. Proceeding from this 7 variants of structures of maintenance of service by spare elements (*SMSSE*) which most often are used in practice are offered. They are presented on fig. 1.

The first variant reflects the most widespread *SMSSE* in which has reserved $Z_{s.p}^{O}$ replenishes directly from an external source. This external source will be understood hereinafter as an external warehouse, base, a factory, etc. which limitation at updating elements in calculation is accepted will not be. In default at the locomotive what or an element in the complete set $Z_{s.p}^{O}$ the application which is immediately satisfied acts if the corresponding spare element there is available. At absence of a spare element the application becomes in "turn" and waits to not appear yet an opportunity her to satisfy. The length of turn of unsatisfied applications can be various and depends on main principles and conditions functioning of system of logistics.

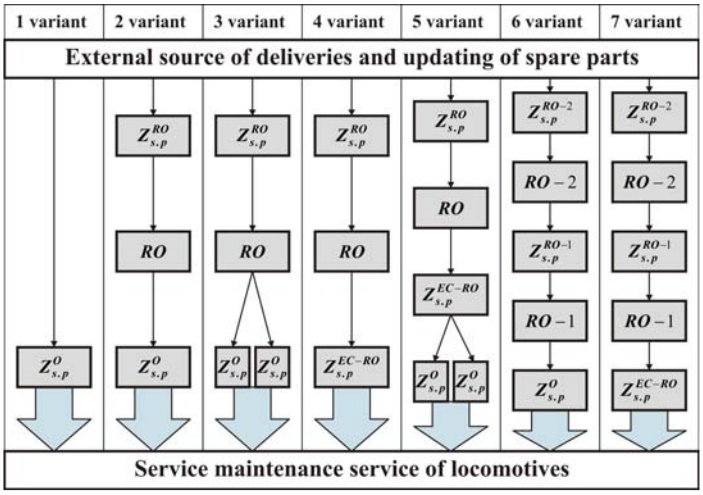

Fig. 1. Variants of service maintenance with spare elements

Thus, in the first variant the application for a spare element which has arrived from object in the complete set $Z_{s.p}^{O}$, can be satisfied or immediately, or with some delay.

In the second variant the complete set $Z_{s.p}^{O}$ replenishes from repair body *RO* which in turn has the complete set $Z_{s.p}^{RO}$ and filled up of an external source.

The third variant provides, that the complete set $Z_{s.p}^{O}$ is given to each type of the locomotive. These complete sets replenish also from repair body *RO* which in turn has the complete set $Z_{s.p}^{RO}$ and filled up of an external source (as well as in the second variant).

In the fourth variant for service the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which directly replenishes from repair body *RO* is given.

For the fifth variant it is installed, that each complete set $Z_{s.p}^{O}$ for service replenishes from the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which too directly replenishes from repair body *RO*.

In the sixth variant updating of the complete set $Z_{s.p}^{O}$ for service is provided directly from several repair bodies *RO*-1 and *RO*-2 in various combinations.

The seventh variant provides updating elements for service from the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which too directly replenishes from repair bodies *RO*-1 and *RO*-2 in various combinations.

For an estimation of sufficiency of the concrete complete set $Z_{s.p}^{O}$, following data are necessary.

1. Quantity of types of replaceable elements N_0 in a product;

2. On each type of replaceable constructive elements the data card with initial data is made

i	Λ_{iO}	T_{iO}	n_{iO}	ρ_{iO}

(1)

where: i - number of type of elements under the nomenclature of the complete set $Z_{s.p}^{O}$; Λ_{iO} - intensity of a stream of applications for elements of i-th type from a product in the complete set $Z_{s.p}^{O}$; T_{iO} - average time of restoration of one element of i-th type in $Z_{s.p}^{O}$ (i.e. average time which passes between withdrawal of a spare element from the complete set $Z_{s.p}^{O}$ and receipt in this complete set of a similar serviceable element instead of withdrawn); n_{iO} - initial amount of spare elements of i-th type in the complete set $Z_{s.p}^{O}$; ρ_{iO} - the maximal possible length of turn of unsatisfied applications for elements of i-th type of century $Z_{s.p}^{O}$ (the whole positive value ρ_{iO} corresponds to cases of the limited turn of unsatisfied applications. At ρ_{iO} = 0 it is accepted, that the length of turn is unlimited).

Intensity Λ_{iO} is defined by a stream of replacements of elements of i-th type in products (not necessarily conterminous with a stream of refusals), and also a stream of refusals of elements of i-th type at storage in the complete set $Z_{s.p}^{O}$

$$\Lambda_{iO} = k_{iE}(m_i\lambda_i + l_i\lambda_i) + (1-k_{iE})(m_i + l_i)\lambda_{iSt} + n_i\lambda_{iSt}, \quad (2)$$

where: m_i - quantity of basic elements of i-th type in a product; l_i - quantity of reserve elements of i-th type in a product; k_{iE} - factor of intensity of operation of a product; λ_i - failure rate of one basic element of i-th type; λ_{iSt} - failure rate of one basic element of i-th type at storage.

To calculate a parameter of sufficiency *EC-RO* following initial data is necessary.

1. N_{EC} - quantity of types of elements on which applications in *EC-RO* can come;

2. On each of N_{EC} types of elements to set the data card of initial data:

i	Λ_{iEC}	$\grave{O}_{iEC}$	n_{iEC}

(3)

where: Λ_{iEC} - intensity of a stream of applications for spare elements of *i*-th type, acting in *EC-RO* from served samples of object or the complete set $Z_{s.p}^{O}$, i.e. average quantity of applications for elements of *i*-th type in unit of time; $\grave{O}_{iEC}$ - average time of repair of one element of *i*-th type in *RO*; n_{iEC} - initial quantity of elements of *i*-th type in *EC-RO*.

To calculate value Λ_{iEC} it is necessary to summarizes on all samples of object in the group, intensity of streams of replacements of elements of *i*-th type served to data *RO* in object [19]

$$\Lambda_{iEC} = \sum_{K=1}^{S} \Lambda_{iEC}^{K}, \tag{4}$$

where: *S* - quantity of samples of objects in group; Λ_{iEC}^{K} - intensity of a stream of replacements of an element of *i*-th type in To-th the sample of object.

Intensity of a stream of replacements of an element of *i*-th type in *K*-th the sample of object Λ_{iEC}^{K} is defined as

$$\Lambda_{iEC}^{K} = k_{i\hat{a}}(m_i\lambda_i + l_i\lambda_i) + (1 - k_{i\hat{a}})\,(m_i + l_i)\lambda_{ixp} + n_i\lambda_{ixp}, \tag{5}$$

where: m_i - quantity of basic elements of *i*-th type in a product; l_i - quantity of reserve elements of *i*-th type in a product; $k_{i\hat{a}}$ - factor of intensity of operation of a product; λ_i - failure rate of one basic element of *i*-th type; λ_{ixp} - failure rate of one basic element of *i*-th type at storage.

To calculate value of a parameter of sufficiency $Z_{s.p}^{R\hat{I}}$ following initial data are required.

1. $N_{R\hat{I}}$, - quantity of types of completing elements which can be demanded for job *RO*;

2. On each type of completing elements to set the data card of initial data:

j	$\Lambda_{jR\hat{I}}$	$\alpha_{jR\hat{I}}$	$\grave{O}_{jR\hat{I}}$	$\tau_{jR\hat{I}}$	$n_{jR\hat{I}}$

(6)

where: *j* - number of type of elements under the nomenclature $Z_{s.p}^{R\hat{I}}$; $\Lambda_{jR\hat{I}}$ - intensity of a stream of applications for elements of *i*-th type, acting in $Z_{s.p}^{R\hat{I}}$, i.e. average quantity of applications for elements of *j*-th type in unit of time; $\alpha_{jR\hat{I}}$ - the type of strategy of updating of a stock of elements of *j*-th type of century $Z_{s.p}^{R\hat{I}}$. Value $\alpha_{jR\hat{I}}$ can accept values 1, 2, 3. At $\alpha_{jR\hat{I}}$ =1 stock of elements of *j*-th type replenishes periodically. At $\alpha_{jR\hat{I}}$ = 2 updating of a stock of elements of *j*-th type is made with emergency deliveries, i.e., besides scheduled periodic restoration of a stock, it is supposed also his off-schedule restoration up to an initial level if the element of *j*-th type is required for

job *RO*, and the stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ is empty. At $\alpha_{jR\hat{I}}$ = 3 stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ replenishes due to repair of the given up elements in special RO_s. (distinct from that *RO* to which it is given data $Z_{s.p}^{R\hat{I}}$); $\grave{O}_{jR\hat{I}}$ - key parameter of strategy of updating of a stock of elements of *j*-th type. At $\grave{O}_{jR\hat{I}}$ = 1 or $\grave{O}_{jR\hat{I}}$ = 2 value $\alpha_{jR\hat{I}}$ is the period of updating of a stock of elements of *j*-th type. At $\grave{O}_{jR\hat{I}}$ = 3 value $\alpha_{jR\hat{I}}$ is average time of repair of one element of *j*-th type; $\tau_{jR\hat{I}}$ - additional parameter of strategy of updating of a stock of elements. At $\tau_{jR\hat{I}}$ = 1 or $\tau_{jR\hat{I}}$ = 3 value $\alpha_{jR\hat{I}}$ is equal to zero. At $\tau_{jR\hat{I}}$ = 2 value $\alpha_{jR\hat{I}}$ represents average duration of emergency delivery of elements from an external source of updating; $n_{jR\hat{I}}$ - initial quantity of elements of *j*-th type of century $Z_{s.p}^{R\hat{I}}$.

For the decision of a problem of calculation $Z_{s.p}^{R\hat{I}}$ following initial data are required.

1. $N_{Ð\hat{I}}$ - quantity of types of completing elements which can be demanded for $Z_{s.p}^{R\hat{I}}$.

2. On each type of spare elements the data card of initial data is made

j	$\Lambda_{jR\hat{I}}$	$\alpha_{jR\hat{I}}$	$\grave{O}_{jR\hat{I}}$	$\tau_{jR\hat{I}}$	$\tilde{N}_{jR\hat{I}}$

(7)

where: parameters j, $\Lambda_{jR\hat{I}}$, $\alpha_{jR\hat{I}}$, $\grave{O}_{jR\hat{I}}$, $\tau_{jR\hat{I}}$ have the same sense, as in the data card (6), and $\tilde{N}_{jR\hat{I}}$ - expenses for 1 element of j-th type $Z_{s.p}^{R\hat{I}}$.

Calculation of a parameter of sufficiency $Z_{s.p}^{R\hat{I}}$ is made under the formula

$$\Delta t_{RO}^{D} = \frac{\sum_{j=1}^{N_{RO}} \Lambda_{jRO}\ \Delta t_{jRO}}{\Lambda_{RO}}\ , \qquad (8)$$

where: Δt_{RO}^{D} - a parameter of sufficiency of a stock of elements of *j*-th type of century $Z_{s.p}^{R\hat{I}}$.

Depending on strategy of updating of a stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ (i.e. depending on a preset value $\alpha_{jR\hat{I}}$ =1, 2, 3) the parameter of sufficiency of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ can be certain under following formulas.

1. In case of $\alpha_{jR\hat{I}}$ =1 (when updating of a stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ occurs periodically) the parameter of sufficiency is defined from expression

$$\Lambda_{jRO}\Delta t_{jRO} = \frac{1}{a_j} e^{-a_j} \sum_{k=1}^{\infty} K \sum_{i=n_{jRO}+K+1}^{\infty} \frac{a_j^i}{i!}\ , \qquad (9)$$

where:

$$a_j = \Lambda_{jRO} T_{jRO}\ . \qquad (10)$$

Calculations under the given formula it is made as follows. The size originally pays off

$$\varepsilon_j = \frac{a_j \varepsilon_{RO} \Lambda_{RO}}{2N_{RO}} \ , \tag{11}$$

where: ε_{RO} - the set accuracy of calculation of a parameter of sufficiency.

Under tables of distribution Puasson [18]

$$F(n,a) = e^{-a} \sum_{K=n}^{\infty} \frac{a^K}{K!} \ , \tag{12}$$

Values $F(n_{jRO}+2, a_j)$, $F(n_{jRO}+3, a_j)$ …. until the inequality for the first time will not be executed are found

$$F(n_{jRO}+K^*+1, a_j) \le \frac{\varepsilon_j}{K^*} \ . \tag{13}$$

In conformity with the found values $F(n_{jRO}+K^*+1, a_j)$, $K = 1, 2, \ldots . K^*$ the size is defined

$$\Lambda_{jRO} \Delta t_{jRO} = \frac{1}{a_j} \sum_{K=1}^{K^*} K \cdot F(n_{jRO}+K, a_j) \ . \tag{14}$$

2. In case of $\alpha_{jR\hat{I}}$ = 2 (when updating of a stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ occurs periodically to emergency deliveries) the parameter of sufficiency is defined from expression

$$\Lambda_{jRO} \Delta t_{jRO} = (\frac{\tau_{jRO}}{T_{jRO}}) \omega(n_{jRO}, a_j) (\frac{1+\Lambda_{jRO}\tau_{jRO}}{2}) \ , \tag{15}$$

where:

$$\omega(n_{jRO}, a_j) = e^{-a} \sum_{K=1}^{\infty} \sum_{i=K(n_{jRO}+1)}^{\infty} \frac{a_j^i}{i!} , \tag{16}$$

and

$$a_j = \Lambda_{jRO} T_{jRO} . \tag{17}$$

To calculate values of the function $\omega(n_{jRO}, a_j)$ set by the sum infinite of some (16), we act as follows. Under tables of distribution Puasson we define values $F(n_{jRO}+1, a_j)$, $F(2n_{jRO}+2, a_j)$ … until first time the inequality will not be executed

$$F(K^* \cdot n + K^*, a) \le \frac{\varepsilon_{RO}}{N_{RO}} \Lambda_{RO} \ , \tag{18}$$

where: ε_{RO} - the set accuracy of calculation of a parameter of sufficiency.

On the found values $F(K^* n + K^*, a)$ it is defined

$$\omega(n, a) = \sum_{K=1}^{K^*} F(K \cdot n + K, a) \ . \tag{19}$$

3. In case of $\alpha_{jR\hat{I}}$ = 3 (when elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ can be repaired) the parameter of sufficiency of a stock of elements is defined as

$$\Lambda_{jRO}\Delta t_{jRO} = e^{-a_j} \sum_{\hat{E}=n_{jRO}+1}^{\infty} (K - n_{jRO}) \frac{a_j^K}{K!}, \quad (20)$$

and

$$a_j = \Lambda_{jRO} T_{jRO}. \quad (21)$$

On the basis of calculations by the given technique sufficiency of quantity of spare parts by each variant of their formation for diesel locomotives 2TE116 has been certain. These data are resulted in table.

Table 1. **The list of spare parts for service TO-2 of diesel locomotives**

The name	Unit of measure	Quantity
1	2	3
1. Atomizer of a diesel engine	un.	4
2. Cover of the viewing hatch	- " -	2
3. The fuel pump of a high pressure	- " -	4
4. Pneumatic screen wiper	- " -	5
5. Regulator of a voltage PHT-6	- " -	2
6. The block of management БА-520 У3	- " -	1
7. The block of slipping ББ-320А	- " -	1
8. The panel of rectifiers	- " -	1
9. The force relay	- " -	2
10. The gate ВВ-1	- " -	2
11. The gate ВВ-1111	- " -	2
12. Section of the storage battery	- " -	1
13. The crane of machinist	- " -	1
14. The crane of an auxiliary brake	- " -	2
15. The valve of the compressor КТ7	- " -	2
16. The trailer crane	- " -	2
17. Trailer sleeve	- " -	4
18. Reducer of a measuring instrument of speed	- " -	1
19. Match for the bearing	- " -	4
20. The platen of brake transfer	- " -	12

CONCLUSIONS

Seven basic variants of formation of stocks in view of their updating from external sources, and also the corresponding repair divisions which are carrying out restoration of units and details of locomotives are certain. The technique of definition of sufficiency of the generated variant of a stock which considers quantitative and qualitative characteristics of applications from a place of replacement, intensity of a stream of replacements of details, the nomenclature of details for concrete type of the locomotive, and also technical equipment of repair-regenerative bodies is offered. On the basis of the given technique sufficiency of spare parts for service of locomotives is certain.

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ОПРЕДЕЛЕНИЕ ДОСТАТОЧНОСТИ ЗАПАСНЫХ ЧАСТЕЙ ПРИ СЕРВИСНОМ ОБСЛУЖИВАНИИ ТЕПЛОВОЗОВ

Александр Бабанин, Сергей Сметанин

Аннотация. Рассмотрена методика определения достаточности запасных частей при сервисном обслуживании тепловозов. Классифицированы ситуации и предложены основные структуры обеспечения сервисного обслуживания запасными частями, которые наиболее часто используются на практике. Предложены методы количественного определения запасных частей по каждой структуре, которые включают номенклатуру, интенсивность потока заявок, среднее время восстановления, а также отдельные ценовые факторы. Рассчитана достаточность запасных частей для сервисного технического обслуживания тепловозов 2ТЭ116.

Ключевые слова: достаточность, запасные части, комплект, обменный фонд, пополнение, ремонтный орган, сервис, снабжение, структура, тепловоз..

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SELECTION OF OPTIMAL PARAMETERS DOSATOR WITH HORIZONTAL DISC ON THE DEGREE OF DEVIATION FACTUAL LAW DISTRIBUTION OF SEED MAIZE FROM NORMAL

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Summary. Results of multifactorial experiments by rotatable planning matrix for three factors: height and diameter of seed tube, rotary speed of seed disk are presented. Experiment results were analyzed according to generally accepted methods. Adequate model was received. Influence of each factor on degree of deviation factual law distribution of seed maize from normal and optimal value of each factor were determined.

Key words: degree of deviation factual law distribution of seed maize from normal, influence of factors, optimization.

INTRODUCTION

Degree the deviation factual law distribution of seed from normal, including exponents asymmetry A and excess E, directly influences on uniformity of distribution of seeds placing in a row [1, 5-20]. It is the major reserve of increasing of productivity grain and row-crop cultures by creation of conditions for the fullest using by plants of nutrients, moisture, warmth and sunlight. For row-crop cultures, except decreasing of productivity, non- uniformity of seeding leads to sharp increasing of “superfluous” plants. The aspiration to provide necessary density of plants become causes application of the increased norms of seeding, that leads to the over-expenditure of a sowing material.

OBJECTS AND PROBLEMS

The degree of deviation factual law distribution of seed from normal was calculated on the formula [4]:

$$y = f(A,E), \tag{1}$$

where: $A=\sum_{1}^{N}\left(x_i-\bar{x}\right)^3/\left(ND^{3/2}\right)$; $E=\sum_{1}^{N}\left(x_i-\bar{x}\right)^4/\left(ND^2\right)$ — exponents of asymmetry and excess accordingly; N — totality accidental values x_i (current importance of intervals between seed on the row); D — displace dispersion of intervals ($D=\sigma^2=\sum_{1}^{N}\left(x_i-\bar{x}\right)^2/N$); $\bar{x}=\upsilon_1$ — middle importance ($\bar{x}=\upsilon_1=\sum_{1}^{N}x_i/N$).

When $A=E=0$ statistical curve $p(x)$ coinside with normal distribution; when $A_1>0$ to stretch out [4] right-hand lot; when $A_2<0$ — to stretch out left-hand lot; when $E>0$ peak of statistical curve $p(x)$ more sharp than by curve $p(x)$ normal distribution; when $E<0$ curve $p(x)$ statistical distribution more slightly. When $A_1>0$ curve of distribution slope left-hand, a $\upsilon_1<\upsilon_0$ (υ_0 — mathematical expectation of intervals, when $A=0$) and $\upsilon_1=\sigma/\upsilon_1>V_0$ (V_0 — coefficient variation of intervals, when $\upsilon=V_0$ and σ (standard) — constant); when $A_2<0$, conversely, $v_2=\sigma/\upsilon_2<V_0$. From here it is possible with drowal, that sum absolute values $|A|+|-E|$ correspond increasing $V=\sigma/\upsilon_1$, and sum $|-A|+|E|$ — his decreasing; with register of exposition, when in the experiment was observed:

1. $A>0$, $E>0$, that $y=|A-E|$; 2. $A<0$, $E<0$, that $y=\|E|-|A\|$;
3. $A>0$, $E<0$, that $y=A+|E|$; 4. $A<0$, $E>0$, that $y=1/(|A|+E)$. (2)

In the capacity of apparatus with a horizontal disc the sowing of a seeder of CKHK-type, which is installed on a special framework over a ribbon of the stand of a generally accepted construction was used. Three factors were varied: $x_1(D)$ — diameter of a seed tube, $x_2(h)$ — seed tube altitude, $x_3(v_0)$ — peripheral velocity of twirl of a seed disc.

Factors $x_1(D)$ and $x_2(h)$ were set by of round metal tubes and the factor $x_3(v_0)$ — change of a reduction ratio of the mechanism of the drive (replaceable starlets). Levels of factors varied according to central composition rotatable uniforms — planning of the second order for three factors [2].

Speed of driving of a ribbon of the stand was fixed and equal 2 m/s. The calculated intervals between seeds at speed $v_0=0{,}275$ m/s was equated 200,0 mm; seeds of corn of “Dneprovskaya-247” sort of the thin a fraction by the SKV-153B seed disc were seeded; of 1,0 mm were used an insertion ring by thickness. Intervals of a variation of the factors, chosen a condition of technological working capacity of a dosator, are presented in tab.1.

Experimental data were treated accordingly with the certain methods, recommended for rotatable planning; Kohren criterion (characterizing homogeneous of variances), Student criterion (causing the significance of regression coefficients) and Fisher criterion (pointing out on the adequacy of model) were thus defined; the adequate regression model of the second order with variables in a code designation is a result view:

$$y=b_0+b_3x_3+b_{13}x_1x_3+b_{22}x_2^2, \quad (3)$$

where: $b_0 = 1{,}0537$; $b_3 = 0{,}1215$; $b_{13} = -0{,}2062$; $b_{22} = 1{,}1339$.

Table 1. **Intervals of a variation of the factors $x_1(D)$, $x_2(h)$ and $x_3(v_0)$ for SKNK-type seeder dosator**

Characteristics	Factors		
	$x_1(D)$, mm	$x_2(h)$, mm	$x_3(v_0)$, m/s
The basic level, $x_i = 0$	60,0	350,0	0,275
The interval of variation, J	23,8	59,5	0,134
The upper level, $x_i = 1$	83,8	409,5	0,409
The lower level, $x_i = -1$	36,2	290,5	0,141
The upper star point, $x_i = 1{,}682$	100,0	460,0	0,5
The lower star point, $x_i = -1{,}682$	20,0	250,0	0,05

Influence of each factor separately on response function was defined at levels of other factors, equal 0 and $\pm 1{,}682$. The equation (3) takes a view:

when $x_2 = x_3 = -1{,}682$: $y_{1.1} = 1{,}2281 + 0{,}3468x_1$,

when $x_2 = x_3 = 0$: $y_{1.2} = 1{,}0537$,

when $x_2 = x_3 = 1{,}682$: $y_{1.3} = 1{,}6369 - 0{,}3468x_1$,

when $x_1 = x_3 = -1{,}682$: $y_{2.1} = 0{,}266 + 0{,}1339x_2^2$,

when $x_1 = x_3 = 0$: $y_{2.2} = 1{,}0537 + 0{,}1339x_2^2$,

when $x_1 = x_3 = 1{,}682$: $y_{2.3} = 0{,}6748 + 0{,}1339x_2^2$,

when $x_1 = x_2 = -1{,}682$: $y_{3.1} = 1{,}4325 + 0{,}4683x_3$,

when $x_1 = x_2 = 0$: $y_{3.2} = 1{,}0537 + 0{,}1215x_3$,

when $x_1 = x_2 = 1{,}682$: $y_{3.3} = 1{,}4325 - 0{,}2253x_3$. (4)

Values of function $y_{1.1} - y_{3.3}$ according (4) are computed on the points $x_i = 0$; ± 1; $\pm 1{,}682$; calculation data are presented in tab.2.

Table 2. **The sequence of functions $y_{1.1} - y_{3.3}$ calculation**

x_i	x_i^2	$0{,}3468x_1$	$y_{1.1}$=1,2281+(3)	$y_{1.2}$=1,0537	$y_{1.3}$=1,6369-(3)	$0{,}1339\,x_2^2$	$y_{2.1}$=0,266+(7)
1	2	3	4	5	6	7	8
-1,682	2,829	-0,5833	0,6448	1,0537	2,22	0,3788	0,6448
-1,0	1,0	-0,3468	0,8813	1,0537	1,9837	0,1339	0,3999
0	0	0	1,2281	1,0537	1,6369	0	0,266
1,0	1,0	0,3468	1,5749	1,0537	1,29	0,1339	0,3999
1,682	2,829	0,5833	1,8114	1,0537	1,0536	0,3788	0,6448

Continuation of table 2

$y_{2.2}$=1,0537+ +(7)	$y_{2.3}$=0,6748+ +(7)	0,4683x_3	$y_{3.1}$=1,4325+ +(11)	0,1215x_3	$y_{3.2}$=1,0537+ +(13)	0,2253 x_3	$y_{3.3}$=1,4325- -(15)
9	10	11	12	13	14	15	16
1,4325	1,0536	-0,7877	0,6448	-0,2044	0,8493	-0,379	1,8115
1,1876	0,8087	-0,4683	0,9642	-0,1215	0,9322	-0,2253	1,6578
1,0537	0,6748	0	1,4325	0	1,0537	0	1,4325
1,1876	0,8087	0,4683	1,9008	0,1215	1,1752	0,2253	1,2072
1,4325	1,0536	0,7877	2,22	0,2044	1,2581	0,379	1,0535

According to the tab.2 is built a graphs, presented on the fig.1. From tab.2 and fig.1 is visible, that at levels of other factor, equal $x_1 = x_2 = x_3 = 1{,}682$, the response diminishes when factors x_1, x_3 increases (the lines $y_{1.3}, y_{3.3}$), and the function y grow up when x_1, x_3 increases (in case $x_1 = x_2 = x_3 = -1{,}682$; lines $y_{1.1}, y_{3.1}$); the degree of deviation isn't depend from x_1 (if $x_2 = x_3 = 0$); and it equal $y_{1.2} = 1{,}0537$.

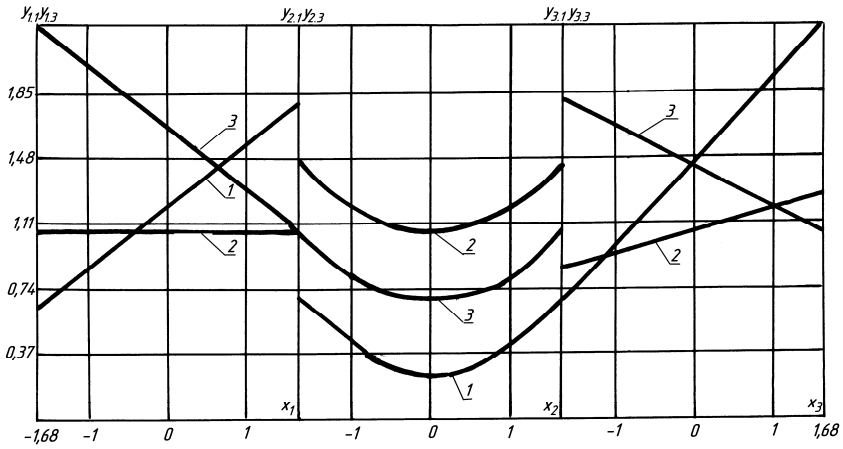

Fig.1. The graph of functions $y_{1.1}$ - $y_{3.3}$ (the degree of deviation factual law distribution of seed maize from normal)

From the factors x_2 the response is depend curvilinely (lines $y_{2.1} - y_{2.3}$) with the minimum of importance when $x_2 = 0$.

Optimization of the parameters the dosator with horizontal disc on the degree of deviation.

Minimum of function y observes in experiment №19 of matrix planning: $y'_{min} = 0{,}51$; $x_1 = x_2 = x_3 = 0.$; Make a matrix for calculation of minimum importance of the response function y by quantization of independent variables (tab.3), [2, 3].

Table 3. **Calculation of response Y_{min} minimum**

№№		b_0 1,0537	x_1	x_2	x_3	b_3 0,1215	b_{13} -0,2062	b_{22} 0,1339	$\hat{y}$
1	2	3	4	5	6	7	8	9	10
1	x_i	1	0	0	0				0,51
2	x_i		-1,682	0	-1,682				
3	$b_i x_i$	1,0537	0	0		-0,2044	-0,5833	0	0,266
4	x_i	1	-1	-1	-1				
5	$b_i x_i$	1,0537				-0,1215	-0,2062	0,1339	0,8599

The tab. 3 is constructed as follows: in the left column independent arguments x_i and their products on regress coefficients b_i are located; in heading — coefficients of regress and their numerical importance. In line 1 conditions of expense (that is to say importance of factors x_i) and minimum importance of function response y from a planning matrix are represented; further in even lines importance of arguments are represented, and in odd – their products on appropriate coefficients of regress. In the right extreme column importance of function $\hat{y}$, foretell by the equation of regress, are placed. From it is visible, that $y_{min} = 0{,}266$, that is to say by the coordinates of a special point S factorial space take conditions of line 2 of tab.3:

$$y_s = 0{,}266;\ x_{15} = x_{35} = -1{,}682;\ x_{2s} = 0. \tag{5}$$

The corner of turn coordinate axes [2, 3]:

$$tg\,2a = b_{13}/(b_{11} - b_{33}) = -0{,}2062/(0-0) = -\infty;\ 2\alpha = arctg(-\infty) = -90^\circ;\ \alpha = -45^\circ \tag{6}$$

The coefficients of regress in initial form are finded on the formulas:

$$B_{11} = b_{11}\cos^2\alpha + b_{13}\cos\alpha\sin\alpha + b_{33}\sin^2\alpha = -0{,}2062\cdot(0{,}707)^2 = 0{,}1031;$$

$$B_{33} = b_{11}\cos^2\alpha - b_{13}\cos\alpha\sin\alpha + b_{33}\cos^2\alpha = -0{,}2062\cdot(0{,}707)^2 = -0{,}1031; \tag{7}$$

The initial form haves view [2, 3]:

$$Y - 0{,}266 = 0{,}1031X_1^2 - 0{,}1031X_3^2, \tag{8}$$

from here:

$$X_3 = \sqrt{X_1^2 - (Y - 0{,}266/0{,}1031)}. \tag{9}$$

The coordinates of the new centre $S(-1{,}681; -1{,}682)$; as signs of coefficients B_{11}, B_{33} are different ($B_{11} = 0{,}1031;\ B_{22} = -0{,}1031$), then lines of an equal exit – hyperboles, and surface of response is the hyperbolic parabolic [2, 3]. Coordinates of hyperbolic were determined according (9) by an exit $y = 0{,}5;\ 0{,}25;\ 0;\ -0{,}05;\ -0{,}1;\ -0{,}25;\ -1{,}5$ (tab. 4).

Table 4. **The sequence of calculation coordinates lines of equal exit for function** Y

y=0, 5	$x_1(\pm)$	x_1^2	$x_3(\pm)$	y=0,25	$x_3(\pm)$	y=0	$x_3(\pm)$
1	2	3	4	5	6	7	8
S'= (0,5- -0,266)=0,234	1,682	2,829	0,75	S'= (0,25- -0,266)=0,016	1,687	S'= (0-0,266)/0,1031= =-2,58	2,33
	1,0	1,0	-		1,0		1,89
	0,5	0,25	-		0,516		1,68
	0,25	0,0625	-		0,28		1,63
	0	0	-		0,126		1,6

y=-0,05	$x_3(\pm)$	y=-0,1	$x_3(\pm)$	y=-0,25	$x_3(\pm)$	y=-0, 5	$x_3(\pm)$
9	10	11	12	13	14	15	16
S'= (-0,05- -0,266)/ /0,1031= -3,065	2,43	S'= (-0,1- -0,266)/ /0,1031=- 3,55	2,53	S'= (0,25- -0,266)/ /0,1031=- 5,005	2,80	S'= (-0,5- -0,266)/ /0,1031=- 7,43	3,20
	2,02		2,13		2,45		2,90
	1,89		1,95		2,30		2,77
	1,82		1,90		2,25		2,74
	1,75		1,88		2,24		2,73

In old system of coordinates $x_1 o x_3$ (fig. 2) the square with the side $2 \cdot 1{,}682$ is construction and the new centre S(-1,682;-1,682) is mark with axes $X_1 X_3$, which are turned on a corner $\alpha = -45^\circ$ to (6). According to fig. 2; the response Y diminished which coordinate x_2 increases.

CONCLUSIONS

1. The degree of deviation factual law distribution of seed from normal was calculated on the formula [4]:

$$y = f(A,E), \tag{1}$$

where: $A = \sum_1^N \left(x_i - \bar{x}\right)^3 / \left(ND^{3/2}\right)$; $E = \sum_1^N \left(x_i - \bar{x}\right)^4 / \left(ND^2\right)$ — exponents of asymmetry and excess accordingly; N — totality accidental values x_i (current importance of intervals between seed on the row); D — displace dispersion of intervals ($D = \sigma^2 = \sum_1^N \left(x_i - \bar{x}\right)^2 / N$); $\bar{x} = \upsilon_1$ — middle importance ($\bar{x} = \upsilon_1 = \sum_1^N x_i / N$).

When in the experiment was observed:

1. $A > 0$, $E > 0$, that $y = \left|A - E\right|$; 2. $A < 0$, $E < 0$, that $y = \left|\left|E\right| - \left|A\right|\right|$,

3. $A > 0$, $E < 0$, that $y = A + \left|E\right|$; 4. $A < 0$, $E > 0$, that $y = 1/\left(\left|A\right| + E\right)$.

Experimental data were treated accordingly with the methods of rotatable planning; the adequate regression model of second order with variables in a code designation is a result view:

$$y = b_0 + b_3 x_3 + b_{13} x_1 x_3 + b_{22} x_2^2, \tag{2}$$

where: $b_0 = 1{,}0537$; $b_3 = 0{,}1215$; $b_{13} = -0{,}2062$; $b_{22} = 1{,}1339$; x_1, x_2 — diameter and altitude of a seed tube, x_3 — peripheral velocity of twirl of a seed disc.

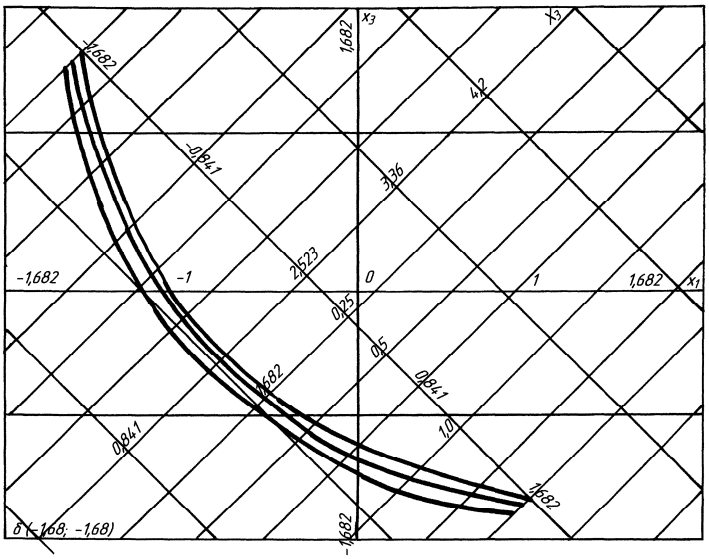

Fig.2. The two-dimensional sections of function *Y* (the degree of deviation) in "almost stationary area" along factors x_1, x_3, when $x_2 = 0$ (lines of a equal exit – hyperboles are shown)

2. Influence of each factor on the degree of deviation was defined at levels of other factors, equal ±1,682 and 0; it is presented in tab.2 and in fig. 1. From them it is visible, that at levels of other factors, equal $x_1 = x_2 = x_3 = 1{,}682$ the response is diminishes when factors x_1, x_3 increases (the lines $y_{1.3}, y_{3.3}$), and the function y grow up when x_1, x_3 increases (in case $x_1 = x_2 = x_3 = -1{,}682$; lines $y_{1.1}, y_{3.1}$); the degree of deviation isn't depend from x_1 (if $x_2 = x_3 = 0$); and it equal $y_{1.2} = 1{,}0537$. From the factor x_2 the response is depend curvilinely (lines $y_{2.1} - y_{2.3}$) with the minimum of importance, when $x_2 = 0$.

3. Coordinates of special point factorial space were determined by quantization of the independent variables (tab.3); from it visible, that $y_{min} = 0{,}266$, that is to say by the coordinates of the special point S factorial space take conditions of line 2 of tab. 3:

$$y_s = 0{,}266; \; x_{1s} = x_{3s} = -1{,}682; \; x_{2s} = 0. \qquad (5)$$

The two – dimensional sections of function Y, necessary for research of "almost stationar area", was carried out at factors x_1, x_3 with using of model (3). Coordinates of lines equal exit (tab.4) were defined from initial form (9), they are presented on fig.2. According to fig.2 the response diminished when coordinate X_3 increases.

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ВЫБОР ОПТИМАЛЬНЫХ ПАРАМЕТРОВ ДОЗАТОРА С ГОРИЗОНТАЛЬНЫМ ДИСКОМ ПО СТЕПЕНИ ОТКЛОНЕНИЯ ФАКТИЧЕСКОГО ЗАКОНА РАСПРЕДЕЛЕНИЯ СЕМЯН КУКУРУЗЫ ОТ НОРМАЛЬНОГО

Виктор Белодедов, Павел Носко, Павел Филь, Марина Мазнева

Аннотация. Представлены результаты многофакторного эксперимента, поставленного по матрице ротатабельного планирования для трех факторов: высоты и диаметра семяпровода, а также скорости вращения высевающего диска. Результаты экспериментов обработаны в соответствии с методикой, характерной для ротатабельного планирования, получена адекватная математическая модель процесса, по которой установлено влияние факторов и оптимальные условия высева.

Ключевые слова: степень отклонения фактического закона распределения от нормального, влияние факторов, оптимизация.

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DESIGN TECHNIQUE OF THE PNEUMOTRANSPORT CRITICAL REGIME AT MINOR DIFFERENTIAL PRESSURE

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Summary. The design technique parameters of the pneumotransport critical regime at minor differential pressure is worked out. The design technique is illustrated.

Key words: pneumatic transport, bulk materials, industrial pneumotransport systems

INTRODUCTION

Solid dispersed materials pumping through pipelines by means of air flow is widely used in all fields of industry. But the reliability and the effectiveness of the pneumotransport installation work depends generally on the design data of the main pneumotransporting parameters chosen at the installation design stage. One of the main pneumotransport parameters is the critical velocity of the air flow. At this velocity solid particles fallout on the bottom of the horizontal pipe wall starts, that is at which the pipeline blockage begins. It is evident that the reliable design technique of the pneumotransport installation critical regime is necessary for the insurance of the stable work.

Many design functions for the definition of the pneumotransporting critical velocity have been known by present time [1 – 13]. But they are of empirical character and the fields of their application are limited by the experiment conditions. Limitation and in some cases prohibitive low accuracy degree of these functions do not always meet modern requirements of the industrial pneumotransport system design.

RESEARCH OBJECT

In this article a theoretically well-grounded and more reliable design technique of the pneumotransportation critical velocity is worked out.

RESULTS OF EXPERIMENTAL RESEARCH

The task is to define the mass flow rate $G_{W,K}$ and the medium velocity $U_{W,K}$ of the air flow corresponding to the pneumotransporting critical regime for the designed mass flow rate G_S, density ρ_S and medium grain size d_S of the solid material particles, diameter section D and the relative equivalent roughness δ / D of the pipeline. Moreover the question is about pneumotransport at minor differential pressure when air compressibility may be neglected and its density may be considered unchangeable along the pipeline.

In case of the stable and continuous pneumotransporting regime the conditions of mass flow rate of solid material and air are carried out:

$$\rho_S S V_S F = G_S , \tag{1}$$

$$\rho_W (1-S) V_W F = G_W , \tag{2}$$

where: S is a medium by pipe cross section volumetrical concentration of solid particles; ρ_W is air density; V_S and V_W are medium real velocities of solid particles and air movement; F is the area of the pipe cross section. By definition the real velocities of V_S and V_W are:

$$V_S = \frac{Q_S}{SF} , \tag{3}$$

$$V_W = \frac{Q_W}{(1-S)F} , \tag{4}$$

where: Q_S and Q_W are volumetrical flow rate of the solid material and air. If this flow rate refers to the whole area F then the medium velocities U_S and U_W of the solid particles and gas are:

$$U_S = \frac{Q_S}{F} , \tag{5}$$

$$U_W = \frac{Q_W}{F} , \tag{6}$$

comparing (3) and (4) with the corresponding expressions (5) and (6) we get

$$U_S = S V_S , \tag{7}$$

$$U_W = (1-S) V_W . \tag{8}$$

As $Q_S + Q_W = Q$, where Q is a volumetrical flow rate of air and particles, the expressions (5) and (6) may be written as follows:

$$U_S = S_\rho U , \tag{9}$$

$$U_W = (1-S_\rho) U , \tag{10}$$

where: $S_\rho = \frac{Q_S}{Q}$ is a flow rate volumetrical concentration of solid particles; $U = \frac{Q}{F}$ is a medium velocity of air and solid particles mixture movement. Having excluded (9) and (10) from the equalities the velocity U we get:

$$U_S = \frac{S_\rho}{1 - S_\rho} U_W . \tag{11}$$

In view of equalities (7) and (11) the formula takes the form:

$$\rho_S \frac{S_\rho}{1 - S_\rho} U_W F = G_S .$$

Hence we get:

$$U_W = \frac{G_S}{\rho_S F} \cdot \frac{1 - S_\rho}{S_\rho} . \tag{12}$$

Formula (12) is competent for the medium air velocities $U_W \geq U_{W,K}$, that's why in case of the critical pneumotransporting regime it takes the form:

$$U_{W,K} = \frac{G_S}{\rho_S F} \cdot \frac{1 - S_{\rho,K}}{S_{\rho,K}}, \tag{13}$$

where: $S_{\rho,K}$ is a flow rate volumetrical concentration of solid particles in critical pneumotransport regime.

Thus to define the meanings of the critical velocity $U_{W,K}$ by formula (13) it is necessary to know the quantity $S_{\rho,K}$ that depends on the concentration S_K and characteristics of the solid material. In case of minor differential pressure when the air may be considered as incompressible medium airdynamic processes at pneumotransport should be qualitatively similar to the hydrodynamic processes at hydrotransport [14 – 16]. That's why to define the quantity $S_{\rho,K}$ we use the formula obtained as a part of the pipeline hydrotransport study [17]. It takes the form:

$$S_{\rho,K} = S_K \left[1 - \varphi\left(Re_S \right) \left(1 - \frac{S_K}{S_m} \right)^{2,16} \right], \tag{14}$$

$$\varphi\left(Re_S \right) = 0,45 \left[1 + signf \cdot th\left(0,967 \left| f \right|^{0,6} \right) \right], \tag{15}$$

$$f = \lg Re_S - 0,88 . \tag{16}$$

Here S_K is a medium volumetrical concentration corresponding to the critical regime; S_m is the maximum possible concentration of the solid particles; $signf$ is a sign of quantity f; $Re_S = \frac{W_S d_S}{\nu_n}$ is Reynold's number for solid particles, where W_S is

a falling free velocity of an isolated solid particle with the d_S diameter in the stationary air; ν_S is the kinematic viscosity of air.

It should be noted that the formulas (14) - (16) are not empirical as they represent results approximation of the numerical design of the flow rate concentration based on the theoretical research of the fields with averaged concentrations and velocities in turbulent suspended flows. This formula is tested on various experimental material as for the measurement of the flow rate concentration and is characterized by a rather high degree of reliability.

As (14) consists of concentration S_K, the quantity of which is unknown, the set of simultaneous equations (13) and (14) makes it impossible to determine the velocity $U_{W,K}$ as there are two equations and three unknown quantities $U_{W,K}$, $S_{\rho,K}$ and S_K. Thus, for closure of a set of equations (13) and (14) it is necessary to form one more equation connecting the velocity $U_{W,K}$ with the parameters defining it. For this we proceed from the following considerations.

Let's add the quotations (9) and (10) together and we shall have:

$$U_S + U_W = U\ ,$$

or

$$U_W = U - U_S\ . \tag{17}$$

Being substituted in (17) instead U_S the quantity $\frac{G_S}{\rho_S F}$ takes the form:

$$U_W = U - \frac{G_S}{\rho_S F}\ . \tag{18}$$

As the formula (18) is competent for the velocities $U_W \geq U_{W,K}$ and $U \geq U_K$ the following equation is fulfilled in the critical regime of pneumotransportation:

$$U_{W,K} = U - \frac{G_S}{\rho_S F}\ , \tag{19}$$

where: U_K is a critical air and solid particles mixture velocity of motion. To define the quantity U_K we use the technique worked out for hydrotransport having adapted it to pneumotransport conditions. The above mentioned design technique U_K is grounded enough and connects the quantity U_K with the flow characteristics, solid particles and the pipeline. It takes into account, in particular, uneven character of solid particles distribution in depth of flow and the main asymmetry of high velocity field typical for the critical regime of transporting. The equation of the critical regime of hydrotransporting [3] thus obtained takes the form:

$$\frac{\rho_{0,K}}{\rho_W} \cdot \frac{\lambda_K}{(1-\alpha_K)\omega_K^2} \cdot \frac{U_K^2}{2gD} = \frac{K_0(\Delta_S - 1)\beta S_m h_K}{1+\alpha_K}\ , \tag{20}$$

where: $\rho_{0,K}$ is the mixture density at the upper horizontal pipe wall; α_K is a parameter of the axial asymmetry of the velocity field defined as the quantity ratio Δ_r, that is the distance from the kinematic axle of the flow to geometric axle of the pipe, to diameter D of this pipe; λ_K is a coefficient of the hydraulic friction at the motion of the medium carrier in the pipe having the diameter $D(1-\varepsilon_K)$; ω_K is a parameter representing a maximum average velocity ratio in the medium carrier to the maximum average velocity in the medium carrier and solid particles mixture flow at the equal average velocities of the flows; K_0 is a coefficient of the solid material friction sliding; $\Delta_S = \rho_S / \rho_W$ is the solid particles density and medium carrier ratio; β is a coefficient of dilatation ; h_K is the ratio of highly concentrated ground layer of solid particles thickness to the pipe diameter D.

As pneumotransport is usually characterized by minor volumelric concentrations and great Reynold's numbers at which coefficient of hydrolic friction refers to the field of quadric resistance, let's assume that $\frac{\rho_{0,K}}{\rho_W} = 1$, $\omega_K = 1$ and λ_K depends only from the relative roughness of the inner pipe wall with:

$$\lambda_K = \frac{\lambda_W}{(1-\alpha_K)^{0,25}}, \tag{21}$$

where: λ_W is a coefficient of the hydraulic friction at the air motion in the pipe of D diameter set either experimentally or by Shifrinson's formula:

$$\lambda_K = 0,11\left(\frac{\delta}{D}\right)^{0,25}.$$

It is assumed then that quantity h_K for minor volumerical concentrations may be expressed as:

$$h_K = \frac{S_K}{\beta S_m}.$$

In view of above mentioned assumptions equation (20) takes a simplified form:

$$\frac{\lambda_K}{1-\alpha_K} \cdot \frac{U_K^2}{2gD} = \frac{K_0(\Delta_S - 1)S_K}{1+\alpha_K}.$$

Hence it appears:

$$U_K = \sqrt{gD} \cdot \sqrt{\frac{2K_0(\Delta_S - 1)S_K}{\lambda_K} \cdot \frac{1-\alpha_K}{1+\alpha_K}}. \tag{22}$$

Substituting in (19) instead U_K its expression (22) the formula of critical velocity $U_{W,K}$ found:

$$U_{W,K} = \sqrt{gD} \cdot \sqrt{\frac{2K_0\left(\Delta_S - 1\right)S_K}{\lambda_K} \cdot \frac{1-\alpha_K}{1+\alpha_K}} - \frac{G_S}{\rho_S F}. \tag{23}$$

Parameter α_K incoming in (23) is defined according to the expression [3]:

$$\alpha_K = 2,44\sqrt{\frac{Fr_S}{\Delta_S - 1}}\left(0,25 + 0,244\sqrt{\frac{Fr_S}{\Delta_S - 1}}\right)th\left(0,714\sqrt{\frac{S_K}{S_m}}\right), \tag{24}$$

where: $Fr_S = \frac{W_S^2}{gd_S}$ is the Frud number for the solid material particles.

Thus the equation closing the set of equations (13) and (14) is obtained. That's why the solution of the closed system of three equations (13), (14), and (23) makes it possible to define three parameters $U_{W,K}$, $S_{\rho,K}$ and S_K that characterize the critical regime of the pneumotransport. This is what critical regime design technique of the pneumotransport means.

The solution of the above mentioned equation system is realized graphically. For this purpose in view the values of concentration are presented $\left(S_K\right)_1$, $\left(S_K\right)_2$ … and the corresponding values of the flow rate concentration $\left(S_{\rho K}\right)_1$, $\left(S_{\rho K}\right)_2$ are defined by the formula (14) …, then the velocities $\left(U_{W,K}\right)_1$, $\left(U_{W,K}\right)_2$ are determined in line with the formula (13). According to the obtained values $\left(U_{W,K}\right)_1$, $\left(U_{W,K}\right)_2$ … the graph function $U_{W,K} = \phi_1\left(S_K\right)$ is formed.

Then for presenting the values concentrations $\left(S_K\right)_1$, $\left(S_K\right)_2$ the values $\left(U_{W,K}\right)_1$, $\left(U_{W,K}\right)_2$ are found by formula (23), … then the graph of the function $U_{W,K} = \phi_1\left(S_K\right)$. The abscissa of the intersection of curves $\phi_1\left(S_K\right)$ and $\phi_2\left(S_K\right)$ gives the unknown value of concentration S_K and the ordinate – the critical velocity value $U_{W,K}$. According to the velocity value $U_{W,K}$ the mass air flow rate $G_{W,K} = \rho_W U_{W,K} F$ is defined. It is necessary for the pumping over of the solid material with the given mass flow rate G_S along the pipeline with D diameter in the critical pneumotransporting regime.

As an example experimental curves of specific differential pressure dependence $\Delta P/L$ from the average velocity air motion U_W borrowed from [2] are shown. In these experiments the pipe diameter $D = 0,1$ m, the average grain size of solid particles is $d_S = 5$, the density $\rho_S = 595$ kg/m^3.

The curves 1, 2 and 3 correspond to mass flow rate G_S, equal to 0,228 and 380 kg/h. The straight line crossing the curves 2 and 3 corresponds the critical regimes of

pneumotransporting. According to these data $U_{W,K} = 11,7$ m/sec for $G_S = 228$ kg/h and $U_{W,K} = 15$ m/sec for $G_S = 380$ kg/h.

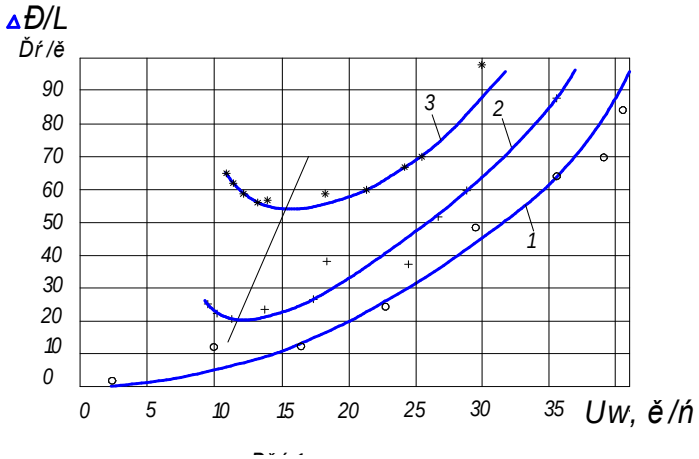

Fig. 1. Experimental curve dependence of the quantity $\Delta\rho / L$ from the velocity U_W borrowed from [2]: 1- $G_S = 0$, 2 - $G_S = 228$ kg/h, 3 - $G_S = 380$ kg/h

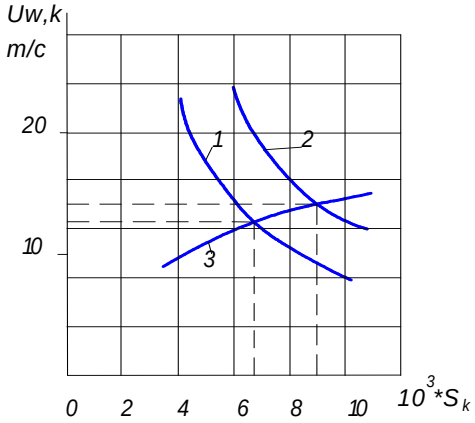

Fig. 2. To the critical regime design: 1 - $\phi_1(S_K)$ at $G_S = 228$ kg/h
2 - $\phi_1(S_K)$ at $G_S = 3800$ kg/h
3 - $\phi_2(S_K)$

The critical regime design technique is done for each of mass flow rate $G_S = 228$ kg/h and $G_S = 380$ kg/h. And here $W_S = 5,1$ m/sec, $K_0 = 0,3$, $\lambda_W = 0,01$, $\rho_W = 1,2$ kg/m^3, $U_W = 0,15 \cdot 10^4$ m^3/sec is taken into account. Calculation of function

$\phi_1(S_K)$ and $\phi_2(S_K)$ is carried out for the values S_K, equal to 0,004; 0,006; 0,008; 0,01. The graphs of these functions are given in Fig. 1. The curves 1 and 2 refer to the function $\phi_1(S_K)$ at $G_S = 228$ kg/h and $G_S = 380$ kg/h accordingly and the curve 3 to the function $\phi_2(S_K)$. The calculated values S_K and $U_{W,K}$ are determined by the curves intersections ϕ_1 and ϕ_2. As a result $S_K = 0,007$, $U_{W,K} = 12,2$ m/sec, for $G_S = 228$ kg/h and $S_K = 0,0093$, $U_{W,K} = 14$ m/sec., for $G_S = 380$ kg/h are obtained (fig.1,2).

CONCLUSION

The calculated values of the critical velocities practically coincide with the experimental ones. It may testify to the reliability of the developed critical regime design technique of the pneumotransporting. Now the solution is to approve this technique on the extensive experimental material.

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МЕТОДИКА РАСЧЕТА КРИТИЧЕСКОГО РЕЖИМА ПНЕВМОТРАНСПОРТА ПРИ МАЛЫХ ПЕРЕПАДАХ ДАВЛЕНИЯ

Михаил Чальцев

Аннотация. Разработана методика расчета параметров критического режима пневмотранспортирования при небольших перепадах давления. Приведен пример расчета.

Ключевые слова: пневмотранспорт, сыпучие материалы, промышленные пневмотранспортные системы

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CYCLONE WITH SHUTTERS LATTICE MODELLING

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Summary. The performance of a new cyclone dust catcher is investigated using RANS-based single-phase computational fluid dynamics (CFD). The pressure drop across the cyclone dust catcher chamber is predicted. Possibility of further improvement of diesel engine air refinement processes by cyclone using is offered here.

Keywords: dust catcher, air refinement, cyclone separator, shutters lattice.

INTRODUCTION

In reliability of transport engines and other machines the important role is played by refinement of ingoing air [Woschni 1987, Johnson 1992, Painter 1992, Dzetsina 2010]. Due to that, the important problem is the development of effective dust-separating apparatuses for air systems of new engines [Gackey 1982, Povarkov 1999, Volodin 2002].

Mechanical dust catchers are apparatuses with gravitational, inertial and centrifugal mechanisms of precipitation. Centrifugal type of separators consists of single, group and battery cyclone separators, vortex and dynamic dust catchers.

Their basic advantages comparing to other gases refinement apparatuses are trapping of dust in a dry aspect, absence of moving parts, reliable activity in broad range of temperatures and pressures, stability of a flow friction, manufacturing and repair simplicity. Thus, they are widely used in air systems of internal-combustion engines, cooling systems of traction motors, in ventilation and compressor systems and in other engineering devices of railway transport due to their manufacturing and maintenance simplicity [Getzov 1999, Volodin 2002].

General weaknesses of cyclone separators are considerable pressure loss (1,2-1,5 kPa) and low effectiveness with dust particles size below 5 microns, that's why they are usually used for first stage air refining.

The recent researches in this field of science involve the development of centrifugal dust catchers that provide sufficient effectiveness at precipitation of superfine dust particles in conditions when other types of dust catchers cannot be

applied. Therefore, despite the peculiarities of application marked above, researches in the field of a centrifugal dust separation remain actual.

OBJECTS AND PROBLEMS

The dust separation effectiveness in centrifugal type apparatuses can be achieved by some improvements of classical cyclones: an intensification of a gas stream twisting at the apparatus input, decrease of secondary flow of a dust, the organization of efficient unloading of the dust, parallel use of other mechanisms of precipitation of suspended particles [Boysan 1983, Fraser 1997]. However, gained effectiveness is usually attained by increase of power and capital outlays, complication of design, increase of manufacturing and operation cost and can cause decrease of reliability. Therefore, the importance of technical service and control equipment of such apparatuses increases.

Many recent works are devoted to creation of new dust removal devices with two or more principles of action in separation process of dust and gas mixture. The apparatus investigated in [Hoekstra 1999] has a cylindrical body with a scroll type of inlet to introduce the fluid tangentially. At the base of the cyclone, a sudden reduction of the cross-sectional area occurs owing to the presence of a vortex stabilizer that also serves to reduce re-entrainment of particles from the collection hopper. The air is exhausted through the exit pipe, or vortex under, at the top of the cyclone.

In [Batluk 2005] principally new vortex dust catcher with shutter lattice is investigated. It is capable to effective separation of particles with pressure loss 1,5 times lower than conventional cyclones and also has 1,3 times smaller overall dimensions. In that direction it is necessary to improve such devices, so they would be able to decrease the discharge of fine-dispersed particles in technological processes.

In [Kutz 2005] hydraulic resistance of step-by-step solid phase extraction cyclone is estimated. The apparatus combines classical cyclone and shutter lattice. It improves effectiveness with decrease of particles concentration near housing walls, therefore, by way of gas stream suction of particles possibility minimization.

In [Syomin 2010] vortex executive devices application for regulation fluid streams in processes with hard working conditions of the equipment is analysed. On the example of industrial application with hydraulic cyclones the possibility of improving both technological and power parameters of such processes is approved.

A good understanding of the fluid dynamics is required to make further improvements to cyclone dust catcher designs. While analytical techniques do not allow changes in geometry to be readily assessed, computational fluid dynamics (CFD) models based on Reynolds-average Navier-Stokes (RANS) provide an economical means of understanding the complex fluid dynamics and how it can be influenced by changes in design and operating conditions. Still validation of results is required to establish confidence in the predictions.

A review of related papers revealed few researches involving simulation of cyclone dust catchers, but significant advances have been made in simulating cyclone separators. [Boysan 1983] who was early users of the CFD technology, applied the algebraic stress model (ASM) to simulations of a cyclone separator. Later [Zhou 1990, Hoekstra 1999, Modigell 2000] applied CFD to this problem with varying success.

Nevertheless, their works dealt only with two-dimensional prediction of the single-phase flow in the cyclones and treated the flow field as axisymmetric and steady.

Numerical simulations in three-dimensions are necessary to perform in order to get more details of the complicated flow field in cyclone devices. Following researchers dealt with numerical simulations of cyclone separators in three-dimensions: [Griffiths 1996, Witt 1999, Zhao 1999, Montavon 2000, Yoshida 2001, Derksen 2003, Schimdt 2003, Wang 2003]. They all tested several turbulence models: algebraic stress model [11], standard k-ε [Witt 1999, Montavon 2000, Yoshida 2001], RNG k-ε [Griffiths 1996], and a Reynolds stress model [Witt 1999, Wang 2003]. The conclusion of these studies is that CFD still cannot produce a very accurate description of the flow field due to difficulties in modeling the swirling flow. The pressure drop obtained experimentally was larger than the calculated one by 60%, 15%, and 16% for standard k-ε [Yoshida 2001], RNG k-ε [Griffiths 1996], and Reynolds stress model [Wang 2003], respectively. So pressure drop calculated results agree moderately well with the experimental data.

To predict the unsteady, spiral shape and vortex core characteristics of a cyclone separator, large eddy simulation (LES) was used [Derksen 2003, Schimdt 2003]. Both in terms of the average velocity and in terms of velocity fluctuations, good agreement with experimental data was obtained. The advantage of the LES approach as compared with the RANS was illustrated but computational cost increased greatly.

The objective of this paper is to present predictions of the gas-phase flow field and pressure drop through a cyclone dust catcher using RANS based CFD. A model developed is run for three-dimensional single-phase gas flow in the cyclone dust catcher. Simulation parameters such as mesh type, turbulence model, and level of mesh resolution are tested to find the best combination for flows of this type. The effects of orifice diameter and chamber height on the pressure drop are investigated. This is the first stage in the development of a computational method for cyclone dust catcher design.

In shutters lattice cyclone, centrifugal and shutter dust catchers mechanisms are united, gas flow is treated as superposition of two flows: flat outflow and flat vortex. Therefore, it is convenient to divide the computational geometry into zones, in which trajectories of particles with different sizes are defined. In addition, the end of previous area trajectory will be used at initial conditions setting for calculation of the following trajectory.

Unlike most calculation models of centrifugal-inertial dust catchers with shutter air outlet or shutter-vortex separators, the essence of step-by-step solid phase extraction cyclone separation effectiveness estimation is in checking that centrifugal force is equal to suction force of radial outflow. This is the second condition and the conception is that balanced particles are turning rotating in the stationary orbit and have the equal possibility to be drained through the clean gas outlet pipe or to be separated.

In step-by-step solid phase extraction cyclone the particles moving in gas stream to clean gas outlet are reflected with certain possibility by shutters lattice. So some of them are also separated with shutter principle from gas stream. Therefore, another way of cyclone performance improvement is connected with the shutters lattice design.

The geometry of the cyclone dust catcher used for the initial numerical investigation is shown in fig. 1, It is characterized by the principal diameter D, and the geometric ratios detailed in [Kutz 2005].

The diameter of the model cyclone dust catcher tested is 400 mm. Automatic initial conditions were set up with the and a required minimum RMS residual level of 10^{-6}. For standard k-ε turbulence model, the tangential velocity was under-predicted at both measurement planes when using the upwind differencing scheme.

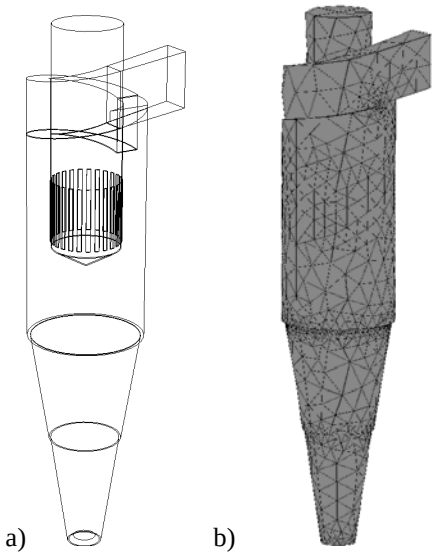


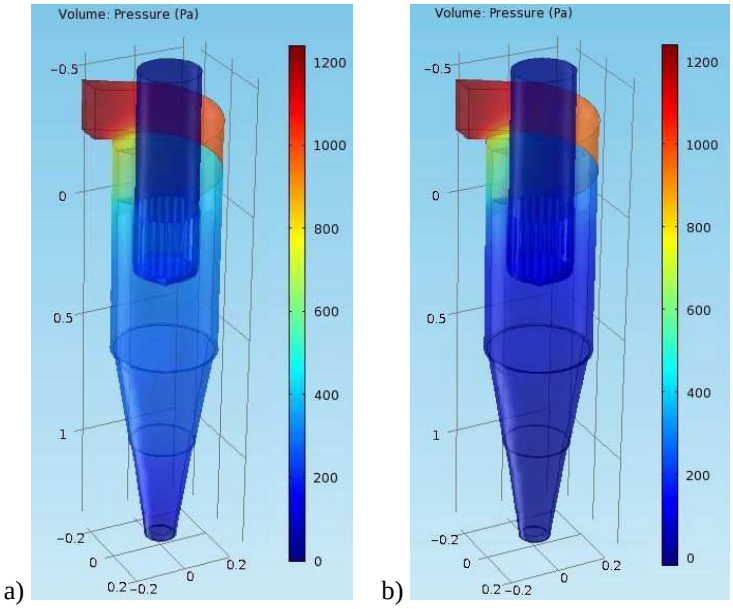
Fig. 1 The geometry of the cyclone dust catcher (a) and computational mesh (b)

The sharp gradient of axial velocity near the cyclone orifice cannot be captured due to the diffusive nature of this differencing scheme. The results below (fig. 2) show the results obtained using the upwind differencing scheme.

The results obtained with the high resolution and second order accurate advection schemes significantly improve the predicted tangential and axial velocity profiles. The second order accurate advection scheme clearly gives much better agreement than the other differencing schemes for both the magnitude and position of the maximum axial and tangential velocity. The pressure drop of the conventional cyclone dust catcher in conical part of cyclone is much higher than for step-by-step extraction type. Therefore, the reverse flow for the later cyclones is reduced. To predict the behavior of solid particles of dust present in gas, the modeling of their motion is done (fig.3).

As can be seen from fig.3, most solid particles leave the cyclone in first and second stage outlets and the rest keep moving down the sand nozzle. Still some of them can reach the clean gas outlet.

The application of investigated cyclone at first stage air refining of air system for transport engine of diesel locomotive leads to increase of air refinement level with moderate hydraulic loss, capital and maintenance costs.



a) b)

Fig. 2 The pressure drop three-dimensional plot of the conventional cyclone dust catcher (a) and for step-by-step extraction (b)

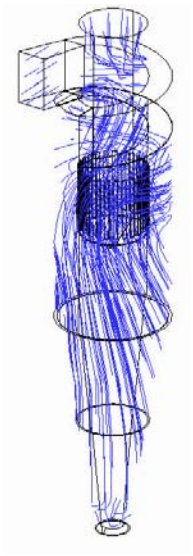


Fig.3 Trajectories of solid particles movement

Anyway, cyclone separator effectiveness changes at variable gas charge and irregular gas streams. This fault should be compensated with using of battery separators,

with the gas stream distributed between parallel cyclones united in one system. In addition, it is necessary to use automation devices for the support of nominal operation parameters, taking into account changes of the cyclone separator characteristics at gas unsteady flow parameters.

CONCLUSIONS

1. The advantage of the LES approach as compared with the RANS for cyclone dust catcher modeling is considerable but computational cost increases greatly.

2. The pressure drop in conical part of conventional cyclone is much higher than for step-by-step extraction type, the reverse flow for the later cyclones is reduced.

3. Most particles leave the cyclone in first and second stage outlets and the rest keep moving down the sand nozzle. Still some of them can reach the clean gas outlet.

3. The application of investigated cyclone at first stage air refining of air system for transport engine of diesel locomotive leads to increase of air refinement level, cyclone separator effectiveness changes at variable gas charge and irregular gas streams should be compensated with using of battery separators.

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МОДЕЛИРОВАНИЕ ЦИКЛОНА С ЖАЛЮЗИЙНОЙ РЕШЕТКОЙ

Дмитрий Дмитриенко

Аннотация. Исследована работа новых циклонных пылеуловителей методами вычислительной гидродинамики для однофазной среды в приближении Рейнольдса. Представлена картина падения давления в циклонах. Предложены пути дальнейшего улучшения процесса воздухоочистки для дизельных двигателей.

Ключевые слова: пылеуловитель, воздухоочистка, циклонный сепаратор, жалюзийная решетка.

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CHOICE OF THE ECONOMICAL METHOD OF WELDING AT MAKING OF STEEL CONSTRUCTIONS

Oleg Druz, Svetlana Gitnaya

Chair «Safety of labour, protection and safety of vital functions»
of the Volodymyr Dahl East-Ukrainian National University, Lugansk, Ukraine.

Summary. In the given article the method of decision of expense of electric energy for various types of welding, comparative analysis of efficiency of different ways of welding, is resulted. Tabl. 3, fig. 5, source 25.

Key words: welding, economy, economy of electric energy.

INTRODUCTION

In different industries of industry will remain basic materials on the nearest decades to steel and alloys on the basis of iron, and leading technological process of receipt of permanent connections – welding.

In the conditions of market competition at making of the welded constructions it is necessary to develop technologies which allow to provide the best quality and the least cost of good.

THE ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

Basic directions of economy in welding production are following [Gedrovich A.I., Druz O.N., 2002, Gedrovich A.I., Druz O.N., 2003, Gedrovich A.I., Gidkov A.B., 2003, Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986]: transition to sheet metal ware (use of metal-roll of small thicknesses, to 10 mm); reduction of prices of process of welding (power reduction) and welding materials.

On today the methods of fuse welding are most developed, that is related to simplicity of their realization. An anchorwomen the role belongs to the arc welding which will in the near future remain the basic type of fuse welding here. Such position of the arc welding is explained by high concentration of thermal energy, universality of process, by possibility of welding under various conditions and spatial positions,

simplicity, by reliability and is relative by the low cost of equipment, stability of strength characteristics descriptions of the welded connections, comparative simplicity of mechanization of process of welding.

THE PURPOSE AND STATEMENT OF PROBLEM OF RESEARCHES

Working up of method of estimation and choice of the most economy method of welding with minimum consumption of electric energy at making of steel constructions from thin metal-roll is the target of the given article.

Most perspective path of development of welding technologies of – economy resources material and power at welding. Here, foremost, it is necessary to mechanize and automatize (robotize) the process of receipt of the welded connection and aspire to the burst performance, with the improvement of terms of labour of welder. However sharp transition to total automation of process of welding is related to the enough large capital investments, therefore it is not needed to renounce the semi-automatic methods of welding. Expediently to modify and combine existent technologies of welding. From the existent methods of fuse welding it is necessary to choose economical and with the least consumption of electric energy.

THE BASIC SECTION WITH RESULTS AND THEIR ANALYSIS

For the decision of method of fuse welding with minimum consumption of electric energy their comparison was conducted. In technical literature estimated dependences on the decision of power consumptions (electricity charges) on 1 kg of weld metal and on 1 m of the welded stitch [Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986, Karnauh A.K., Mazur A.A., Panashenko N.I., 1995, Mazur A.A., Karnauh A.K., Panashenko N.I., 1996, Panashenko N.I., 1996, Panashenko N.I., Gavva V.M., Karnauh A.K., 1996, Panashenko N.I., Karnauh A.K., 1995, Panashenko N.I., Mazur A.A., Karnauh A.K., Beynish A.M., 1995] are brought over, basic design formulas (1 – 5) are resulted in the table 1.

In our opinion the analysis of consumption of electric energy must be conducted on 1 m of welding stitch, as not in all methods of welding a adding electrode metal is used.

For the calculation of consumptions on electric energy the dependence (5) from table is most preferable. 1, as it takes into account the losses at idling of arc welding source. The sentinel expense of electric energy at idling can makes 15...27 % sentinel expense during burning of welding arc at the use of transformers of direct current, 2,5...12,5 % – at rectifiers and 3,5...6,5 % – at transformers. Along with it the recommended dependences (tabl. 1) for the calculation of consumption on electric energy do not take into account its expense to work of electric motors of mechanisms of serve of electrode wire, works and adjusting moving of welding vehicle or welded product. They do not take into account also the losses of electric energy in a network.

Table 1. **Formulas for the decision of power consumptions at welding**

Design formula	Table of symbols
$C_e = qQ_wP_e$, (1)	C_e – consumptions on electric energy per 1 m of stitch, q – expense of electric energy per 1 kg of weld metal (kW·h/kg), P_e – price 1 kW·h electric energy (monetary items), U – tension on a welding arc, (V), η – output-input ratio of arc welding source, W_i – power of idling of arc welding source, (kW), a_m – coefficient of basic time, equal to attitude of basic time toward piece calculation time of welding, Q_w – mass of the weld metal per 1 m of welding stitch, (kg), S – speed of welding deposition or welding, (kg/h), I – welding current, (A), α_d – coefficient of welding deposition, (g/A·h), t_0 – basic time of welding per 1 m of stitch, (h/m).
$C_e = \frac{t_0 IUP_e}{\eta 1000}$, (2)	
$C_e = \frac{Q_w IUP_e}{S\eta 1000}$, (3)	
$C_e = \frac{Q_w UP_e}{\eta \alpha_d}$, (4)	
$C_e = t_0\left(\frac{IU}{\eta 1000} + W_i \frac{1-a_m}{a_m}\right)P_e$. (5)	

For setting of norms of consumptions of electric energy per 1 m of stitch at all arc methods of welding it is recommended to use the following dependence:

$$N_{em} = E_{bm} + E_{im} + E_{em}, \quad (1)$$

where: E_{bm} – expense of electric energy for basic time of welding;
E_{im} – specific losses of electric energy in the alternated mode of operations of welding source in the period of idling;
E_{em} – electric energy consumption by an engine.

The E_{bm} value is determined on the following formula:

$$E_{bm} = \frac{IUT_{bm} \cdot 10^{-3}}{\eta}, \quad (2)$$

where: I – strength of welding current (A);
U – tension on a welding arc (V);
T_{bm} – basic time of welding 1 m of stitch or fuse welding 1 kg of metal (period of burning of arc) (h/m); $T_{bm} = 1/v_w$, for the automatic welding and $T_{bm} = M / I\alpha_d$, for the manual arc welding and semi-automatic welding
M – mass of added metal on 1 m of stitch (g);
η – output-input ratio of arc welding source.

The E_{im} value is determined on the following formula:

$$E_{im} = P_w \cdot T_{bm} \cdot K_i, \quad (3)$$

where: P_w – power of arc welding source on idling (kW);
K_i – coefficient taking into account the period of idling of welding source in relation to basic time of welding.

The mean values P_w for a single-operator transformer make 1,2...1,6 kW, for a semiconductor rectifier – 0,2...0,3 kW, for a transformer – 0,35...0,4 kW.

The mean values K_i for the terms large-scale production and mass production make 0,4...0,6, and for individual production and small-scale production – 0,7...0,8.

Or $K_i = (1 - K_0)/K_0$, K_0 – coefficient of time of burning of arc in common time on welding.

The E_{em} value is found on the following formula:

$$E_{em} = \sum_{i=1}^{n} P_i \cdot K_{pi} \cdot T_{pi} \quad (4)$$

where: P_i – the installed power for one electric motor (kW);
K_{pi} – activity factor for one electric motor on power;
T_{pi} – duration of work one electric motor (h/m).

It Is Recommended η_i to accept equal: 0,75…0,94 for welding solvent sealing; 0,54...0,94 for the manual arc welding by the covered electrodes; 0,7...0,85 for welding in inert gases; 0,7...0,94 for welding in active gases and mixtures of gases; 0,66…0,86 for welding of flux-cored welding and superficially activated.

Graphic presentation of distributing of middle output-input ratio of welding processes is represented on the fig. 1.

We will define the consumptions of electric energy on the butt-seam single-pass arc welding in the air quality of protective gases of two leaves from construction steel plate (type of the connection C4) thickness 4 mm (GOST 8713-79). We will adopt length of stitch of equal 1 m, individual production, for all methods of arc welding as a welding source the semiconductor rectifier of the type VDU-1001 is used. We adopt the modes of welding from reference data [Kitaev A.M., Kitaev Ya.A., 1985, Lihachev V.L., 2004, Nikiforov N.I., 1999, Asnis A.E., 1980, Malishev B.D., 1989, Chernishov G.G., Mordinskiy V.B., 2004]. The technological modes and output computation are taken in table 2 and represented on the fig. 2. The middle consumptions of electric energy per 1 m of the welded stitch of the connection C4 for different ways of welding are represented on the fig. 3.

However, In spite of such distributing of consumption of energy on the methods of welding, cost 1 m of stitch to it short of, that is related to the additional consumption on the receipt of the welded connection (cleaning of the welded edges, assembling for welding, pay-envelope of welders and auxiliary personnel, consumption for repair and production service, welding materials and etc) [Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986, Mazur A.A., Karnauh A.K., Panashenko N.I., 1996, Panashenko N.I., 1996, Panashenko N.I., Gavva V.M., Karnauh A.K., 1996, Panashenko N.I., Karnauh A.K., 1995, Panashenko N.I., Mazur A.A., Karnauh A.K., Beynish A.M., 1995]. Average cost 1 m of the end joint stitch C4 at the thickness of sheet 4 mm of got different ways of the arc welding is represented on the fig. 4.

From tabl. 2 and the fig. 2 is visible, that minimum consumption of electric energy, other things being equal, the methods of welding are had in protective gases (their mixtures) with activators. Welding under water and welding in the environment of aquatic steam can be de bene esse considered welding in an active gas environment, consisting of products of decomposition of water (pair) and gases selected at dissociation of stock of powder-like wares [Asnis A.E., 1980, Gusachenko A.I., Kononenko V.Ya., 1989, Zorbidi V.N., 1989, Kononenko V.Ya., Ribchenkov A.G., 1994, Pohodnya I.K., Gorpenyuk V.N., Kononenko V.Ya., Ponomarev V.E., Maksimov S.Yu., 1990, Smiyan O.D., Kononenko V.Ya., 1987].

Table 2. **Welding conditions of automatic methods butt-welded joint C4 and power imputs per 1 m of stitch on a design formula (6)**

Welding conditions					Power imputs per 1 m of stitch, (κW·h/m)	Method of welding
I, (A)	U, (B)	V_w, (m/h)	D_{ei}, (mm)	Performance index		
1	2	3	4	5	6	7
250	26	24	2	0,75	0,4094	Automatic welding in the protective environment CO_2
350	30	40	2	0,75	0,3790	Automatic welding in the mixture $70\%CO_2+30\%O_2$
370	30	40	2	0,75	0,3990	Automatic welding in a mixture a $85\%CO_2+15\%O_2$ wire with additions Ce and La
540	26	50	4	0,75	0,3976	Automatic solvent sealing on melt backing
480	30	49	4	0,75	0,4155	Automatic solvent sealing on copper-melt backing
280	28	25	2	0,75	0,4645	Automatic welding in inert gases (Ar)
280	28	30	2	0,75	0,3871	Automatic welding in the mixture $85\%Ar_2+15\%CO_2$
170	28	25	2	0,75	0,3003	Automatic welding in the protective environment Ar on the layer of activator (welding compound)
180	28	25	2	0,75	0,3152	Automatic welding in a mixture $85\%Ar+15\%CO_2$ on the layer of activator (welding compound)
280	40	45	2	0,75	0,3576	Automatic welding in the protective environment CO_2 on the layer of activator (welding compound)
200	28	20	2	0,75	0,4313	Automatic welding under water by a bare wire without additional defense
250	23	30	2	0,75	0,2942	Automatic welding under water by a bare wire with the additional defense CO_2
200	28	20	1,6	0,75	0,4313	Automatic welding under water by the powder-like wire PPC-5AN
180	30	20	1,6	0,75	0,4180	Automatic welding under water by the powder-like wire PPC-AN1
160	30	20	2	0,75	0,3780	Automatic welding in the environment of aquatic steam

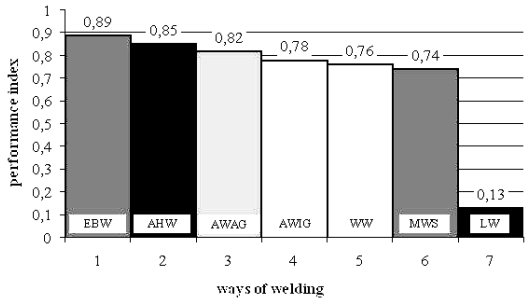

Fig. 1. Distributing of middle output-input ratio (performance index) of various ways of welding: EBW – electron-beam welding; AHW – automatic hidden arc welding; AWAG – automatic arc welding in active gases (CO_2); AWIG – automatic arc welding in inert gases (Ar); WW – welding by a powder-like wire; MWS – manual arc welding by a stick electrode; LW – laser welding

For the input analysis energies use comparative descriptions of heat source (thermal energy), for example, rate of energy input welded elements, which is determined on a formula [Kuzminov S.A., 1974]:

$$q_n = \frac{\eta_r Q}{V_w} = 0{,}24\frac{I_w U_d}{V_w}\eta_r\,, \tag{5}$$

where: q_n – rate of energy input of the welded elements (cal/sm);
V_w – middle speed of welding (sm/s);
η_r – effective output-input ratio of process of heating by an arc.

Table 3. **Descriptions of thermal current of welding arcs**

Description of welding arc	Maximal specific thermal thread, (cal/ (sm^2·c))	Coefficient of concentration K, ($1/sm^2$)
Arc of unfluxible carbon electrode	1000—2000	1—1,5
Arc of unfluxible electrode (tungsten) in the Ar stream	500—600	6—14,0
Arc opened of fluxible electrode (iron)	1000—2000	1—1,5
Arc submerged arc of fluxible electrode (iron)	6000	6—10,0

The indexes of efficiency of welding sources of heat (arcs) are: degree of localization of input of heat in product, maximal power of welding source, maximal effective input in the center of spot of heating, output-input ratio of the use of power. In the table 3 comparative descriptions of sources of heat are resulted.

The concentrated of heating of article within the limits of spot of heating at the use of various sources of heat is represented on the fig. 5. Approximately distributing of thermal thread on the surface of spot of heating is determined to the curve of Gauss:

$$q_2(r) = q_{2m} \cdot e^{-Kr^2} \tag{6}$$

where: $q_2(r)$ – intensity of specific thermal thread in any place of spot (W/sm^2);

q_{2m} – the most specific thermal thread (W/sm^2);
r – radial distance from the axis of symmetry of source to the examined point (sm);
K – coefficient of concentration, characterizing the geometrical form of curve, 1/sm^2 (coefficient K is determined by an experimental path and relied on the type of thermal energy source and its thermal power);
e – foundation of natural logarithm.

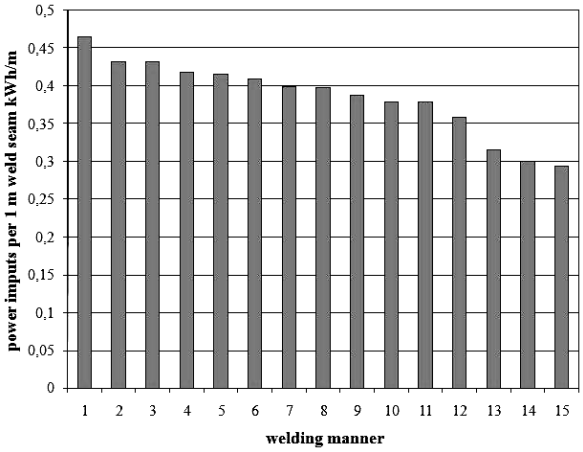

Fig. 2. Cost sharing of electrical energy per 1 m of stitch of the connection C4 for various ways of the arc welding in protective gases: 1 – automatic welding in the environment of inert gases (Ar); 2 – automatic welding under water by a bare wire without additional defense; 3 – automatic welding under water by the powder-like wire PPC-AN5; 4 – automatic welding under water by the powder-like wire PPC-AN1; 5 – automatic solvent sealing on copper-melt backing; 6 – automatic welding in the protective environment CO_2; 7 – automatic welding in a mixture by a 85%CO_2+15%O_2 electrode wire with additions Ce and La; 8 – Automatic solvent sealing on melt backing; 9 – automatic welding in the mixture 85%Ar_2+15%CO_2; 10 – automatic welding in the mixture 70%CO_2+30%O_2; 11 – welding in the environment of aquatic steam; 12 – automatic welding in SO_2 on the layer of activator (melt);13 – automatic welding in a mixture 85%Ar+15%CO_2 on the layer of activator (melt);14 – automatic welding in the protective environment Ar on the layer of activator (melt);15 – automatic welding under water by a bare wire with the additional defense CO_2

Most maximal power is practically attained at the slag welding – 250 kW and arc welding – 100kW. By the range of powers to 50 kW electron-beam welding set are characterized. Maximal power 30 kW is achieved in setting for welding by a laser. Maximal power of the practically applied gas welding flame is limited 10 kW.

On the useful use of power of energy (on the effective input of heat in the welded article) source by the most high value of output-input ratio an cathode ray and welding arc are characterized. The use of power of laser and gas welding flame is less effective considerably.

It ensues from the above-mentioned data, that on the given stage of development of welding technologies it is necessary to work at development, first of all, arc welding

in the environment of protective gases and their mixtures, as one of the most alternative technology and technology of permanent connection simple in realization (automations).

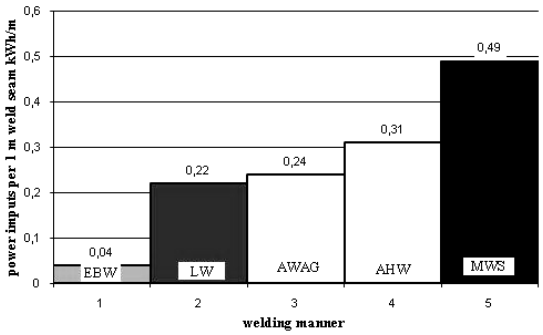

Fig. 3. Cost sharing of electrical energy per 1 m of stitch of the connection C4 for various ways of the welding: EBW – electron-beam welding, LW – laser welding, AWAG – automatic arc welding in active gases, AHW – automatic hidden arc welding, MWS – manual arc welding

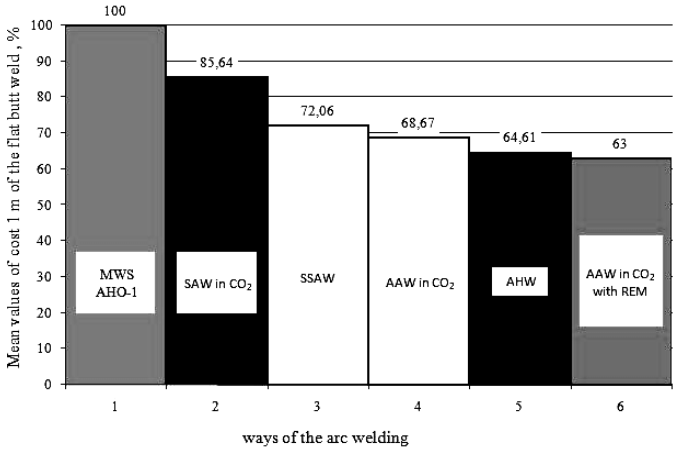

Fig. 4. Mean values of cost 1 m of the flat butt weld C4 at the thickness of sheet 4 mm in relative units (the hang-the-expense approach method of welding is accepted after 100%) on various ways of the arc welding: MWS AHO-1 – manual arc welding by the custom-made electrode of the AHO-1 brand, SAW in CO_2 – semi-automatic arc welding in the protective environment CO_2, SSAW – semi-automatic submerged arc welding, AAW in CO_2 – automatic arc welding in the protective environment CO_2, AHW – automatic submerged arc welding, AAW in CO_2 with REM – automatic arc welding in the protective environment CO_2 with additions of rare-earth metals to the electrode

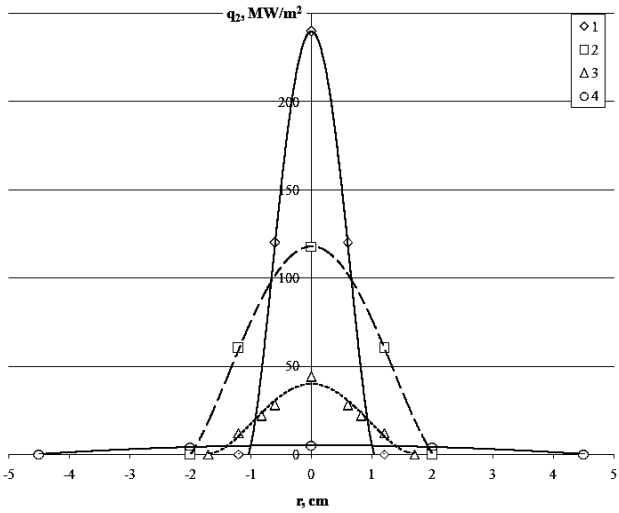

Fig. 5. Graph of efficiency of thermal action of various sources of heat: *1* – metallic submerged arc (q=27,5 kW); *2* – metallic arc opened (q=29,1 kW); *3* – metallic arc opened (q=9,9 kW); *4* – gas flame (q=9,4 kW; head № 7)

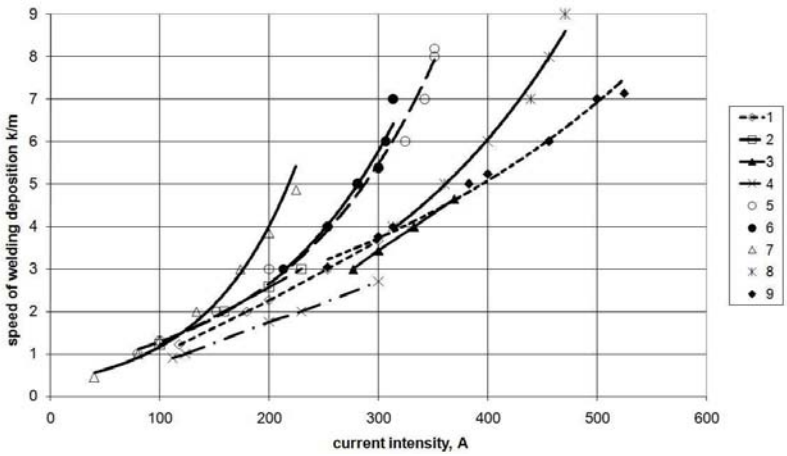

Fig. 6. Dependence of productivity welding deposition of arc methods of welding on strength of current: 1 – manual arc welding, electrode with basic coverage; 2 – manual arc welding, electrode with cellulose coverage; 3 – manual arc welding, electrode with retile coverage and ferrous powder; 4 – manual arc welding, electrode with retile coverage; 5 – welding in a protective environment the CO_2 wire the diameter 1,2 mm; 6 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT5); 7 – welding in a protective environment the CO_2 wire the diameter 0,8 mm; 8 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT1); 9 – powder-like wire the diameter 2,4 mm (brands – FCW AWS E6XT1)

In practice often the economic factors of arc welding are determined by productivity of welding deposition. Dependence of speed of welding deposition on welding current strength represented on the fig. 6.

CONCLUSIONS

1. Perspective for application, development, improvement and modification there is the method of the arc welding in the environment of protective gases and their mixtures with additions of activators, steel with thickness to 10 mm.

2. Application of plasma, electron-beam and laser methods of welding are expedient only in case of impossibility of the use of other methods of welding.

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ВЫБОР ЭКОНОМИЧНОГО СПОСОБА СВАРКИ ПРИ ИЗГОТОВЛЕНИИ СТАЛЬНЫХ КОНСТРУКЦИЙ

Олег Друзь, Светлана Житная

Аннотация В данной статье приведена методика определения расхода электрической энергии для различных видов сварки, сравнительный анализ эффективности различных способов сварки. Табл. 3, рис. 5, ист. 25.

Ключевые слова: сварка, экономия, сбережение электрической энергии.

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METHODS OF CHOICE OF MELT FILTRATION SYSTEM IN THE PORCESS OF SECONDARY POLYMER MATERIAL EXTRUSION

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Summary. Analysis of the system of melt filtration in the process of reprocessing of secondary polymer materials was done, advantages and disadvantages of existing systems were considered, methods of filtration system choice was offered.

Key words: filtration, polymer material, secondary reprocessing, extrusion, melt, pressure.

INTRODUCTION

Extrinsic substances and impurities of different size and number, which negatively affect the process of extrusion, appear in the process of reprocessing of secondary polymer materials in the polymer melt. Such impurities and heterogeneities lead to the destruction of fibers, blackouts in polymer film, resistance changes in cable coat, or vulnerabilities in polymer pipes. The research showed that the presence of particles of more than 300 micrometers size may lead to cracking and rupture of polymer pipe in 15-20 years. That is why producers of gas pipes which give 50 years and more guarantee period on them must be sure that the melt does not contain particles of more than 300 micrometers size [Gneuss 2007].

There is a melt filtration stage by means of so called filtration systems for collecting solid particles form the melt in the process of extrusion (fig.1) [Dyadychev 2010].

Thus, filtration provides two directions. First, the reprocessing of secondary polymer materials and spoilage in production enables to get additional economic profits. Secondly, it provides the necessary melt filtration quality in production of the range of plastics, for example, production of polyamide granules for usage in optical systems such as mobile devices displays.

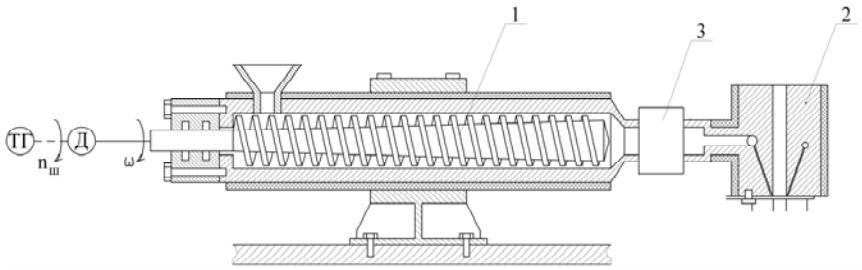

Fig.1. Extruder constructional scheme
1 – extruder, 2 – extrusion head, 3 – filtration system

RESEARCH OBJECT

There are filtration systems of sampling and continuous action. Systems of continuous action are economically effective as the extrusion production process is not interrupted during filtration elements change. Systems of sampling action are used for lightly foul polymers or, if filtration elements may be easily changed, when extruder is brought to a stop by other reasons, such as change of polymer, colour, extrudate profile and etc [Dyadychev 2010].

Filtration systems of sampling action are the systems of candle and cassette type. In the system of candle type cylinder candle (lathing) is wrapped in expanded lath and the melt goes from extruder through array inside of the candle and goes out from it bottom-up in the head that it is forming. The candle should be taken out to change arrays. In the systems of cassette (gate) type (fig.2) flat lathing with array is set crosswise the melt current, and the arrays change is fulfilled when the cassette is moved aside. Both system types demand the stop of the production for arrays change, but as the useful filtration surface in candle filters is much bigger than this of cassette type then the change of filtration arrays occurs in this type more rarely. So, though cassette filters seem to be handier, but in practice candle filters are more advantageous, cassette filters are used mostly for polymers of low thermostability which are sensitive to dead spaces and prolonged polymer stay in the filter capacity (for instance, polyamides)

Fig.2. Cassette (gate) filter construction

The simplest systems of continuous action are two-piston and have the following construction: there are two pistons in the frame in which filtration elements are fixed. Permanent frame heating is realized by means of alternative heat bringing. The frame is isolated by thermal insulation for heat drain prevention.

Polymer melt is separated inside the frame (fig.3) in two identical currents, each of which goes to filtration hole of the pistol where filtration elements are fastened. For filtration element change the corresponding pistol is put out the frame, where the change is carried out, and then the pistol takes its operating position.

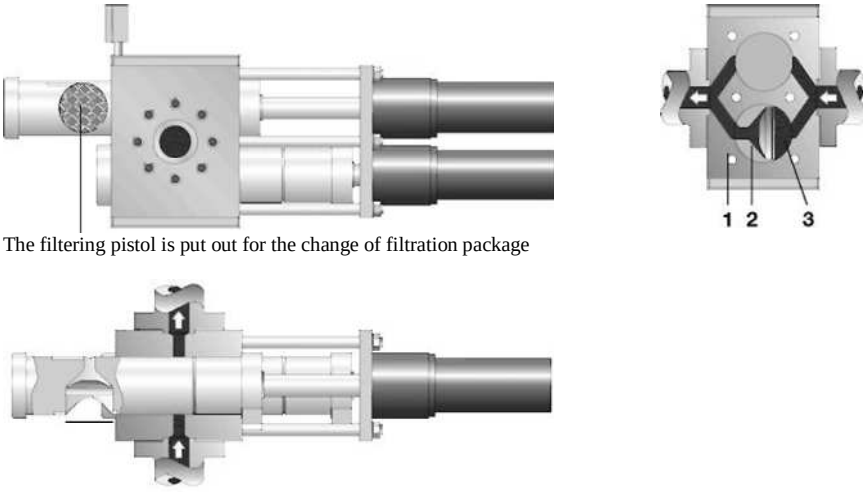

Fig.3. Two-pistol filter's construction and functioning
1 – frame, 2 – pistol, 3 - melt

The main peculiarity of rotation type filter systems construction is the disk that rotates in certain cycle between two blocks and filter elements fastened on it in circle (fig.4).

In rotary filters of the given type depuration of bolts is carried out according to the system of "back-flushing" (fig.5).

The usage of filters with reverse depuration is often recommended in reprocessing of very foul materials, the filter elements are rinsed with a small quantity of filtered polymer melt. In traditional filter adjustments it contributes to the material loss the capacity of which changes depending on the filtration technology used. When using expensive raw material components such as, for example, polyethylene terephthalate or polyamide, the factor of material flow considerably affects the efficiency of production process [Gneuss 2007].

Rotary filtration systems provide optimal melt rheological properties and short time of its going through filter. Stable production of quality products is achieved due to rotary technologies; this process is not violated during the filter elements replacement (fig.6).

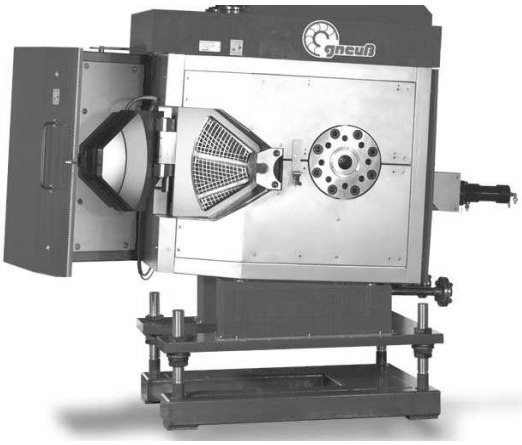

Fig.4. Rotary filter

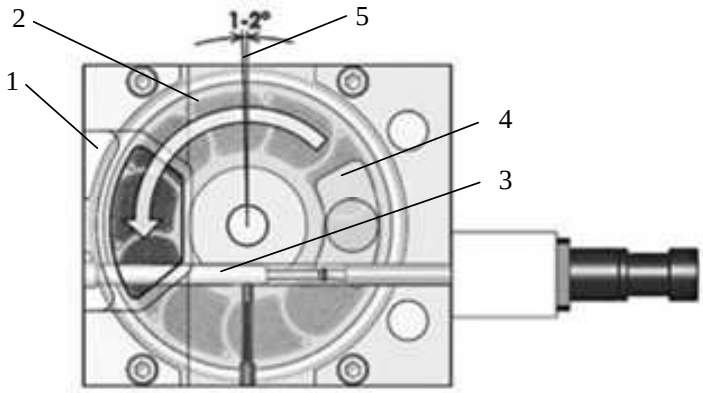

Fig.5. Scheme of the process of bolt rinse in rotation technology filtration systems
1 – door for bolt change, 2 – bolt sector, 3 – pistol of reverse injection
4 – filtration active area, 5 – progressive disk rotation in 1-2°

Rotary filtration systems contribute to high-quality goods production at the expense of higher quality filtration, on the one hand, and, on the other hand, provide wide opportunities on the use of low-grade raw materials for reprocessing, for example, production wastes and waste collected from the population, which significantly reduces production material costs [Narisava 1987].

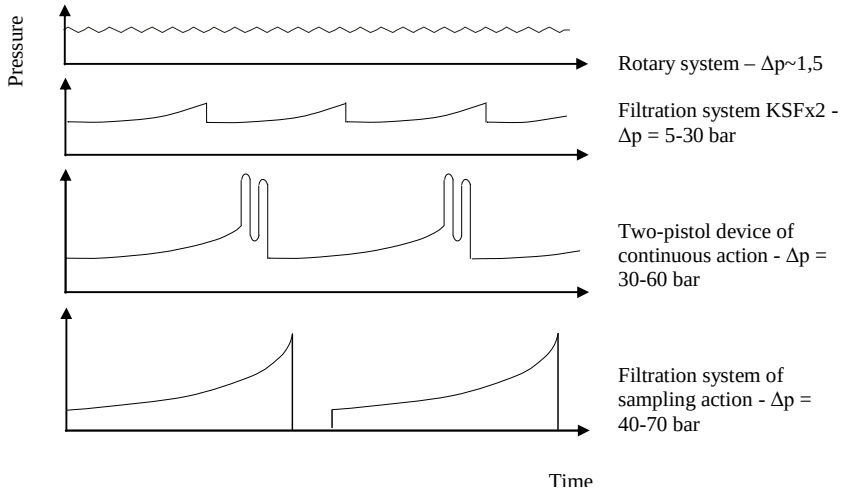

Fig.6. Comparison of the nature of the pressure changes when using different filtration systems

RESULTS OF EXPERIMENTAL RESEARCH

When choosing polymer melt filtration technology for the concrete line of extrusion the two questions should be asked: what kind of filtration is technologically necessary for the production of goods of acceptable quality, and what filtration system it is rational to use from the economical point of view.

Extrusion lines are equipped with simple cassette filters of flat and one-pistol construction type with manual changing of filter arrays during which cassette devices are put into action using hydraulic or electromechanical devices.

These filter types belong to sampling action systems where change of foul filter elements entails a complete shutdown of extrusion line and, as the result, loss in production output.

Two-pistol bolt-changing devices, in which during normal reprocessing process flow two filtration surfaces are used simultaneously (fig.7a), belong to so called systems of continuous action, besides double filter adjustments where during filtering elements change the reserve filter is used. When the arrays in one of the filter pistols (fig.7b) is changed the production process although is not interrupted, but the filtration surface reduces accordingly.

The peculiarities of the listed above filtration technologies may cause different problems. First, as the filter arrays contaminate with mechanical impurities the resistance to melt movement grows, what causes pressing of the soft particles of the fouling and the blockage of the filtering surface with them. As the result the capacity of the system reduces, extrusion process slows. Especially sharply it is manifested during the direct change of filtering elements in two-pistol systems of continuous action as at this moment, as it was noticed before, the filtration area, partially filled with fouling, reduces.

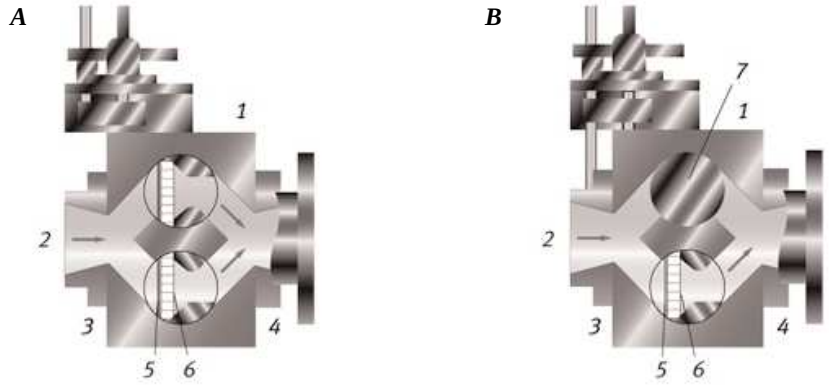

Fig.7. Scheme of the bolt changing two-pistol filtration device in full work (A) and during array change (B)
1 – filter frame; 2 – polymer melt current; 3 – input transition adapter (flange); 4 – output transition adapter (flange); 5 – perforated plate; 6 – array; 7 – closed filtration surfaces during array or bolts changing

Besides this, the products of cracking in the form of plastic particles that appear on the open surfaces of the pistols as the result of the contact with the environment and also in unavailable for clearing space between the meshes of bolts get in the main melt channel together with filtered material when the arrays are changed in this filtration systems.

These defections during filter elements change result in destabilization of technological process and production of such goods that are substandard, which will be realized at low prices, or goods that are to be reprocessed as production wastes. That is why it is necessary, if possible, to combine the arrays change with planned breaks on equipment service when using usual filtration adjustments.

The increase of the period of time between arrays change may be achieved by the following means: installation of rougher filtration or usage of clearer material. But, in the first case the goods quality will worsen, in the second case the material expenses, which occupy a considerable part in production costs, will grow.

CONCLUSION

Filtration systems influence the efficiency and quality of the production process considerably because of the range of certain factors. In this regard, it is appropriate and reasonable to decide closely and carefully during the packaging and purchase of certain new line what filtration technology is rational and effective. The filtration type proposed by manufacturers that complete and supply equipment is often economically profitable for them, but it is not rational for the final user of the line.

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МЕТОДИКА ВЫБОРА СИСТЕМЫ ФИЛЬТРАЦИИ РАСПЛАВА В ПРОЦЕССЕ ЭКСТРУЗИИ ВТОРИЧНОГО ПОЛИМЕРНОГО МАТЕРИАЛА

Валерий Дядичев, Татьяна Терещенко, Ирина Дядичева

Аннотация. Проведен анализ систем фильтрации расплава в процессе переработки вторичных полимерных материалов, рассмотрены достоинства и недостатки существующих систем, предложена методика выбора системы фильтрации.

Ключевые слова: фильтрация, полимерный материал, вторичная переработка, экструзия, расплав, давление.

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ANALYSIS OF CONSTRUCTION PRINCIPLES OF DISTANCE LEARNING SYSTEM INSTRUMENTAL ENVIRONMENT

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Summary. Development and application of current distance learning system is described. Instrumental environment's functionality is marked out: system functions, instructor's instruments, student's instruments, knowledge control system. The analysis of the content and construction principles of instrumental environment for creation and support of distance learning process is made.

Key words: distance learning, system functions, instruments, interactive systems.

INTRODUCTION

Nowadays alongside with traditional educational process many educational institutions begin to use distance learning technologies more intensively. Distance learning advantages in comparison with traditional forms of educational process organization shows that distance learning enables to: organize the educational process in the most efficient way (without leaving the place of residence, in the process of production activity, under the individual schedule and depending on individual needs), reduce the cost of training, improve the education quality by implementing unique educational programs and combining courses, remove the moral age restrictions [Agaponov 2003]. Distance learning enables to preserve the accumulated experience and didactic materials for the future generations.

The use of distance learning is connected with the need to improve the education quality in universities, especially the part-time studies.

Distance learning problems are the subject of the research for specialists of various scientific fields [Kozlakova 2002]. Thus, the research in distance learning sphere is lead in many Ukrainian and Russian universities: International Research and Educational Center of Information Technologies and Systems (subdivision of V.M. Glushkov Cyber Center), virtual distance learning laboratory of Kharkov Technical University of Radioelectronics, Research Institute of Educational Technologies in Moscow State University of Economics, Statistics and Informatics (A.A.Andreyev), Moscow State K.E. Tsiolkovsky Aviation Technical University (S.M. Avdoshyn),

Moscow Institute of Electronics and Mathematics (S.M. Moiseyev), Moscow State Experimental Center of Computer Training (V.L. Latyshev).

Though the majority of publications are concerned only with the didactic aspect of distance learning, informational and organizational-methodological directions are not less important. Education quality depends on the way the distance learning course is organized in the aspect of information flows transmission [Andreyev 1999]. The problem of creation, control and updating of the content of distance learning courses in methodological aspect requires special study.

OBJECTS AND PROBLEMS

The aim of this article is to make analysis of structure and principles of instrumental environment construction for distance learning courses creating and support. Approaches to e-learning creation technology and environments are considered in the article. Development and implementation of the current system of the distance learning process support is described.

Introduction of distance learning technologies does not always go smoothly. Traditional educational process, as it is well known, consists of the following elements: purpose of training, learning content, students, teachers, methods, means and forms of training, control and correction.

Distance learning process peculiarities' analysis shows the actual functioning of a larger number of elements, as well as changing the content of some traditional. Additionally included elements represent normative-legal, financial and economic, identification-control and marketing systems. Certainly, these subsystems are present in implicit form with varying degrees of detailing in canonical educational system too, but their significance for the normal course of the pedagogical process is not as principled as when it comes to distance learning [Polat 1998].

Modern researchers agree that the best assistant in distance learning technologies implementation is the Internet global web [Soldatkin 2003]. Modern Internet is a hypermedia system of information presentation, interactive environment containing material that needs analysis and is capable to assess the user's actions and provide the feedback immediately.

Distance learning course oriented on the Internet contains a large number of text materials, graphics and multimedia. Different parts of distance learning course are connected by hypertext links (hyperlinks). But the number of connections in normal distance learning course may become so large that manual linking is no longer acceptable as the courses' structure may be lost. In addition, Internet oriented distance learning uses a large number of new network technologies such as: public bulletin boards, forums, chats, interactive knowledge control systems, etc. [Dyadychev 2010].

The solution to this problem is to develop automated tools of distance learning technology organization. At the moment large number of instrumental shells of distance learning courses' development and support are known. The most famous of them are western systems Blackboard, eCollege.com, TopClass, WebCT, IVLE, Virtual-U and others [Ignatiev 2004]. The given systems have a big disadvantage – their ownership cost is very high. There are also shareware western and domestic developments which

may be used at the initial stage of distance learning organization. However, if to summarize the requirements to the work of distance learning instrumental shell, significant flaws may be found at once. Firstly, it is not full coverage of functionality of the distance learning system oriented on the Internet. Secondly, it is the complexity of localization. Thirdly, it is inability to enhance the functionality by means of new modules adding (in many cases the given peculiarity is available in commercial version), etc. More detailed analysis is beyond the scope of this article.

To achieve the necessary functionality and ability to develop further the instrumental shell of distance learning courses' design and support there was integrated system of distance learning process support developed. It got the name of XML Education System Framework (XESF). This software is called so because its functioning is based on several advanced technologies, the main of which is XML. XSLT, Perl-CGI, DHTML are used also. The shell is created by the modular principle, and therefore it easily provides the further extension of software product functionality (fig.1).

Let us count the main XESF facilities at the moment. They are collected in three groups: system functions, tutor's instruments and student's instruments.

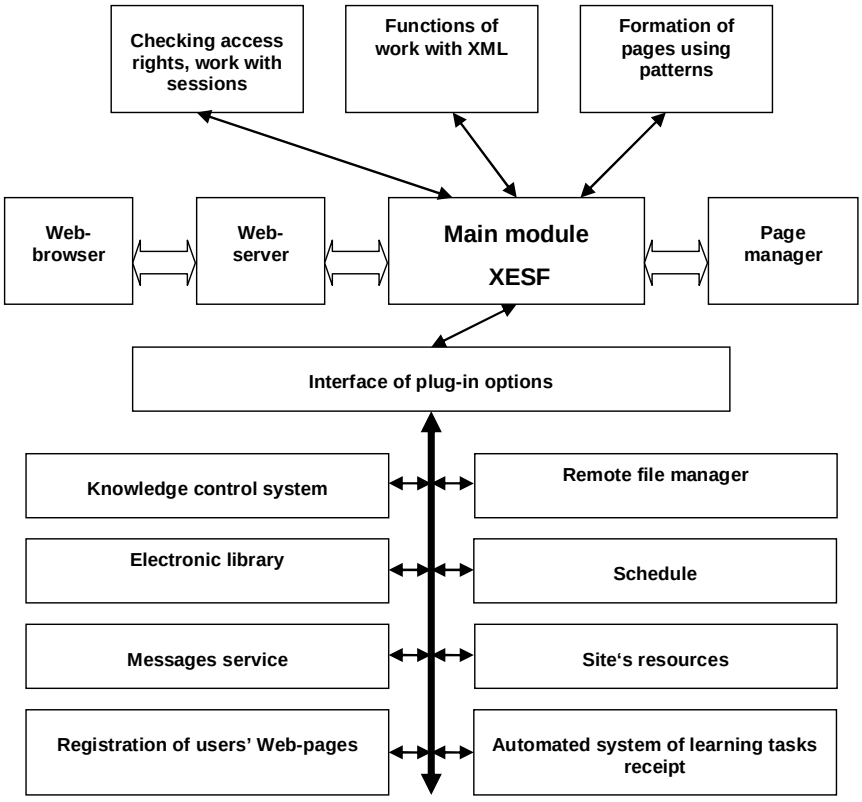

Fig.1. Scheme of XESF system's work

Student's instruments

1. Personal identification of students (at every moment of time the system "knows" who is working with it and therefore is capable to control user's actions).
2. Personal e-mail (it is not the part of distance learning system as the most convenient form of e-mail organization is using of special e-mail clients).
3. Access to materials interface description (integrated assistance system is implemented).
4. Message board (by means of this tool any student can send a message to all students, group of students, all teachers or someone personally (a teacher or a student)).
5. Personal file space with simple way to download files.
6. Rating system.
7. Ability to pass tests in the training mode (no time control, etc.).
8. Publication of the work results and other materials by students.
9. Electronic library with integrated navigation system.
10. Distribution of access to educational materials (student or group can see only those courses (sections, materials) which they have access to).
11. Distribution of access depending on time.

Tutor's instruments

1. Ability to add materials efficiently (implemented by means of FTP).
2. Unified design.
3. Configurable look (implemented by means of using patterns).
4. Support of multiple formats of information representation: regular text – TXT, HTML, XML or launching of special program of materials display.
5. Ability to preview.
6. Sections hierarchy (navigation on courses and their materials is fulfilled by means of the hierarchy tree).
7. Testing (specialized interactive testing system (look further)).
8. Summing up the learning process.

System functions

1. Subprograms of forming content on the basis of patterns.
2. Subprograms of XML conversion by means of XSLT. XML format is the main format of data storage and/or transfer.
3. Subprograms of distance learning site sections hierarchy support.
4. Subprograms of personal student's identification and means of access restriction.
5. Plug-in options support functions.
6. Subprograms of administration.

Peculiarities of knowledge control system

1. Representation of introduction, general information about text and conclusion, interpretation of the test results.
2. Support of different types of questions: choosing one option among many others, choosing many options among many others, short answer, active image creating.
3. Prompts to the tested person.

4. Flexible evaluation system, opportunity to set number of points for each question: for the correct answer, not correct answer or for the prompt, or to use the default settings.
5. Ability to set the number of tries for answer to each question.
6. Easy work with the multimedia content through hyperlinks.
7. Configurable reaction in case of the correct or not correct answer and even in choosing of concrete variant.
8. Ability to set time limit (by tools of the system).
9. Random mixing of questions and answer variants sequence.
10. Ability to store the test results and collect statistics (when working jointly with tools of identification).
11. Ability to set required number of questions for certain test from the general base.
12. Program working with data base for tests creation, storage and control.
13. Easy textual XML format for storing ready tests.

Currently the XESF system is used by students of both part-time and full-time students, the informational filling of the system and new courses creation are in process, the creation of distance learning groups is planned.

CONCLUSIONS

The analysis of the content of instrumental environment of distance learning courses support on the basis of several commercial and shareware distance learning systems was made in the article. General principles of the similar environments' structure were identified; the implementation of the XESF instrumental system of distance learning support was described.

The promising directions of the given problem's study are: improvement of constructing techniques of instrumental environments of distance learning support, ways of organization of interaction between different environments.

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АНАЛИЗ ПРИНЦИПОВ ПОСТРОЕНИЯ ИНСТРУМЕНТАЛЬНОЙ СРЕДЫ СИСТЕМЫ ДИСТАНЦИОННОГО ОБУЧЕНИЯ

Валерий Дядичев, Анатолий Жуковский, Александр Дядичев

Аннотация. Описана разработка и применение действующей системы дистанционного обучения. Выделена функциональность инструментальной среды: системные функции, инструментарий инструктора, инструментарий студента, система контроля знаний. Проведен анализ состава и принципов построения инструментальной среды для создания и поддержки процесса дистанционного обучения.

Ключевые слова: дистанционное обучение, системные функции, инструментарий, интерактивные системы

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ON THE ISSUE OF ENERGY EFFICIENCY OF INDUSTRIAL LOCOMOTIVES

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Summary. The analysis of research results of fuel consumption by diesel locomotives is done. The structure and different variants of defining the rates of fuel consumption by industrial locomotives are examined.

Key words: fuel consumption, diesel locomotives, modernization, consumption rate.

INTRODUCTION

The length of industrial railway tracks in Ukraine comprises 25, 000 km, including broad gauge with 18,700 km. The industrial rail transport functions as a component part of production and transports 1 billion tons (more than 70 %) of goods of enterprises [Kategorenko 2005].

From the total volume of expenses for the operation of shunting locomotive, 80% goes onto the fuel expense ratio, 10% onto the locomotive crew salary, and another 10% goes onto the depreciation charges [Dan'ko 2005].

In the operation it is accepted to record the quantity of fuel, acquired by every diesel locomotive in the handling plant, to take into account the fuel consumption during the shift according to the running schedule, which should contain the data about the fuel consumption by diesel locomotive during the shift as the fuel level difference in the diesel locomotive tank.

The use of fuel meters is the alternative method of fuel consumption assessment. There are a lot of flow meters and different ways of fuel consumption assessment [Sirota 1973, Voskoboynik 1978, Mokridenko 1982, EI VINITY 1988].

OBJECTS AND PROBLEMS

The urgency of the topic is defined by the nagging problem of energy saving on the rail transport and in the whole country. The analysis of enterprises work of rail transport showed that the average expenses on the locomotive sector comprise 31,6%

from the total sum of expenses on the enterprises, which is the biggest part among other sectors of rail transport. In connection with the price increase on the diesel fuel, for some diesel locomotive depots the part of expenses comprises 40% and more operating costs. The decrease of these expenses is a great reserve of raising the effectiveness of locomotive traction [Bojelarskiy 2007, Orlov 2009].

The science-based rates of fuel consumption are the basis of defining the real quantity of necessary energy consumption, which answer the level of technological equipment, the organization of technological process of transportation and designated amount of transport work. These rates should represent the technical and economic parameters of diesel locomotives, the rates of using the diesel generating capacity and diesel stock, the peculiarities of the tracks, the work of energy-transducing devices and other factors, which define the efficiency of energy consumption. The saving of diesel fuel in the diesel locomotives depends on good technical condition of diesel locomotive, skillful driving of trains by crews, proper organization of train formation and many other factors. Along with this important source of fuel saving and its careful use, there is the decrease of quantitative and qualitative fuel loss during transportation, drain, storage and its delivery to the diesel locomotives.

The setting of the explained rates of fuel consumption for the shunting operation will allow to improve the accuracy of planning its needs, evaluate the efficiency of expenses, stimulate the rational and economic use of diesel fuel. In connection with this, the task of improving the methodic of diesel fuel rationing for the shunting operation is very important and urgent.

The aim of the article is to analyze the determining factors on the improvement of diesel fuel rationing during shunting operation for the increasing the efficiency of shunting locomotive.

It is necessary to *define* the main factors, which influence the fuel consumption during performing the designated amount of shunting work, to *analyze* present diesel locomotive stock, methods of rationing the diesel fuel consumption ad to suggest the cost method of diesel fuel consumption.

The continuous control of diesel locomotive parameters during operation is one of the ways of increasing their operation efficiency. It can be achieved at the expense of improving the rationing of diesel fuel consumption on the basis of objective information about the diesel locomotive operating conditions and diesel fuel consumption in the operation; the increase of reliability of power plant work as a result of timely detection and prevention of emergency operation, the improvement of technical and heat engineering condition of diesel locomotive.

The subsystem of control the diesel fuel quantity in the diesel locomotive tanks is one of the most important components of the continuous control systems of diesel locomotive parameters in the operation. The experience shows that it is the measuring of diesel fuel quantity, which allows solving the tasks of assessing the diesel fuel use for the train traction, as far as it provides the possibility of quantity control of not only consumed, but also of filled diesel fuel [Molchanov 2004].

The main factors, which influence the diesel fuel consumption by diesel locomotive during the operation at the iron-and-steel plant, are observed in a number of works [The manual 1967]. The main amount of transport work at the industrial

enterprises is done by shunting locomotives, which so far are not equipped with the devices of automatized assessment of diesel fuel consumption.

It has been revealed that technical rates of diesel fuel rationing for the shunting operation are not set, that is why the fuel consumption rates are defined by practice. There is no data about the traction-energetic registration certificates for shunting locomotives of class TGM, TEM and others in the Manual [1967]. On the basis of analysis of given methods, the necessity of defining the initial rate of diesel fuel n0 consumption for the diesel locomotives of stated classes and average power of diesel locomotives Ncp, used on different sectors of enterprises, has been found out.

Since in the first decade of new millennium it has been predicted the end of service life of diesel locomotives, produced during the Soviet Union time, the board of Ukrzaliznitsya had to develop the strategy of proving the transport work on the rail tracks in Ukraine. The main directions of developing the diesel locomotive sector of Ukrzaliznitsya and its technical re-equipment were formulated there [The strategy 1998].

All the diesel locomotives, produced by the plant, will reach the end of its service life till the end of the Program on the reforming rail transport.

The problem of **rolling** stock replacement is being solved at the expense of increasing the efficiency and usage of today's **rolling** stock through modernization and prolonging the service life of today's rolling stock at the expense of overhaul reconditioning. The modernization also gives the possibility to improve technical and economical rates of diesel locomotive work, and also to improve its ergonomic rates, to increase power and traction parameters of diesel locomotive [Dzetsina 2010]. The example can be OAO "Teplovozoremontniy zavod" (Open JSC "The diesel locomotive repair plant") in Poltava. It carries out the complex modernization of shunting locomotives ChME3, TEM7 and others, produced by Czech republic.

The parameters of diesel locomotives before and after modernization are shown in the tables 1 and 2.

As it can be seen from the table 1 and 2, the main diesel engines under modernization are the diesel locomotives of class D49, produced by diesel locomotive plant in Kolomna (Russia).

The family of diesel engines, produced in Kolomna, has different energy forcing depending on the purpose of diesel locomotive. The main parameters of diesels are given in the table 3.

The heat engineering condition influences the diesel fuel consumption by diesel locomotive.

The diesel fuel equipment, piston-cylinder-unit, turbocompressor and discharge section of gas-air flow duct are ones of the major units and diesel devices, which influence the diesel fuel consumption. In all the cases of disturbance into the normal process of diesel fuel combustion, the efficiency of diesel engine deteriorates and the exhaust opacity increases.

During driving the train, the locomotive driver should choose the most advantageous mode of diesel operating and generator set, to use skillfully the kinetic energy of train, and also antiskid and brake means, to support constantly the optimal temperate of oil and cooling water in the diesel, as long as the decrease of oil's temperature on 4-5 ^{0}C increases the diesel fuel consumption on 1%.

Table 1. **Comparative parameters of main diesel locomotives before and after modernization**

Locomotive	Old engine / New engine	KVA (h.p.)	Crankshaft speed, revolutions per minute	Specific diesel fuel consumption on the full power, g/KVA per hour	The hourly diesel fuel consumption on the idle running, kg per hour	Specific oil consumption on the full power, g/KVA per hour	The service life before the first overhaul, number of kilometers traveled	The service life before complete overhaul, number of kilometers traveled
TE10	10D100	2206 (3000)	850	226	23	1,74	200	800
	1A-9DG	2206 (3000)	850	198	13,5	0,9	400	1600
M62	4-14DG	1470 (2000)	750	215	16	1,7	250	1200
	5-26DG	1470 (2000)	750	202,5	9	1,1	300	1500
class 232	1-9DG	2232 (3035)	1000	204	15	1,63	10000	40000
	12D49M	2206 (3000)	1000	203	10	1,1	32000	60000
TE114	3-9DG T2	2059 (2800)	1000	208	16	1,63	12000	50000
	3-26DG	2059 (2800)	1000	204	10	1,14	16000	64000

Table 2. **Comparative parameters of shunting locomotives before and after modernization**

Locomotive	Old engine / New engine	KVA (h.p.)	Crankshaft speed, revolutions per minute	Specific diesel fuel consumption on the full power, g/KVA per hour	The hourly diesel fuel consumption on the idle running, kg per hour	Specific oil consumption on the full power, g/KVA per hour	The service life before the first overhaul, months or hours	The service life before complete overhaul, years or hours
TEM2	PD1M	882 (1200)	750	210,8	5,2	1,1	36	9
	3-36DG	882 (1200)	750	200	5,2	1,1	36	9
ChME3	K6S310DR	993 (1350)	750	220,3	9	2,7	18	7,5
	4-36DG	993 (1350)	750	200	5,2	1,1	36	9
TGM8, TGM6	3AE-6D49	588 (800)	860	218,9	8,5	1,2	16000	60000
	7-6D49	588 (800)	860	215	5,7	1,1	20000	80000
TEM 7	2-26DG	1470 (2000)	1000	208	9	1,9	8000	40000
	12-26DG	1470 (2000)	1000	191,5	8	1,14	12000	60000

For the purpose of economic diesel fuel use, the operation manuals should be created in every locomotive depot on the basis of generalization best practices of driving trains in the diesel locomotive sector. These manuals should contain the most rational positions of controller, the speed on the track, the place of applying the brake and other recommendations. It should be also noted that the disfunction of fine and primary purification filters of diesel furl and oil, and also air filters leads to the overuse of diesel fuel.

There is great loss during drain, storage and filling of the diesel fuel to the tanks of diesel locomotives.

One of the elements of saving is the establishment of technically-based rates of diesel fuel consumption and their systematic decrease at the expense of better use of diesel locomotive's energy, skillful driving, the increase of technical level of technical equipment repair, diesel-generator set and maintaining the diesel locomotive in the good work order during operation.

Table 3. **The basic parameters of working processes of main modifications of four-cycle diesel engines D49**

Parameters	D49			
Efficient cylinder capacity Ne_c, $h.p.$	125	150	187	250
Number of revolutions n per minute	1000	1000	1000	1000
Mean effective pressure p_e in kg/cm^2	8,16	7,79	12,23	16,3
Boost pressure $p_к$ in kg/cm^2	1,92	2,28	2,16	2,75
The air temperature after compressor t_K in $°C$.	98	122	117	150
The air temperature after air-cooler t_s in $°C$	98	122	63	70
Indicated efficiency η_i	0,475	0,465	0,46	0,455
Mechanical efficiency η_m	0,811	0,848	0,873	0,905
Effective efficiency η_e	0,385	0,394	0,402	0,412
Specific diesel fuel consumption in g (h.p. per hour)				
Indicated g_i	128,1	134	135.3	135,75
Effective g_e	158	158	155	150
Excess air factor α_c	2,3	2,2	2,0	2,0
The temperature of exhaust fumes before the turbine t_T, ^0C	520	570	610	650

The rate of diesel fuel consumption for diesel locomotives is set on 10,000 t-kms gross in the trains with single and double-header during operation; on 100 locomotive-km during single movement (reserve, pushing); on one hour of shunting operation and one hour of staying idle in the working condition. These rates are created on the basis of service, types of traffic and classes of locomotives.

Locomotive's crews should always know and control the diesel fuel consumption in every trip.

Nowadays the assessment and analysis of diesel fuel consumption in the locomotive depots is being carried out on the basis of data, put by the drivers into the running schedule. At the beginning and at the end of shift, the drivers visually estimate the amount of diesel fuel in the tank according to the fuel rack or gage glass. The diesel fuel volume flow is estimated by the difference in measurements. The diesel fuel consumption by mass is estimated on the basis of volume flow and designated diesel fuel density, which is stated in the locomotive servicing.

The works on introduction of fuel measuring systems are being carried out in some depots and sections of the tracks [Molchanov 2004]. They register the temporary characteristics of diesel locomotive work with stating the idle and traffic condition, the work of diesel on the idle running, under the load and stopped diesel, the temporary

characteristics of diesel locomotive's running under the traction and running-out, average road speed and average fuel consumption rate. The expenses during diesel locomotive's running under the traction (with load) and on the idle running with the stating out the diesel fuel amount, given during servicing, are being separated from the total amount of diesel fuel consumption. The assessment of diesel fuel consumption by diesel locomotive during the shift is being carried out with taking into account the operation of diesel during idle running and under the load. The determining of diesel fuel saving or excessive consumption during the shift is being done by comparing the actual expenses with calculated value.

There are many methods of obtaining the calculated value of diesel fuel consumption. The big amount of works is dedicated to the designing the efficient methods of rationing and analyzing the diesel fuel consumption. The most famous works belong to the following authors: A.A. Baklanov, A.I. Volodin, A.I. Dolinzhev, G.A. Ilyin, N.N. Kornev, P.L. Korkhovoy, E.E. Kosov, A.M. Kostromin, A.P. Novikov, S.S. Petrakovkiy, B.G. Postol, Yu.E. Prosvirov, D.K. Sivaev, E.D. Tartakovskiy, V.N. Tveritin, A.V. Tolkachev, N.M. Khutoryanskiy, N.A. Fufrynskiy and others.

The methods of rationing the diesel fuel consumption are given in the fig. 1.

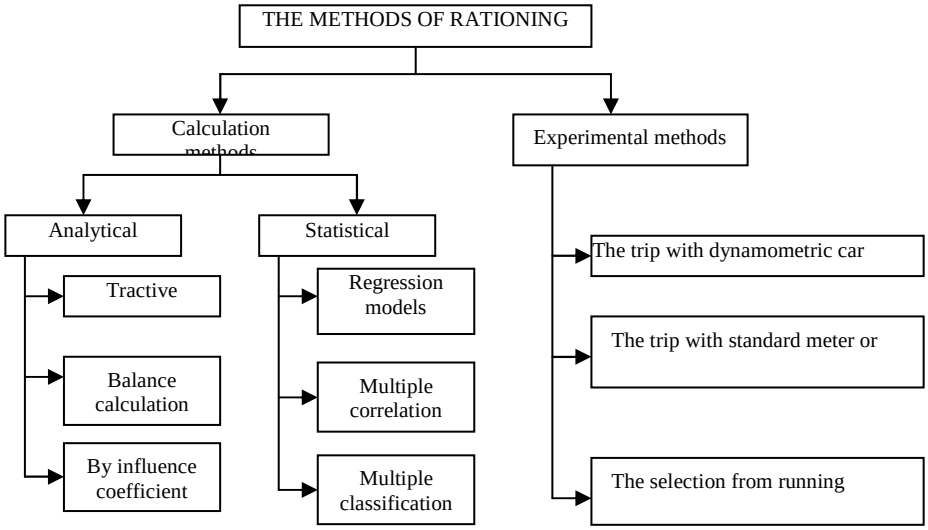

Fig. 1. The methods of rationing energy consumption

The calculation-analytical methods are based on the laws of saving and transforming energy under the following assumptions: the idealization of movement process during the shunting operations and gravity shunting, the constancy of Tractive-energetic characteristics of shunting locomotives during the operation, the input of influence coefficient of operation factors.

Calculation-statistical methods are based on the mathematical treatment of Tractive-energetic tests, initial and periodical reporting.

Operational methods use the results of long-term experience of heat engineering groups of locomotive's depots on the rationing diesel fuel consumption.

In different times, different authors suggested the methods of rationing the diesel fuel consumption in the operating conditions. The following formulas by different authors can serve as the examples.

The formula by Dolinzhev A. [1960]: $b = \left[\frac{3,35 \cdot (\omega_0 + i_k)}{\eta} + g_x \right] \cdot \frac{P+Q}{Q}$,

where: b- is cost per unit of standard fuel, kg/10^4 t-kms gross; ω_0 - is main specific resistance to train movement, N/kN; i_k - is additional resistance to train movement, N/kN; η - is the coefficient of efficiency of diesel locomotive; g_x - is the diesel fuel consumption during idle running, kg per hour; P, Q – the weight of train and locomotive respectively, t;

The formula by Tveritin V. and Korkhovoy P. [1961]: $b = \frac{B_h \cdot 60}{Q \cdot V_{av.t} \cdot 10^{-4}}$,

where: B_h - is the diesel fuel consumption by diesel locomotive in the traction condition per hour, kg per hour; $V_{av.t.}$ - is the average technical speed of train, km per hour.

The formula by Molyarchuk V. [1966]: $e = e_0 \cdot k_\mu \cdot k_\omega \cdot k_t \cdot k_i + Z' \cdot \Delta e_0 + k_x \cdot e_x + Q_c \cdot k'_x \cdot e_x$, where: e_0 - is the initial rate, kg/10^4t.km.gross; $k_\mu, k_\omega, k_t, k_i$ – the influence coefficient of rate stating factors; Z' - is a number of stops, set by train running schedule on 100 train-km; Δe_0 - is the diesel fuel consumption on one stop, referred to 100 train-km, kg/100 t.km; k_x - is the coefficient of train idle running, calculated by working time ratio of diesel locomotive in the idle running to the total amount of time of train running; e_x - is the specific diesel fuel consumption per one hour of idle running; Q_c - is the ratio of time of stops to the total amount of time of train running; k'_x - is the coefficient of diesel locomotive idle running, which is defined as a ratio of diesel locomotive working time during stops to total duration of stops.

The formula by Novikov A. and Sivaev D. [1971]: $e = e_o + \Delta e_k + \Delta e_{ew} + \Sigma \Delta e_{st}$, where: e_0 - is the main component of specific diesel fuel consumption, kg/10^4 t.km.gross; $\Delta e_k, \Delta e_{ew}, \Delta e_{st}$ - are the additional components of diesel fuel consumption, caused by corresponding change of loading the wagon axes, number of empty wagons and train stops.

It is necessary to note that the majority of works on rationing the diesel fuel consumption in the operation is based on statistical information and refers to main diesel locomotives. A number of works on rationing the diesel fuel consumption by shunting locomotives have been done during the last years.

Many others state the fact the heat engineering condition of diesel locomotive influence greatly the diesel fuel consumption. Taking into account the fact of mass modernization of diesel locomotives, in which the replacement of power units in diesel locomotives takes place, which served its life on the diesels of Д49 class, the

prospective can be the creating of method of rationing the diesel fuel consumption in the operation on the basis of parameters, characterized by heat engineering condition of diesel locomotive.

CONCLUSIONS

1. The operation efficiency is achieved on the basis of objective information about modes of diesel locomotive operation and diesel fuel consumption in the operation.
2. There are different ways of obtaining this information and they are defined by designated task and financial possibilities.
3. The majority of enterprises carry out the modernization at the expense of diesel locomotives of diesel locomotive plant in Kolomna.
4. Having the data on the results on heat engineering experiments of diesel locomotives of D49 class, it is possible to specify the calculation method of rationing the diesel fuel consumption by diesel locomotives in the operation.

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К ВОПРОСУ ЭНЕРГЕТИЧЕСКОЙ ЭФФЕКТИВНОСТИ ПРОМЫШЛЕННЫХ ЛОКОМОТИВОВ

Олег Дзецина, Виктор Федорченко

Аннотация. Выполнен анализ результатов исследования расхода топлива тепловозов. Рассмотрены структура и различные варианты определения нормы расхода топлива промышленными локомотивами.

Ключевые слова. Расход топлива, тепловозы модернизация, норма расхода.

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THE INFLUENCE OF A RAIL LATERAL BENDING ON THE STRESS – STRAIN STATE OF A WHEEL - RAIL CONTACT

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Summary. The aim of the article is to evaluate the influence of a rail lateral bending on wheel – rail contact interaction. At first the rail lateral bending is modeled using FEM and then the normal contact problem is solved with and without results obtained; the simulation results are given.

Key words: rail lateral bending, wheel – rail contact, normal problem

INTRODUCTION

Traditionally the wheel – rail contact is divided into the normal and the tangential problems. The aim of solving the normal problem is contact patch shape and size detection, and also normal pressure distribution within, while the aim of solving the tangential problem – wheel – rail coupling force definition using data achieved from normal program solution. This division is usually justified because the friction has negligible influence on contact patch size and pressure distribution if the bodies are treated as elastic ones. The division is necessary for the simplification of the solution since the treatment of the contact problem in general case, when the contact area is not known a priori, is still not achieved.

Only a finite number of treatises is known, that describe the approximative analytical solutions of different contact problem classes [Hertz 1881], [Carter 1926], [Cattaneo 1938], [Mindlin 1949], [Mossakovskiy 1956]. Therefore the various numerical methods are used to solve the wheel – rail contact problem today: variational and non-variational methods, and also finite and boundary elements methods.

The variational principle use the modern variations calculus ideas and methods. Its foundations were laid by Signorini [Signorini 1955] and for elastic bodies in contact are advanced by Kalker [Kalker 1990], Golubenko [Golubenko 1993], Boucly and Nelias [Boucly 2007]. Despite the variational inequalities theory progress, the solution of the contact problem entails great difficulties: the problem is posed in a three-dimensional formulation; when replacing the covariance inequalities by the sequence of

variational ones, that have an equivalent extremal formulation, one need to solve the linear programming task (which is complicated itself) for several times to obtain solution

The nonvariational principle has a basic in a classical contact problem formulation in the form of equality and inequality constraints on contact surface. A search of solution for a contact problem may represent a sequence of elasticity theory problems with qualifying boundary conditions, that defines the terms of contact interaction (works [Johnson 1985.], [Kostyukevich 1991], [Yazykov 2004], [Bokiy 2006]). The disadvantage of this approach is that to obtain a solution one need to solve the elasticity theory problem for several times. A convergence of the iterative process for obtaining a solution is not theoretically proved, though it turns out well to get a numerical result with a desirable precision in practice.

Due to the increase in efficiency of modern computing machinery during the last two decades the finite elements method (FEM) is wide used for simulating a wheel – rail contact (works [Telliskivi 2001], [Damme 2006], [Zhao 2009]). The main advantages of FEM are: highly realistic results can be obtained; no restrictions on geometry of contact surfaces; complex material behaviour models. However grids in FEM models contain tens and even hundreds thousand of nodes, that make calculations sufficiently time consuming.

Boundary elements method (BEM) is extremely suitable for contact modeling, because unlike FEM only surfaces of contacting bodies have to be discretized. Besides that BEM is semy-analytical, that make it more accurate, especially for high stress concentration provlems. However even that the quantity of computational nodes in the grid is much smaller than in FEM, the matrixes are non – symmetrical and dense, that makes calculations time consuming too. An application of BEM for wheel – rail contact problems is studied in [Rudas 2000], [Abascal 2010].

As it can be seen, a wide range of contact models exist to define the wheel-rail interaction. Having the aim to compare accuracy and efficiency of existing theoretical models of wheel – rail contact and those that will be developed, a group of researchers of Manchester Metropolitan University have proposed contact benchmark [Iwnicki 2006]. The benchmark consists of prescribed single wheel or wheelset contact study and dynamical vehicle simulation. According to benchmark, normal and tangential contact problems are considered. For normal contact problem the inputs are the wheel and rail profiles and their mutual orientation (lateral displacement and yaw angle), and vertical load on wheelset. However the rail lateral bending when the wheelset balances in track gauge is not provided in. At the same time it is well known from literature that the lateral load from wheel to rail can obtain values 30 – 40 kN even on straight track. This paper aims to evaluate the rail lateral bending influence on wheel – rail contact.

WHEEL – RAIL CONTACT MODELING

Rail lateral bending was simulated using Ansys FEM software [Ansys]. The 3D model of UIC60 rail having length 1m was developed. The obtained value was meshed with 3-D 10-node tetrahedral structural solid elements Solid92. To avoid rail plastic deformation , in the area of load application (middle of the rail) the mesh was refined.

The lateral force of 30 kN was uniformly distributed on small part of rail surface (see fig.1).

The structural FEM analyses was performed with created model. The maximal lateral displacement was obtained in the top point of middle section and has value of 0,2435 mm.

The normal contact problem was solved using the modified method [Bokiy 2006], assuming frictionless contact.

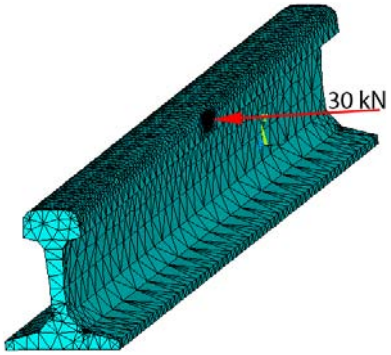

Fig. 1. 3D FEM model of the rail

Let's consider contact interaction of two elastic bodies, each of them is connected with rigid body – rigid support. It is accepted that we can assume the contact surface is flat at any moment t of interaction process and lays in a common tangent plane π, which passes through the initial contact point O. It is assumed that wave and inertial effects are negligible. The interaction is defined with $\Delta_z(t)$ function, which represents forward approach of rigid supports.

Let's introduce $Oxyz$ Cartesian coordinate system, which is linked to lower body ($i=1$). Let's put the origin to O, Ox and Oy axes are placed in π, Oz axis points inside the lower body..

Let's denote normal contact pressure as $P_z(s,t)$; and $w(s,t)$ is a relative displacement function of interacting bodies along *z* axis, defined in *s* point:

$$w(s,t) = w_1(s,t) - w_2(s,t) + f(s) - \Delta_z(t), \quad (1)$$

where: $w_i(s,t)$ - elastic displacements of bodies surfaces; $f(s)$ - initial gap between the bodies. Then the contact interaction condition have the form:

$$w(s,t) \geq 0, P(s,t) \geq 0, P(s,t)w(s,t) = 0, s \in \Omega, t \in [0,T]. \quad (2)$$

Here Ω is assumed contact area.

Let's assume that following relationship takes place:

$$w_1 - w_2 = AP_z \quad (3)$$

A is a linear integral operator with integration domain W. If we approximate bodies with elastic half-spaces , then kernels are defined with Boussinesque-Cerrutti formulas for unit load acting upon the elastic half-space. Then (1) takes form:

$$w(s,t) = AP_z + f(s) - \Delta_z(t) . \tag{4}$$

If we substitute the above expression of $w(s,t)$ in (2), we will get the relationship, which $P_z(s,t)$ must be satisfied. This relationship is equal to linear operator equation relative to $P_z(s,t)$:

$$\begin{aligned} P_z(x,y) &= h(P_z - ED(P_z)) , \\ D(P_z) &= AP_z + f(x,y) - \Delta_z(t) , \\ h(\gamma) &= \begin{cases} \gamma, & \gamma \ge 0 \\ 0, & \gamma < 0 \end{cases} \end{aligned} \tag{5}$$

where: $x, y \in W$, $E(x,y)$ - arbitrary positive function.

The contact pressure determination came to finding $P_z(x,y,t)$ function, defined on set $\Omega \times [0,T]$, which satisfies (5) and initial conditions: $P_z(x,y,0) = 0$ for all $(x,y) \in \Omega$; $\Delta(0) = 0$.

To get the approximate solution of (5) let's proceed to it's discrete analogue. Let's divide the loading process $[0,T]$ into l intervals $(t_0,t_1),(t_1,t_2)$, …, (t_{l-1},t_l). The assumed contact area Ω is covered with grid which consists of N similar quadric elements Ω_i ($i = \overline{1,N}$) with sides parallel to Ox, Oy axes. The normal contact pressure $p_i(t_m)$ and also the corresponding elastic displacements on every boundary element Ω_i in time t_m are constant within the element and equal to values in (x_i, y_i) - Ω_i elements center.

Based on the discretization made and taking into the account that the normal problem solution under continuous loading doesn't depend on loading history, for contact pressure definition in time t_m we arrive to the next system of equations :

$$\begin{aligned} p_i(t_m) &= h(\gamma_i(t_m)) , \\ \gamma_i(t_m) &= p_i(t_m) - E_i\left(\sum_{k=1}^{N} a_{i,k}\, p_k(t_m) + g_i(t_m)\right) , \\ g_i(t_m) &= f(x_i, y_i) - \Delta_z(t_m) , \end{aligned} \tag{7}$$

where: $i = \overline{1,N}$, $m = \overline{1,l}$, $E_i > 0$, a_{kd} are the coefficients of flexibility matrix, defined according to A kernel formulas. If $i = j$ and quadric boundary element Ω_i with side h:

$$a_{i,i} = 4c_1 \ln(1+\sqrt{2})$$

If $i \neq j$ then the distributed load on element Ω_i is replaced with resultant force acting on the element's center:

$$a_{i,j} = \frac{c_1 \omega}{\rho_{ij}} ,$$

where: $i, j = \overline{1,N}$, $w = mes(\Omega_i)$, $\rho_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$, $c_1 = 2\frac{1-\nu^2}{\pi E}$.

For solving the system of equation (7) we can apply nonlinear analogue of Seidel method for linear equations system. Let's assume that on $(m-1)$ step the contact pressures are known and equal to $p_k(t_{m-1})$, $(k = \overline{1,N})$, and $E_i = 1/a_{i,i}$ $(i = \overline{1,N})$, then on m step contact pressures $p_k(t_m)$ can be found using the following iterative process:

$$p_i^{n+1}(t_m) = h(\gamma_i^{n+1}(t_m))$$

$$\gamma_i^{n+1} = -\frac{1}{a_{i,i}}\left(\sum_{k=1}^{i-1} a_{i,k}\, p_k^{n+1}(t_m) + \sum_{k=i+1}^{N} a_{i,k}\, p_k^{n}(t_m) + g_i(t_m)\right)$$

$$g_i(t_m) = f(x_i, y_i) - \Delta_z(t_m)$$

As a criterion of stopping the iteration process on each load step is suitable to use rms difference

$$\sqrt{\frac{1}{N}\sum_{k=1}^{N}(p_k^{n+1}(t_m) - p_k^{n}(t_m))} \le \varepsilon$$

The given algorithm of solving the normal contact problem was realized as a software in C++ Buider 6.0 programming environment.

For a numerical simulation the wheel S1002 and rail UIC60 profiles from Manchester Contact Benchmark were used. Those profiles are depicted on fig.2. The other inputs are: Wheel rolling radius=460 mm, Gauge width=1435 mm, Flange-back spacing=1360, Vertical load=100 kN, Young's modulus E = 2.1×10^{11} Па, Poisson ratio ν =0.28.

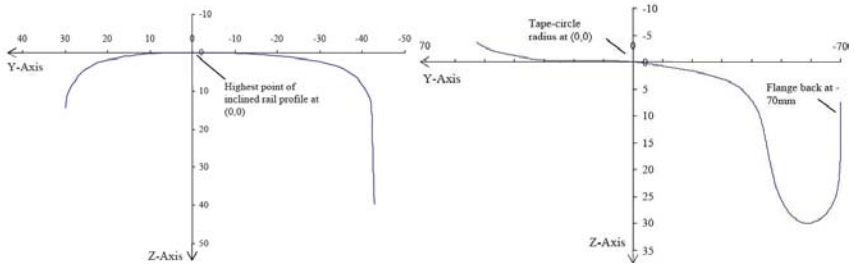

Fig. 2. Wheel and rail profiles [Iwnicki 2006]

The initial contact points locations were defined using algorithm introduced in [Kostyukevich 1991].

The simulation results are shown on fig.3. The wheel and rail profiles without rail bending are drawn with a solid green line, and the one with rail bending with a dashed gray line.. It must be admitted that the changing in position of wheel profile is connected with the lateral rolling motion of the wheelset. The points of initial contact with and without bending are marked with maroon circles.

As it can be seen from the figure, a rail bending has a significant impact upon the size and a shape of a contact patch. In Case 1 (without rail bending) the maximum

pressure is 1175 MPa, the contact patch area - 185 mm^2. In Case 2 (with rail bending) the maximum pressure is 1330 MPa, , the contact patch area - 127 mm^2. Hence, the difference between the contact patches' area exceeds 30%.

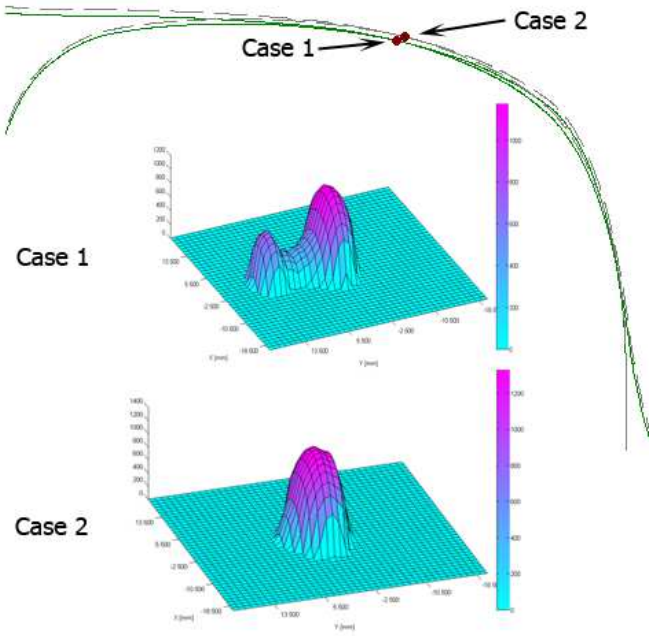

Fig.3. The normal problem solution results (1 –without rail bending, 2 – with one)

CONCLUSIONS

The mathematical model of normal contact between the wheel and the rail is developed. It is shown that the solution of the normal contact problem without rail lateral bending may lead to significant (over 30%) errors in contact area detection.

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ВЛИЯНИЕ БОКОВОГО ОТЖАТИЯ РЕЛЬСА НА НАПРЯЖЕННО – ДЕФОРМИРОВАННОЕ СОСТОЯНИЕ В КОНТАКТЕ «КОЛЕСО - РЕЛЬС»

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Аннотация. Целью данной статьи являтся оценка бокового отжатия рельса на процесс взаимодействия колеса с рельсом. Сначала боковое отжатие рельса моделируется с помощью метода конечных элементов, а затем решается нормальная контактная задача с учетом полученных результатов и без; приведены результаты численного моделирования.

Ключевые слова: боковое отжатие рельса, контакт «колесо - рельс», нормальная задача

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BIOMASS STANDARDIZATION AS A BASE FOR ITS SUFFICIENT USE

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Summary. The article provides technical and economic characteristic of terms and methods that ensure higher economic and ecological sufficiency of usage of different types of local fuel on the grounds of biomass. It also determines the proficiency of fuel gasification on the grounds of biomasses for power that allows creating terms for their complex standardization.

Key words: biomass, standardization, gasification, gas-generator.

INTRODUCTION

There are three Laws adopted in the field of renewable energy in Ukraine, 42 National Standards are approved, seven National Programs are on. Biomass is the fourth world significant fuel covering 1250 mln. of tons of equivalent fuel totaling 15 % of primary sources in the world (up to 45 % in developing countries). According to the forecasts of World Energy Council [1] the part of biomass will total from 350 to 800 mln. of tons of equivalent fuel, or 42-46% of total excavating fuels until 2020 p. This proves the formation of powerful world market of fuel biomass.

Energy Equipment that works on the biofuel has certain requirements to fuel, the adhering of which determines it energy sufficiency, durability and technical and economic indexes. That is why the main issue on the Ukrainian energy resources market is to provide status of standardized energy resource to biomass.

OBJECTS AND PROBLEMS

Vegetable wastes are various according the nature structure and technological waste structure in the end of processing or processing primary raw material. As a result we have different physical and chemical peculiarities of wastes for fuel that depend on the terms of growth, processing technology, climate and soil. However, the most

important characteristics from the point of view of usage of them as energy resources (combustion heat of unit, chemical composition) are very close [2].

The classification of vegetable wastes according to its form and size of fuel part allows not only to research the diversity of wastes in Ukraine it is also useful for studying their characteristics and for choosing preparation technology and usage.

The base of the suggested classification of vegetable waste (seven classes are reviewed) is their main biological feature that determines natural form of plant or the one that we get as a result of gathering and primary processing. The classification of solid biofuels starts with determining origin which can be subdivided into following groups: biofuels on the base of wooden wastes, biofuels on the base of grass wastes, biofuels on the base of secondary biomass. The characteristics of classes of vegetable wastes were determined by the next physical features: stem, grain of two size classes, leaf, and characteristics of wooden waste – by the solidity of wood species.

Each class affiliates with subclasses that combine wastes with more individual structure peculiarities, and, finally, the subgroup is subdivided into separate groups of vegetable wastes groups with sole physical characteristics.

Additional opportunity of classification of vegetable fuel is according to its improvement. Not-improved fuel is the one when produced the raw material is not chapped or packed with any change of mechanic peculiarities. Such type of fuel includes traditional wood, chock, chips, pressed wooden wastes, wood processing wastes (saws, chips). Accordingly, the improved include fuels the mechanical peculiarities change in the preparation stage (for instance, pellets or cakes).

Wooden fuel biomass is subdivided into the one from forest trees, energetic trees and secondary use (disposed wastes).

Fuel biomass is represented by the varity of physical forms that specify the diversity of it processing to fuel technologies [3].

The chemical composition of biomass (represented in dry, ash-free condition) more finished by its composition than in other solid fuels. The main characteristics of fuel that specify the possibility and appropriateness of its gasification are: mechanical possibility, ash content, composition of organic mass, heat production. The heat production can be determined for the dry-and-ash-free fuel on operational fuel. The heat production of dry-and-ash-free fuel is determined by the amount of heat that is released by the dry-and-ash-free components. Besides them, the duel contains metal – mineral mixtures (ash) and water that decrease heat productivity of fuel when combusting it. The heating effect when combusting or gasification of 1 kg of fuel is determined by the composition of dry-and-ash-free mass and the amount of metal in fuel, in other words by the composition of operating fuel.

The quality estimation of gas generated fuel according to high level of heat production on dry-and-ash-free mass (Q_v^g) does not give anything distorting its quality. Instead we should use low heat production of operating fuel (Q_n^p) that migh total up to 50% of Q_v^g .

The less metal the fuel contains the better fuel characteristics and higher caloricity.

Formula $\frac{Q_n^p}{Q_v^g}$ (operation heat production of fuel coefficient) inverted proportionally to content of metal in fuel — ash and moisture:

$$\eta_p^m = \frac{Q_n^p}{Q_v^g} \cdot 100\%. \quad (1)$$

This coefficient allows giving total estimation of fuel quality according to its heat production in metal content. The decrease of metal content in fuel increases its quality that is why it is a significant qualification feature.

In order to create reasonable terms for carrying out gasification process the fuel shall have certain minimal moisture content. The decrease of moisture to below set one might affect gasification process and quality of generated gas. It is important to define best definition of η_p^m, which might serve as general criteria for different types of solid fuels. Furthermore, different sources consider different meaning of biomass moisture. Thereby some scientists estimate moisture according to the factual biomass weight (2), others according to their dry weight (3).

$$MCW = \frac{M - C}{M}, \quad (2)$$

$$MCW = \frac{M - C}{C}, \quad (3)$$

where: M is factual weight; C is dry weight.

On the grounds of gasification practice and theoretical generalization in this field we know [7] that the best content of weight W^p and minimum possible content of ash A^p for different types of fuel that varies within figures stated in table 1. Those values define the best level η_p^m for different typrs of fuel.

Comparing the obtained values η_p^m with the fuel characteristics in the view of their gasification it is easy to determine their correspondence.

The calculation give the opportunity to divide the listed above fuels according to their heat production qualities into four groups (table 2).

The estimation of fuels by their heat production cannot be limited by the stated above calculations. We should define the fuel consumption in kilograms and Joule per 1 kW of output power. When researching we obtained data for different types of fuel and equipment of different power, the equivalents of solid fuels to petroleum – standardized fuel that can serve as ethanol.

In order to estimate the quality of fuels when using them in gas generating installments of transport type it is important to know the amount of heat which is released by the volume unit of fuel (for instance, 1 l or 1 м^3), because the amount of fuel that can be processed in gas generator is define by the volume of tank, while the calculation set forth the loaded fuel mass.

Table 1. **The best content of moisture and minimally possible content of ash for different types of fuel**

Type of gas generated fuel	Content, %		Best value, η_p^m
	A^p	W^p	
1	2	3	4
Birch chops	0,7	18	71,0
Birch coal	0,9	10	89,0
Top peat	4,0	30	59,5
Peat briquettes	5,0	15	78,4
Peat charred coal	6,0	8	84,1
Brown coal	5,0	18	57,9
Blind coal	3,0	6	82,1
Semi charred coal	4,0	8	86,2
Wooden coal briquettes	2,0	6	90,0
Briquettes from agriculture wastes	5,0	12	76,5
Soft species pellets	0,5	10	83,8
Solid species pellets	0,4	8	84,3

Table 2. **The classification of fuels by their heat production characteristics**

Fuel Group	Value η_p^m	Fuel Quality
1	2	3
I	More than 90	Excellent
II	From 85 to 90	High
III	From 80 to 85	Good
IV	From 65 to 80	Satisfactory
V	Less than 65	Undervalued

Therefore the heat production of fuel shall be defined by:

$$\frac{Q_k \cdot q}{1000} = Q_l, \tag{4}$$

where: Q_k — is heat production of 1 kg of fuel, Joule,

q — volumetric (loading) weight of 1 м^3 fuel,

Q_l — heat production 1 l of fuel, Joule.

The correlation of $\frac{Q_l}{Q_k}$ gives the value of unit density of fuel that can be expressed through the coefficient of heat density *i*:

$$i = \frac{Q_l}{Q_k} \cdot 100. \tag{5}$$

This coefficient allows estimating heat production of fuel including such significant index as a loading weight. The fuel characteristics give comparative estimation by the most important index – heat production including ash content, moisture and volumetric weight.

However, the decisive indexes of fuel quality used fir gas generating installments is the quality of generating gas, amount of gas that we ibtain from unit volume of fuel, heat production. Those indexes varies for different types of fuels depending on their content. The content of metal in fuel chops the heat of its burning, as a result of correspondent decrease of amount of dry-and-ash-free mass. That is why, the fuels with the constant content of dry-and-ash-free mass and with little of ash content, the burning heat is defined by the moisture content. Except carbon and hydrogen the dry-and-ash-free mass contains nitrogen gas and oxygen. Each percent of nitrogen gas decrease heat when burning up to 1 %. The amount of nitrogen gas in dry-and-ash-free mass is miserable (less than 1 %) therefore it affects a little on heat burning of fuel biomass.

Each percent of chemically connected oxygen that contains in dry-and-ash-free mass additionally decreases burning heat up to 110 kJ/kg.

In order to conduct comparative estimation of fuels we need to consider physical and chemical features necessary for ensuring perseverance of gasification process. They include: 1) reactivity; 2) volatile matters content; 3) the nature of charred coal remains; 4) mechanical strength; 5) lightness of gasification; 6) transportability.

There is no final index of gasification index and solidly of solid fuel on the grounds of biomass. It is very difficult to obtain due to the amount of factors that define this index. In order to ease classification and unification of fuels we need to implement index in the form of scale of using easiness of fuel for gasification in gas generating installments. The project of classification in gas generating fuels by their sufficiency to use is represented in table 3. This peculiarity is better to standardize.

It is clear that each solid fuel requires special terms regarding to the construction of gas generator. The experience of different types of solid duels showed that they can be divided into five big groups that define the choice of gas generator construction. The unification of construction of gas generator that based on standardization of output gas generating fuels, simplifies the issue of their use and manufacture, which, in its turn allows decreasing their price. The possibility of gasification of various types of fuels in generator of one type extends the use in different regions of Ukraine.

Table 3. **The classification of gas generating fuels by the sufficiency to use**

Class of use for gasification	Description	Type of fuel
1	2	3
I	No difficulty. Can be used without preparative operations. Possibility of automated fuel feeding.	Wooden pellets.
II	No difficulty. Can be used with preparative operations.	Wooden coal (when correlation to its sizes of technical requirements), wooden briquettes.
III	Previous fuel processing is necessary (drying, chopping).	Wooden chops, wooden coal.
IV	Upfront selection, processing or enrichment of fuel is necessary and also additional work when operating gas generator (clearing ash-bin, stoking fuel, etc.).	Peat, peat briquette, brown coal, semi charred coal of coal, peat coal.
V	The use of fuel is possible only after complicated processing (briquetting, thermal processing, etc.) or special selection of species. When operating there might be difficulties to ensure normal work of gas generating installment.	Brown coal and peat with increased ash content, coal (increased quality), anthracite, coal. Straw in briquettes.
VI	Using fuel within Trading and Tariffs Agreement by physical and chemical peculiarities is difficult and not reasonable economic wise.	Coal.

CONCLUSIONS

The combination of experiment and theory is natural for gasification in transport gas generators in contemporary machinery building field. This is conditioned by the deficit of technical information and research results. Due to these facts we provided the extended analysis of perspective of standardization of solid fuels on the base of biomass in order to substitute excavating fuels is of significant value.

The adoption of standards for biofuel will create conditions for setting market of fuel biomass, the need for which initiates creation of energetic plantations in woodless regions of Ukraine, creating of which has a significant social and economic aspect – will give an opportunity to open labor vacancies and increase the living level of people.

The standardized energy resource status will create conditions for vigorous development of energy market in Ukraine and ensure stable characteristics of equipment that works on fuel biomass.

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СТАНДАРТИЗАЦИЯ БИОМАССЫ, КАК ОСНОВА ЕЕ ЭФФЕКТИВНОГО ИСПОЛЬЗОВАНИЯ

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Аннотация. В статье представлена технико-экономическая характеристика условий и методов, обеспечивающих наивысшую экономико-экологическую эффективность использования различных видов местного топлива на основе биомассы. Определяется рентабельность использования твердых топлив на основе биомассы в силовых целях, что создает предпосылки для их комплексной стандартизации.

Ключевые слова: биомасса, стандартизация, газификация, газогенератор.

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INFLUENCE OF OPERATONAL FACTORS ON REDISTRIBUTION OF WHEEL PAIRS VERTICAL LOADS UPON RAILS

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Summary. The article investigates the problem of load redistribution of wheel pairs upon rails in mode of traction forces realization. Dependences revealing influence of operational factors on engagement weight utilization factor have been obtained on the basis of experiment planning theory. The solution on regulation of additional loading device effort in operation taking into account obtained dependences has been proposed.

Key words: engagement weight utilization factor (EWUF), experiment planning theory, traction qualities, redistribution of vertical loads of wheel pairs upon rails, correlation.

INTRODUCTION

Achievement of high traction qualities at design and operation of modern locomotive is an actual task. Redistribution of wheel pairs static loads upon rails in operation is the main reason of locomotive traction qualities degradation, their accelerated wear, increased influence upon rail road and as a result leads to decrease of rail road transporting and carrying capacity and rail road derangement.

While designing a locomotive, static loads of wheel pairs static loads upon rails are supposed to be equal [Konyaev A.N., Spiryagin I.K., 1971]. In reality, they have certain deviations from calculated values [Gorbunov N.I., Kravchenko K.A., Popov S.V., 2009]. It is connected with different design and operational factors analysis of which is presented in scientific papers of Golubenko A.L. [Golubenko A.L.., 1986], Gorbunov N.I. [Gorbunov N.I., 1987], Konyaev A.N. [Konyaev A.N., 1972] and other authors [Gorobchenko O.M., 2007, Ivanov V.N., Belyaev, A.I., Oganyan E.S., 1979, Tasang E.N., Yakovenko V.V., Saffron E.N., 2000, Gorbunov N.I. Kashur A.L., Popov S.V., Kravchenko K.A., Fesenko A.I., 2008, Kravchenko K.A., 2010, Gorbunov N., Kostyukevich A., Kravchenko K.A., 2010].

The aim of the given scientific paper is estimation of operational factors influence on locomotive traction qualities. It is generally accepted that engagement weight utilization factor may be effectively used as an estimation criterion [Yevstratov

A.S. 1987, Lions N.V., 1979, Biryukov I.V., Savoskin A.N., Burchak G.P., 1992, Minov D.K., 1965]. Results of mathematical simulation and experiment planning theory have been used in providing such estimation.

MAIN MATERIAL AND RESULTS OF INVESTIGATION

Method of experiment planning theory allows to decrease a number of experiments substantially and to obtain mathematical model of process under investigation, to estimate mutual and independent influence of every factor on the process of traction force realization. Method of experiment planning provides for the choice of factors, their levels and intervals of variation, determination of system response, planning matrix compilation, and obtaining of regression equation [Evdokimov Y.A., Kolesnokov V.I., Teterin A.I., 1980, Adler Y.P., Makov E.V., Granovsky Y.V., 1971, Gorbunov N.I., Kravchenko K.A., Popov S.V., Krysanov M.A., Kovtanets M.V., 2009, Kadomskaya K.P., 2002].

As applied to defined problems for carrying out numerical experiment the following factors been varied: change of the first wheel pair diameter caused by wear; change of locomotive mass due to consumption of servicing materials stock and change of wheel pair weight caused by wheel tyres wear; influence of frictional damper in the first stage of the spring suspending; change of the first and the second stages of the spring suspending rigidity in the process of operation (tabl. 1).

Calculations have been done for six-axes main-line diesel locomotive 2TE116 type and four-axes yard diesel locomotive TEM103 type.

The second stage of TEM103 yard diesel locomotive spring suspending has an increased rigidity – 45 kH/mm. The results of static simulation proved that rigidity of such a quantity does not affect engagement weight utilization factor. That is why this factor has not been investigated for a yard diesel locomotive. Influence analysis of frictional dampers placed on the first stage of locomotive spring suspending 2TE116 type, at the expense of spring suspending blocking considerably reduces engagement weight utilization factor. At designing yard locomotive TEM103 rationalization proposal as to placing hydraulic dampers in the first stage of spring suspending has been made. That is why blocking of spring suspending by dampers has not been considered at the stage of numerical experiment planning. Thus a number of factors for the main-line diesel locomotive 2TE116 equaled six factors, and four factors for a yard locomotive.

For the 2TE116 locomotive design a number of pair interrelations equals 15, a number of triple ones – 20; for TEM103 locomotive design – pair – 6, triple – 4.

The solution of the problem i.e. establishment of dependence of maximum engagement weight utilization factor on factors under investigation has been obtained in the form of following equation:

$$y = f(x_1,...,x_k),$$

where: f – response function; x_1, x_2 – factors; $y = \eta$.

Table 1. **Critical values of variables**

Parameter	Locomotive type	
	TEM103	**2TE116**
Wheel pair weight, *kH*		
$x_{1\max}$	20,51	17,7
$\overline{x}_1$	19,01	16,23
$x_{1\min}$.	17,5	14,76
Servicing materials weight, *kH*		
$x_{2\max}$	553,87	863,3
$\overline{x}_2$	529,25	813,03
$x_{2\min}$.	504,62	762,75
Rigidity of the first stage of spring suspending, *κHm*		
$x_{3\max}$	2,0	2,0
$\overline{x}_3$	1,9	1,9
$x_{3\min}$.	1,8	1,8
Rigidity of the second stage of spring suspending, *κHm*		
$x_{4\max}$	-	11,0
$\overline{x}_4$	-	10,4
$x_{4\min}$.	-	9,8
Locomotive wheel radius, m		
$x_{5\max}$	0,525	0,525
$\overline{x}_5$	0,5215	0,5215
$x_{5\min}$.	0,518	0,518
Friction damper rubbing power, *κH*		
$x_{6\max}$	-	8,0
$\overline{x}_6$	-	4,0
$x_{6\min}$.	-	0

Datum point (basic or zero level), around which experimental points symmetric to zero level are determined, is chosen to make s plan of numerical experiment. Results of the experiment based on the chosen set of factors allow to make a model used to determine values in other points of factor space.

The search of a mathematical model starts with the consideration of possible states of the system under investigation.

Regress equations have been obtained in the result of mathematical simulation all calculations being done using the computer program “Planning experiment for rail-road transport” (certificate № 31722 от 21.01.2010) developed by the authors of the article [Gorbunov N.I., Kravchenko K.O., Krisanov M.A., 2010].

Value EWUF in the centre of the plan for 2TE116 equals 0,79875, estimation of regress equation absolute term – 0,79875. Values of EWUF in the centre of the plan for TEM103 – 0,86075 , estimation of an absolute term – 0,86075 .

Regress equation of engagement weight utilization factor 2TE116 locomotive depending on operation factors in a encode form may be presented as:

$$\begin{aligned}\eta &= 0{,}79875x_0 + 0{,}005937x_1 + 0{,}009125x_2 - 0{,}00281x_3 + 0{,}002437x_4 - \\ &+ 0{,}0115x_5 + 0{,}008187x_6 - 0{,}0001875x_1x_2 + 0{,}0001875x_2x_3 + \\ &- 0{,}0005x_2x_5 + 0{,}000125x_1x_5x_6.\end{aligned} \quad (1)$$

Final regress equation in natural coordinate system is:

$$\begin{aligned}\eta &= -2{,}514 + 0{,}0188m_{wp} + 0{,}00164m_{sm} - 0{,}00585GI + 0{,}0041GII + \\ &+ 5{,}99R + 0{,}0533F_{fr} - 0.00000254m_{wp}m_{sm} - 0{,}0243m_{wp}R + \\ &+ 0{,}00136m_{wp}F_{fr} + 0{,}000037m_{sm}GI + \\ &- 0{,}00285m_{sm}R - 0{,}0985RF_{fr} + 0{,}006m_{sm}RF_{fr},\end{aligned} \quad (2)$$

where: m_{wp} – the first wheel pair weight; m_{sm} – servicing materials weight; GI – rigidity of the first stage of spring suspending; GII – rigidity of the second stage of spring suspending; R – locomotive wheel radius, F_{fr} – friction damper rubbing power.

Regress equation of engagement weight utilization factor TEM103 locomotive dependence on operation factors in an encode form may be presented as:

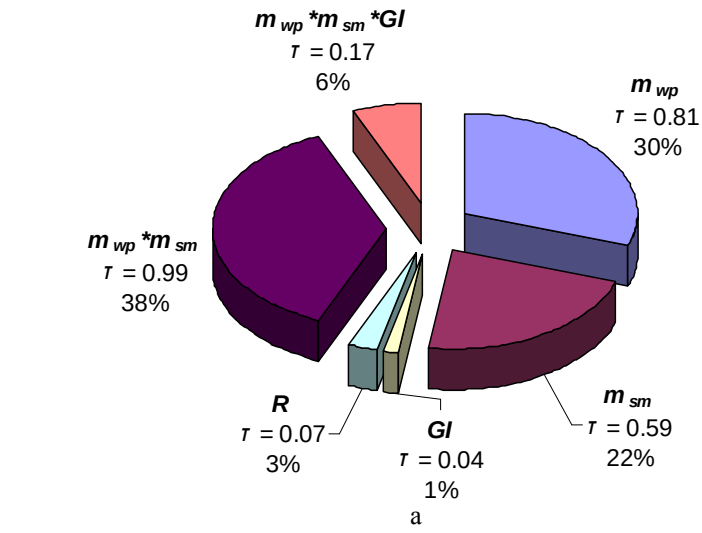
$$\begin{aligned}\eta &= 0{,}86075x_0 + 0{,}0055x_1 + 0{,}004x_2 + 0{,}00025x_3 - 0{,}0005x_4 - 0{,}00025x_1x_2 + \\ &+ 0{,}00025x_1x_2x_3.\end{aligned} \quad (3)$$

Final equation for TEM103 locomotive is:

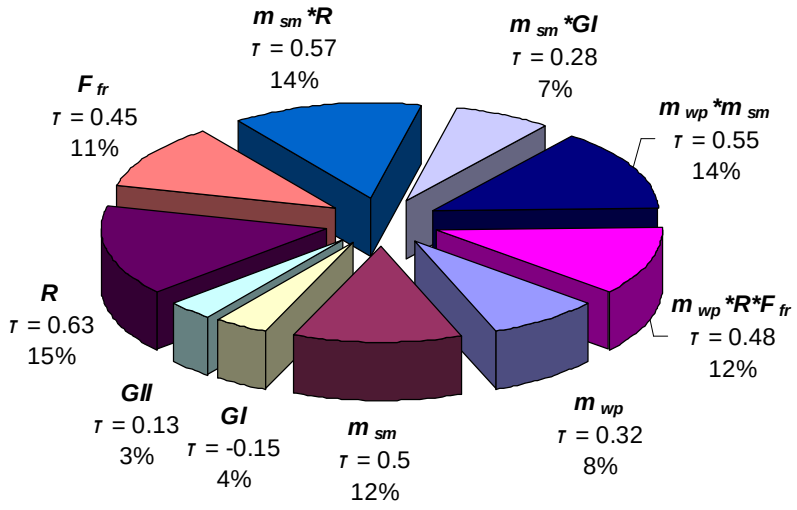
$$\begin{aligned}\eta &= -0{,}582 + 0{,}075m_{wp} + 0{,}0027m_{sm} + 0{,}681GI - 0{,}143R - 0.000135m_{wp}m_{sm} + \\ &+ 0.0357m_{wp}GI - 0.00128m_{sm}GI + 0.0000675m_{wp}m_{sm}GI.\end{aligned} \quad (4)$$

Obtained regress equations (2) and (4) allow to estimate influence of locomotive variable in operation factors on EWUF.

Total negative effect resulting from functioning of all factors for the main-line diesel locomotive 2TE116 equaled to 8,5 %, for the yard diesel locomotive TEM103 - 2,4 %. Influence degree for each of the factors on final parameter (EWUF) has been determined using pair correlations (τ_{xy}) [Pozhidaev V.F., 2006]. Calculations results are presented in the diagram (fig. 1), the calculations show that the most negative influence on the locomotive TEM103 produces pair action of wheel pair weight change and body weight change resulting from servicing materials, for 2TE116 locomotive – bending diameter change along the rolling circle taking into account wheel pair wear.



a



b

Fig. 1. Influence of operational factors on locomotive traction qualities:
a – TEM103; b – 2TE116

CONCLUSIONS

Redistribution of vertical loads of wheel pairs upon rails produces negative effect on locomotive traction qualities. Supposition that static loads of wheel pairs upon rails

are the same is not true. Calculated values have deviations from calculated ones which is connected with different construction and operation factors. Conducted investigations resulted in compiling analytical EWUF dependences on operation factors. It was stated that total effect of operation factors, locomotive EWUF 2TE116 type has been reduced by 8,5%, locomotive TEM103 type – by 2,4%.

Incompatibility of engagement weight utilization factor to normative demands may be compensated by setting additional loading device between body and bogie, their description and operation have been presented in authors' patents [Gorbunov M.I., Kashura O.L., Kravchenko K.O., Popov S.V., Kovtanets M.V. Golembievsky K.V., 2008, Gorbunov N.I., Kravchenko K.O., Popov S.V., Fesenko A.I., Grishchenko S.G., Nesterenko V.I., Lewandowski V.O., 2009, Gorbunov N.I., Kashura A.L., Kravchenko K.A., Popov S.V., Dogadin V.A., Bogopolskii E.M.,Osenin J.J., 2009]. Effectiveness of the given solution is confirmed by engagement weight utilization factor by 6,8%. As vertical loads of wheel pairs upon rails are changed in operation, additional loading device effort should change within the 2% limit for locomotives TEM103 type and within the 6% – limit for locomotives 2TE116 type.

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ВЛИЯНИЕ ЕКСПЛУАТАЦИОННЫХ ФАКТОРОВ НА ПЕРЕРАСПРЕДЕЛЕНИЕ ВЕРТИКАЛЬНЫХ НАГРУЗОК ОТ КОЛЕСНЫХ ПАР НА РЕЛЬСЫ

Николай Горбунов, Александр Костюкевич,
Екатерина Кравченко, Максим Ковтанец

Аннотация. В статье рассмотрен вопрос перераспределения нагрузок от колесных пар на рельсы в режиме реализации тяговых усилий. На основе использования теория планирования эксперимента получены зависимости, показывающие влияние эксплуатационных факторов на коэффициент использования сцепного веса. Предложено решение по регулированию усилия догружающего устройства в процессе эксплуатации с учетом полученных зависимостей.

Ключевые слова: коэффициент использования сцепного веса, теория планирования эксперимента, тяговые качества, перераспределение вертикальных нагрузок от колесных пар на рельсы, корреляция.

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ALTERNATIVE FUELS FOR TRANSPORT

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Summary. The review of automotive gas generators to produce generator gas for internal combustion engines is made. the properties of different types of gas-producing fuels and their comparative analysis are considered. The indicative equivalent of different kinds of fuel mass to gasoline and diesel fuel, and analysis of prices of major fuels is shown. A comparative environmental analysis of various types of fuels is conducted. The main parameters of the gasification process, depending on the type of fuel are calculated. The comparative analysis of standards on pellet fuel in Germany, Austria and Sweden is represented.

Key words: automobile gas generator, biofuel, pellets, gasification options.

INTRODUCTION

In accordance with the National Energy Program of Ukraine up to 2010 the need for fuel resources will amount to 273 million tones of a.f.\year. Now Ukraine covers its needs in energy resources at the expense of domestic production less than 50%, while the rest is imported. In addition, the steady decline in world reserves of fossil fuels and their constantly growing price makes energy supply of Ukraine one of the most important national problems. One of the strategic objectives is the efficient use of both renewable and non-renewable energy resources. [1, 2]

The alternative to hydrocarbon raw materials for the internal combustion engines operation is the use of transportational gasgenerators, that process the local solid fuel oil or fossil (wood, peat and brown coals), as well as derivatives of these fuels (wastes of timber and wood, plants biomass, mixture of coal fines (upto 25mm) and coal dust, in ratio 1:2, peat bricks, semi). [Geletukha 1998, Samylin 2005]

OBJECTS AND PROBLEMS

Produced at present, automotive gasifiers, do not require any major alterations in the car are set: on the trailer - towing gas generator as «Imbert» company VOLVO, company «Attik» Ukraine; inside the body of trucks - gasification truck, Framce; between body and cab - УГК-150 with the size of the gas generator, diameter 600 mm,

height 1800 mm, total weight - 300 kg, which uses waste wood as fuel for engines for ZIL and GAZ - upto LAZ and LuAZ, Ltd. «Nasha Energia», Ukraine, Group of Companies "Adaptika", Russia; on the the cockpit - a tractor with the gas generator as "Imbert" France [Samylin 2005]

A disadvantage of known automobile gas generators is, that they reduce the effective area of the vehicle or require the use of trailer.

To increase the effective volume and area of gas generator truck body seems appropriate to create new automated gas-motor vehicles, that would have minimum dimensions for height in order to install them under the car body.

One of the variants of solutions to this problem is the separation of the reaction and bunker zone gasifier. To implement such separation it is necessary to choose the form of solid fuel.

The aim of this work is to choose the solid fuel for automated gas-producing installations, that are used for industrial vehicles, minimised in height and weight.

The fuel for gas-producer vehicles, must have: a certain size pieces; specific humidity, lowest ash content and ash melting, which should not exceed the established limits; a certain amount of volatile; high reactivity capacity; sufficient mechanical strength or abrasion, that the fuel couldn't be scattered during transportation, storage and gasification in the gasifier; high specific heat value; low cost. The last figures determine the profitability of a particular type of fuel, and other parameters affect the flexibility and stability of the process of gasification gas generator vechicle, reliability of gas generators, frequency of reloading. According to indicators, fuel is divided into classes: 1 - fuel of good quality, 2 – fuel quality is quite satisfactory, 3 – fuel of satisfactory quality. Characteristics of gas-producing fuels are presented in Table.1 [19, Ovsyanko 2007, Fomin 2005, Yudushkin 1955, Obemberger 1998, Shchadov 2007].

Table 1. **Characteristics of gas-producing fuels**

The fuel	Class	Size pieces, mm	Content in % by weight not more than				The melting point of ash, C^0 not less than	Bulk density, kg / m^3	Calorific value of bulk volume, MJ / kg	Abradability, %
			moisture $W_{a\acute{o}c}$	Ash A^e	Volatile V^r	Sulphur S^c				
Waste wood	1	30x40x60	30	0,4 -1	75 - 80	- - - -	1400	220 - 360	10,3	
Pellets with low crust (first grade)		<∅8 *l* 0,5-30	5-7%	< 0,7	8-12			600	18,9	Not more 1
Industrial pellets the content of the crust over 0,7-1,5%		∅ 8-12 *l* 0,5-30	5-7%	>0,7				500	18,9	Notmore 1
Semi	2	10-40	9	8-11	9	1,0	1100	400-450	12,2	
Anthracite	3	6-13	3-8,5	7-10	5-7	1-1,5	1250	900-1000	26,9	

Dimensions of fuel affect their bulk density and consequently on the volume of equipment, as well as on the efficiency of passage through the auger feed system for automated generator sets and attrition. Bulk density - a indicator which is associated with the cost of pellets transporting and storing. The lower price - more expensive transportation. Bulk density of pellets depends on the density of fuel pellets and their diameter. The density – the rate, which affects the efficiency of the furnace, burning rate, transportation costs, storage. The greatest bulk density is anthracite and then pellets with low bark. For these fuels is possible to use bunker of smaller volume. For screw feed system of small diameter the use of anthracite is most effective and then pellets with low bark. Moreover, Many well-known modern heating plants because of the construction of supply system, work better with a 6 mm pellet. Equipment manufacturer specifies the type and diameter of the pellets to be used. The use of pellets of other sizes is not recommended, as to begin with, automatic system of the boiler is configured for optimal air flow and pellet diameter of this particular, secondly the use of pellets of larger size than it is recommended, leads to increase the stress on the mechanics of the boiler, that can lead to premature failure of the system. With regard to abrasion it is obviously, it will be the smallest of anthracite, because it has the greatest strength [Tokarev 1955], and further waste.

Humidity - indicator that affects not only the calorific value, but also on storage stability, excluding the self-ignition, minimizing losses. This indicator also affects the gas generator, reducing its efficiency. This is due to the fact that part of the energy in the gasification of wood goes to evaporating the water contained therein. The smallest is approximately the same value of moisture content has coal and pellets of different varieties.

Ash content is a necessary measure, as its content in the fuel leads to a decrease in the efficiency of gas generators, complicates the application of automation. In the gas generators the gasification chamber is slaggingIn the case of ash with a low melting point (fuel of the second and third class) and leads to emissions of particulate matter. The lowest ash content in fuels is in the fuels of the first, and the highest – of the second and third class.

Although, that most of the sulfur refers to combustible matter of fuel - it is a harmful impurity. Resulting during the combustion of sulfur dioxide pollutes the environment and destroys the metal surfaces of the gas generator, purification systems for gas and engine. From the above data follows that the most appropriate fuel for the gasification is the fuel of the first class.

Indicator of volatile substances is used to select the type of gas generator. Obviously, for fuel made of wood waste gasifier must be applied with a reversed process, and for other fuels – direct gasification process [Geletukha 1998, Bridgwater 2002]. The reduce of volatile substances in the fuel pellet is connected with the peculiarities of their manufacture.

The great importance has the economical efficiency of the fuel. Approximate equivalent of different types of fuel mass (German fuel classification for gas generators) using (vistapellets.com) data is presented in Table. 2 .

Table 2. **Approximate equivalence of different types of fuel by mass**

Fuel Type	Amount of solid fuel in kilograms attributable	
	to one liter of gasoline	To one liter of diesel fuel
Wood (Holz)	2-3	3,2-3,8
Peat (Torf)	2,5-3	4,5 кг
Lignite (Braunkohle)	2,5	3,5
Charcoal (Holzkohle)	1,3	-
Anthracite (Anthrazit)	1,2-1,6	1,8-2,2
Pellets	1,25-1,87	2

The expected price of fuel depends on the size of calculated working calorific value capacity taking into account the moisture and ash content. This index has a value in terms of the cost of transporting fuel in large volumes. Recent calculations and analysis of prices of major fuels show, that the pellets are in many cases superior to traditional fuels (not only waste wood and coal, and diesel fuel) by the economy of use. It is necessary to consider not the price of 1 ton of fuel, but the cost of 1 kilowatt of energy, produced when using this fuel (table. 3) [19].

Table 3. **Analysis of prices of major fuels**

Fuel Type	Heating value, kW•h/ kg	Efficiency, %	Fuel price, EUR / tonne	The cost of heat, EUR / kW • h
Diesel fuel	11,63	80	250	0,027
Coal	4,65	50	45	0,019
Electricity		95		0,033
Waste wood	2,0	60	19	0,016
Pellets	4,8	85	90	0,022

When burning pellets the efficiency reaches 85%, which corresponds the use of gas and liquid fuels. The cost of heat using wood pellets can be reduced with the increase in combustion efficiency upto 97%, that is achieved by burning pellets in boilers with burners bulk-type [Geletukha 1998, Obemberger 1998].

In connection with the entry into force the Kyoto Protocol to the UN Framework Convention Climate Change becomes a legitimate format for JI projects (Article 6 of the Kyoto Protocol). This means, that when we choose the fuel for automobile producer gas plants its environmental safety must be taken into account. One of the indicators of the environmental security is the amount of ash appeared after combustion according LLC “Resayklers.ru”:

- the burning of brown coal ash produces up to 40% by weight of fuel burned;
- coal combustion – appr. 20%;
- the burning of wood – 0,5-3%.

The obvious advantage when used as fuel wood has. In this case, the ashes from wood burning can be used as fertilizer, and slag from coal combustion contains heavy metals and has though weak, but the high radioactivity [Hasler Ph , Jorgensen 1996].

The next indicator of environmental security is the amount of pollutants emitted into the atmosphere by burning of fuels (Table. 4).

Table 4. **Emissions of harmful substances during combustion of different fuels (According to "Promgaz")**

Fuel Type	Particulates (kg/Gkal)	Benzapyrene (kg/Gkal)	Heavy metals (10^{-6} kg/Gkal)
Gas	0,004-0,017	0,057-0,129	-
Fuel oil	0,2-0,4	0,046-0,69	1,1
Lignite	0,26-26,0	0,1600,67	-
Coal	8,7-12,3	0,07-0,44	0,96-64,0
Peat	3,8-11,4	1,0	0,8-3,1
Firewood	8,07	1,36-4,95	-

Heavy metals – in this case this is the sum of the content of vanadium pentoxide, arsenic, chromium and mercury in gas emissions.

These data show, that wood fuel is more environmentally friendly, than coal, with preference, apparently, should be given to the gasification plants.

The calculation of basic parameters of the gasification process, depending on the type of fuel, presented in Table 1, is presented on the elements in accordance with procedures [Samylin 2005, Yudushkin 1955, Tokarev 1955] for gasoline 4-stroke engine UMP-4215.10 (EURO-0) [5, 6] in Table 5. Working volume, 2890 куб. см. Compression ratio 8.2. The filling ratio of the engine generator gas 0.53. Engine speed 2400 rpm.

Table 5. **The main parameters of the gasification**

Parameter	Fuel				
	Waste wood	**Pellets** (first class)	Industrial Pellets	Semi	Anthracite
Gas output of 1 kg of fuel, m^3/kg	1,84	2,579	2,566	4,059	4,299
Air consumption for the gasification of 1 kg of fuel, m^3/kg	1,162	1,628	1,619	2,557	2,915
Gas moisture content, kg /m^3	0,392	0,183	0,184	0,063	0,015
Efficiency of the gas generator, %	78,7	83,9	83,9	66	81
Air consumption for combustion of 1 m^3 of gas generator, m^3/m^3	1,014	1,129	1,129	0,824	1,138
Calorific value of gas-air mixture, kkal/m^3	561,4	591,157	591,157	514,77	572,11
Hourly consumption of solid fuel, kg / h	27,372	18,48	18,578	13,73	11,038
The diameter of the gasification chamber, mm	264,39	183,62	184.18	241,76	237.44

Anthracite along with pellet fuel has good performance, but the process of burning coal can not be automated, gas contains a high content of sulfur compounds, should be disposed of slag.

Based on the drawn analysis, it is obvious, pellet fuel is the best for the creation of automated gas-producing installations, used for industrial vehicles, with minimum dimensions for height and weight.

Since the pellets are made from different kinds of raw materials it is necessary to determine their effect on quality (table 6).

Table 6. **Indicators of pellets quality, made of different raw materials according to the companies "EKOROSS"**

Quality indicators	Feedstocks		
	Sawdust		
	Soft-wood	Soft-hardwood	Mixture (50% pine and 50% hardwoods)
Density	1,147	1,141	1,144
Bulk density, kg/dm^3	526	511	520
Ash content, %	05		
Calorific value, MJ / kg	18,9	18	18,4
Abradability	0,21	0,2	0,2
Humidity	8,5	8,5	8,3
The content of SO and SCb in gases of pellets combustion , %	0		
Homogeneity, the absence of impurities	No extraneous		

Table 6 should be clear that the quality of pellets, obtained from softwood and soft-hardwood by pelleting sawdust do not differ from each other. Since the content of the fuel component (C и H) in the wood of different species varies slightly (the softwood contains carbon 50,5 %, hardwood 49,6%, hydrogen is equal -6,2%), the influence of wood on the calorific value of pellets is not much.

As mentioned above, the cost of pellet fuel is substantially affected by transport costs, therefore it is not less important to produce it in Ukraine. Pellet market in Ukraine today is at an early stage of development and according to the results of the company D & P Consult analysts estimation the annual pellet production in Ukraine in 2008 is about 190-200 tons (about 90% of it is exported to Europe). Shaped pellets production in Ukraine today are represented by maximum of 15-18 local companies. The volume of pellet production in Ukraine since 2007 to 2010 is shown in Fig. 1 (assessment of D & P Consult).

As seen in Figure, wood pellets occupy about 30-35% of total pellet production other pellets are made of sunflower husk and other crops. It is impossible to show the structure of the Ukrainian market of pellets according to product quality (first grade, industrial). The company D & P Consult explaines this fact as the specific of the Ukrainian pellet market. A large number of medium and small enterprises make pellets for their own consumption and often do not pay special attention to the quality and composition. In Ukraine there are no standards for the quality of the product. Companies that manufacture wood pellets for European markets follow standards:

- German Standard DIN 51731/DIN plus, grade 2;
- Swedish Standard SS 18 7120;

- Britisch BioGen/ United Kingdom, the Code of Fair Trade Practices;
- Austrian standard ONORM M 7135.

Fig. 1. Volume of pellet production in Ukraine from 2007 to 2010 (evaluation of the company D&P Consult).

CONCLUSIONS

It is established, that for automated gas plants producers for vehicles the first class pellets, low bark, diameter of 6 mm optimum fuel pellets are the most optimal choice. The cost of pellets of the first class is up to 2-2,5 times lower than the cost of gasoline. The use of pellet fuel enables to organize its continuous supply from the horizontal separately located from the gasifier storage bunker by the screw conveyor to the zone of fuel gasification. This allows the low-power sets to run on a single load during the whole day without unsealing the gasifier and install the gas generator under the body of the truck. The volume of gasification chamber for pellets is correspondingly smaller than that for other fuels, and so the size of the entire gas generator is reduced as a whole. With the gasification of the pellets gasifier efficiency is 85%, while using the bulk-type burners the efficiency of the use of pellets could increase to 97%. The use of pellets facilitates automation - gasification process is subject to certain physical conditions (temperature, pressure), that control microprocessors, automation and other analyzers. Lambda probe and the air sensor, for example, are installed almost in all modern cars. Pellets are environmentally friendly type of fuel.

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АЛЬТЕРНАТИВНОЕ ТОПЛИВО ДЛЯ ТРАНСПОРТА

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Аннотация. Сделан обзор автомобильных газогенераторов с целью получения генераторного газа для ДВС. Рассмотрены свойства различных видов газогенераторных топлив и проведен их сравнительный анализ. Представлен ориентировочный эквивалент разных видов топлива по массе к бензину и дизельному топливу и анализ цен на основные виды топлива. Проведен сравнительный экологический анализ различных видов топлив. Рассчитаны основные параметры процесса газификации в зависимости от вида топлива. Представлен сравнительный анализ норм на пеллетное топливо Германии, Австрии и Швеции.

Ключевые слова: автомобильный газогенератор, биотопливо, пеллеты, параметры газификации.

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ERROR OF AVERAGE VELOCITY FLOW MEASUREMENT IN VENTILATION SYSTEM CHANNELS

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Summary. Influence estimation on exactness of measuring average velocity turbulent flow of radius setting velocity sensor is produced. Analytical dependences, relating the measuring error with the Reynolds number are got. The expressions for determination radiuses of average velocity in ring cylindrical channel are established.

Key words: industrial discharges, velocity, Reynolds number, velocity, flow.

INTRODUCTION

One of the most important problem of ventilation systems parameters control of anthropogenic dangerous objects is determination of harmful discharges total volume. It is set depending of gas flow volume of stream in ventilation pipes, directly carrying out the harmful discharges.

Methods and instrumentation of measuring flow rate are various [1, 2], but aerodynamic method [3] is the most reliable and it obtain the most application. The flow rate is determined by average velocity value, found on difference between total and static pressure,

$$Q = u_0 S ,$$

where: u_0 is average velocity; S is cross-sectional area of vent channel.

The velocity sensor is set on the length no less than 20 hydraulic diameters of channel from entrance [3, 4], in order to have the formed velocity profile in control section. The flow measurement accuracy also depends on the place of setting sensor on channel section, as velocity flow is unevenly distributed on channel section. In addition, velocity distribution depends on the Reynolds number [2, 5, 6], i.e. from the average velocity or flow rate. And, if for the round cylindrical channels the recommendation on location of velocity sensors at the developed turbulent flow are present [3], then for the ring channels such information is absent in literature. At the same time, ring cylindrical channels are used frequently as outlet for vent systems, for example, the discharge of

the ventilation systems of atomic power units in the emergency-repair mode is carried out through such channels.

Analytical dependences, relating the measuring error of average velocity with the radius of sensor location in round cylindrical pipe and Reynolds's number at the turbulent flow mode are established in the presented work. Also, the expressions for the estimation of zero systematic error radius of average velocity measuring in ring cylindrical channel are determined.

Velocity distribution at turbulent flow in round cylindrical pipe for gas flow at velocities up to 70 m/s and Reynolds numbers Re > 10^4, looks like [5, 6]

$$\frac{u}{u_0} = \frac{(n+1)(n+2)}{2}\left(1-\frac{r}{r_0}\right)^n, \tag{1}$$

where: u_0 is flow average velocity; n - index of degree, depending on Reynolds number (for example, n=1/7 for Re=10^5); r is radius of arbitrary point, counted out from the pipe axis; r_0 is pipe radius.

Reynolds number:

$$\mathrm{Re} = \frac{u_0 d}{\nu}.$$

Here ν is kinematics viscidity.

Dimensionless deviation of velocity from average value

$$\varepsilon_u = \frac{u-u_0}{u_0} = \frac{u}{u_0} - 1,$$

therefore systematic error of average velocity measuring with a glance of (1), represented in percents, will make

$$\delta_u = \left|\frac{(n+1)(n+2)}{2}\left(1-\frac{r}{r_0}\right)^n - 1\right| \times 100,\%. \tag{2}$$

Calculations show that at setting the sensor in pipe center the error exceeds 20% for Re=10^5.

The value of average velocity radius can be determined, putting the $u = u_0$ in expression (1),

$$r^* = \frac{d}{2}\left(1-\left(\frac{2}{(n+1)(n+1)}\right)^{\frac{1}{n}}\right). \tag{3}$$

For determination of average velocity radius at the arbitrary Reynolds numbers we will use the experimental data [6] of values of degree in distributing index (1) of velocity on the pipe section. The n values for the row of Reynolds numbers Re are presented in table.1.

Table 1. **Values of degree index in velocity distributing**

Re	$4{\cdot}10^3$	$2{,}3{\cdot}10^4$	10^5	$1{,}1{\cdot}10^6$	$3{,}2{\cdot}10^6$
n	1/6	1/6,6	1/7	1/8,8	1/10

Tabular data is approximated on least-squares method by the next dependence

$$n = 0{,}252 - 2{,}29\times10^{-2}\lg \mathrm{Re}\ . \tag{4}$$

Taking into account approximation dependence (4) it is possible to determine relation between average velocity radius with the Reynolds number for round cylindrical channel. However, as calculations show, the average velocity radius practically does not depend on the Reynolds number and matters $\approx 0{,}76r_0$ in the range of $\mathrm{Re}=10^5 \div 10^6$, which is working band for industrial vent systems.

We will present next algorithmic expression for determining the power dependence for the velocity profile in ring cylindrical channel

$$\frac{u}{u_m} = \begin{cases} \left(\dfrac{r-r_1}{r_m-r_1}\right)^n, r_1 \le r \le r_m; \\ \left(\dfrac{r_2-r}{r_2-r_m}\right)^n, r_m \le r \le r_2; \end{cases} \tag{5}$$

where: u_m is maximum velocity; r_1, r_2 are radiuses of internal and external surfaces; r_m is maximum velocity radius.

We use next empiric dependence for the maximum velocity radius [7]

$$\frac{r_m - r_1}{r_2 - r_m} = \left(\frac{r_1}{r_2}\right)^{0{,}343}\ . \tag{6}$$

Because average velocity

$$u_0 = \frac{Q}{\pi\left(r_2^2 - r_1^2\right)},$$

and flow rate

$$Q = 2\pi\left(\int_{r_1}^{r_m} urdr + \int_{r_m}^{r_2} urdr\right),$$

in recognition (5) possible to get

$$\frac{u_0}{u_m} = \frac{2}{(n+2)(n+1)}\frac{r_2 + r_1 + nr_m}{r_2 + r_1}\ . \tag{7}$$

On basis of (7) we will transform dependence (5) to the form

$$\frac{u}{u_0} = \frac{(n+2)(n+1)}{2}\frac{r_2 + r_1}{r_2 + r_1 + nr_m}\times$$

$$\times\begin{cases} \left(\dfrac{r-r_1}{r_m-r_1}\right)^n, r_1 \le r \le r_m; \\ \left(\dfrac{r_2-r}{r_2-r_m}\right)^n, r_m \le r \le r_2. \end{cases}$$

Putting equality $u=u_0$ here, we determine expression for two average velocity radiuses

$$r_1^* = r_1 + (r_m - r_1)A^{\frac{1}{n}}, \tag{8}$$

$$r_2^* = r_2 - (r_2 - r_m)A^{\frac{1}{n}}, \tag{9}$$

where:

$$A = \frac{2}{(n+2)(n+1)} \frac{r_2 + r_1 + nr_m}{r_2 + r_1}.$$

Rough estimation of Reynolds's number influence on the radius of zero systematic error of velocity measuring is possible to execute on the basis of approximation dependence (4). However calculations show that, as well as in the case of round cylindrical channel, in the working range of industrial vent systems Reynolds numbers, the value of average velocity radius changes not substantially.

CONCLUSIONS

Thus, the accuracy of average velocity measuring of turbulent stream substantially depends on the radius of sensor location. At the sensor location on the radius of average velocity measuring error practically does not depend on the Reynolds number in the range of Re = $10^5 \div 10^6$. From two radiuses of average velocity in ring cylindrical channel, radiuses of internal and external surfaces determined coming from correlation, in practice it is recommended to use greater, where because of less radial gradient of velocity weaker the error of sensor setting shows up on exactness of average velocity measuring.

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ПОГРЕШНОСТЬ ИЗМЕРЕНИЯ СРЕДНЕЙ СКОРОСТИ ПОТОКА В КАНАЛАХ ВЕНТИЛЯЦИОННІХ СИСТЕМ

Елизавета Гусенцова, Алим Коваленко, Манолис Пилавов

Аннотация. Произведена оценка влияния на точность измерения средней скорости турбулентного потока радиуса установки датчика скорости. Получены аналитические зависимости, связывающие погрешность измерения с числом Рейнольдса. Установлены выражения для определения радиусов средней скорости в кольцевом цилиндрическом канале.

Ключевые слова: промышленные выбросы, скорость, число Рейнольдса, расход.

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THE PROBLEM OF WORKERS PROFESSIONAL DISEASE ARISE IN CONNECTION WITH DISPARITY OF THEIR PSYCHOPHYSIOLOGICAL PREPARATION TO REQUIREMENTS OF CERTAIN LABOUR ACTIVITY RESEARCH

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Summary: In the article the analysis of the traumatism condition is conducted on enterprises, reasons of workers professional diseases origin and grounded obligatory psychophysiological examination introduction necessity on the enterprises of Ukraine. Fig. 4. Ref. 15.

Key words: labour protection, worker, traumatism, professional disease, psychophysiological examination.

INTRODUCTION

On the modern stage of labour protection development its European model expressly determines measures on the improvement of labour protection and worker health protection in the workplace in accordance with a directive № 89/391/ ECC [http://zakon.rada.gov.ua].

The dynamics of professional diseases did not especially change in the last few years. From labour medicine Institute of AMS in Ukraine data an index of professional morbidity frequency on 10 thousands workers in 2005 was 4,61. Among 38 Europe countries on the professional morbidity indexes Ukraine occupies 21 place, while, for example, Denmark which occupies the firstplace on frequency of professional morbidity registers 438,6 cases on 100 thousands of workers [B. Panov, 2008].

Every year in the world, according to information of IOW, approximately 270 million accidents, related to implementation professional duties, and 160 million professional diseases are registered. Almost 354 thousands of workers perish on a production, from them in countries with the developed market economy – 16,2 thousands, in former social countries – 21,4 thousands, in China – 73,6 thousands, in

Indium – 48,2 thousands, in other countries of Asia and Pacific ocean – 83 thousands, in countries Near east – 28 thousands, in the countries of Africa in the south of Sahara – 54,7 thousands, in the countries of Latin America and Caribbean pool – 28,6 thousands. Unfortunately, about 12 thousand of died – children. It is also necessary to take into account the amount of workers which got professional disease and were excluded from a production process, for example, in 2004 2,2 million persons are incorporated, thus 32% the oncologic made, 23% – warmly vascular, 19% – traumatology, 17% are infectious diseases. As a result of illness every day in the world is absence on the workplace about 5% labour force. Through charges, related to the industrial accidents, lost to 1250 milliards dollars, or about 4% of world gross domestic product [Labour safety, 2008].

Professional activity of workers of many branches of industry remains dangerous, without regard to technical progress, as related to mobilization of functional backlogs, and in many cases passes in extreme and emergency situations, that requires enhanceable physical and emotional firmness. Exactly such workers which are added an enhanceable risk for a health require the special attention from the side of the state. Ukraine for the amounts of mortal accidents on 1000 workers substantially (negatively), as an analysis of the state of industrial safety testifies, exudes between the economic developed countries and former socialistic countries of Europe (Ukraine – 0,104, countries with a market economy – 0,038, former socialistic countries of Europe – 0,053). According to [A. Ena, 2008] Ukraine occupies the second after Portugal on a traumatism and 20 place after China for deaths of people on a production.

Most failures happen through fault of human factor. Results of analysis of production traumatism and death rate from industrial accidents for 2000-2006 in Ukraine confirm, that reason of plenty of accidents are mistakes of workers, through what every year injured to 75% and all of about 80% victims perished, group accidents also took a place through fault of «human factor» – 75-85% (after statistical materials of Ukrainian State mountain industrial supervision bulletins).

RESEARCH OBJECT

Every year, in spite of measures which are conducted in different countries, level of production traumatism, in including mortal investigation, and the amount of professional diseases grows [Labour Safety, 2008]. It concernes those countries, where sufficient attention spared this problem. In the field of labour protection examined all questions, related with the psychophysiological state of worker. In the economic developed countries health of worker is a necessary condition which directly influences on a production process and quality of mined-out products: «a diseased producer can not produce quality commodity».

The purpose of the article is necessity of introduction obligatory psychophysiological examination on the Ukrainian enterprises research.

RESULTS OF EXPERIMENTAL RESEARCH

For the last decades dynamics of revealing professional diseases in Ukraine differs fluctuations. So in 1993-1995 there was its increase, related to passing an Act «About a labour protection», which gives a right for the patients to get a substantial financial indemnification of the health damage, but to 2000 – diminishing in connection with stopping of regressive payments for professional disease. However from 2001 with entering into the arm of the law «About obligatory state social security from an industrial accident and professional disease, that resulted in the loss of capacity» there was growth of professional morbidity level again (fig. 1).

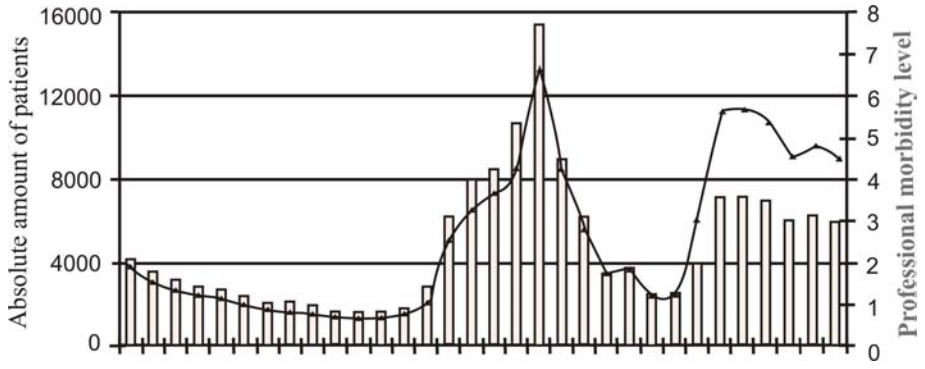

Fig. 1. Absolute amount of patients (▭) and professional morbidity level in Ukraine on 10 thousands workers (—▲—) (1976-2007)

The professional morbidity indexes in the highly developed countries of the world serve as evidence of it. According to [A. Basanets, 2008] every year in Ukraine 6-8 thousands of professional diseases are registered with fluctuations in different years from 2,5 to 15,5 thousand Sanitary-hygenic description of supervision objects specifies on an amount:

- workers on the objects of supervision;
- objects which are under control of Statesanepidemservice;
- objects which answer the requirements of sanitary norms (fig. 2...4).

At the same time in Russia – 10-12 thousands, in Japan – 15 thousands, in the USA – 190 thousands are registered diseases accidents. If in Ukraine a level of population professional diseases on 100 thousands of workers was 13,3, on the whole in the countries of Europe – 30,1.

Among diseases the first place is occupied by illnesses of breathing organs (pnevmokonios, chronic bronchitis), then disease of the bone-muscularsystem and connecting tissues, oscillation illness, by the way professional diseases of skin are almost not registered. The most accidents of professional diseases and poisonings is registered in the Dnepropetrovsk, Donetsk, Lugansk and Lviv regions. Basic branches in which found out the biggest amount of professional diseases are machine-building, metallurgical, coal industry.

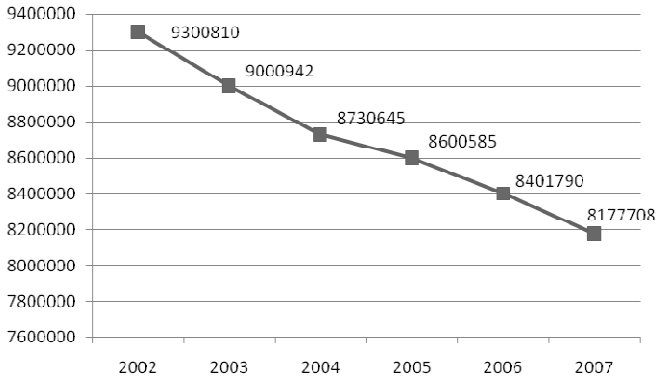

Fig. 2. An amount of workers is on the objects of supervision (2002-2007)

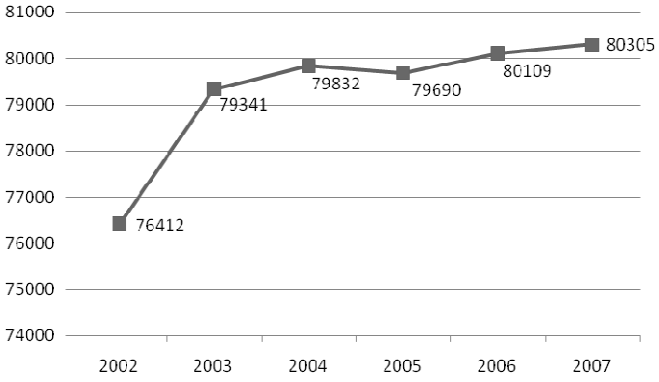

Fig. 3. Amount of objects which are under control Statesanepidemservice (2002-2007)

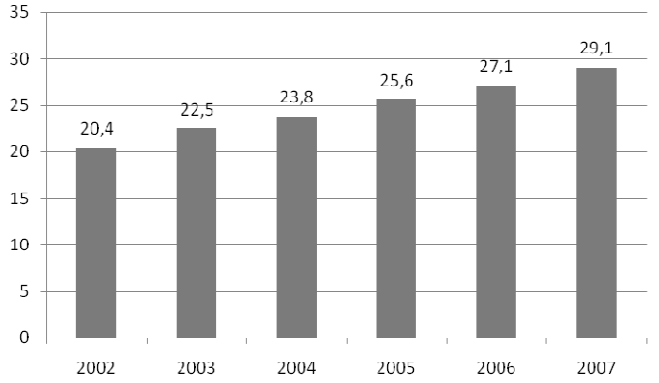

Fig. 4. Amount of objects (%) which answer the requirements of sanitary norms

In connection with an economical situation which was folded in Ukraine, the brightly expressed forms of chronic diseases and disability which comes as a result of the ill-timed measures use are all more frequent registered, thus among the persons of young capable working age. Transformation, which is observed in character, flowing and terms of professional diseases development related to diminishing of technological actions intensity, increase of psychoemotional tension level and decline the physical loadings. In same queue, modern pattern of production change, unwillingness of employers instrumental in the exposure of professional diseases on the their development early stages, for avoidance of additional charges on treatment and rehabilitation of a victim, incuriosity of workers in the exposure of professional diseases through possibilities to lost a job is reasons of low exposure and registration of professional diseases.

As a rule, an accident rate and traumatism through fault of «human factor» is conditioned: by insufficient motivation of observance of safety; by the low level of professional preparation on questions of workers safety; admitting to implementation risky jobs of people with the enhanceable traumatism risk, psychophysiological qualities of which do not answer the requirements of certain labour activity; by the presence of factors which reduce reliability and safety of worker activity (fatigue, exhaustion, excitation et ctr.).

As practice shows, in Ukraine of expense on measures in relation to a labour and prophylaxis of accident rate and production traumatism protection in once or twice below than financial losses from failures. In spite of that during realization of any measures it is necessary to take into account financial charges, much major to spare the special attention the social consequences of failures and catastrophes – loss of health, life of citizens and country labour potential, increase of incomplete families amount and children-orphans. Combination of ecological and professional factors with psychological overloads, from data of WOH, is reason of most diseases. Approximately 30-50% workers of the developed countries grumble about stress overloads to the parahypnosiss, depression, cardiovascular pathology.

Analysis and research of practical results which are conducted in the different countries of the world, show a dependences of the state of health and capacity of workers on their psychophysiological qualities high degree, that testifies about expedience on enterprises with the enhanceable level of production danger psychophysiological selection and psychophysiological examination. Such approach, as developed countries experience testifies, results to diminishing of the technical systems depending on appearance and terms of activity accident rate level on 40-70%, diminishing of technogenic catastrophes amount – on 20-25%, decline of traumatism level as a result of «human factor» – on 40-45% [A. Ena, 2008].

A professional psychophysiological selection and psychophysiological examination is the problems of «human factor» directed on a production and substantially influence decision on the production increase of strength security, maintainance of workers health.

The enhanceable danger works are characterized by the psychophysiological factors of production danger presence – physical (static and dynamic overloads, hypodynamia) and psychological (mental overstrain, labour monotony, emotional

overloads, overstrains of analyzers). The indicated factors draw change in the human state under act of weight and labour tension.

The enhanceable danger works implementation and such which require a professional selection, as a rule, foresees the presence of permanent or temporal harmful or dangerous factors which can be conditioned:

- by the deficit of information for making a decision;
- by physiology discomfort – disparity of labour terms normative requirements;
- by the deficit of time for making a decision and implementation of actions;
- by enhanceable complication of task;
- by the presence of the real threat to life or health;
- by the enhanceable cost of erroneous actions;
- by less congestion information (sensory deprivation);
- by the overload of information.

These terms quite often provoke exceeding of physiology norm at implementation of professional duties which are accompanied maximal tension of physiology and psychical functions. In the case of disparity of psychophysiological professionally important qualities of worker quickly a capacity goes down the requirements of profession, gross violations, erroneous actions, are assumed, blowing off activity et ctr. Such activity is characterized mionectic reliability and efficiency, and the state of worker – by the enhanceable risk of accident origin, although some time the professional duties implementation can take a place noninfringement and derangements due to the permanent overstrain of the regulator organism systems. But by the result of such state proof functional changes development, boundary disorders which hardness to find out at an ordinary medical review can become very quickly. The protracted flowing of such unfavorable situation draws development of different diseases, in thereby except for the enhanceable risk of workers psychophysiological qualities diseases origin which answer the profession requirements not fully, there is an enhanceable risk of accident origin.

For example, to the loss of ability with the proper speed and exactness to react on external influences, that promotes the risk of accident origin conducts violation of connection between the sensory and motive centers of the nervous system for workers higher departments. And also experiencing of danger feeling can strengthen failings which arise up concertedly, co-ordinations of motions. Such violations often appear in co-ordination of especially exact and difficult hands motions.

The change of emotional processes also influences on probability of accident origin. For example, emotional instability, unexpected changes of gladness and spite, sharp emotional reaction, is enhanceable on insignificant external irritations strengthen propensity of worker to the threat of accident origin and diminish his protected.

Psikhofiziological examination is conducted on the basis of statistical calculation the developers of the program "The Programmatic test complex for the professional psychophysiological selection of specialists, busy on works with an enhanceable danger", producer the State enterprise the "Main educational-methodical center of Ukraine State mountain industrial control".

At the special statistically grounded algorithms of decision approval it is possible to get the most reliable forecast estimation of worker activity progress and reliability. In a conclusion, which is given after passing of worker psychophysiological examination

about accordance to the professional requirements to implementation of enhanceable danger works and such which need professional selection, a group PFO is specified and recommendations are given in relation to accordance to the professional requirements for indicated works implementation. For present moment utillize 4 groups of PFO admittance after marks:

1 group PFO: 56-80 – it is an excellent result, sufferet to implementation of the indicated works;

2 group PFO: 50-55 – it is a good result, sufferet to implementation of the indicated works;

3 group PFO: 45-49 – it is a satisfactory result, sufferet to implementation of the indicated works, but it is recommended to get the repeated examination in 1 year;

4 group PFO: below 45 – it is an unsatisfactory result, not recommended to implementation of the indicated works.

Conclusion of psychophysiological examination of worker about accordance to the professional requirements to implementation of enhanceable danger works and those which need professional selection, has recommendation character and necessarily given at passing of medical reviews the certain categories workers in obedience to [Order HSM, 2007; Order HSM, 1994; Order HSM, 1995].

During the research leadthrough with SE Lugansk ETC NSEI FS and LS statistical information (tab. 1) was got in relation to the amount of workers which passed psychophysiological examination in the last few years.

Table 1. **The results of workers psychophysiological examination passing, busy on works of enhanceable danger in a period from 01.04.2006 to 01.04.2010 [Letter, 2010]**

	01.04.2006-01.12.2006	01.01.2007-01.12.2007	01.01.2008-01.12.2008	01.01.2009-01.12.2009	01.01.2010-01.04.2010	In total
1 group PFO	222	216	141	83	36	698
2 group PFO	819	3032	5106	3511	1610	14078
3 group PFO	557	1610	1931	1333	583	6014
4 group PFO	194	436	408	229	78	1345
People passed in total	1792	5294	7586	5156	2307	22135

The modern development stage of this researches direction characterizes the accumulation of actual material and wideuse of psychophysiological selection for the practical tasks decision [Andrianova, 2011]. In Ukraine first officially "List of works, where necessary a professional selection" was ratified the order of Health protection ministry and State mountain industrial control in 23.09.94 № 263/121, also became the important stage of professional selection system introduction [Order HSM, 2007].

The psychophysiological examination combine the problems of medical, biological and psychological branch of science and practice. As a result in 2008 organization and order of psychophysiological examination leadthrough for the normative settlement the project of separate normative act – «Order of organization and leadthrough of psychophysiological workers examination was developed for implementation of enhanceable danger and such which require a professional selection

works» with claim of it the general order of Health protection ministry and State mountain industrial control, however now so remained in the stage of project.

Actual subsequent scientific developments, directed on technology of the psychophysiological testing perfection, psychophysiological state monitoring and register of workers for enhanceable danger works implementation and such which require a professional selection [Krushelnitska, 2000; Dushkov, 2002; Agapov, 1991; Klimov, 1991].

On the way of economic and social development of our state non-acceptance of effective measures serves as a substantial obstacle for the improvement of workers health in Ukraine. In this connection there was a necessity of measures complex program development, directed on the professional disease prophylaxis and making healthy of labour terms, and also perfection of medical- social help in the real economic terms.

SUMMARY

It is set as a result of the executed research, that financial losses, which are tested by enterprises in case of accidents or failures occurring as a result of insufficient psychophysiological preparation which does not answer the requirements of certain labour activity, more than charges are on the professional selection leadthrough. Therefore the got results specify on expedience of psychophysiological examination leadthrough necessity on the enterprises of all patterns of ownership and production industries.

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ПРОБЛЕМЫ ВОЗНИКНОВЕНИЯ ПРОФЗАБОЛЕВАНИЙ РАБОЧИХ В СВЯЗИ С НЕСООТВЕТСТВИЕМ ИХ ПСИХОФИЗИОЛОГИЧЕСКОЙ ПОДГОТОВКИ ТРЕБОВАНИЯМ ОПРЕДЕЛЕННОЙ ТРУДОВОЙ ДЕЯТЕЛЬНОСТИ.

Николай Касьянов, Александра Андрианова, Светлана Маврич

Аннтоция: в статье проведен анализ состояния травматизма на предприятиях, причин возникновения профессиональных заболеваний работников и обоснована необходимость внедрения обязательной психофизиологической экспертизы на предприятиях Украины.

Ключевые слова: охрана труда, работник, травматизм, профессиональное заболевание, психофизиологическая экспертиза.

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TIRE LIFE ADJUSTMENT ON THE COEFFICIENTS OF OPERATIONAL AND ROAD CONDITIONS

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Summary. The article investigates the problem of adjustment of tire life from the coefficients of working conditions and road conditions. On the basis of a methods the actual tire life for trucks of the enterprises of Donetsk region is corrected. The decision under the detailed analysis and specifications of factors which influence indicators of operating life, working capacity and wear rate of tires during operation of wheeled vehicle is offered.

Key words: tire life, factor correction, wheeled vehicle, road conditions, norm of an average of tire life, operational factors.

INTRODUCTION

Tires are an element which influences many operational factors of vehicles. Tires are expensive, disturbance of their condition considerably raises operating costs [1, 2, 3, 4]. The important role is occupied by questions of normalization of tire life which it is has to revise because of used new materials, operating conditions [5, 6, 7, 8].

The norm is a caused by changes in the area of activity for which these norms are established. Therefore normalization of use of resources includes following stages: working out of norms; updating and revision of norms which operate; the statement and finishing to industrial subsections [8, 9].

The existing methods of calculation of tire life in Ukraine does not always produce positive results. Research of tire life in enterprises of Donetsk region [10, 11, 12] found that more than 95% of design life is less than actual. This leads to several negative consequences: increased stockpiles of tires, part of working expenses are derived from turnover, quality of tires in storage inevitably deteriorates. Consequently, the design procedure of tire life on correction coefficients has got the greatest prevalence, which is based on statistical processing of run of many models of tires in various road conditions in practice.

RESEARCH OBJECT

To improve methods of correcting of tire life on coefficients of operational and road were conducted observation of work of truck Volvo FM 400 and KAMAZ 6520-61 the Donbas's company: limited company "DISK-SERVICE" and limited company "DISK-CONCRETE" (Donetsk), Structural subdivision "Avtobaza" State enterprise "Ordzhenikidzeugol" (Enakievo).

According to [11, 12, 13] two final correction factor is formulated for dump trucks and concrete mixing machine. In view of the constancy of the routes trucks within the organization, plan routes vehicles is analyzed in the work with instructions of run on roads of population aggregate and behind them, with instructions of a condition of a pavement in experiment carrying out on route sites.

Since the Donbas refers to the central climate region, we are guided by the corresponding data [11, 12, 14]. So, 80% of dump trucks route runs along the roads of asphalt carpet in satisfactory condition, and 20% - on roads with similar cover in unsatisfactory condition. Moving through a career in all three cases doesn't exceed one kilometer.

RESULT OF RESEARCHES

Rationing of tire life in Ukraine is arisen on the basis of operational norms of an average life of pneumatic tires of wheeled vehicle and special vehicles which are executed on wheel chassis [9]. As appropriate, the norms correct for actual operating conditions that differ from normal or especial conditions by following equation:

$$N = N_{NC} \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6, \quad (1)$$

$$N_{NC} = N_{SC} \cdot k_3 \cdot k_5, \quad (2)$$

where: N_{NC} – the norm average life of pneumatic tires for normal operating conditions, thousand km (motor-hours); N_{SC} – the norm average life of pneumatic tires for special application conditions, thousand km; k_1 – the correction coefficient depending on traffic and climatic conditions of operation; k_2 – the correction coefficient depending on operation rate of pneumatic tires; k_3 – the correction coefficient depending on service life of pneumatic tires; k_4 – the correction coefficient depending on load-carrying capacity use; k_5 – the correction coefficient for pneumatic tires of tractor-lorry-trailer combination which are constantly used with trailers; k_6 – the correction coefficient depending on the ratio of kilometres travelled in the city to the kilometres travelled outside the city.

Norms are corrected by means the coefficients $k_1 - k_6$, which are established for normal operating condition, the coefficients k_3 and k_5 norms for special application conditions. Apply only the correction coefficients which relate to certain operating conditions, and it is certain by these Norms (the use of all the coefficients are not necessarily). If all the features of the actual operating conditions can not be taken into

account, using these coefficients, the temporary regulations are being developed for the average life of pneumatic tires.

The correction coefficient k_1 of the norms depending on traffic and climatic conditions of operation determined as:

$$k_1 = k_{11} \cdot k_{12} \cdot k_{13}, \quad (3)$$

where: k_{11} – the correction coefficient of norms by the type of road surfacing; k_{12} – the correction coefficient of norms by the longitudinal inclination of road; k_{13} – the correction coefficient of norms by the degree chemical pollution.

The values of the correction coefficients are presented in tab. 1.

Table 1. **The correction coefficients of norms depending on traffic and climatic conditions of operation**

Climatic zone	The correction coefficient of norms by the type of road surfacing in satisfactory (unsatisfactory) technical state (k_{11})			The correction coefficient of norms by the longitudinal inclination of road (k_{12})			The correction coefficient of norms by the degree chemical pollution (k_{13})		
	asphalt-concrete	cement-concrete	stone block, sledged stone	no more than 40 %	from 40 to 60%	over 60 %	I	II	III, IV
North	1,0 (0,96)	0,88 (0,80)	0,84 (0,76)	1,0	0,98	0,96	1,0	0,98	0,96
Central	1,0 (0,96)	0,88 (0,80)	0,84 (0,76)	1,0	0,98	0,96	1,0	0,98	0,96
South	0,95 (0,90)	0,79 (0,76)	0,76 (0,73)	1,0	0,98	0,96	1,0	0,97	0,95
Mountain	0,97 (0,93)	0,82 (0,78)	0,80 (0,76)	1,0	0,98	0,96	1,0	1,0	1,0

The correction coefficient k_2 of norms depending on operation rate of pneumatic tires defines by the table 2.

Table 2. The correction coefficients k_2 of norms depending on operation rate of pneumatic tires

Operation rate, thousand km (motor-hours) / month	The coefficient k_2
from 1,0 (0,04) to 1,5 (0,06)	0,95
over 1,5 (0,06) to 3,0 (0,12)	0,98
over 3,0 (0,12)	1,0

If the operation rate wheeled vehicle characterizes the average monthly run of less than one thousand kilometers (40 motor-hours to an operating time) which answers the period of operation of the tire over 5 years, for each of following after the fifth year of operation the coefficient k_3 is: for the 6th, 7th, 8th, 9th and 10th years of operation, respectively: 0,96; 0,92; 0,88; 0,82; 0,75.

The correction coefficient k_4 depending on load-carrying capacity use defines by the table 3. Intermediate values, if necessary, determine the interpolation.

The correction coefficient k_5 norms for tractor-lorry-trailer combination determine on conditions that k_5 = 0,9 in the case of 100% of the first run with single trailer and k_5 = 1,0 – when run carried out without the trailer.

Table 3. **The correction coefficients k_4 of norms depending on utilization factor load-carrying capacity k_l wheeled vehicle**

Wheeled vehicles	Value of utilization factor load-carrying capacity k_l (seating capacity k_s)								
	to 0,4	0,4	0,5	0,6	0,7	0,8	0,9	0,95	1,0
	The coefficient k_4								
Truck vehicle-borne, trailers, bolster-type tractor, semitrailers	1,03	1,03	1,0	1,0	1,0	0,98	0,98	0,97	0,97
Dual-purpose vehicles	1,03	1,03	1,02	1,0	1,0	1,0	0,98	0,98	0,97
Dump trucks	1,04	1,04	1,03	1,03	1,0	1,0	1,0	1,0	0,98

Dependence of coefficient k_6 depending on the ratio of kilometres travelled in the city to the kilometres travelled outside the city defines by the table 4. Intermediate values, if necessary, determine the interpolation.

Table 4. **The correction coefficients k_6 of norms depending on the ratio of kilometres travelled in the city to the kilometres travelled road public network**

The ratio of kilometres travelled of road public network in the city to total kilometres travelled, %	0	20	40	60	80	100
The coefficient k_6	1,04	1,02	1,00	0,99	0,98	0,97

This methods has showed oneself to good advantage and it has been continuing to improve, for instance the work [15, 16].

In compliance with methods we will calculate for dump truckVolvo FM 400 8x4 and concrete mixer vehicle model KAMAZ 6520-61:

$$k_{11_{Volvo}} = 1,0 \cdot 0,8 + 0,96 \cdot 0,2 = 0,992;\ k_{11_{KAMAZ}} = 0,76 \cdot 0,2 + 1,0 \cdot 0,8 = 0,95.$$

According to data obtained during the investigation:

$$k_{12_{Volvo}} = 0,98 \cdot 0,7 + 0,96 \cdot 0,3 = 0,974;\ k_{12_{KAMAZ}} = 0,98.$$

The Donetsk region is one of the most ecologically adverse and chemically contaminated regions of Ukraine. Because of this factor k_{13}, corresponding to III and IV levels of chemical contamination, is k_{13} = 0,96.

At the time of the experiment, monthly kilometres travelled of dump truck Volvo FM 400 8x4 varied from 3,5 to 8 thousand km and concrete mixer vehicle model

KAMAZ 6520-61 - 1200...3000 km. On this basis, we take the largest value of the coefficient k_2, according to table 2: $k_{2_{Volvo}}$ = 1, $k_{2_{KAMAZ}}$ = 0,98.

The enterprise operation life of tires on trucks not exceeding five years, because the correction coefficient k_3 takes exactly one, k_3 = 1,0.

By controlling the weight of data it is known that the loading of dump trucks ranging from 26 to 30 tons at the nominal weight of cargo that is transported 26 tons and critical weight is 32 tons. Consequently, it is advisable to take k_l = 1,0, then $k_{4_{Volvo}}$ = 0,98. The coefficient of utilization load-carrying capacity for concrete mixer vehicle depends mainly on the type of concrete. Prescription composition and the density depend on the type of mixture. In most cases, the company produces and transports the mixture, in which the coefficient of utilization load-carrying capacity is 0,8 ... 0,95. In this case, taken $k_{4_{KAMAZ}}$ = 1,0.

Trucks carry the entire run without a trailer. Therefore, k_5 = 1,0. Guided by the data on the route of dump trucks Makeyevka-Red liman-Makeyevka the percentage of run makes 36%; Makeyevka-Prosjanoe-Makeyevka - 26%; Makeyevka-Telmanovo-Makeyevka - 17%. Thus, the average ratio of runs is 23%. We establish by interpolation method $k_{6_{Volvo}}$ = 1,017. About 90% tire life concrete mixer vehicle carried out within the city limits. According to the data of table 4, it is calculated:

$$k_{6_{KAMAZ}} = 0,97 \cdot 0,9 + 1,04 \cdot 0,1 = 0,977.$$

Concluding correction coefficient for trucks:

- Volvo FM 400 8x4 tires Michelin models XZY-2 and XDY-3

$$k_{xzy,xdy} = 0,992 \cdot 0,974 \cdot 0,96 \cdot 1,0 \cdot 1,0 \cdot 0,98 \cdot 1,0 \cdot 1,017 = 0,924;$$

- concrete mixer vehicle model KAMAZ 6520-61 tires model ID-304 Y-4 is

$$k_{ID\text{-}304} = 0,95 \cdot 0,98 \cdot 0,96 \cdot 0,98 \cdot 1,0 \cdot 1,0 \cdot 0,977 = 0,86.$$

According to [17], tire model ID-304 Y-4, which are installed on concrete mixer vehicle model KAMAZ 6520-61, the base average tire life is 80 thousand km. For tires Michelin [18] models XZY-2 and XDY-3, which are mounted on trucks Volvo FM 400, the base average tire life is 65 thousand km. Guided by this data, we calculate the tire life with a glance real-time use.

Dump truck:

$$N_{xzy,xdy} = N_{NC_{xzy,xdy}} \cdot k_{xzy,xdy} = 65000 \cdot 0,924 = 60060 km.$$

Concrete mixer vehicle model KAMAZ 6520-61:

$$N_{ID\text{-}304} = N_{NC_{ID\text{-}304}} \cdot k_{ID\text{-}304} = 80000 \cdot 0,86 = 68800 km.$$

Let's check up a methods for the tires XZY-2 and XDY-3, following the norms of firm Michelin [19]. We accept, in accordance with recommendations of the manufacturer, middle wear rate equal 0,1 mm / 1000 km. Then, whereas the initial height of protector XZY-2 - 18 mm, and protector XDY-3 - 25 mm, will calculate a height, to the limiting wear, if height of protector, at which a tire is subject to decommissioning is 1,6 mm:

$$h_{xzy} = 18,0 - 1,6 = 16,4 mm; \quad h_{xdy} = 25,0 - 1,6 = 23,4 mm.$$

Knowing the height of protector which wears out to attainment of critical value, the base tire life is calculated:

$$N_{xzy} = \frac{16,4}{0,1} \cdot 1000 = 164000\text{km}; \quad N_{xdy} = \frac{23,4}{0,1} \cdot 1000 = 234000\text{km}.$$

Then, in accordance with correction coefficients, calculated before, will get:

$$N_{xzy} = 164000 \cdot 0,924 = 151536\text{km}; \quad N_{xdy} = 234000 \cdot 0,924 = 216216\text{km}.$$

The results of calculations for different tire life are offered in a table 5 and fig. 1.

Table 5. **The results of calculations for different tire life**

Model of tire	State guidelines, km	Guidelines of producer, km
Michelin XZY-2	65000	164000
Michelin XDY-3	65000	234000
ID-304	80000	-

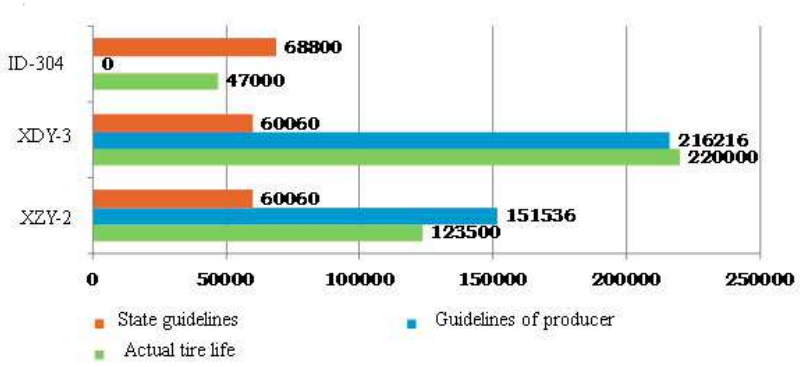

Fig. 1. Charts of tire life after state and actual data, km

The results of calculations show that tire life to writing off does not correspond to the facts, under the recommended [17] standards, as the tire foreign and domestic production. According to the data received during the experiment, tire Michelin XZY-2 which are installed on operated axes of dump truck Volvo FM 400, by the time of writing-off on the average overcome 123,5 thousand km, and Michelin XDY-3 that are installed on leading axes of the same dump trucks, to writing off overcome 220 thousand km.

Tires model ID-304 Y-4 which are installed on all axes concrete mixer vehicle model KAMAZ 6520-61 leave operation after overcoming, on the average 47 thousand km.

CONCLUSIONS

Having analysed the above-stated, it is can conclude following:

1. To this effect necessary to design high-quality tires and norms the average tire life.

2. It is necessary to consider in details factors which influence indicators of reliability of automobile tires. The main factors note that influence the tire life.

3. For real operating conditions wheeled vehicles it is necessary to consider norms average tire life and their correct.

4. Mathematical models concerning calculation wear rate of tires do not consider the real conditions in which the wear process of tire wheeled vehicles is taking.

5. Design procedure of run of run of tires of wheeled vehicles from the correction coefficients is the most practical and based on statistical data of tire in specific conditions.

6. The mentioned facts indicate the need to revision the adjustment factors for all models of tires.

7. It is necessary to improve system concerning control over elements of suspension mechanized of wheeled vehicles.

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КОРРЕКТИРОВАНИЕ РЕСУРСА ШИН ПО КОЭФФИЦИЕНТАМ ЭКСПЛУАТАЦИОННЫХ И ДОРОЖНЫХ УСЛОВИЙ

Александр Кравченко, Ольга Сакно

Аннотация. В статье рассмотрен вопрос корректирования ресурса шин по коэффициентам эксплуатационных и дорожных условий. На основе методики скорректирован фактический ресурс шин для грузовых автомобилей предприятий Донецкой области. Предложено решение по детальному анализу и уточнения факторов, которые влияют на показатели долговечности, работоспособности и на интенсивность износа шин в процессе эксплуатации транспортных средств.

Ключевые слова: ресурс шин, коэффициент корректирования, колесно-транспортное средство, дорожные условия, норма среднего ресурса, эксплуатационные факторы.

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MODELLING OF DISCRETE RECOGNITION AND INFORMATION VULNERABILITY SEARCH PROCEDURES

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Summary. The article to contain results of the researches, allowing to raise level of protection of the automated and intellectual information systems enterprises (AIS). The article discusses the use of discrete procedures to detect threats for information resources.

Key words: information security, threat detection, discrete process.

INTRODUCTION

Information security management has become a critical and challenging business function because of reasons such as rising cost of security breaches, increasing scale, scope and sophistication of information security attacks, complexity of information technology (IT) environments, shortage of qualified security professionals, diverse security solutions from vendors, and compliance and regulatory obligations.

The sophistication and effectiveness of cyber attacks have steadily advanced. These attacks often take advantage of flaws in software code, use exploits that can circumvent signature-based tools that commonly identify and prevent known threats, and social engineering techniques designed to trick the unsuspecting user into divulging sensitive information or propagating attacks. These attacks are becoming increasingly automated with the use of botnets - compromised computers that can be remotely controlled by attackers to automatically launch attacks. Bots (short for robots) have become a key automation tool to speed the infection of vulnerable systems [Ahmad D. 2005, Chi S.-D. 2001, Gorodetski V. 2002, Knight J. 2002, Templeton S. 2000, Xiang Y. 2004].

RESEARCH OBJECT

Mission-critical information systems (MCIS) are understood as the electronic communication development objects, by means of which collection, processing, storage and transmission of information are performed with the purpose to ensure the handling processes. Their exceedance of allowable values may lead to the malfunction or their endamagement.

To evaluate security of such a system, a security analyst needs to take into account the effects of interactions of local vulnerabilities and find global vulnerabilities introduced by interactions. This requires an appropriate modeling of the system. Important information such as the connectivity of elements in the system and security related attributes of each element need to be modeled so that analysis can be performed. Analysis of security vulnerabilities, the most likely attack path, probability of attack at various elements in the system, an overall security metric etc. is useful in improving the overall security and robustness of the system. Various aspects which need to be considered while deciding on an appropriate model for representation and analysis are: ease of modeling, scalability of computation, and utility of the performed analysis. The analysis of the protection of information systems and automated control systems for transport companies has yielded the following results (period 2008 -2010), fig. 1, 2.

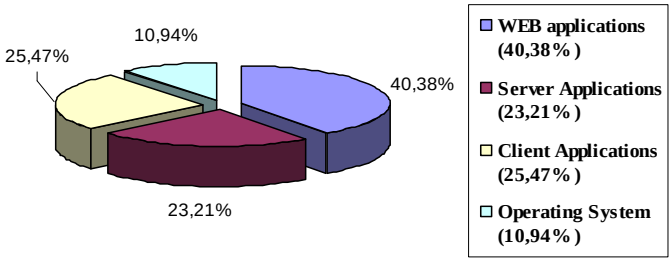

Fig. 1. Statistics application vulnerabilities AIS

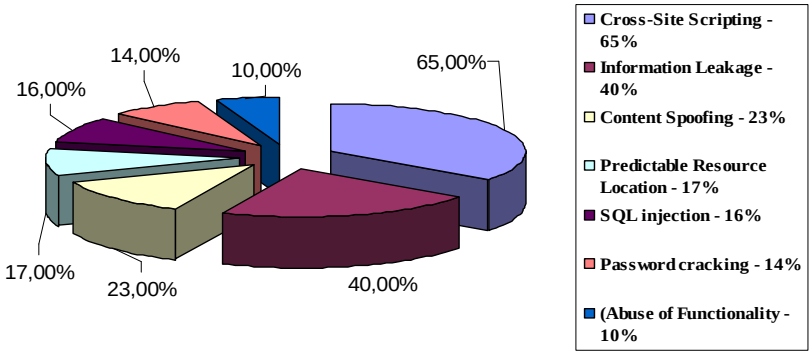

Fig. 2. The probability of detecting vulnerabilities of different types

The decision of questions of complex maintenance of security and stability of functioning of the automated systems (AS) in the conditions of unauthorized access (UNA), including, influences of computer attacks, demands the system analysis and synthesis of possible variants of construction of means of counteraction UNA means. At complex formation it is necessary to co-ordinate and inter connect functions and parameters of the EXPERT, protection frames of the information from UNA, anti-virus means, gateway screens, the communication equipment, the general and special software and perspective means of counteraction to computer attacks [Chapman C. 2003].

The main peculiarity of the concerned recognition and software and network vulnerability search procedures, which are later called discrete or logical procedures, is the possibility of obtaining a result without any information about functions of character meaning distribution and on availability of little training samples. The knowledge of metrics in the space of objects' description is not needed also. In this case a binary function of value proximity should be determined for each of the characters, which allows distinguishing the objects and their sub descriptions [Baskakova L. 1981, Vayntsvayg M. 1973].

The main task of discrete recognition and vulnerability search procedures (DRVSP) building is search of informative sub descriptions (or description fragments) of objects.

We consider informative objects to be the objects that reflect certain regularities in description of objects used for training, that is presence or, vice versa, absence of these fragments in the object, which is being considered, allows attributing it to one of classes. The fragments that are met in descriptions of one class objects and cannot be met in descriptions of other classes' objects are considered to informative in DRVSP. The regarded fragments as a rule have a substantial description in terms of designing information safety systems (ISS).

RESULTS OF RESEARCH

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A notion of an elementary classifier is introduced by building discrete recognition and vulnerability search procedures for information safety systems. An elementary classifier is understood as a fragment in a description of a training sample. A certain multitude of elementary classifiers with preset properties are built for each

$(KL_1,...,KL_l)=(B_{p_{a1}},...,B_{p_{al}})$ class. As a rule, the classifiers, which are used, can be met in descriptions of one class objects and cannot be met in descriptions of other classes' objects, thus describing only some training objects of the class. On the other hand, sets of character values not used in descriptions of any training objects of the class characterize all objects of this class and are more informative form this perspective. That is why so actual is the question of constructing discrete recognition and vulnerability search procedures based on the principle of "nonreoccurance" of character legitimate values' sets, fig. 3, 4.

Another problem is presence of objects which are on borderline between classes $(KL_1,...,KL_l)=(B_{p_{a1}},...,B_{p_{al}})$ among the study samples of objects. Each of such objects is not "typical" for its class, as it resembles to descriptions of objects belonging to other classes. Presence of untypical objects extends the length of fragments used to distinguish objects belonging to different classes. Long fragments are less frequent in new object, thus extending the number of unrecognized objects.

The necessity of building effective realizations for discrete recognition and vulnerability search procedures is directly connected to problems of metric (quantitative) characters of informative fragments' multitudes. The most important and technically complex are the problems of obtaining asymptotical estimates for typical number values of (impasse) covering and the length of integer matrix (impasse) covering and also the problems of obtaining analogical estimates for permissible and maximum conjunctions of a logical function, which are used for synthesis of circuit hardware-based ISS solutions.

There is, as a rule, no reliable information about the structure of *PA* multitude available while solving tasks connected with projecting an effective AIS information safety system, that's why having built a discrete recognition and vulnerability search procedures algorithm we cannot guarantee its high performance on new objects different from $\{sp_{a1},...,sp_{am}\}$. Nevertheless, if the training samples are quite typical for the considered multitude of objects, than the algorithm that makes infrequent mistakes in studies will show acceptable results with unknown (not included in training samples) objects also. In this connection correctness of discerning algorithm is the problem that should be paid great attention. The algorithm is considered to be correct if it discerns all the training samples correctly.

The simplest example of a correct algorithm is the following: the considered object sp_{an} is compared to descriptions of every training sample $\{sp_{a1},...,sp_{am}\}$. In case if the sp_{an} object's description coincides with a description of a sp_{an} training sample, the sp_{an} object is attributed to the same class as the $\mathrm{sp}_{\mathrm{ai}}$ object. In other case the algorithm declines to recognize the object. There is no difficulty noticing that though the foregoing algorithm is correct, it is not able to discern any object which description does not coincide with description of any training sample.

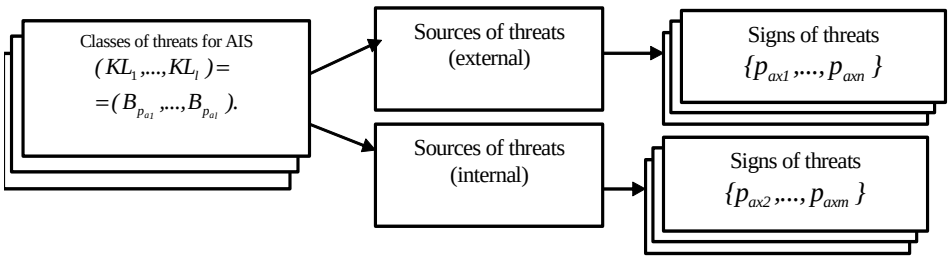

Fig. 3. The structure of the classification of “Sources of Threats”

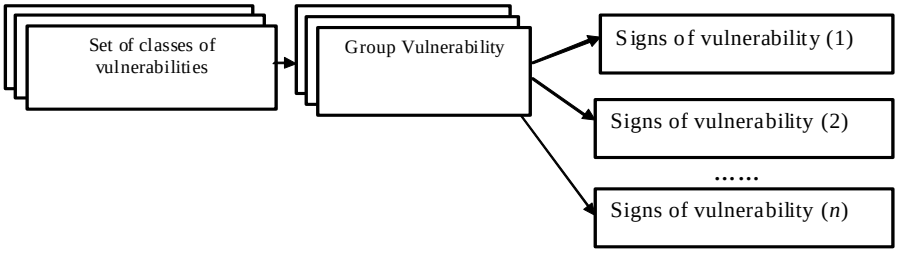

Fig. 4. The structure of the classification of “vulnerability”

Let’s introduce the following symbols. Let NP_{p_a} stand for a set of r_{p_a}, $r_{p_a} \le MI$ different integer-valued characters of $\{p_{aj_1},..., p_{aj_r}\}$ kind. Proximity of $sp'_a=(\alpha p'_{a1},\alpha p'_{a2},...\alpha p'_{aMI})$ and $sp''_a=(\alpha p''_{a1},\alpha p''_{a2},...\alpha p''_{aMI})$ belonging to *PA* by the NP_{p_a} set of characters we will estimate by the following value

$$BN(sp'_a, sp''_a, NP_{pa}) = \begin{cases} 1, & if \quad \alpha p'_{j_{ti}} = \alpha p''_{j_{ti}} \ the \ value \ of \ ti = 1,2,..., r_{p_a}, \\ 0 & otherwise \ . \end{cases} \quad (1)$$

Thus, the schematic circuit of estimation algorithm building for information safety systems is the following. The whole range of different $NP_{p_a}=\{p_{aj_1},..., p_{a_{MI}}\}$, $r_{p_a} \le MI$ type sub multitudes is picked out inside the $\{p_{a_1},...,p_{a_{jMI}}\}$ character system. Later the picked sub multitudes are named reference multitudes of the algorithm, and their whole range is designated by ΩMI.

Further let us set the following parameters:

- po_{sp_a} is a parameter characterizing significance of a sp_{ai}, *i= 1, 2,..., PA* target (object);

- $po_{NP_{pa}}$ is a parameter characterizing significance of an object belonging to a reference multitude $NP_{p_a} \in \Omega MI$.

The considered object sp_{an} is compared to every training sample sp_{ai} of every reference multitude. A $\Gamma(sp_a, KL)$ estimation of sp_a object belonging to *KL* class is calculated for each vulnerability class of AIS *KL*, $KL \in \{KL_1,...,KL_l\}$ in the following way:

$$\Gamma(sp_a, KL) = \frac{1}{|LW_{KL}|} \sum_{sp_{ai} \in KL} \sum_{NP_{Pa} \in \Omega MI} po_{sp_a} \cdot po_{NP_{pa}} \cdot BN(sp_a, sp_{ai}, NP_{p_a}), \quad (2)$$

where: $|LW_{KL}| = |KL \cap \{sp_{a1},...,sp_{aMI.}\}|$.

The sp_{an} object is attributed to the class that has the highest estimate. In case if there are several classes with the highest estimate, discerning fails.

Let's regard the situation, when the objects of the considered PA multitude are described by the characters, each possessing values of the {0, 1,..., k_{p_a} - *1*} multitude. Let's associate the (σ_{DOP}, NP_{pa}) elementary classifier, where $\sigma_{DOP} = (\sigma_{DOP_1},...,\sigma_{DOP_r})$, NP_{pa} is a set of characters numbered $j_1,...j_{r_{pa}}$, with an elementary conjunction $\Re = p_{axj_1}^{\sigma_{DOP_1}} ... p_{axj_{r_{pa}}}^{\sigma_{DOP_{r_{pa}}}}$.

Let's show that building a multitude of $(KL_l) = (B_{p_{al}})$ class elementary classifiers for the models previously considered in the article adds up to finding permissible and maximum conjunctions of the characteristic $(KL_l) = (B_{p_{al}})$ class function, which is a double-valued logical function possessing different values for training samples of KL_l и $\overline{KL_l}$.

After completion of all the previously mentioned stages one can start the work on forming the model of information threats for all the information resources of the enterprise on the basis of the derived classifiers. The initial data for simulation are classes of vulnerabilities, threats and attacks, and also multitudes of AS attack realization means and categories (classes) of malefactors.

The problem of using proper characteristic functions was not considered in corpore within the bounds of this research, as there are different mathematical approaches to descriptions of characteristic functions, which can be found for each class of information attack targets. For example, the following methods are used for solving problems connected with simulating the speed of malicious software spreading, that is measuring the percentage of infected computers within the network:

- models based on changed systems of differential equation, formulated in classic epidemiologic models;

- models based on calculation of Hamiltonian path length in the part of the analogous graph, where spreading is still possible;
- other.

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МОДЕЛИРОВАНИЕ ДИСКРЕТНЫХ ПРОЦЕДУР РАСПОЗНАВАНИЯ УГРОЗ И ПОИСКА УЯЗВИМОСТЕЙ ИНФОРМАЦИИ

Валерий Лахно, Александр Петров

Аннотация. Статья содержит результаты исследований, позволяющие повысить уровень защиты автоматизированных и интеллектуальных информационных систем предприятия (АИС). В статье предложено использовать дискретные процедуры для выявления угроз информационным ресурсам.

Ключевые слова: информационная безопасность, обнаружения угроз, дискретный процесс.

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COMPLEX RESEARCH RESULTS OF THE EVAPORATIVE CONDITIONER FOR DIESEL LOCOMOTIVE CAB

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Summary. A set of theoretical and experimental research of evaporative air conditioner unit has provided a design that can be used on railway rolling stock and that meets the requirements of regulations of the microclimate parameters of the locomotive cab.

Keywords: evaporative conditioner, diesel locomotive, air flow, the metal nozzle.

INTRODUCTION

When providing comfortable sanitary and hygienic indoor microclimate parameters [Pankova, 2000] it allows people to increase the productivity of work and reduce the probability of professional diseases. The results of statistical studies show that the diseases of the locomotive crews' workers depend to a large extent on the unfavourable climatic conditions in the cab of the locomotive, and are reflected in the cardiovascular, musculoskeletal, and nervous systems. Moreover, the absence of favorable climatic conditions in the work of the locomotive driver and the driver's assistant accumulates fatigue, lethargy, and similar phenomena that affect the security of movement in the similar way.

RESEARCH ANALYSIS

To maintain the necessary sanitary and hygienic parameters of microclimate on the modern locomotives [Sorokin, 1996; Sokolov, 1998] the air-conditioning system, which typically consists of a steam compressional air conditioner with hermetic compressor or compressor of packing design and a heating-ventilation unit is used. This scheme has many flaws which at pesent do not allow to solve the problem of conditioning on the railway rolling stock completely:

- taking into account the fact that locomotives use air conditioners that can not work as a heat pump, the additional use of the heating-ventilation unit, which makes the design of the system more complicated and increases its value becomes obvious;

- steam compressional conditioners are structurally complex, expensive and dangerous for environment; during the operation due to vibration and sudden accelerations, the depressurization of the cooling system is possible;

- the use of one-piece scheme of the conditioner and considering its complex structure it makes the layout of the locomotive and the further rational distribution of air masses in the driver's cab more complicated;

- steam compressional conditioners use much energy consumption, resulting in additional operational costs.

Elimination of flaws relevant to the currently used air conditioning system in the locomotive cab is possibly by using of the evaporative cooling water systems. The settings of such type are clean, reliable, and structurally simple. The main advantages that characterize the evaporative coolers are the follows: environmental cleanliness, the use of renewable sources of energy, little energy consumption (comparing to steam compressional air conditioners is 10 ... 15 times lower), absence of non-ferrous metals, simple design and operation [Doroshenko, 1983; Maysotsenko, 1987; № 85.4.14.010, 1986].

The given design uses the following means of air cooling:

- evaporation of water from the surface of the porous nozzle, which is moistened by vertical capillary rise of fluid from the reservoir;

- evaporation of water from the surface of liquid film formed by the forced irrigation of a metal nozzle from the top to the bottom with the subsequent collection of fluid in the reservoir;

- separation of air flow, moving on "wet"and "dry" channels of the nozzles; in the "wet" channels the water film and nozzles are cooled, the air saturated with moisture from the "wet" channel entering the atmosphere; in the "dry" channel the air is cooled and then goes to the cab of the vehicle.

The presented schemes of the air coolers have the following disadvantages:

- the use of porous nozzles results in a reduction of their height taking into account the limits of capillary rise of liquid; the reduction of heat transfer due to the low coefficient of thermal conductivity of the nozzle material, to their pollution resulting in the deterioration of capillary fluid rise and the reduced cooling capability of the device;

- the use of metal nozzles assumes the strict film flow in the "wet" channels, which is structurally difficult to implement provided there are some "dry" channels on the back of the nozzle;

- the use of both types of nozzles, which ensure the air cooling and assumes the realization of the small values of the average coefficient of heat transfer (≈40-60 $Вт/м^2К$) from the wall to the air flow;

- both schemes are one-piece and very complex, which causes the problems with their installation on the locomotive and further air distribution in the driver's cab.

THE AIM AND THE TASK OF THE RESEARCH

The elimination of defects and the adaptation of the evaporative cooler to be used on the railway rolling stock is possible when the following positions are realized:

- during the evaporation it is preferable to use the cooled water which will cool the air directly through recuperative heat exchangers which realize the great values of the heat transfer coefficient;
- to divide the conditioner into two parts: evaporative (with nozzles, fan, water pump) and cooling (with a recuperative heat exchanger and fan);
- to use metal nozzles, which during the rotation come into the lower part, irrigated by the water and further, having passed the compressor's device go out to the top, where they are blown by the air flow;
- to connect the cooling unit of the conditioner with the cooling system of internal combustion engine of the locomotive and use it as a heating unit for locomotive cab in the cold season.

RESULTS AND THEIR ANALYSIS

Mathematical modeling of the presented processes for selecting the rational parameters of structural and regime parameters is given in the work [Lutsenko, 2011].

When considering the cooling surface of the direct evaporative cooler, the thermal balance equation [Neduzhyj, 1981; Ysachenko, 1981] can be presented as:

$$q_a = -q_w = q_\beta - q_\alpha , \quad (1)$$

where: q_a, q_w - the heat flow density in the air and to the water film on the nozzle respectively; q_α, q_β - the heat flow density defined by the heat transfer from the air to the water film and formed by evaporation of the water film.

Solving (1) is possible by using the analogy between hydrodynamic, thermal and diffusive boundary layer of the air when producing the distance from the liquid film and determining the coefficient of heat transfer, flow steam mass density and others.

The distribution of the relative velocity along the hydrodynamic boundary layer [Shlikhting, 1974] on the flat plate was defined as $u/U_\infty = f'(\eta_1)$, where u - the current speed in the boundary layer at the distance from the surface; U_∞ - the air flow rate outside the boundary layer and approximated by the following polynomial:

$$f'(\eta_1) = -3{,}57 \cdot 10^{-2}\eta_1^2 + 0{,}377\eta_1 ; \quad (2)$$

where: $\eta_1 = 5y/\delta$ - dimensionless boundary layer coordinate; $\delta = 5 \cdot \sqrt{\nu x/U_\infty}$ - boundary layer thickness; x – distance from the starting edge of the plate to the given point; ν - kinematic air viscosity.

With the flow mode in the channel between the nozzles, we finally get the equation for the flow outside the boundary layer:

$$U_\infty = \frac{G_\Sigma}{\rho b\left(H - 0{,}7\delta\right)}; \quad U_{\max} = \frac{G_\Sigma}{0{,}65\rho bH}. \quad (3)$$

Considering the thermal boundary layer, the temperature distribution will be defined as $\frac{\vartheta}{\vartheta_\infty} = \frac{t - t_w}{t_\infty - t_w} = f'(\eta_2)$, where the distribution function on the basis of previously obtained distribution of the relative speed (2)

With the temperature gradient at the nozzle surface, the coefficient of heat transfer is defined as:

$$\alpha = \frac{\lambda}{\vartheta_\infty}\left(\frac{\partial \vartheta}{\partial y}\right)_{y=0} = \frac{1{,}89\lambda}{k}, \tag{4}$$

Based on the analogy of speed and concentration profiles of the water steam at the border layer, the density of mass flow of steam in the boundary layer is defined as

$$j_п = 1{,}89\frac{D(p_н - p_\infty)}{\delta R_п T}. \tag{5}$$

where $p_н$ - saturated steam pressure near the surfaces of the water film; p_∞ - steam pressure outside the boundaries of the boundary layer in the channel between the nozzles.

The given analysis of the processes occuring in the channel between the nozzles between the air flow and the basic platform of the nozzle allow to solve the equation (1) and determine the change of the air flow parameters.

Based on the equations of the density of heat flow going through the nozzle, taking into account the heat taken away from it and the liquid film at a time, the temperature difference of on the surface of liquid film contacting with air when changing the thermal state of the "nozzle - liquid – air" is defined as:

$$\Delta t_w = \frac{q_w \Delta\tau - (\psi - \psi')(\chi_н \delta_w + \chi_w(\delta_н + 2\delta_w)/2)}{\chi_н + \chi_w}, \tag{6}$$

where: $\psi' = (t'_н - t'_w)/(\delta_н + 2\delta_w)$, $\psi = (t_н - t_w)/(\delta_н + 2\delta_w)$, $\chi_н = c_н \rho_н \delta_н/2$, $\chi_w = c_w \rho_w \delta_w/2$ - equation coefficients.

With the heat taken away from the air at a time we can specify the current temperature change in the thermal boundary layer

$$\Delta t_\infty = \frac{2q_\alpha \Delta\tau - 0{,}74k\Delta t_w c_p \rho_a}{(H - 0{,}74k)c_p \rho_a}. \tag{7}$$

Let's define the specific steam mass located between the wall of the nozzle and the middle of the channel between the nozzles:

$$m_{п_F} = \frac{0{,}622}{R_a}\left[\frac{\delta}{5}\int_0^5 \frac{p_н - (p_н - p_\infty)(A_1\eta_1^2 + B_1\eta_1)}{T_w + (T_\infty - T_w)(A_2\eta_1^2 + B_2\eta_1)} d\eta_1 + \frac{p_\infty}{T_\infty}\left(\frac{H}{2} - \delta\right)\right]. \tag{8}$$

When giving $\int_0^5 \frac{p_н - (p_н - p_\infty)(A_1\eta_1^2 + B_1\eta_1)}{T_w + (T_\infty - T_w)(A_2\eta_1^2 + B_2\eta_1)} d\eta_1 = p_н F_1 - (p_н - p_\infty)F_2$ we get:

$$F_1 = \frac{1}{A_2 (T_\infty - T_w)(q-s)} \ln \left| \frac{(q-5)s}{(s-5)q} \right|, \tag{9}$$

$$F_2 = \frac{1}{A_2 (T_\infty - T_w)} (A_1 \chi_1 + B_1 \chi_2), \tag{10}$$

$$\chi_1 = \frac{1}{q-s} \left[5(q-s) + q^2 \ln \left| \frac{q-5}{q} \right| - s^2 \ln \left| \frac{s-5}{s} \right| \right], \tag{11}$$

$$\chi_2 = \frac{1}{q-s} \left[q \ln \left| \frac{q-5}{q} \right| - s \ln \left| \frac{s-5}{s} \right| \right]. \tag{12}$$

where: s, q – the root of quadratic equation $T_w + (T_\infty - T_w)(A_2 \eta_1^2 + B_2 \eta_1) = 0$.

Using similar methods of mathematical and physical picture of the coolant one can get some dependences, describing the processes of heat exchange in the rrigated part of the evaporation unit, such as:

- the speed of the fluid in the core of the flow in the channelbetwen the nozzles

$$U_\infty = G_\infty \left[\rho b (H - \delta_1) \right]^{-1}; \tag{13}$$

- displacement thickness of the turbulent boundary layer:

$$\delta_1 = 4{,}6 \cdot 10^{-2} x \left(\frac{\nu}{U_\infty x} \right)^{\frac{1}{5}}; \tag{14}$$

- local heat transfer coefficient:

$$\alpha' = \frac{\lambda}{\vartheta_\infty} \left(\frac{\partial \vartheta}{\partial y} \right)_{y=0} = \frac{\lambda}{k_1}, \tag{15}$$

The definition of speed and air and water pressure in curvilinear flow is defined by the following equations:

$$u = \exp(C_1 - \ln R), \tag{16}$$

where: $C_1 = \ln(u_m R_m)$ - integration constant; $u_m = G_\Sigma (\rho H R_m)^{-1}$ - the average speed in the channel between the nozzles; R_m - radius of the middle of the current lines.

$$p = C_2 - 0{,}5 \rho \exp\left[2(C_1 - \ln R) \right], \tag{17}$$

where: $C_2 = p_{atm} + 0{,}5 \rho \exp\left[2(C_1 - \ln R_m) \right]$ - integration constant; p_{atm} – atmospheric pressure at the entrance of air flow in the curvilinear plot.

Since the calculation of the process of heat and mass exchange at evaporative cooling was performed numerically [Karimberdieva S., 1983, Patankar S.V., 1984, Peyre R., Teylor T.D., 1986], the nozzle and the direction and heat carriers were covered by polar nets, and when constructing them the minimum radius of the air flow lines was determined from the dependence:

$$R^a_{\min} = R_н \Big/ \left[2 \cos(\alpha/2) \right] \tag{18}$$

where: $R_н$ - nozzle radius; α - angle of the coverage of the irrigated nozzle surface.

The maximum radius of the current water lines was defined as:

$$R^{w}{}_{\max} = R_{н} tg\,\alpha/2\,. \tag{19}$$

Polar coordinates of the net knot are defined as:

- in the air

$$\begin{cases} R^{a}{}_{i} = R^{a}{}_{\min} + i\Delta R; \\ \phi^{a}{}_{j} = \phi^{a}{}_{j\max} - j\Delta\phi, \end{cases} \tag{20}$$

- in the water

$$\begin{cases} R^{w}{}_{i} = R^{w}{}_{\max} - i\Delta R; \\ \phi^{w}{}_{j} = \phi^{w}{}_{j\max} - j\Delta\phi, \end{cases} \tag{21}$$

where: ΔR, $\Delta\phi$ - the step of the change of radius and angle of the net model; $\phi^{a}{}_{j\max}$ - maximum angle of the net opening to air at the current R_i; $\phi^{w}{}_{j\max}$ - maximum angle of the net opening for water at the current R_i; i, j – net knot indices.

Based on the developed model and calculation program, numerous experiments with the influence of cooling efficiency of mode and design parameters of the evaporation unit have been carried out and the results are presented as approximating dependencies:

$$\bar{Q}_{xp} = 688{,}48 + 69{,}83z_1 + 7{,}67z_2 - 3{,}57z_1^{\,2} - 10{,}87z_2^{\,2} + 8{,}98z_1z_2\,, \tag{22}$$

$$\bar{Q}_{xp} = 1722{,}8 - 185{,}6x_1 + 885{,}5x_2 + 330{,}1x_3 + 43{,}2x_1^{\,2} + 10{,}9x_2^{\,2} - \text{-}251{,}1x_3^{\,2} \text{-} 40{,}8x_1x_2 - 10{,}1x_1x_3 + 76{,}4x_1x_2 \tag{23}$$

where: z_1 – the air speed when entering the channel, м/с; z_2 – the speed of the nozzle rotation, хв$^{-1}$; x_1 – the nozzle radius, мм; x_2 – nozzle thickness, мм; x_3 – the distance between the nozzles.

The analysis and the calculations based on the developed mathematical model allowed to identify the main design parameters that affect the energy, mass and size characteristics and identify their rational measures: the rotating nozzle diameter, which determines the surface area of heat and mass exchange $D_н$=200…400 мм; the nozzle thickness, which characterizes the possibility of accumulation and transfer of heat (cold) $\delta_н$=1,5…2,5 мм; the distance between nozzles, which determines the flow of heat carriers H=7…8 мм.

The experimental studies on stand models [Idelchik I., 1975, Bagan I.P., 1989, Gerschenko O.A., 1984] of the air conditioner of the evaporative cooling and its elements resulted in obtaining its power, aero-and hydrodynamic characteristics depending on the mode characteristics of the heat flow and heat carriers and environmental parameters [Mohyla V.I., Lutsenko O.A., 2011].

CONCLUSIONS

The results of the research present the following:

- the increase of the air flow speed in the channel between the nozzles to the values of 8 m / s allows to increase the cooling capacity ranging from 1900 to 4000 W without any deterioration in the work of the device, the great values of the air speed corresponding to the great values of the nozzle rotation and consequently on the contrary;

- when the rotation frequency of the nozzle is 100 and 80 rpm and consequently the air speed in the channel between the nozzles is 10 and 16 m/s and more, one may notice the drop removing of the liquid phase, with the smaller values of the nozzle rotation and in the range of the air speed, the moisture removing hasn't been observed;

- the realization of the maximum cooling capacity of the unit, which amounted to 4200 W when the removing of the liquid phase is absent provides the rotation speed of 1980 rpm and the air flow speed of 12 m/s, which allows to define these modes as rational;

- aerodynamic resistance of the air path for these parameters is 340 Pa;

- the cost of mechanical power to the nozzle drive when changing the rotation speed from 40 to 100 rpm amounted to the value in the range from 25 to 100 W.

Considering the experimental studies and the obtained results [Reho, 1987] we may state thefollows:

- there are rational parameters of the air flow speed in the channel between nozzles and the nozzle rotation speed corresponds to 12 m /s and 80 rpm, which provides the maximum cooling capacity of the evaporative unit of the conditioner; these modes do not allow any drop removing of the water environment, which provides the best possible technical and economic parameters of the device of this type;

-the optimum water flow rate was defined ($6 \cdot 10^{-3}$ м^3/s) in the irrigated part of the evaporative unit of the conditioner, which provides the maximum cooling capacity and consequently the heat balance between the energy processes of evaporative cooling in the air part of the nozzle and the processes of heat and mass trasfer in the irrigated part of the nozzle;

- the change of the water temperature entering the evaporator unit of the conditioner makes the proportional impact on its cooling capacity, which contributes to the flexible regulatory characteristics when changing the parameters of microclimate in the locomotive cab;

The use of the results obtained allows to realize the cooling efficiency of the conditioner to the values of 2580 W, which provides the temperature of +26 °C in the locomotive driver's cab 2TE116 at the environmental temperature +45 ^{o}C and the relative humidity 90%.

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РЕЗУЛЬТАТЫ КОМПЛЕКСНЫХ ИССЛЕДОВАНИЙ ИСПАРИТЕЛЬНОГО КОНДИЦИОНЕРА ДЛЯ КАБИНЫ МАШИНИСТА ТЕПЛОВОЗА

Александр Луценко, Валентин Могила

Проведений комплекс теоретичних и експериментальних исследований испартельного кондиционера обеспечил получение конструкции устройства, которая может использоваться на подвижном составе железных дорог и отвечает требованиям нормативных документов относительно параметров микроклимата кабины машиниста локомотива.

Ключевые слова: испарительный кондционер, тепловоз, поток воздуха, металлическая насадка.

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METHOD OF THE DYNAMIC ANALYSIS OF THE MECHANISM

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Summary. The iterative method of the law of movement of an initial link of the lever mechanism in time of settled regime definition, not connected with dynamic synthesis, is offered.

Key words: lever mechanism**,** link of reduction, settled regime, dynamic analysis, law of movement

INTRODUCTION

As it is known from the educational literature (see the list of referred sources), for the decision of a problem of the dynamic analysis of the mechanism, it is necessary to know parameters of its dynamic model (the angular speed, the resulted moment of inertia, change of kinetic energy) at least in one position defined in the generalized coordinate. Traditional methods [Korenyako 1970] suggest to use as such position, where angular speed of a link of reduction has extreme value set by the coefficient of non-uniformity of movement. But maintenance of the set coefficient of non-uniformity of movement is a condition of dynamic synthesis of the mechanism, which is not always necessary. Thus, it appears that without dynamic synthesis, when this factor is not known also it only it is necessary to define, the dynamic analysis is impracticable. Possibility of definition of the law of movement of an initial link in this case opens the nonconventional approach to the decision of a problem of dynamic synthesis [Malkov 2008].

OBJECTS AND PROBLEMS

Let the resulted moment of inertia of the lever mechanism will be presented as follows:

$$J(\varphi) = J_{const} + J_{\text{var}}(\varphi),$$

where: J_{const} - the constant component allocated in such a manner, that a variable component $J_{\text{var}}(\varphi)$ has the minimum 0; φ - the generalized coordinate.

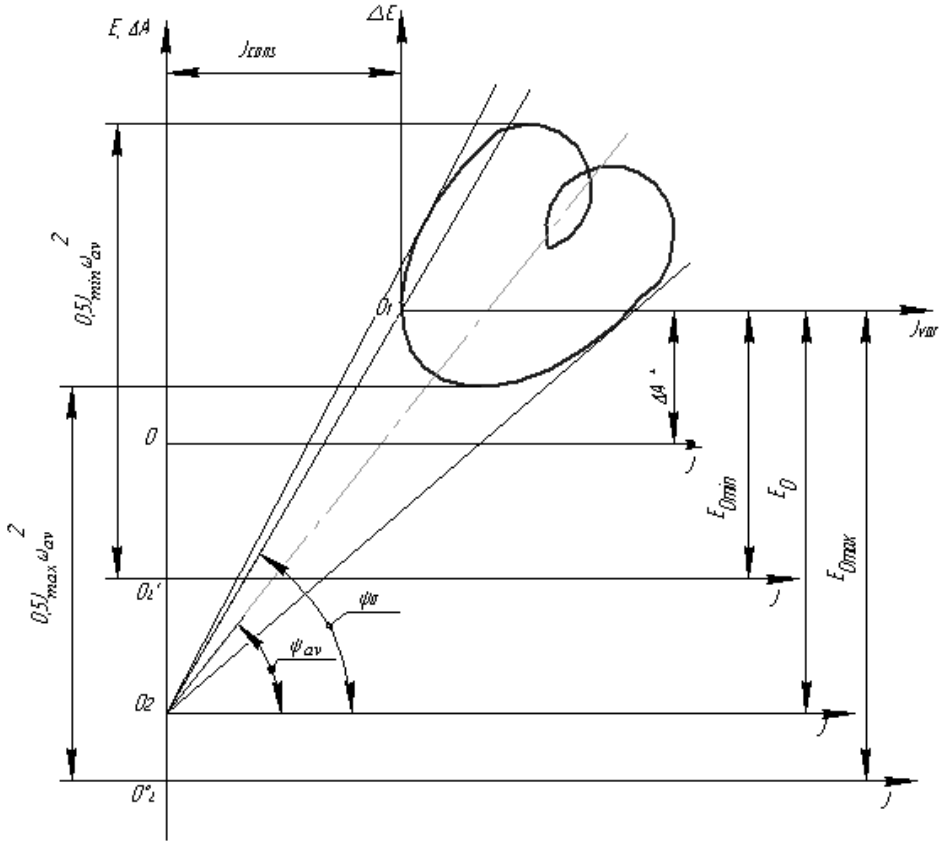

Fig. 1. To the dynamic analysis of the mechanism

In figure 1 the curve of energy-mass (Vittenbauer's diagram) received in the traditional way in system of coordinates $JO\Delta A$, expressing conformity of values of total work $\Delta A(\varphi)$ to values of the resulted moment of inertia of the mechanism $J(\varphi)$ is represented. After an exception of a constant component of the resulted moment of inertia J_{const}, having passed to new system of coordinates $J_{\text{var}}O_1\Delta E$, it is possible to write down:

$$J_{\text{var}}(\varphi) = J(\varphi) - J_{const}$$

and

$$\Delta E(\varphi) = \Delta A(\varphi) - \Delta A^{*},$$

where: J_{const} - the minimum value of the resulted moment of inertia in old system $JO\Delta A$, ΔA^{*} - ordinate corresponding to this value in the same system, $\Delta E(\varphi)$ - a

variable component of change of kinetic energy of the mechanism in new system of coordinates $J_{\text{var}}O_1\Delta E$.

Point O_2 of crossing of tangents to a curve of the energy-mass, defining unknown the maximum $\omega_{\max}$ and minimum $\omega_{\min}$ values $\omega(\varphi)$, is the beginning of system of coordinates JO_2E, in which the curve of energy-mass describes dependence of full kinetic energy of the mechanism from the resulted moment of inertia $E = E(J)$. It is possible to present this dependence as follows:

$$E = E_0 + \Delta E(\varphi) = \frac{(J_{const} + J_{\text{var}}(\varphi)) \cdot \omega^2(\varphi)}{2}. \quad (1)$$

Here $E_0 = \frac{J_{const} \cdot \omega_0^2}{2}$ - an unknown constant component of kinetic energy, where ω_0 - some unknown angular speed at $J_{\text{var}}(\varphi) = 0$ and $\Delta E(\varphi) = 0$. To this speed on fig. 1 there corresponds straight line O_2O_1, inclined at an angle ψ_0 to an axis of abscisses.

Thus, having E_0, from expression (1) it is possible to define current values of angular speed:

$$\omega(\varphi) = \sqrt{\frac{2 \cdot (E_0 + \Delta E(\varphi))}{J_{const} + J_{\text{var}}(\varphi)}} = \sqrt{\frac{2 \cdot (E_0 + \Delta E(\varphi))}{J(\varphi)}} \quad (2)$$

The problem of the dynamic analysis can be solved an iterative way, using the received dependence (2). The method essence is easy for understanding, having addressed to figure 1. In this case the curve of energy-mass set in system of coordinates $JO\Delta A$, it is necessary to transfer in system of the coordinates JO_2E, which beginning O_2 settles down on continuation of an axis of ordinates ΔA in a point of intersection from the straight line corresponding to set average angular speed ω_{av}, i.e. inclined at an angle ψ_{av} to an axis of abscisses. It is required to define position of this point. The block diagram of algorithm of the decision of a problem is represented in figure 2.

Having set by the initial data $J(\varphi)$, $\Delta A(\varphi)$, ω_{av} and an admissible relative deviation from size of average angular speed Δ_ω, it is necessary to pass from system $JO\Delta A$ in system $J_{\text{var}}O_1\Delta E$, as it is described above. The least value of the resulted moment of inertia $J_{\min} = J_{const}$ is thus defined. Then its greatest value $J_{\max}$, and also the greatest ΔE_{max} and least $\Delta E_{\min}$ values of function $\Delta E(\varphi)$ are also defined.

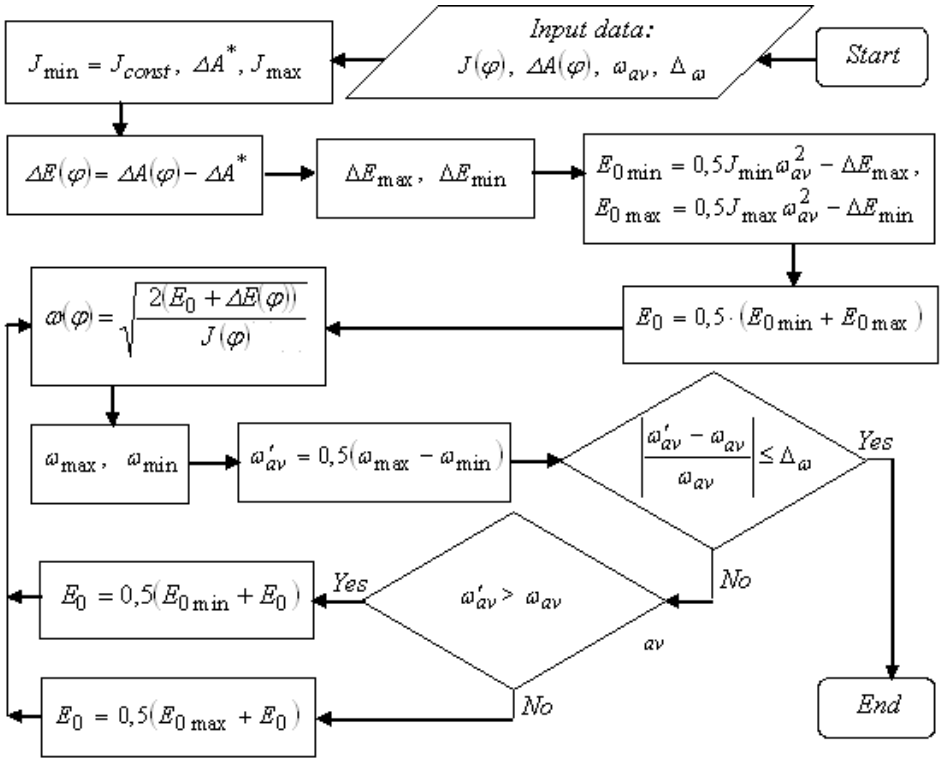

Fig. 2. The block diagram of algorithm of the dynamic analysis of the mechanism

Position of point O_2 is defined by size of kinetic energy E_0, which it is offered to search a method consecutive approaches. It is obvious, that the point O_2 settles down on a piece $O_2'O_2''$, which borders O_2' and O_2'' will arrange from the top and bottom points of a curve of energy-mass on distances, that with sufficient accuracy are defined by energy sizes accordingly $0,5J_{\min}\omega_{av}^2$ and $0,5J_{\max}\omega_{av}^2$, and from an axis of abscisses of system of coordinates $J_{\text{var}}O_1\Delta E$ in sizes

$$E_{0\min} = 0,5J_{\min}\omega_{av}^2 - \Delta E_{\max} \text{ and } E_{0\max} = 0,5J_{\max}\omega_{av}^2 - \Delta E_{\min}.$$

At the first stage it is possible to accept, that $E_0 = 0,5\cdot(E_{0\min} + E_{0\max})$. Then under the formula (2) angular speed of a link of reduction in all positions of the mechanism is calculated. Its extreme values and new value of average angular ω'_{av} speed are defined. The last is compared to the set ω_{av}. If the absolute relative size of their difference exceeds the set admission Δ_ω, it is necessary to find new position of the beginning O_2 of system of coordinates JO_2E, having accepted new value E_0.

Thus in a case, when $\omega'_{av} > \omega_{av}$, the point O_2 settles down on the midpoint of piece $O_2O'_2$, differently – on the midpoint of piece $O_2O''_2$. Procedure repeats. Iterative process proceeds until the deviation of the calculated value of average angular speed of a link of reduction from a preset value will not appear within the admission.

Angular acceleration of a link of reduction can be defined traditional [Frolov 1999] or nonconventional [Malkov 2008] methods.

CONCLUSIONS

Some advantages of the stated method.

- Possibility of performance of the dynamic analysis without dynamic synthesis.
- Possibility of creation of simple algorithm for the machine account.
- Continuity in relation to traditional methods and basic ideas.
- Presentation owing to possibility of application of a simple graphic illustration.

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МЕТОД ДИНАМИЧЕСКОГО АНАЛИЗА МЕХАНИЗМА

Валерий Мальков, Алла Власова, Павел Носко, Валерий Ставицкий

Аннотация. Предлагается итерационный метод динамического анализа, позволяющий определить закон движения звена приведения механизма при установившемся режиме независимо от динамического синтеза.

Ключевые слова: рычажный механизм, звено приведения, установившейся режим, динамический анализ, закон движения.

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THE THEORY OF MATRIX MAGNETOSENSITIVE SENSOR ON THE BASIS OF FERROPROBES

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Summary: The mathematical models of field, which allow to determine the interaction of ferroprobe cores in a matrix with the influence of a constant magnetic field of article are considered. The models allow to execute numerical calculation of an electromagnetic field in cores created by both the field of a defect, and the field excitation. The calculation allows to receive datas for the rational arrangement of ferroprobe cores in the matrix, and also to determine the transformation function of the matrix sensor.

Key words: control of defect, field of defect, ferroprobe.

INTRODUTION

The matrix disposition of ferroprobes for control of defect in ferromagnetic article has a number of advantages such as possibility of surface control without mechanical scanning, forming a three — dimensional information signal about defect with the help of computer, possibility of curvilinear surface control. The impulse schemes of excitation [Krotov L.N. 1985; Gaichenko V.Y. 1992] are applied simplification of the schemes of treatment of output signals of ferroprobes. The close disposition of elements in the matrix sensor (MS) influences the transformation function of every ferroprobe by the inductive connection of a coils of excitation. In this paper two problems are decided. One problem allows to determine the magnetization in the cores caused by the magnetic field of defect, the second one assesses the influence of MS elements on each other, caused by a current in windings of excitation.

OBJECTS AND PROBLEMS

For the construction of the mathematical model the following assumptions are made:

- the magnetization area, in which the defect is located, does not vary at a measuring of the MS field;

- the field strength of the source, which magnetized of an article is considered to be known.

The mathematical model of the field of defect represents an integral equation [Vinokurov V.E. 1991]

$$\overline{H} = \frac{1}{4\pi}\int_S \frac{\left[\overline{M}\left(\overline{R}'\right)\cdot\overline{n}\right]\left(\overline{R}-\overline{R}'\right)}{\left(\overline{R}-\overline{R}'\right)^3}dS' - \int_{V'}\frac{div\overline{M}\left(\overline{R}'\right)\left(\overline{R}-\overline{R}'\right)dV'}{\left(\overline{R}-\overline{R}'\right)^3} + \overline{H}_0\,, \qquad (1)$$

where: $\overline{M}$ is the vector of a ferromagnetic material magnetization; $\overline{R}$ and $\overline{R}'$ are vectors of points of observation and sources; $\overline{n}$ is the normal to a ferromagnetic surface; $\overline{H}$ is the magnetic field strength in a point of observation; $\overline{H}_0$ is the magnetized field strength.

By the approximation of area or a ferromagnetic material with elementary volumes (EV), which have the shape of rectangular prisms, inside which the vector of a magnetization is constant, the equation (1) will be transformed in a system of the algebraic equations

$$\overline{H}_i = \left[A_{ij}\right]\overline{M}_{ij}\left(H_j\right) + \overline{H}_{0i}\,, \qquad (2)$$

where: *i, j* are points of observation and source.

The elements of the matrix $\left[A_{ij}\right]$ are determined by geometric parameters of the defect and the space adjoining to it and are calculated for each EV by the following formula:

$$a_{ij} = \frac{1}{4\pi}\sum_{k=1}^{6}\oint_{S_k}\frac{\overline{n}\left(\overline{R}_i-\overline{R}_j\right)}{\left(\overline{R}_i-\overline{R}_j\right)^3}dS_k\,. \qquad (3)$$

The system of equations (2) is supplemented by the function of a nonlinear dependence of the module of the ferromagnetic material magnetization vector of an inspected article on the strength for the first and the second quadrant of the hysteresis loop

$$M_j = f\left(H_j\right), \qquad (4)$$

which is approximated by the cubic splines. The system of equations (2) is solved by an iterative mode with the help of algorithm offered in [Shvedchicova I. 1996].

Electric circuit of the ferroprobe is shown on the fig. 1.

For excitation circuit it is possible to write down

$$\frac{d}{dt}\left(\psi_{a1}+\psi_{b1}\right) + H_b\frac{l}{W}R = e(t), \qquad (5)$$

where: ψ_{a1}, ψ_{b1} — magnetic-flux linkage of excitement windings of ferroprobes semi-elements a and b; H_b — field intensity in the cores of semi-elements; *e(t)* — excitation voltage of ferroprobe.

Output voltage of ferroprobe is determined from the following expression

$$u_2 = \frac{d}{dt}\left(\psi_{a2} - \psi_{b2}\right), \tag{6}$$

where: ψ_{a2}, ψ_{b2} — magnetic-flux linkage of output winding of ferroprobe. The task of further theoretical construction is the determination of magnetic-flux linkages ψ_{a1}, ψ_{b1}, ψ_{a2}, ψ_{b2}.

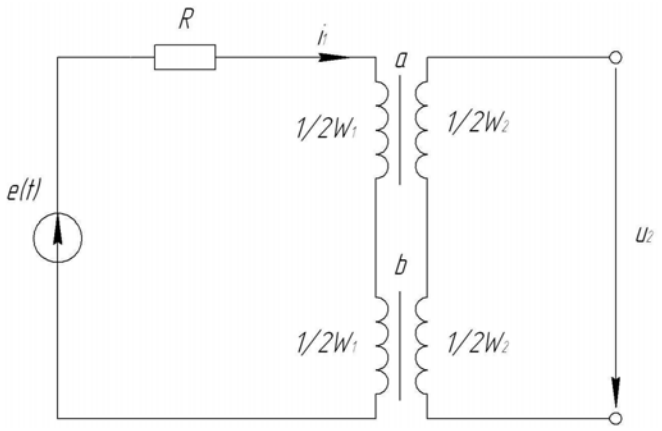

Fig. 1. Electric basic circuit of ferroprobe

According to the theorem of reciprocity [Polivanov K.M. 1974] the magnetic-flux linkage in the winding of the semi-element is equal to

$$\psi_u = \frac{1}{i_u}\left[\sum_{u=1}^{U}\int_V \overline{H}_u \cdot \overline{M}_u dV_u + \int_V \overline{H}_p \cdot \overline{M}_p dV_p\right] \tag{7}$$

where: $\overline{M}_u$ — magnetization in the cores of ferroprobes, caused by excitation voltage; $\overline{M}_p$ — magnetization of the defect area; $\overline{H}_u$, $\overline{H}_p$ — field intensity, created by excitation current in the cores and in the area of defect location.

While dividing the ferroprobes cores into EV (each core is given as K EO located along the core length), ratio (7) is presented in the form of U-quantity of semi-elements in the group.

$$\psi_u = \frac{1}{i_u}\left[\sum_{u=1}^{U}\sum_{k=1}^{K} \overline{H}_{uk} \cdot \overline{M}_{uk} \Delta V_{uk} + \sum_{p=1}^{P} \overline{H}_p \cdot \overline{M}_p \Delta V_p\right], \tag{8}$$

where: ΔV_{uk}, ΔV_p — EV of corresponding areas; P — quantity of EV in the area of defects.

Functioning of MS takes place both under excitation of one ferroprobe, and under excitation of the group or all ferroprobes.

It is quite sufficient to consider the influence of a group of cores on each other and located near each other.

There are three variants of a group of cores location, influencing each other in the matrix MS (fig. 2) — groups 10, 6, 4 according to the number of cores of semi-elements in the group, surrounding one ferroprobe (the cores of the considered ferroprobe are lined, the direction of the excitation field are shown by crosses and dots).

As a mathematical model of the vector field of magnetization in the cores an integral equation (1) is used. It is represented by a system of algebraic equations while dividing the volume of ferroprobes cores into EV

$$\overline{H}_i = \left[C_{ij}\right]\overline{M}_j\overline{H}_j + \left[D_{ip}\right]\overline{M}_p + \overline{H}_b, \tag{9}$$

where: $\left[C_{ij}\right]$ the matrix with dimension L×L , where $L = K \cdot U$; $\left[D_{ip}\right]$ — matrix for calculation of intensity in i-EV, created by j-m magnetized EV defect; $\overline{H}_b$ — intensity vector of excitation field.

The system of algebraic equations (9) is added by the dependence of magnetization on the field intensity for ferromagnetic material of ferroprobes cores

$$M_j = \varphi\left(H_j\right) \tag{10}$$

The elements of the matrix [C] and [D] are calculated through the formula analogous to (3).

Transformation function of ferroprobe is determined by the following ratio:

$$S = \frac{U_{2m}}{H_0} \tag{11}$$

where: U_{2m} — amplitude value of outlet ferroprobe signal, H_0 — intensity of the measured field.

While calculating the transformation function the system of equations (9) is simplified, as the vector H_0 is used instead of the vector $\left[D_{ip}\right]\overline{M}_p$ in (9). Its direction coincides with longitudinal axis of ferroprobe.

The algorithm of the coefficient of ferroprobe transformation is the following.

The function of the excitement voltage of the ferroprobe is approximated by the function

$$e(n) = e(n\Delta t) \cdot 1(t - n\Delta t), \tag{12}$$

where: $n = 1 \ldots N$; $1(t - n\Delta t)$ — single function; Δt — the time of quantization; N — quantity of time intervals of quantization

Differential non-linear equation (5) is solved through numerical method

$$\psi_{a1}^{(n)} + \psi_{b1}^{(n)} = \psi_{a1}^{(n-1)} + \psi_{b1}^{(n-1)} + \left[e(n) - qH^n\right]\Delta t, \tag{13}$$

where: $q = \frac{l}{W} \cdot R$.

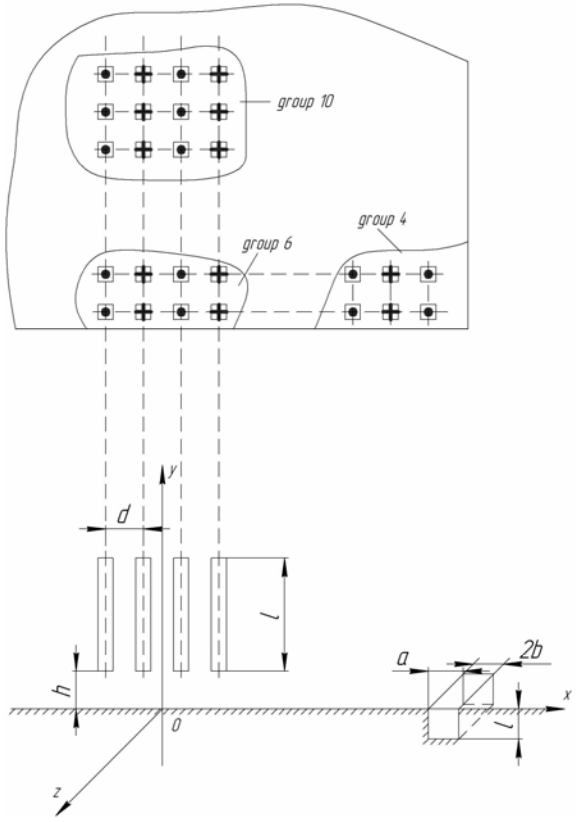

Fig. 2. The disposition of the ferroprobe matrix over the inspected surface

The intensity of magnetic field in the core of ferroprobe is calculated by the method of sequence approximations

$$H^{(n)} = \frac{1}{q} e(n) - \frac{1}{q\Delta t}\left[\psi_{a1}^{(n)} + \psi_{b1}^{(n)}\right] + \frac{1}{q\Delta t}\left[\psi_{a1}^{(n-1)} + \psi_{b1}^{(n-1)}\right] \qquad (14)$$

the value of magnetic-flux linkage in the cores of ferroprobes is determined by formula (8) after the solution of algebraic equations (9). All the calculations being made with the account of the direction of current in the windings of semi-elements of ferroprobes.

In the usual of numerical calculations the values of magnetic-flux linkages of the excitement windings $\psi_{a1}(n)$, $\psi_{b1}(n)$ are obtained and it permits to determine the output voltage of ferroprobe from the ratio

$$u_2(n) = \frac{1}{\Delta t}\left[\psi_{a2}(n) - \psi_{b2}(n)\right] \cdot 1(t - n\Delta t) \qquad (15)$$

where: $\psi_{a2}(n)=\frac{\omega_2}{\omega_1}$; $\psi_{b2}(n)=\frac{\omega_2}{\omega_1}$; ω_2 — number of turns of excitement windings and output winding.

CONCLUSIONS

The output signal of the single ferroprobe which measured the vertical component of the scattering field of defect with a breadth 2b=0,2 mm, depth t=0,5 mm and length a=10 mm on a flat surface of steel ШХ18 are calculated. The distance between ferroprobe and surface of steel h was 0,2 mm. The ferroprobe core has a geometric parameter 3×0,5×0,025mm; a winding of excitation has $\omega_e = 50$ coils; an output winding — $\omega_2 = 30$ coils. The ferroprobe was excited by unipolar impulses with an amplitude 15V and duration 1 mks. In the fig. 3 the plot of an output signal single ferroprobe is shown at transition one above the defect (dashed line) and ferroprobe, which were in an environment 10, 6 and 4 ferroprobes in the matrix.

The distances between the cores of ferroprobe made up $\alpha = d/l = 1$. Relative change of the transformation coefficient of the ferroprobe in the groups 10, 6 and 4 form the value α is shown on the fig. 4.

The charts snow that the stronger change of the transformation coefficient is obtained at α < 1 and depends on the quantity of cores which surround the ferroprobe. The obtained data correspond to experimental ones given in [Vinokurov V.E. 1991].

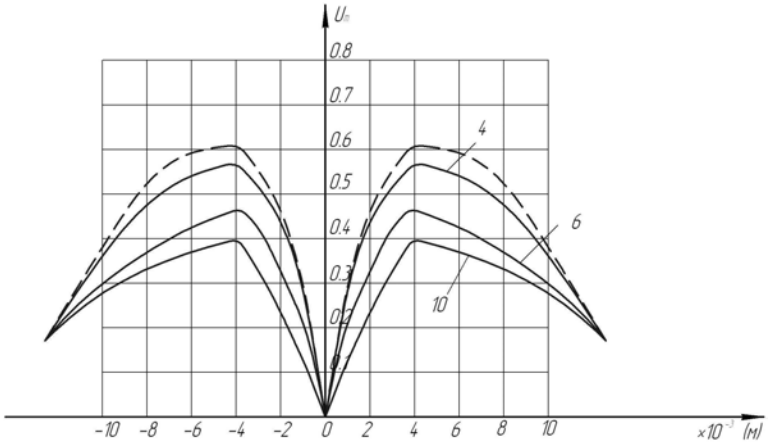

Fig.3. The plot of output signal of ferroprobe for the three groups of cores 10, 6, 4 at $\alpha = d/l = 1$

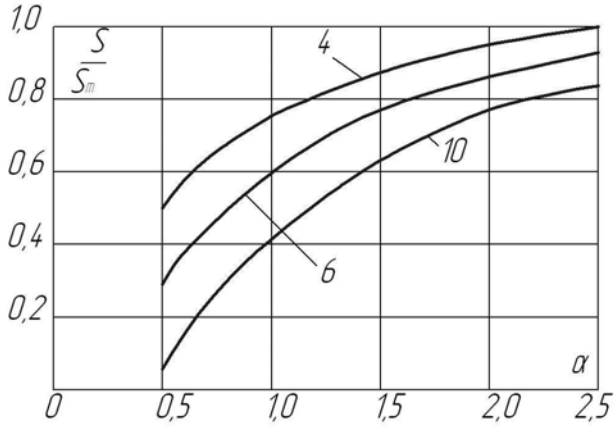

Fig. 4. The plot of conversion coefficient of ferroprobe in groups 10, 6 and 4 again the distance between cores

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ТЕОРИЯ МАТРИЧНОГО МАГНИТОЧУВСТВИТЕЛЬНОГО ДАТЧИКА НА ОСНОВЕ ФЕРРОЗОНДОВОВ

Вадим Мирошников, Николай Карманов, Сергей Костин

Аннотация: В статье рассматриваются математические модели поля, которые позволяют определять взаимодействие феррозондовых элементов в матрице с влиянием постоянного магнитного поля. Модели позволяют выполнять численное вычисление электромагнитного поля в элементах, созданных как областью дефекта, так и полем возбуждением. Вычисления позволяют получать данные для рационального использования феррозондовых элементов в матрице, а также для определения передаточной функции матричного чувствительного элемента.

Ключевые слова: контроль дефекта, область дефекта, феррозонд.

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CALCULATION OF THREE-DIMENSIONAL FIELDS IN TASKS OF DEFECTOSCOPY

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Summary: The mathematical models of magnetic field, which allow to determine. leakage field of defects considering of a presenting the researched domain ferromagnetic cores of the magnetically sensitive element are considered in article. The models allow to execute numeral calculation of an electromagnetic field in cores created by both the field of a defect, and the field excitation. The calculation allows to receive datas for the rational arrangement of ferromagnetic cores, and also to determine the transformation function of the magnetically sensitive element.

Key words: magnetic field, field of defect, defectoscopy.

INTRODUCTION

In defectoscopy the solution of field tasks of calculation of leakage field of defects, forming of a field in cores of magnetic systems etc. is the basic condition of creation of highly effective inspection systems. The task of calculation of a magnetostaticfield can be divided into three stages. At the first stage the mathematical formulation of a problem based on the Maxwell's equation is developed and reduced to getting the integral or differential equations for a considered boundary problem. At the second stage the simplifications and assumptions in distribution of fields and sources in considered domains are entered. The third stage is devoted to getting of numerical results.

According to the modern publications devoted to problems of the numeral solution of magnetostatics tasks, three methods are the most common: finite difference method (FDM), finite element method (FEM) and integral equation method (IEM).

In FDM the problem is initially formulated as differential equations in partial derivatives [Demirchan K.S., Chechyrin V.L., 1986; Il'in V.P., 1985; Marchyk G.I., 1980; Samarskiy A.A., 1971]. In the researched domain a quantity of discrete points associated with the set — grid, and functions of continuous argument associated with functions, determined on a grid. For each mesh point differential difference equation

associated with differential is written approximately, which consideration of boundary conditions, make system of the algebraic equations.

The theory FEM for the solution of the elliptic equations is expound in works [Zenkevich O., Morgan K., 1986; Sil'vester P. Ferrari R., 1986; Streng G. Fix J., 1977; Norri D., de Friz J., 1981]. This method is reduced to research of global function representing the considered phenomenon in all points of analyzed domain. The whole domain is divided into final adjacent subareas (final elements), the sought global function is drawing in parts on each of these elements.

The main drawback of FEM and FDM is the necessity to limit the calculated domain which leads to more calculation errors. The error of results of calculation by these methods can be determined by realization of repeated calculation with increased number of elements.

Recently IEM based on the theory of the potential of surface or volumetric distribution of field sources has been used widely [Grinberg G.A., 1962; Aleksandrov G.A., Fillipov E.S., 1983; Tozoni O.V., 1975]. Transition from differential equations of the electromagnetic field to integral equations is done by the Green function. Characteristic in IEM is the existence of the large variety of the integrated equations, differed on properties of solution and of the forms of writting. Therefore the search of economic mathematical models and constructions of effective computing algorithms of the solution of the integrated equations is rather urgent. The analysis of the references on IEM shows, that its using is most expedient to calculation of three-dimensional fields.

OBJECTS AND PROBLEMS

The magnetic field in homogeneous anisotropic environment is created by distribution of direct currents with density $\vec{\delta}$, located in domain V_i, limited surface S. The vector of inductance $\vec{B}$ and the field vector $\vec{H}$ submit to the equations

$$\mathrm{rot}\vec{H} = \vec{\delta} \tag{1}$$

$$\mathrm{div}\vec{B} = 0 \tag{2}$$

in domain V_i and to the equations

$$\mathrm{rot}\vec{H} = 0 \tag{3}$$

$$\mathrm{div}\vec{B} = 0 \tag{4}$$

in unlimited domain V_e, which is external in relation to V_i. Choosing the Cartesian system of coordinates, where datum lines x, y, z are parallel to the main lines of tensor of absolute permeability $\tilde{\mu}_a = \mu_0 \mu_{ij}$, and let $\tilde{\mu}_a$ a diagonal tensor of relative permeability, and μ_x, μ_y, μ_z to be its diagonal components (other components are equal to zero). Then

$$\vec{B} = \vec{i}\,\mu_0 \mu_x H_x + \vec{j}\,\mu_0 \mu_y H_y + \vec{k}\,\mu_0 \mu_z H_z . \tag{5}$$

Put vector potential by means of a correlation $\vec{B} = \mathrm{rot}\vec{A}$. Granting that $\vec{H} = \dfrac{\vec{B}}{\tilde{\mu}_a}$ is from (1) and we get the equation relative to $\vec{A}$

$$\mathrm{rot}\frac{1}{\tilde{\mu}_a}\mathrm{rot}\vec{A} = \mu_0\vec{\delta}\,. \tag{6}$$

Having entered new expression for vector potential $\vec{A}_1 = \tilde{\mu}\vec{A}$, assume $\mathrm{div}\vec{A}_1 = 0$. (That the given condition can be really executed as it is established below). Then, after replacement variables $x = \sqrt{\mu_x}\,x_1$, $y = \sqrt{\mu_y}\,y_1$, $z = \sqrt{\mu_z}\,z_1$, the equation (6) can be written down as one vector Poisson's equation

$$\frac{\partial^2\vec{A}_1}{\partial x_1^2} + \frac{\partial^2\vec{A}_1}{\partial y_1^2} + \frac{\partial^2\vec{A}_1}{\partial z_1^2} = -\mu_0\mu_x\mu_y\mu_z\vec{\delta}\,. \tag{7}$$

The solution of the given equation can be written down as

$$\vec{A}_{1q} = \mu_0\mu_x\mu_y\mu_z\frac{1}{4\pi}\int\limits_{V_{1q}}\vec{\delta}_{1q}\frac{dV_{1q}}{R_1}\,. \tag{8}$$

Passing to original coordinates x, y, z and function $\vec{A}$, we receive for it the following expression

$$\vec{A}_q = \mu_0\sqrt{\mu_x\mu_y\mu_z}\,\frac{1}{4\pi\tilde{\mu}}\int\limits_{V_i}\vec{\delta}_p\frac{dV_p}{R_a}\,, \tag{9}$$

where:

$$R_a = \sqrt{\frac{(x_q - x_p)^2}{\mu_x} + \frac{(y_q - y_p)^2}{\mu_y} + \frac{(z_q - z_p)^2}{\mu_z}}\,. \tag{10}$$

Granting that $\vec{A}_1 = \tilde{\mu}\vec{A}$, it is easy to notice, that a condition $\mathrm{div}\vec{A}_1 = 0$, with the help of which (6) received (7) is carried out, if

$$\mathrm{div}_q\int\limits_{V_i}\vec{\delta}_p\frac{dV_p}{R_a} = 0\,. \tag{11}$$

If $\mathrm{div}\,\vec{\delta} = \sqrt{a^2 + b^2}$ in volume V_i, that follows from the equation (1), then the equality (11) will be identity at anyone differentiable function, put on a place R_a^{-1} [Tamm I.E., 1976]. Thus, the formula (9) really gives the solution of the equation (6), through which vectors $\vec{B}$ and $\vec{H}$ can be evaluated in equations (1) — (4). In particular for the field vector $\vec{H} = \dfrac{\mathrm{rot}\vec{A}}{\tilde{\mu}_a}$ we receive the formula

$$\vec{H}_q = \frac{1}{4\pi\sqrt{\mu_x\mu_y\mu_z}} \int_{V_i} \frac{\left[\vec{\delta}_p,\ \vec{r}\right]}{R_a^3} dV_p , \tag{12}$$

where: $\vec{r} = \vec{i}\left(x_q - x_p\right) + \vec{j}\left(y_q - y_p\right) + \vec{k}\left(z_q - z_p\right)$; and the function R_a is determined by the formula (10). For a linear current with force I in the closed circuit l the formula (12) becomes

$$\vec{H}_q = \frac{1}{4\pi\sqrt{\mu_x\mu_y\mu_z}} \oint_l \frac{\left[d\vec{l}_p,\ \vec{r}\right]}{R_a^3} dV_p . \tag{13}$$

This formula evaluates the Biot-Savart-Laplace law for homogeneous anisotropic environment.

There is the formula similar to (9) that will be used in construction of the integral equations:

$$\vec{A}_q = \mu_0\sqrt{\mu_x\mu_y\mu_z}\ \frac{1}{4\pi\tilde{\mu}} \oint_S \vec{i}_p \frac{dS_p}{R_a} dV_p , \tag{14}$$

where $\vec{i}_p$ is density of superficial currents.

The exceptional vector potential also needs the scalar potential for calculation of a magnetic field in piecewise homogeneous anisotropic environment. The differential equation for it, is got out from the equations (3) and (4):

$$\mu_x \frac{\partial^2\varphi}{\partial x^2} + \mu_y \frac{\partial^2\varphi}{\partial y^2} + \mu_z \frac{\partial^2\varphi}{\partial z^2} = 0 . \tag{15}$$

The fundamental solution of the given equation is the function R_a^{-1}, where R_a is determined by the formula (10). Considering, that in some domain of anisotropic environment V the volumetric magnetic charges with density ρ are located, doing the same as at a formula construction (9), it is possible to find:

$$\varphi_q = \frac{1}{4\pi\sqrt{\mu_x\mu_y\mu_z}} \int_V \rho_p \frac{dV_p}{R_a}$$

— and the similar expression for potential of a simple layer of charges distributed on a surface S:

$$\varphi_q = \frac{1}{4\pi\sqrt{\mu_x\mu_y\mu_z}} \oint_S \sigma_p \frac{dS_p}{R_a} \tag{16}$$

Nothing, that potential (16) satisfies equation (15) everywhere outside of S.

Considering nowadays the technique of the construction of the integral equations, we use the following model problem. The constant currents with given density $\vec{\sigma}_0$ are located in unlimited domain V_e of anisotropic environment with diagonal tensor of magnetic permeability $\tilde{\mu}_{ae} = \mu_0\tilde{\mu}_e$ (fig. 1).

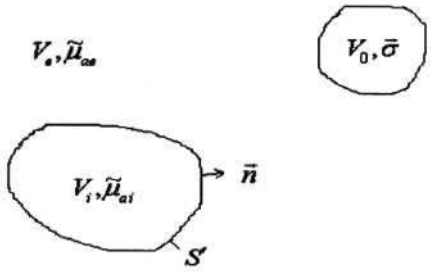

Fig.1.

The internal limited domain V_i is also filled with anisotropic environment with the diagonal tensor of magnetic permeability $\tilde{\mu}_{ai} = \mu_0 \tilde{\mu}_i$ ($\tilde{\mu}_i \neq \tilde{\mu}_e$). The constant currents are located in domain $V_0 \in V_e$. The vectors $\vec{H}_i$, $\vec{H}_e$ of a secondary field caused by secondary sources S, should submit to the equations: $\vec{H}_e$ — equation (1) in domain V_0 and equation (3) in domain $V_e - V_0$; a vector $\vec{H}_i$ — equation (3) in domain V_i. The vector $\vec{B}$ should satisfy with the equation (2) in all space, excluding S.

On environment interface the conditions of a continuity tangential components of making complete field vectors should be carried out: $\vec{H}'_i = \vec{H}_i + \vec{H}_{0i}$, $\vec{H}'_e = \vec{H}_e + \vec{H}_{0e}$. The vector $\vec{H}_{0i}$ of a field of the given currents is determined only in domain V_i on conditions that all space is filled of homogeneous anisotropic environment with tensor $\tilde{\mu}_{ai}$, similarly the vector $\vec{H}_{0e}$ is determined only in domain V_e on conditions that all space is filled of homogeneous anisotropic environment with tensor $\tilde{\mu}_{ae}$. According to the given representation of an external field, tangential components of vectors of a secondary field should submit to a boundary condition

$$\left[\vec{n}, \vec{H}_e - \vec{H}_i\right] = \left[\vec{n}, \vec{H}_{0i} - \vec{H}_{0e}\right]. \tag{17}$$

Besides on a surface S the normal components of the induction of a complete field $\vec{B}'_i$, $\vec{B}'_e$ should be continuous. It will give one more boundary condition

$$\left(\vec{n}, \tilde{\mu}_e \vec{H}_e - \tilde{\mu}_i \vec{H}_i\right) = \left(\vec{n}, \tilde{\mu}_i \vec{H}_{0i} - \tilde{\mu}_e \vec{H}_{0e}\right). \tag{18}$$

To construction of the integral equations in the given task it is necessary to apply the domain separated method, according to which the domains V_i, V_e, the special representations for field vectors $\vec{H}_i$, $\vec{H}_e$ should used. In domain V_e a sought vector we shall present as $\vec{H} = \mathrm{rot}\vec{A}_e$, where $\vec{A}_e$ we shall determine by the formula (14). In result

$$\vec{H}_{iq} = \frac{1}{4\pi m_e} \int_S \frac{\left[\vec{i}_p, \vec{r}_e\right]}{R_{ae}^3} dS_p, \tag{19}$$

where: $m_e = \sqrt{\mu_x \mu_y \mu_z}$; R_{ae} is determined by the formula (10) at $\mu_x = \mu_{xe}$, $\mu_y = \mu_{ye}$, $\mu_z = \mu_{ze}$, $x = x_e$, $y = y_e$, $z = z_e$.

In domain V_i vector $\vec{H}_i$ is determined as gradient of potential (16):

$$\vec{H}_{iq} = \frac{1}{4\pi\tilde{\mu}_i m_i} \iint_S \sigma_p \frac{\vec{r}}{R_{ai}^3} dS_p , \qquad (20)$$

where: $m_i = \sqrt{\mu_x \mu_y \mu_z}$; R_{ai} is determined by the formula (10) at $\mu_x = \mu_{xei}$, $\mu_y = \mu_{yi}$, $\mu_z = \mu_{zi}$, $x = x_i$, $y = y_i$, $z = z_i$.

In expressions (19), (20) vectors $\vec{H}_i$, $\vec{H}_e$ are determined outside of S. To use boundary conditions (17), (18), it is necessary to find limiting value of expressions $\left[\vec{n}, \vec{H}_e\right]$, $\left[\vec{n}, \vec{H}_i\right]$, $\left(\vec{n}, \tilde{\mu}_e \vec{H}_e\right)$, $\left(\vec{n}, \tilde{\mu}_i \vec{H}_i\right)$ on a surface S. Considering that the point q is normal to a surface S in domain V_e (outside of S). According to it S as a Lyapinov surface [4], we shall take up expression

$$\left[\vec{n}_q, \vec{H}_{eq}\right] = \frac{1}{4\pi m_e} \iint_S \frac{\left[\vec{n}_q \left[\vec{i}_p, \ \vec{r}_e\right]\right]}{R_{ae}^3} dS_p . \qquad (21)$$

Using the formula $\left[\vec{a}\left[\vec{b}, \vec{c}\right]\right] = \vec{b}(\vec{a}, \vec{c}) - \vec{c}\left(\vec{a}, \vec{b}\right)$, where $\vec{a}, \vec{b}, \vec{c}$ are an arbitrary vectors, reduce (21) to assume:

$$\left[\vec{n}_q, \vec{H}_{eq}\right] = \frac{1}{4\pi m_e} \iint_S \vec{i}_p \frac{\left(\vec{n}_q, \vec{r}_e\right)}{R_{ae}^3} dS_p - \frac{1}{4\pi m_e} \iint_S \vec{r}_e \frac{\left(\vec{n}_q, \vec{i}_p\right)}{R_{ae}^3} dS_p . \qquad (22)$$

In this expression at $q \in S$ the second part is improper integral, that is possible to show with the help of the theory of potential [Gunter N.M., 1953]. In the first part we shall make replacement of variables: $x_1 = \frac{x_e}{\sqrt{\mu_{xe}}}$, $y_1 = \frac{y_e}{\sqrt{\mu_{ye}}}$, $z_1 = \frac{z_e}{\sqrt{\mu_{ze}}}$, with the result that it looks like

$$\frac{1}{4\pi} \iint_{S_1} \vec{i}_{1p} \frac{\left(\vec{n}_{1q}, \vec{R}_1\right)}{R_1^3} dS_{p1} ,$$

where: index "1" indicate on using coordinates x_1, y_1, z_1; and $R_1 = \sqrt{\left(x_{1q} - x_{1p}\right)^2 + \left(y_{1q} - y_{1p}\right)^2 + \left(z_{1q} - z_{1p}\right)^2}$. This expression is normal derivative of potential of a simple layer with density $\vec{i}_{1p}$. Its limiting value on S is known [Gunter N.M., 1953]:

$$\frac{1}{4\pi}\iint_{S_1}\vec{i}_{1p}\frac{\left(\vec{n}_{1q},\vec{R}_1\right)}{R_1^3}dS_{p1}\Bigg|_{q\to S_1}=\frac{\vec{i}_{1q}}{2}+\frac{1}{4\pi}\iint_{S_1}\vec{i}_{1p}\frac{\left(\vec{n}_{1q},\vec{R}_1\right)}{R_1^3}dS_p\,. \quad (23)$$

Coming back to variables x_e, y_e, z_e and substituting the received expressions in (22), we shall receive, that on S:

$$\left[\vec{n}_q,\vec{H}_{eq}\right]=\frac{\vec{i}_{1q}}{2}+\frac{1}{4\pi m_e}\iint_S\frac{\left[\vec{n}_q\left[\vec{i}_p,\ \vec{r}_e\right]\right]}{R_{ae}^3}dS_p\,. \quad (24)$$

The limit of expression $\left[\vec{n},\vec{H}_i\right]$ on a surface S, where the vector $\vec{H}_i$ is submitted by the formula (20), is singular integral existing as the principal value [Mixlin S.G., 1977]. In result, substituting the received expressions for $\left[\vec{n},\vec{H}_i\right]$, $\left[\vec{n},\vec{H}_e\right]$ in boundary conditions (17), we receive first of the sought integral equations:

$$\vec{i}_q+\frac{1}{2\pi m_e}\iint_S\frac{\left[\vec{n}_q\left[\vec{i}_p,\ \vec{r}_e\right]\right]}{R_{ae}^3}dS_p-\frac{1}{2\pi\tilde{\mu}_e m_i}\iint_S\sigma_p\frac{\left[\vec{n}_q,\vec{r}_e\right]}{R_{ai}^3}dS_p=2\ \left[\vec{n}_q,\vec{H}_{0iq}-\vec{H}_{0eq}\right] \quad (25)$$

For construction of the second integral equation it is necessary to calculate limiting value on S with the expression $\left(\vec{n},\tilde{\mu}_i\vec{H}_i\right)$, where $\vec{H}_i$ is determined by the formula (20). Doing the same as at a formula construction (23), we shall receive, that on S

$$\left(\vec{n},\tilde{\mu}_i\vec{H}_i\right)=-\frac{\sigma_p}{2}+\frac{1}{4\pi m_i}\iint_S\sigma_p\frac{\left(\vec{n}_q,\vec{r}_i\right)}{R_{ai}^3}dS_p\,. \quad (26)$$

The limit of expression $\left(\vec{n},\tilde{\mu}_e\vec{H}_e\right)$ on a surface S, where the vector $\vec{H}_e$ is submitted by the formula (19), is singular integral. In result, substituting $\left(\vec{n},\tilde{\mu}_i\vec{H}_i\right)$ and (24) in boundary conditions (18), we receive second of the sought integral equations:

$$\sigma_p+\frac{1}{2\pi m_i}\iint_S\sigma_p\left[\frac{\left(\vec{n}_q,\vec{r}_i\right)}{R_{ai}^3}-k_1\right]dS_p+\frac{1}{2\pi m_e}\iint_S\frac{\left(\vec{n}_q\tilde{\mu}_i\left[\vec{i}_p,\ \vec{r}_e\right]\right)}{R_{ae}^3}dS_p=2\left(\vec{n}_q,\tilde{\mu}_i\vec{H}_{0i}-\tilde{\mu}_e\vec{H}_{0e}\right). \quad (27)$$

The equations (25), (27) form sought system of integral equations are for the solution of the following model problem. The constant k_1 is added to a nucleus of first integral that is equivalent to execution of a condition

$$\iint_S\sigma_p\,dS_p=0\,, \quad (28)$$

which is necessary for unique system solution (25), (27).

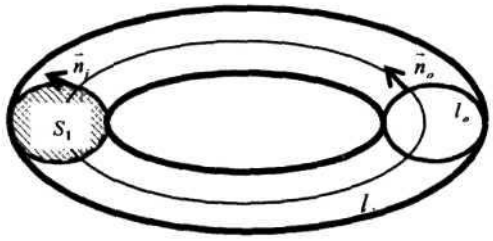

Fig. 2.

If the sources of an external field are located in area V_i, the sought system of the equations can be constructed on the same way. In area V_i tensity of a secondary field is determined as $\vec{H} = \frac{\mathrm{rot}\vec{A}}{\tilde{\mu}_a}$, where:

$$\vec{A}_i = \frac{1}{4\pi\tilde{\mu}_{ae} m_i} \oint\!\!\!\!\!\!\int_S \vec{i}_p \frac{dS_p}{R_{ai}}$$

There is this area V_e $\vec{H}_e = -\nabla\varphi_e$, where:

$$\varphi_e = \frac{1}{4\pi m_e} \oint\!\!\!\!\!\!\int_S \sigma_p \frac{dS_p}{R_{ae}}$$

The formulas for defined values $\left[\vec{n},\vec{H}_i\right]$ and $\left(\vec{n},\tilde{\mu}_e\vec{H}_e\right)$ on S are

$$\left[\vec{n},\vec{H}_i\right] = -\frac{i_q}{2} + \frac{1}{4\pi m_i} \oint\!\!\!\!\!\!\int_S \frac{\left[\vec{n}_q\left[\vec{i}_p,\ \vec{r}_i\right]\right]}{R_{ai}^3} dS_p \tag{29}$$

$$\left(\vec{n},\tilde{\mu}_{ae}\vec{H}_e\right) = -\frac{\sigma_p}{2} + \frac{1}{4\pi m_e} \oint\!\!\!\!\!\!\int_S \sigma_p \frac{\left(\vec{n}_q,\vec{r}_e\right)}{R_{ae}^3} dS_p \tag{30}$$

After substitution of expressions for $\vec{H}_0$, $\vec{H}_e$ in boundary conditions (17), (18) and using the correlations (29), (30) the following system of the equations similar on structure to system (25), (27) will turn out:

$$\vec{i}_q + \frac{1}{2\pi m_i} \oint\!\!\!\!\!\!\int_S \frac{\left[\vec{n}_q\left[\vec{i}_p,\ \vec{r}_i\right]\right]}{R_{ai}^3} dS_p + \frac{1}{2\pi\tilde{\mu}_{ae} m_e} \oint\!\!\!\!\!\!\int_S \sigma_p \frac{\left[\vec{n}_q,\vec{r}_e\right]}{R_{ae}^3} dS_p = 2\ \left[\vec{n}_q,\vec{H}_{0i} - \vec{H}_{0e}\right] \tag{31}$$

$$\sigma_p + \frac{1}{2\pi m_e} \oint\!\!\!\!\!\!\int_S \sigma_p \frac{\left(\vec{n}_q,\vec{r}_e\right)}{R_{ae}^3} dS_p + \frac{1}{2\pi\tilde{\mu}_{ai} m_e} \oint\!\!\!\!\!\!\int_S \frac{\left(\vec{n}_q\left[\vec{i}_p,\ \vec{r}_i\right]\right)}{R_{ai}^3} dS_p = 2\left(\vec{n}_q,\vec{H}_{0i} - \vec{H}_{0e}\right) \tag{32}$$

This system has the unique solution, if area V_i is one connected system. The integrated operator rather σ in the second equation does not need updating, as the

integrated equation of an external Neumann's problem has the unique solution. If the area V_i is biconnected and limited by surface of a toroidal type, it is necessary to use an additional condition as

$$\int_{l_e} \left(\vec{i}, \vec{n}_e \right) dl = 0 ,$$

where: l_e is closed circuit laying on the external part of S; $\vec{n}_e$ is the unit vector of normal to l_e, laying in a flatness, which is tangent to S (fig. 2). The given condition provides equality to zero of circulation of a vector $\vec{H}_e$ on any circuit covering the surface S. After multiplication on $k_1 \vec{n}_e$ it should be added to the equation (31), that will supply the unique system solution of (31), (32).

CONCLUSIONS

The offered technique of construction of the integrated equations allows to calculated leakage fields of defect considering of a presenting the researched domain ferromagnetic cores of the magnetically sensitive element. As the cores deform a field of defect and they are sources of an electromagnetic field, so exact definition of size of a field of defect necessary for the subsequent definition of the size of defect, needs the joint solution of system of the equations describing as a field of the core, as a field of defect on a surface of test object.

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РАСЧЕТ ТРЕХМЕРНЫХ МАГНИТНЫХ ПОЛЕЙ В ЗАДАЧАХ ДЕФЕКТОСКОПИИ

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Аннотация: В статье рассматриваются математические модели поля, которые позволяют определять поле рассеяния дефекта с учетом нахождения в расчетной области ферромагнитных сердечников магниточувствительных элементов. Модели позволяют выполнять численное вычисление электромагнитного поля в элементах, созданных как областью дефекта, так и полем возбуждением. Вычисления позволяют получать данные для рационального использования ферромагнитных сердечников, а также для определения передаточной функции магниточувствительных элементов.

Ключевые слова: магнитное поле, область дефекта, дефектоскопия.

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THE COOLING DEVICE OF LOCOMOTIVE WITH VAPORIZING COOLANT

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Summary: The analysis of the intensification methods of heat transfer processes, a comparative analysis of the effectiveness of the radiator sections when they work in the traditional system and using them as a condensing unit in the evaporative cooling system have been presented.

Key words: diesel, radiation section, condensing unit, coolant, heat transfer ratio, pressure.

INTRODUCTION

The cooling devices of modern locomotives are known to be the main consumers of the power transferred from the diesel for the auxiliary engine needs. For instance, for locomotive 2ТЭ116 this power is 225,5 кW [Filonov S. P, Gibalov A. I, Nikitin E. A., 1996] (10,02% of the diesel power), 183,2 кW giving out on the fans and pumps drive of the cooling device of the locomotive. Besides, the heat exchangers of diesel engines are made of expensive scarce non-ferrous metals (mainly copper and its alloys) [Lebedev P. D., 1972], and significant dimensions of the elements of cooling devices are serious obstacles when weighing and setting today's powerful diesel locomotives [Drobinsky V. A., Egunov P. M., 1980]. All these facts indicate a great importance of measures and scientific publications devoted to the improvement of the cooling device of the locomotive.

THE MAIN OBJECTIVE OF THE ARTICLE

To improve the efficiency and to reduce the dimensions and materials of heat exchangers of the locomotive cooling device, it is necessary to analyze and systematize the methods of intensification of heat transfer, and to consider their impact on the flow of heat transfer process and the functioning of the cooling system as a whole. Much attention will be paid to the water-air radiator section (the most expensive element of the cooling system) where locomotive 2ТЭ116 will be taken as an example. In this

paper, a comparative analysis of the effectiveness of the radiator sections of the size BC (68 tubes, plates step 2.3 mm, the surface area of 29 m^2, operating height 1206 mm) [Kulikov U. A., 1988] for their work in the traditional system and using them as a condensing unit in evaporative cooling system.

RESEARCH ANALYSIS

There is a great deal of scientific works devoted to the problem of improving the efficiency of the radiator locomotive sections. In this research it was determined that the main factors affecting the intensity of heat transfer are [Isachenko V. P., 1975]:

1) geometrical parameters of the radiator (and the presence of turbulators) [Vinogradov S. N., Tarantsev K. V., Vinogradov O. S., 2001];
2) the velocity of coolant circulation in the tubes;
3) the mass flow rate of cooling air in front of the radiator sections;
4) temperature difference.

The influence of these parameters on the dimensions of the radiator can be represented in the following formula [Kamaev A. A., Apanovich N. G., Kamaev V. A., 1981]:

$$n_s = \frac{Q}{t'_w - t'_a}\left(\frac{1}{KF} + \frac{1}{2u_w c_{pw} S_w} + \frac{1}{2u_a c_{pa} S_a}\right); \quad (1)$$

where: n_s – the required number of radiator sections;
Q – the heat load of the device, W;
t' – the input temperature of the radiator, ^oC;
K – the heat radiator section ratio, $W/(m^2K)$;
F – the surface area washed by air, for one section, m^2;
u – the mass velocity, $kg/(m^2s)$;
c_p – average specific heat capacity, kJ / (kgK);
S – a cross section for heat transfer, m^2.

Indices w and a are used for water and air respectively.

To go back from the mass velocity to linear one can through simple relation: $u = w\rho$ [Wong H., 1979].

Fig. 1 shows the dependence of the heat transfer ratio of pure radiator sections on the factors listed above [Shamshin A. A., Renov A. I., 1971] (Note: the graph also shows the curve corresponding to the mass rate of air 8.6 kg /(m^2s), which is of the the same actual value as on locomotive 2ТЭ116 [Bugaevsky S. B., 2006]).

As it can be seen from the graph, the effect on heat transfer ratio of the radiator coolant circulation speed in the tubes is much lower than the influence of the mass velocity of cooling air. This is explained by the fact that the heat transfer ratio of the air-water section of the radiator can be presented in the following formula [Kamaev A. A., Apanovich N. G., Kamaev V. A., 1981]:

$$K = \frac{1}{\left(\frac{1}{\alpha_1} + \frac{\delta}{\lambda}\right)\frac{F_2}{F_1} + \frac{1}{\alpha_2}} \quad (2)$$

where: K – the heat transfer ratio of the radiator section, W/(m^{2}K);
α – the heat transfer ratio, W/(m^{2}K);
δ – the wall thickness, m;
λ – the ratio of thermal conductivity of wall material, W/(mK);
F – the surface area washed by the coolant, m^2.

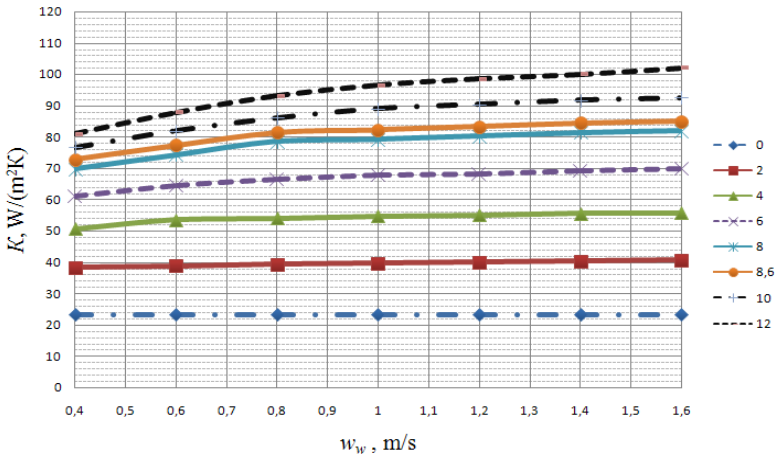

Fig. 1. The dependence of the heat transfer ratio of pure radiator sections on the rate of coolant circulation in the coolant tubes in sections at different values of mass velocity of cooling air

Indices *1* and *2* are used for water and air respectively.

In this case, the heat transfer ratio from the air is 58 ... 175 W / (m^{2}K), while the heat transfer ratio from the water is equal to 4650 ... 6400 W / (m^{2}K) [Kamaev A. A., Apanovich N. G., Kamaev V. A., 1981]. It is quite obvious that the heat transfer ratio of the radiator section depends mainly on the component $1/\alpha_2$. However, when comparing the traditional cooling system and evaporative system, mass flow rate of cooling air is not tied to the processes occurring in the coolant, and depends only on the fans performance [Malinov M. O., Kulikov U. A., Chertok E. B., 1962]. Hence, the further mass velocity of the cooling air will be taken as constant and equal to 8.6 kg/(m^{2}s) [Bugaevsky S. B., 2006].

THE PROBLEM SOLVING

Now taking an example of "cold" circuit (the cooling of the engine's oil), we consider in more detail the influence of the circulation rate of the coolant in the radiator tubes of the sections on the effectiveness and efficiency of the cooling device of the locomotive. As it is seen in Figure 1, the increase in the circulation speed of the coolant leads to an apparent increase in the ratio of heat radiator sections. However, it also increases the value of hydraulic resistance Δp radiator sections (fig. 2), and consequently, the costs of power for pumping the coolant in the cooling system. In addition, the continuity equation of fluid flow [Tchizhyumov S. D., 2007] shows that

the increase in fluid circulation rate in the radiator sections results in increase in fluid circulation rate in pipes and water-oil heat exchanger. Hydraulic resistance Δp of water-oil heat exchanger can be calculated by the formula [Kamaev A. A., Apanovich N. G., Kamaev V. A., 1981]:

$$\Delta p_w = z_w(0{,}31\frac{L_t}{d_{it}}\beta_t + 1{,}4)(w_w^2\rho_w)/2 \quad (3)$$

where: Δp_w – hydraulic resistance of water-oil heat exchanger of the water way of water-oil heat exchanger, Pa;
z_w – the number of coolant moves (water), W/(m^{2}K);
L_t –the full length of the tubes, m;
d_{it} – the inner diameter of the tubes, m;
β_t – the ratio depending on temperature and water velocity;
w_w – the speed of water in tubes, m/s;
ρ_w – the water density, kg/m^3.

It is seen from formula 3 that the value of hydraulic resistance Δp of water-oil heat exchanger is also steadily increasing (fig. 2.) with the rate of coolant circulation in the cooling system.

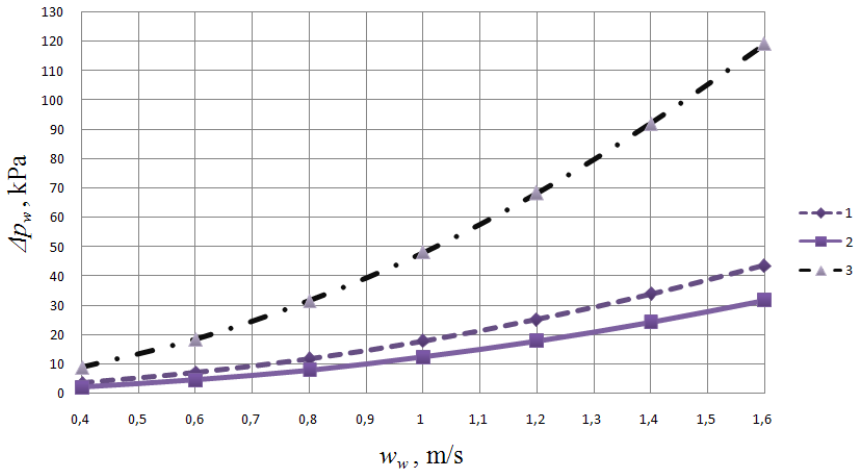

Fig. 2. The dependence of hydraulic resistance on the velocity of circulation of coolant:
1 - hydr. resistance of one section of the radiator, 2 - hydr. resistance of water-oil heat exchanger;
3 - total hydr. resistance of "cold" circuit

Let's consider the work of "cold" circuit of evaporative cooling system [Mohyla V. I., Gorbunov N. I., Sklifus Y. K., Shevchenko R. K., 2010]. The main features of such a system are:

a) the speed of the liquid coolant in the evaporator (water-oil heat exchanger) is zero;

b) the movement of steam from the evaporator to the condenser unit is independent (without any work applied) because of pressure difference in the

evaporator and condenser units associated with phase transitions [Isachenko V. P., 1977].

Point *a* indicates the absence of power costs in the evaporator, except for small costs for adding the coolant to maintain a constant liquid level. However, considering the fact that the mass flow of coolant by evaporation is at about 54 times less than when heated (at a temperature drop in heat exchanger 10 ^{o}C) [Mohyla V. I., Sklifus Y. K., 2010], we can conclude about low power costs power for adding the coolant and can neglect them in future.

Point *b* makes even greater interest. If the heat transfer surface of the capacitor unit is reduced, the amount of exhaust heat won't be enough for the condensation of the incoming steam. Having arranged a compressor before the condensing unit, it is possible to achieve a constant value of mass flow of steam, having applied a certain amount of power. It will result in the steam pumped into a closed volume with high pressure, leading to an increase in its actual temperature [Vukalovich M. P., Novikov I. I., 1968] and the condensation [Mohyla V. I., Sklifus Y. K., 2010]. The consequence of the above given information is that we get the increase in the temperature drop, which leads to the increased intensity of the heat transfer of condensing unit according to the formula [Zhukauskas A. A., 1982]:

$$Q = F \cdot K \cdot \Delta t \tag{4}$$

where: Q – the quantity of the heat output, W;
F – the heat exchange surface area, m^2;
K – the heat transfer ratio, W/(m^{2}K);
Δt – temperature difference (the difference of average temperatures of the coolant), ^{o}C.

For water and liquid solutions of [Gerasimov Y. I., Gejderih V. A., 1980] the increase in pressure within the three atmospheres entails the increase in the temperature of condensation (boiling) of about 0.198 ^{o}C per kPa [Pozin M.E., Grigorov O. N., 1966]. Thus, having applied the same power to the coolant circulation in the radiator sections working in the traditional system and when using them as a condensing unit, we also obtain the increase in temperature drop in the evaporative cooling system.

Taking into account the fact that the heat transfer ratio α_1 during the condensation is equal to α_1 of the traditional system, and is significantly higher than α_2, and ignoring the slight increase in K when the temperature drop is increased, we will make a comparative graph of the dependence of required relative surface area of the heat transfer F' on the pressure of coolant in the radiator sections of p' for "cold" traditional circuit and evaporative cooling systems (fig. 3.). In the graph on the vertical axis the relative heat exchange surface area F', which represents the ratio of the actual surface area of heat transfer surface area F of a radiator section (F_2 = 29 m^2) is shown. The horizontal axis represents the pressure of coolant in the radiator sections p' which is the ratio of the actual pressure taking into account Δp to atmospheric pressure p_{at} .

The graph in fig. 3 shows that when p' = 1,334 (which corresponds to the hydraulic resistance of radiator sections Δp = 33.77 kPa at a coolant circulation rate w = 1,4 m/s [Bugaevsky S. B., 2006] in the traditional cooling system), the required relative area of the heat transfer surface F' of the condensing unit 2.767 (13.766 %) lower than F' of traditional radiator system. With further increase in p' this difference increases.

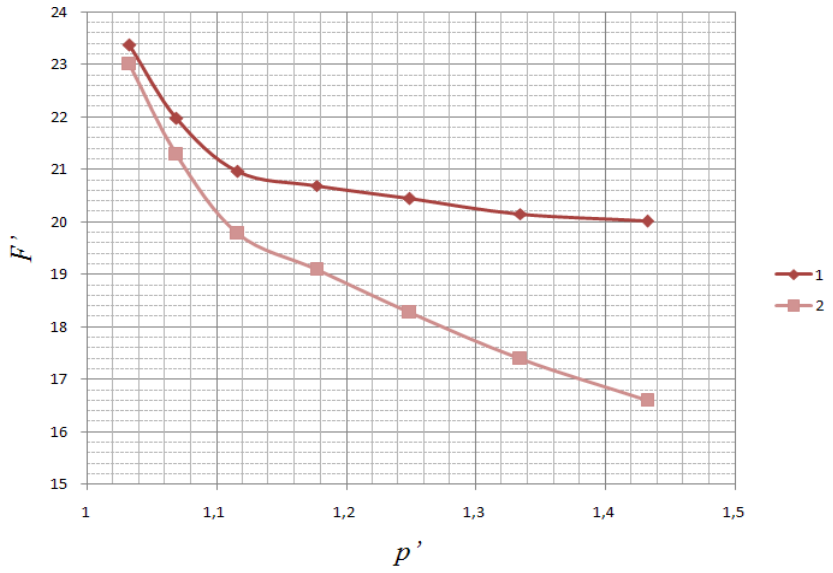

Fig. 3. The dependence of the required relative surface area of the heat transfer on the pressure of coolant in the radiator sections: 1 - traditional cooling system; 2- evaporative cooling system

CONCLUSIONS

When using the radiator sections in the evaporative cooling system of diesel engine it is possible to raise the temperature difference by increasing the coolant pressure by means of a compressor that has a positive effect on the overall size of the refrigerator of the locomotive. Thus, evaporative cooling system is superior to the traditional one, even under the existing costs of power and with the further increase of the section capacity of the locomotive this superiority is becoming more significant.

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ОХЛАЖДАЮЩЕЕ УСТРОЙСТВО ТЕПЛОВОЗА С ИСПАРИТЕЛЬНЫМ КОНТУРОМ ТЕПЛОНОСИТЕЛЯ

Валентин Могила, Николай Горбунов, Ярослав Склифус

Аннотация. В статье представлен анализ методов интенсификации процессов теплообмена, проведен сравнительный анализ эффективности радиаторных секций при работе их в традиционной системе и при использовании их в качестве конденсаторного блока в испарительной системе охлаждения.

Ключевые слова: дизель, радиаторная секция, конденсаторный блок, теплоноситель, коэффициент теплопередачи, давление.

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IMPROVING THE ENERGY EFFICIENCY OF DIESEL LOCOMOTIVES BY RATIONAL USING THE ENEGRY OF ELECTRODYMANIC BRAKING

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Oleg Ignatev, Vladimir Nozhenko

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Summary. The results of the studies of rational using the energy of electrodynamic braking of the locomotive have been presented. A locomotive scheme where some amount of the braking energy is taken away to fuel zonation, the efficiency of which is confirmed by the results of theoretical and experimental research, as well as the scheme of the locomotive where some amount of the braking energy is taken away to produce hydrogen have been developed.

Key words. A locomotive, a diesel, an electrodynamic braking, a fuel.

INTRODUCTION

The railway transport holds one of the leading positions in Ukraine's economy. The traffic volume of the Ukrainian railways takes the 4th place on the Eurasian continent, and the traffic density exceeds the leading European states' indicators in 3-5 times [Sergienko 2010]. However, the moral and physical wear of the rolling stock of Ukrzaliznytsya (UZ) (99% diesel locomotives and 83% of electric locomotives [Sergienko 2010]) and accordingly, the increased cost of rail transport reduce its competitiveness, which is especially important for Ukraine to get out of economic crisis and for the Final of European Football Championship in 2012.

One of the major priorities of restructuring UZ is to take measures to reduce the energy consumption.

OBJECTS AND PROBLEMS

The main factor determining the cost effectiveness of any means of transport is the complete use of its technical facilities [Kuznecov 2004], the rational use and economic consumption of energy resources. According to [Osipov, Mironov, Revich,

1979], the efficiency ratio (ER) of the locomotive depends on the technical perfection of all the systems of the locomotive on the whole:

$$\eta_{lok} = \eta_{diesel} \cdot \eta_{p.t.} \cdot \beta, \quad (1)$$

where: η_{diesel} - ER of the diesel; $\eta_{p.t.}$ - ER of the power transmission; β - the coefficient taking into account the amount of power taken away for the additional needs.

Thus, the issues of increasing the energy efficiency of the locomotive cover the operation of the vehicle as a complex multifunctional system, both at the design stage, operation, the solution of the above mentioned problem requiring a complex system approach.

When the energy efficiency of the locomotive in operation is increased, the greatest effect can be achieved from the use of the energy of electrodynamic braking of the locomotive, the maximum value of which is 1 - 1,2 N_e of the diesel locomotive [Basov, Bykadorov, Mishchenko, Naysh, 2006]. To identify the ways of rational use of the energy of electrodynamic braking for the needs of the locomotive, including the increase in its fuel efficiency, more research and evaluation of the expediency and its possible use are needed.

The experiments on the locomotives in the mode of electrodynamic braking showed that the power developed by the traction motors is 1300 - 4000 kW, and diesel locomotive power in a brake mode is superior in traction in the 1,2 - 1,3 times (table. 1) [Krasnyanskaya 1979].

Table 1. **Diesel locomotive power in traction and brake mode**

The series of the diesel locomotive	Power, кW	
	in traction mode	in brake mode
130	2206	1300
140	2941	1800
TE114	1912	1300
2TE116	2206	2700
TEP 70	2941	3600
TEP 75	4411	3600
2TE121	2941	4000

The analysis of existing designs of electrodynamic brakes showed that according to the method of accumulation and use of obtained braking energy, all the known technical solutions can be divided into [Golubenko, Mogila, Nozhenko 2007]:

- an energy storage device with a mechanical energy accumulator in which the energy is used for acceleration (the flywheel [Nikishin 2005], the pneumatic accumulator [Miagkov 2002], the springs [Vahrushev 1999]);
- an energy storage device with the heat energy accumulator in which the energy is used for additional needs of vehicle [Lakhno 2003];
- an energy storage device with electrical and chemical energy accumulator in which the energy is used for additional needs of vehicle [Kossov, Azarenko, Komarnitsky, 2007].

The analysis of the use of braking energy on the locomotive showed [Mogila, Nozhenko 2007] that the efficiency of electrodynamic brake does not meet the modern requirements as for the economic criteria:

- 84 - 90% of the energy is absorbed by the electrodynamic braking resistors that are through transforming it into heat, dissipate it into the environment;

- other ways to use this energy in the locomotive (the creation of the compression moment in diesel, the drive of auxiliary machines, the use of energy storage, the use of energy storage devices etc.) proved to be ineffective and therefore are not currently used.

Taking into account the above mentioned facts and based on the complex approach to solving the problem of energy efficiency of the locomotive, there was an attempt to construct a locomotive scheme with the 'ideal' use of braking energy (fig. 1) [Mogila, Nozhenko 2010],where it was proposed to use it for various needs of the locomotive, beginning from the use of energy storage devices [Kossov, Azarenko, Kornev, Komarnitskiy, 2008], activation of the working media [Golubenko, Tiupalo, Nozhenko, Mogila, Vasilev, Ignatev, 2009], electrification of sand [Gorbunov, Kravchenko, Popov, Kovtanec, Nozhenko, 2009], obtaining hydrogen [Lakhno 2003] and ending with production of carbon monoxide from the exhaust gases to use it for creating the microclimate and improving the traction characteristics [Gorbunov, Kravchenko, Kovtanets 2009].

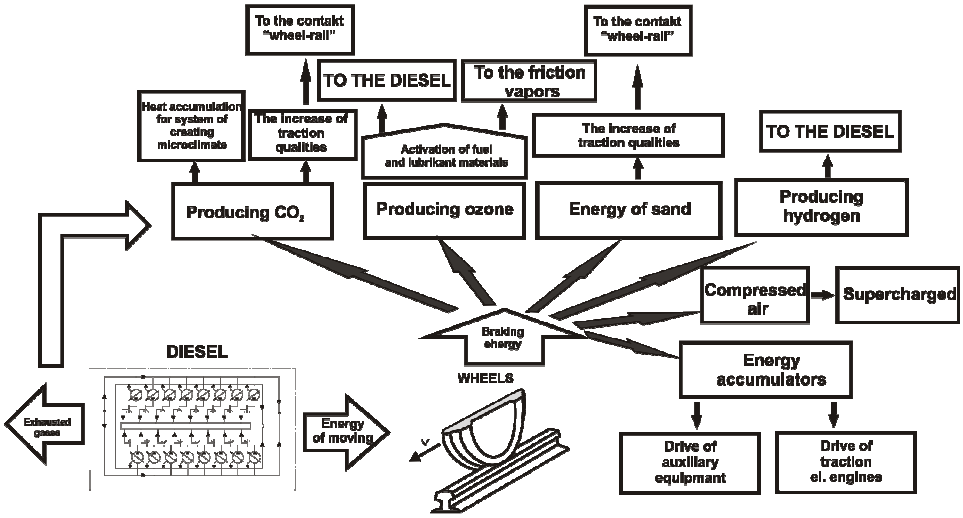

Fig. 1. The locomotive scheme with rational use of the braking energy

All the proposed methods to use the energy of electrodynamic braking, many of which seem to be extravagant, are perspective and require a detailed study.

The scientists from the East-Ukrainian National University named after Volodymyr Dahl worked out two of the proposed methods to use the energy of electrodynamic braking, i.e. the activation of the fuel and lubricants by ozone and obtaining the hydrogen to be added it to the fuel.

The use of ozone as an oxidizing additive to fuel is not new in the scientific world. Even in the 50 years of the twentieth century there were studies on the use of ozone as an oxidizer of rocket fuel [Pappok, Semenido 1962], which afterwards were implemented into life [Doktorov 2000]. For the motor fuel, the ozone was considered as an oxidant instead of the traditional air mixture. The researches in this direction were carried out in the late 80's - early 90's both in our country [Stepanov, Dychkov, 1968; Lewis, Elbe, 1968] and abroad [Lee, Park, Cha, Chung 2005; Stan, Guibert, 2004; Gluckstein, Morrison, Khammash, 1955; Nasser, Morris, James, 1998]. The prerequisites of using ozone instead of oxygen are based on its physical and chemical properties. A detailed study of petrol ozonation with the purpose of reducing fuel consumption and the emissions of exhaust gases [Stoliarenko 2000] has been done and it was proved that the ozone delivery in the fuel is more efficient than the delivery of the ozonized air to the carburetor.

The scheme of implementing the proposed method of increasing the energy efficiency of the locomotive is shown in fig. 2 [Nozhenko, Mogila, Basov ets. 2010]. It includes the following: some energy of electrodynamic braking, which is generated by traction motors TEM, is taken from the braking resistors R_r and is spent for ozone production, which is in the bubble chamber (for example, located in the fuel tank) fills the fuel with ozone ($DF+O_3$), activating it and giving it new properties (because of its high oxidative capacity), and further the power installation of the locomotive works on the ozonized fuel (DIESEL).

Thus, the increase of the fuel efficiency of diesel and the rational use of the energy of electrodynamic braking are achieved, which allows eventually to improve the efficiency of the locomotive as a whole.

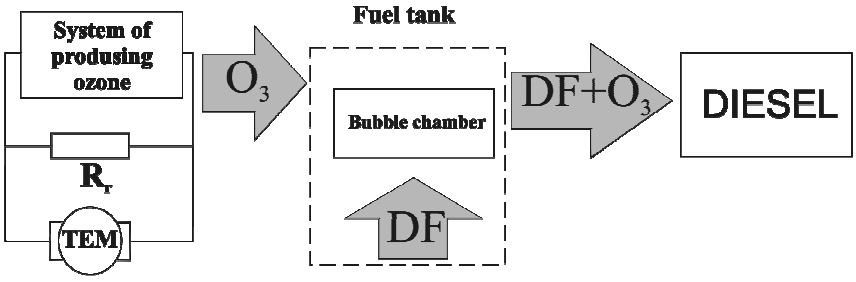

Fig. 2. The scheme of use of the energy of electrodynamic braking for obtaining ozone with further ozonized fuel

Experimental and theoretical studies of the ozone activation of diesel fuel showed that when implementing the proposed system on locomotive 2TE116U, produced by JSC HC “Luganskteplovoz” at a certain rational ozone concentration in the fuel k_{O_3} = 0,125 g/l the decrease in average operational fuel consumption of the effective specific fuel consumption was 1, 6% (the results of the studies on the positions of controller driver are shown in fig. 3).

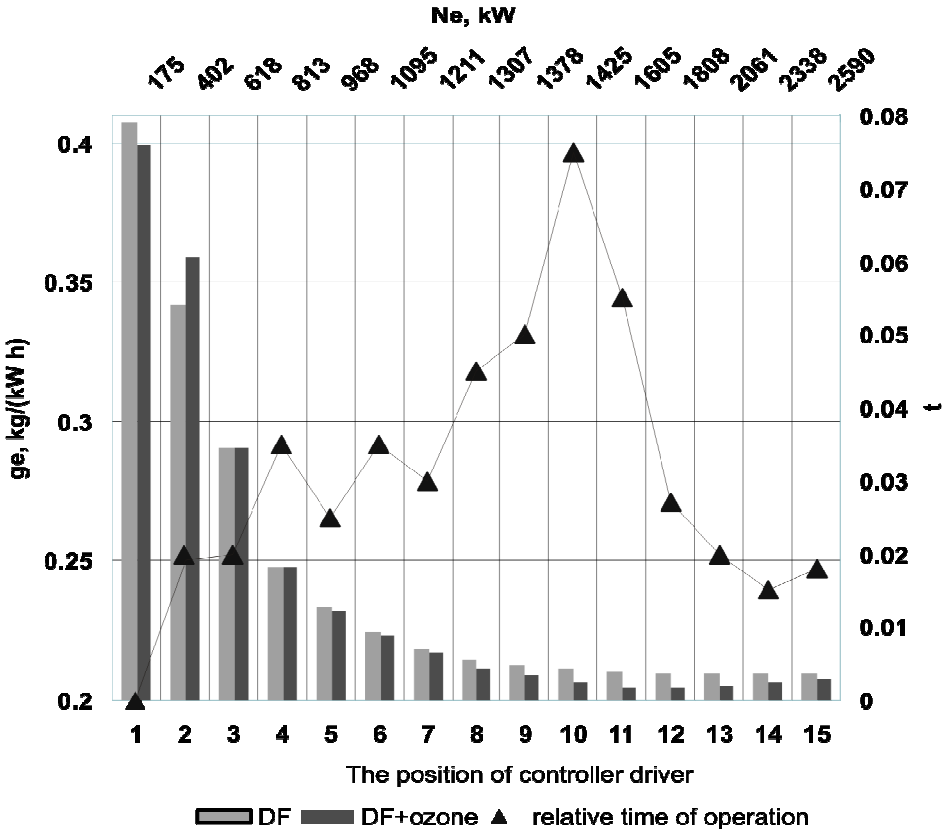

Fig. 3. Changes in specific fuel efficiency for diesel 16GHN 26/26 of locomotive 2TE116U in operation according to the diesel characteristic

Thus, the greatest effect of the fuel ozonation was observed in 11 position of controller driver, where the effective specific fuel consumption decreases by 2,5%. The results of changing the exhaust opacity of the exhaust gases on the positions of the controller driver are shown in fig. 4.

It is also developed and tested by us method of using a worthless power of EDB for producing hydrogen from water or steam that is of great interest due to its technical uniqueness. Hydrogen, when combined with an oxidizer, takes the first place in calories per 1 kg of among all the fuels used to generate electricity and heat. An obstacle to the wide use of hydrogen in energy is an expensive way to obtain it, which in certain cases is not economically justified, as the electrolysis or reactor installations applied are inefficient and energy intensive.

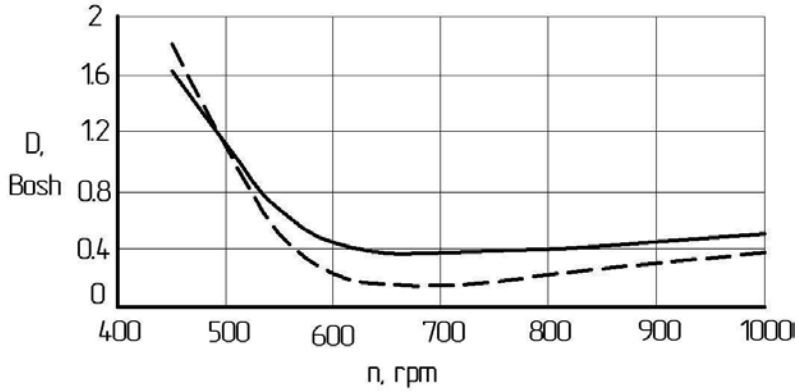

Fig. 4. The change of the exhaust opacity at operation according to the locomotive characteristic of diesel 16GHN 26/26 of locomotive 2TE116U

Therefore, in our opinion, on locomotives with EDB there is a real opportunity periodically to produce hydrogen and then use it as diesel fuel. One of the features of the method and system as a whole is the superheated steam by heating water of the cooling wall of the electrolysis or reactor installations. The investigations showed that the final products of the molecular decomposition of superheated steam may be hydrogen and oxygen in proportion 1:5; hydrogen-oxygen-nitrogen mixture; the hydrogen-nitrogen mixture, and ozone. It depends on the design and technological parameters of the installation associated with the voltage and amperage values applied to the electrodes, the water vapor and temperature consumption, air consumption and many other factors.

CONCLUSION

The analysis of the problem of energy efficiency has shown that it is reasonable to use the energy of electrodynamic braking of the locomotive. It was found out that the percentage of energy when it is returned to the contact network by electrical diesel locomotives is 5 - 8% (Lviv Railway, 2004 - 2008) and is growing every year, and on 01.01.2004 the recuperation of the electrical diesel locomotives' energy was equivalent to 1,7% of total UZ costs. In this regard the proposals for improving the energy efficiency of diesel locomotives by means of using the energy of electrodynamic braking are the promising way of improving the modern rolling stock.

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ПОВЫШЕНИЕ ЭНЕРГЕТИЧЕСКОЙ ЭФФЕКТИВНОСТИ ТЕПЛОВОЗОВ ЗА СЧЕТ РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ ЭНЕРГИИ ЭЛЕКТРОДИНАМИЧЕСКОГО ТОРМОЖЕНИЯ

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Аннотация. Представлены результаты исследований по рациональному использованию энергии электродинамического торможения тепловоза. Разработана схема локомотива с отбором части энергии торможения на озонирование топлива, эффективность которой подтверждена результатами теоретических и экспериментальных исследований, а также схема локомотива с отбором части энергии торможения на получение водорода.

Ключевые слова. Локомотив, дизель, электродинамическое торможение, топливо.

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MANPOWER ROLE IN TRANSPORT LOGISTICS IN GLOBALIZATION CONDITION

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Summary. In the conditions of economy globalization the international transport lanes, providing accelerated promotion of great substantial goods streams between the countries and continents on the basis of introduction of modern logistics technologies of cargo delivery are intensively formed.

Key words: transport, logistics, globalization, economic, intercargo.

INTRODUCTION

The basic signs of economy globalization are international trade expansion, activation of the migratory processes covering resource base of world production, strengthening of integration interaction of the countries.

In international transport lanes (ITL) goods gravitation zone great traffics are concentrated and the coordinated interaction of the various types of transport providing accelerated and qualitative transportations of cargoes with a high degree of service on the basis of uniform documentary based ones, the through rate of tariffs is carried out and at full responsibility of the forwarding agent (operator) for all transportation process.

ANALYSIS OF LAST RESEARCHING AND PUBLICATIONS

Recently development mainstream development and perfection of transport service in manufacturing sphere, distribution and production consumption abroad is the logistics. 25-30% of a total national product of leading foreign countries are connected with logistical systems, such, as the USA, Japan, the Great Britain, France, Germany. Industrial production and standard of living growth in these countries in 70-80th years are often connected with introduction in practice of principles of logistics [Arnold B. Maltz, James R. Giermanski, David Molinf 1996, INTERCARGO, 2010., INTERCARGO, 2005, Caren W. Currie 1996].

GOAL OF RESEARCHING

In article importance of application and the further development of logistical system is proved. Thus, improvement of professional skill of corresponding manpower - strategic problem in which the system of remote training substantially helps to solve, improvements of professional skill.

MATERIALS AND RESULTS OF RESEARCHING

Logistics consideration as the factor of increase of competitiveness assumes, that consequences of accepted decisions in the given area should be given into measurement in respect of their influence and functional expenses and for incomes from sales of the goods and services. In this connection the problem of finding away the control of costs and the indicators most correctly reflecting communication of logistics with the basic economic and financial indicators of firms is staticized.

As the logistics influences almost each aspect of the account of profits and losses of firms, therefore respective alterations in logistical strategy influence financial results of activity of firms and bring the mite in maintenance of their long-term viability. The firms which have taken as adopted logistical strategy, constantly analyze it. The profit and the invested capital are exposed to the careful analysis also to be convinced as peak efficiency of use of resources.

Experience testifies, that use of principles of logistics allows to reduce essentially the cost price of production at the expense of any decrease in "stocks" by delivery under the minute schedule of raw materials, the half-finished products, completing products, etc. to a bookmark place, to a workplace at the conveyor, during installation; reduction of expenses by packing and marks at the expense of use of a wide spectrum of kinds of containers and returnable container; reductions of terms of preselling preparation of the goods; use of the paperless documentation; decrease in expenses for installation and installation of the equipment at the expense of use of railway and automobile conveyors, ships with horizontal or dock loading and unloading (type vessels "ro-ro" and "ro-flow") [IMO 1996].

The considerable part of logic operations on a way of movement of a material stream from a primary source of raw materials before final consumption is carried out with application of various vehicles. Expenses for performance of these operations make to 50% from the sum of the general expenses for logistics.

The technologies of cargo transportation connected with concentration of transport streams and growth of container transportations on intermodal to transport lines, become a basis of a uniform global transport network of the XXI-st century and should be improved constantly.

Transport - branch of national economy which satisfies requirements of all branches of a national economy and the population as for transportations of cargoes and passengers [IMO 2004].

Transport is organically entered in industrial and trading processes. Therefore the transport component participates in setting of logistics problems. At the same time there is independent enough transport area of logistics in which the multidimensional coordination between participants of transport process can be considered beyond direct

communication with the interfaced is industrial - warehouse sites of movement of goods stream.

As problems of transport logistics first of all are referred the problems which decision strengthens coordination of actions of direct sites of transport process.

Logistics application in transport is the same as in manufacturing or trade, transforms counterparts of the competing parties into the partners, complementary with each other in transport process [Jankowski J., Bogdaniuk M. 2007; John L. Kent, Daniel J. Flint 1997].

The logistics as it was marked, is the uniform technics, technology, economy and planning. Accordingly, it is necessary to carry maintenance of technical and technological associativity of participants of transport process, the coordination of their economic interests, and also use of uniform systems of planning problems of transport logistics.

The aggravation of competitive situation in the transport market in the conditions of scientific and technical process in 60-80 years has demanded from agency and forwarding firms in close cooperation with industrial and transport agencies carrying out of the whole complex of the actions directed for perfection of management by their activity on the basis of use of electronic-computer facilities, and also the interconnected technical, organizational and commercial actions allowing most rationally to provide transportation of cargoes in concrete directions from the sender to the consignee. Thus, improvement of professional skill of corresponding manpower - strategic problem in which the system of remote training substantially helps to solve, improvements of professional skill.

These actions in large firms have poured out in new system of the organization and management of transport-technological systems (TTS) [Lloyd's List 2010; Lloyd's List 2008; Paul R. Murphy, James M. Daley 1995].

One of them represents close combination of daily operational practice in market conditions with research activity for creation or introduction of new methods of ways of cargoes processing, transfers goods being dared, goods accomplished as well as with other documentation, loan and designing of new kinds of packing, marks of cargoes and design of the goods which are meeting the requirements of safety, safety of using, transportation and demands of corresponding skill level of shots are referred different aspects of international logistics, which differs from inside logistics for example by papers exchange channel availability. A number of papers referred to international cargo shipping as a rule is great. Besides international logistic efficiency depends on currency exchange variations because these variations cause merchant flows change. Government of different countries try to influence to foreign trade particularly due to the fact that goods and services export favor currency economy, influences positively balance of trade of the country and national currency course. Governments may also act against import, inducing fees and other limits which are called sometimes non-tariff barriers. Governments subsidues development of national Merchant fleet and airlines [Douglas C. Long, Donald F. Wood 1995; Philip B. Senary, Tage Skjott-Larsen 1995].

International raw materials and substances supply supposes the search all round the world initial substances for a certain technological process.

As international logistic being complex type of activity, many companies refer to professional for rendering assistance in export and import bargain. As these foreign professionals are considered cargo forwarding agencies, carriers not in ships tonnage

possession (NVOCC), customs brokers, export packers and others [Arnold B. Maltz, James R. Giermanski, David Molinf 1996; Donald F. Wood, Anthony Barone, Paul Murphy, Daniel L. Wardlow 1995].

At last separate elements of forwarding process taking place in export goods forwarding are referred in the chapter. These are trans shipments to the port or air port loading on air craft board of the ship and goods shipping by sea. International goods substance stores maintenance problems are exposed in the chapter briefly.

So, for example, for constant directions of transportations and for the cargoes defining the basic turn of forwarding firm, COMPUTER programs are made, working under demands of certain personnel knowledge.

Forwarding firms personnel should provide economic and rational delivery of the goods (beginning from raw materials and finishing with finished article) in demanded quantity and in demanded terms. It has appeared possible when technical maintenance of computers communication of commodity producers with forwarding agents computers has been reached, and including use of telespace communications, an exchange between them is provided by electronic documentation and the information and acceptance by means of the COMPUTER of the general optimum operative decisions.

More important role in logistics will be held by electronic data interchange. It differs from traditional exchange of oral messages and document, EDI provides Computer data interchange between sellers and buyers. At present EDI in logistics is widely used for booking orders transferring and clients requirements handling for rendering services. EDI not only speeds up the process of handling orders but lessens mistake possibility [Caren W. Currie 1996; David G. Frentzel, Gary J. Sease 1996; Donald Skelton, Donald Thoma, Michael E. Walczak 1996].

Internet appearance has changed basically logistics activity, because new forms of business appeared and develop and this reliable and cheap all round the world network is being explored by logistics managers. Systems of scientific intellect will be widely spread in logistics operations, considering their high potential in orders and rendering services [Global Logistics Research Team at Michigan State University 1995].

Having been trained specially competent and having got corresponding education in the field of transport logistics, the personnel has an opportunity to use methods and conclusions of transport logistics as a control facility industrial and trading processes, intraindustrial inspection behind movement of raw materials, materials, finished articles.

From the end of 80th the experts problem in the field of transport logistics have started to become complicated: shipper of cargo transportations in the mixed message has started to be transformed to the forwarding agent-operator of the general distribution that includes direct participation in it and the bank financing all operation in its complex.

As the basis of corporate logistics the thought that each campaign, and in some cases and branches, it is expedient to separate taking into account the integrated planning manufacturing it is reasonable to separate manufacture and trade from distribution by transfer in full or in part logistics functions in hands of the specialized companies owning all completeness of accumulation, storage and information sale. To leave on the one hand calculation of requirements and resources, the equipment,

manufacture, the capital, shots, and with another to fix purchase of materials and energy carriers, storage and transportation, sales management, recycling and waste utilization.

During similar logistical problems decision forwarding and agency firms take up production functions of completion, profound processing of raw materials and half-finished products, distribution of its finished articles between consumers. For simplification and rationalization of these operations they carry out intermediate purchases and resale's of the goods and by that specialize on the centralized supplying activity.

Management of transportations – the typical logistical function directed on maintenance of productivity and efficiency of regular transportations of cargoes and passengers.

Application of logistics principles in practice became possible only at certain level of development of computer facilities, skill level of the personnel, its ability to accept, process and transfer the information. So, an integral part of all kinds of logistics is obligatory presence of logistical information stream (information logistics), including data about stream of the goods, their transfer, processing and ordering with the subsequent delivery of the ready information.

Thus, problems of managers, experts in the field of transport logistics have become complicated much more. New prospects in the field of the organization of the international transportations, opening in the conditions of globalization, demand knowledge and practice in various areas of the given science, ability to work with huge files of the information, and to be able to transfer it.

Shots are the important component of system of logistics. Shots are a potential of any organization, a source of increase of competitiveness of the enterprise in long-term prospect. The great value is given to their selection and preparation.

In the conditions of the market interest in improvement of professional skill of an available manpower is considered as the factor providing effective activity of firms – participants of process from manufacture before realization of finished goods and competitiveness of the enterprises participating in TTS.

CONCLUSIONS

In the last chapter are referred some problems which mostly will influence future development of logistics. It is supposed that these trends will change substantially logistics sphere. Fast growing trade and operations will take new shape. National companies will depend upon export and import at more full extent. Some companies will become multinational.

Services sphere extension is expected in the world. It means that the economical activity share concerning rendering services will increase and a share of economy connected with goods manufacturing will decrease. Logistics systems is required to be reorientated from substantial goods delivery for rendering services.

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РОЛЬ ТРУДОВЫХ РЕСУРСОВ В ТРАНСПОРТНОЙ ЛОГИСТИКЕ В УСЛОВИЯХ ГЛОБАЛИЗАЦИИ

Григорий Нечаев, Галина Гаркуша, Марина Макаренко

Аннотация. Приводится обзор проблем формирования международных транспортных коридоров, в условиях глобализации экономики, обеспечивающих ускоренное продвижение крупных товарноматериальных потоков между странами и континентами, даются практические рекомендации внедрения современных логистических технологий доставки грузов.

Ключевые слова: транспорт, логистика, глобализация, экономика, международные перевозки.

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METHOD OF QUASIFREQUENCY-PHASE SPEED CONTROL OF INDUCTION MOTORS

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Summary. Method of speed control of induction motors down from the nominal, multiple of integer, by overturning the corresponding half-waves of sinusoidal voltage is proposed. Through the use of the phase method of voltage regulation, this method allows to withstand the constant ratio between the frequency and voltage. The circuit diagram that implements quasifrequency-phase method is developed, and design formula for determination of the moment of time of the phase angle t_α of the speed of asynchronous motors. Figs. 3, sources 20.

Key words. Quasifrequency-phase method, speed control, underfrequency, speed control, induction motor

INTRODUCTION

Speed control of induction motors (IM) is necessary for many technological processes. For example, IM are used as a drive in the exhaust fan on the boiler and, depending on the intensity of the burning fuel is necessary to adjust the value of draught in the exhaust air ducts, notably, induction motor speed.

There are following methods of speed control of IM: change in the number of pole pairs, undervoltage, rheostatic control (only for IM with wound rotor), frequency control. Undervoltage is inefficient because the voltage drop leads to a reduction in the rigidity of the mechanical characteristics,so this method is used for speed control drives with a fan loading. Rheostatic speed control of IM is used only for motors with wound rotor, and electric drive that implements this method has low efficiency. These two methods allow to adjust the speed of IM just down from the nominal. Frequency method allows to adjust the speed of IM both up and down from the nominal. However to realize this method is not always possible, because it is expensive due to the presence of controlled rectifier, autonomous inverter, which should work in the modes of forced, artificial and natural commutation. For IM of high capacity to solve problems with commutation is rather difficult because of the large inductance value. [Chilikin M.G., 1981]

UNDERFREQUENCY OF SUPPLY SINUSOIDAL VOLTAGE OF IM BY PARTIAL RECOMMUTATION OF HALF-WAVE

The essence of the proposed method is to lower the frequency of supply sinusoidal voltage in integer number of times by turning relative to the axis of time t some half waves of sinusoid. For example, with decreasing of frequency in half, as shown in fig. 1, is necessary in the first period T1 to turn the negative half-wave, and the second T2 turn positive half. Next, in odd periods all repeats as in the first period T1, and in even periods, as in the second period. As a result, in odd periods will be two positive half-wave, and in even two negative.

From the oscillogram in the fig. 1, shows that the 1st harmonic of voltage on the phase winding of IM has period:

$$T_{1/2} = T_1 + T_2 \tag{1}$$

Hereby, the frequency of the supply voltage in BP drops two times, compared to the frequency of the network, properly, and the speed decreases two times.

In this case, the ratio should be maintained:

$$\frac{U}{f} = \text{const} \tag{2}$$

where: U - the effective voltage on winding of IM, f - the frequency of 1st harmonic of supply voltage of IM [Gusev V.G., 1990].

Fulfillment of the correlation (2) is realized by using the phase method of regulating the effective supply voltage, notably, control valves are opened to the delay in the phase angle α and, properly, the winding of the IM is fed by only the shaded part of the half-wave of sinusoid (fig. 1). Due to this, the area of half-wave of the first harmonic of supply voltage with low frequency could be equal to the sum of the areas of shaded parts of two half waves of supply voltage and the condition (2) will be implemented.

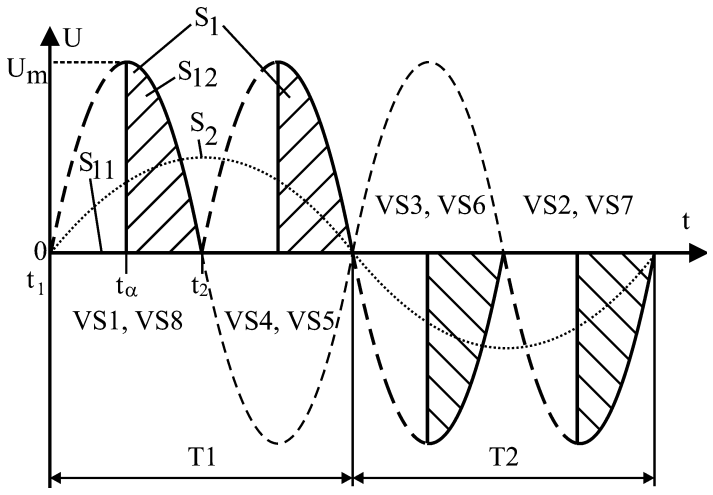

Fig.1. Oscillogram of underfrequency of supply voltage in 2 times

With decreasing frequency in three times as shown in fig. 2, it is necessary in the first period T1 to turn a negative half-wave, the second period T2 to leave intact and in the third T2 to turn a positive half-wave. Next, all repeats in a cycle: in 4, 7, 10, ... periods of half-waves turn, as in the 1st period, 5, 8, 11, ... periods remain intact, as in the second period, and periods of 6, 9, 12, ... half-waves turn, as in the 3rd period.

From the oscillogramin the fig. 2, shows that the 1st harmonic of voltage on the phase winding of IM has period:

$$T_{1/3} = T_1 + T_2 + T_3 \tag{3}$$

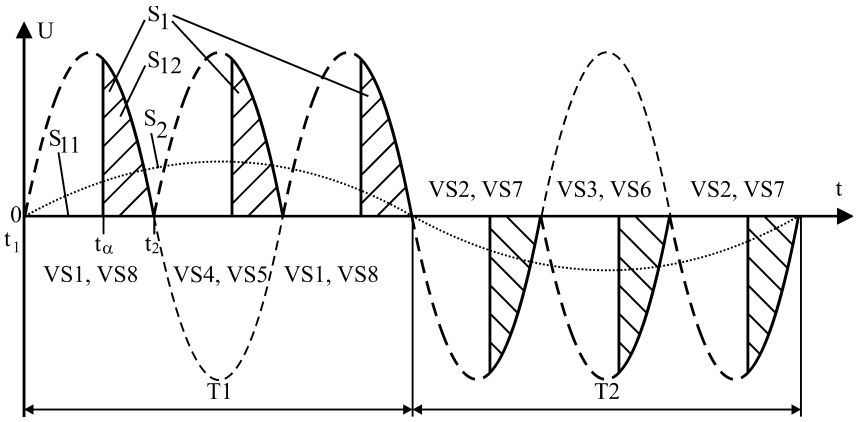

Fig.2. Oscillogram of underfrequency of supply voltage in 3 times

The proposed method allows to adjust the speed of IM down from the nominal and in reasonably wide range, while the frequency of supply voltage of IM is a multiple integer.

SCHEME AND OPERATION OF QUASIFREQUENCY-PHASE CONVERTER

The process of turning half-waves of sinusoidal supply voltage is realized by thyristor quasifrequency-phase converter, by commutation of windings ends of BP at a certain time with a corresponding phase, or "zero".

The stator winding of IM is connected to one end through a thyristor or transistor group of valves (thyristors or transistors) of converter by turn with phase and with "zero" (single-phase or three-phase motor, connection –star) or the other phase (three-phase motor, connection –delta). The other winding end of IM is also connected through another group of valves (thyristors or transistors) of converter by turn with phase and with "zero" (single-phase or three phase motor, connection – star) or the other phase (three phase motor, connection – delta), but in antiphase relatively the first group of valves of the converter.

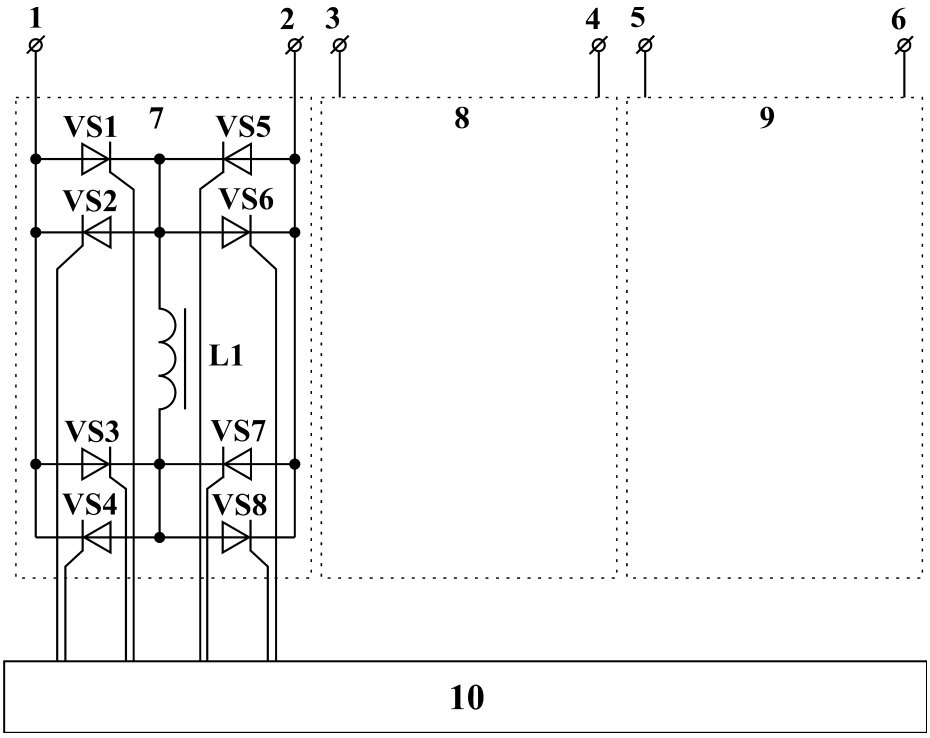

Fig. 3. Scheme of thyristor quasifrequency-phase converter

In parallel, oppositely connect thyristors VS1 with VS2, VS3 with VS4, VS5 with VS6 and VS7 with VS8. Winding beginning of the phase L1 is connected with thyristors VS1, VS2, VS5 and VS6, and the end of this winding is connected with thyristor VS3, VS4, VS7 and VS8. Not connected to the phase winding of IM leads of thyristors VS1, VS2, VS3 and VS4 are connected with the phase of the power supply 1, not connected to the phase winding of IM leads of thyristors VS5, VS6, VS7 and VS8 are connected with another phase of the power supply (or the neutral wire) 2. Block 7 maps connection of winding L1, thyristors VS1-VS8, phase 1 and second phase (neutral wire) 2 for one phase winding of induction motor. Controlling electrodes of thyristors VS1-VS8 are connected with control circuit 10. The other two phase windings of the induction motor, which are contained in blocks 8 and 9 in fig. 3, are connected with other phases of the power supply (or neutral wire) 3, 4, 5 and 6 through the thyristors, which as well as phase windings are not shown in blocks 8 and 9. Blocks 8 and 9 are structurally the same as block 7, but connected with other phases of supply voltage. Controlling electrodes of thyristors in blocks 8 and 9 are also connected with control scheme 10.

When dividing the frequency of power by 2 circuit in fig. 3 works as follows. In the first period of network frequency when on phase 1 comes a positive half-wave, then must be opened thyristors VS1 and VS8 (see fig. 2), but when comes a negative half-

wave, then must be opened thyristors VS4 and VS5. Hereby, in the first period on the winding beginning of phase L1 will pass only the positive voltage half-waves. In the second period the network frequency when on phase 1 comes a positive half wave, then must be opened VS3 and VS6 (see fig. 2), but when comes a negative half-wave, then must be opened VS2 and VS7. Hereby, during this period on the winding beginning of phase L1 will pass only the negative voltage half-waves.

In the control circuit 10 implemented phase voltage regulation, ie by changing the angle of thyristors unlocking α, which is shown in fig. 1 and fig. 2. Changing the order of the turning on of thyristors can be obtained decrease of frequency by 3 times (see fig. 2), as well as any other integral number of times.

DETERMINATION OF THE DEPENDENCE OF INSTANT TIME OF PHASE ANGLE t_α ON VALUE OF REQUIRED SUPPLY VOLTAGE FREQUENCY

Since it is necessary to comply with correlation (2), for voltage and frequency, as well as frequencies and voltages, decreased in 2, 3, 4, etc. correlation (2) is written:

$$\frac{U_N}{f_N} = \frac{U_2}{f_2} = \frac{U_3}{f_3} = ... = \frac{U_k}{f_k} = \text{const} \quad (4)$$

where: U_N, U_2, U_3, U_k – effective network voltage, voltages by dividing the frequency by 2, 3 and k, f_N, f_2, f_3, f_k – network frequency, the frequencies of 1st harmonic, obtained by dividing the network frequency by 2, 3 and k [Gusev V.G., 1990].

Network frequency f_N and voltage U_N are known values. Decreased frequencies $f_2, f_3, ..., f_k$ can be determined through network frequency f_N:

$$f_2 = \frac{f_N}{2};\ f_3 = \frac{f_N}{3};\ ...; f_k = \frac{f_N}{k} \quad (5)$$

Hereof we get the correlation for determining the required voltage with decreasing frequency.

$$U_2 = \frac{U_N}{2};\ U_3 = \frac{U_N}{3};\ ...; U_k = \frac{U_N}{k} \quad (6)$$

In the phase regulation effective voltage with decreasing frequency is determined for the half-period as:

$$U_k = \frac{(t_\alpha - t_1)\cdot U_{N1} + (t_2 - t_\alpha)\cdot U_{N2}}{t_2 - t_1} \quad (7)$$

where: t_1, t_2 – instant time of beginning and end of a half period of network frequency, sec., t_α - instant time of beginning of thyristor unlocking at the phase angle α, sec. U_{N1}, U_{N2} –effective network voltage before and after thyristors unlocking [Nevzlin B.I., 2007].

Accept $U_{N1} = \frac{S_{11}}{t_\alpha - t_1} = 0$, since thyristors at this site of half-period are closed. Effective voltage is determined as:

$$U_{N2} = \frac{S_{12}}{t_2 - t_a} = \frac{\int_{t_\alpha}^{t2} U_{m2} \cdot \sin(2 \cdot \pi \cdot f \cdot t)dt}{t_2 - t_\alpha} \quad (8)$$

where: S_{11} and S_{12} – curvilinear area on plots from $t_1 = 0$ to t_α and from t_α to t_2 (see fig. 1 and fig. 2).

Since voltage $U_{N1} = 0$ (see fig. 1 and fig. 2), the effective voltage with decreasing frequency is determined for the half-period as:

$$U_k = \frac{\int_{t_\alpha}^{t_2} U_{m2} \cdot \sin(2 \cdot \pi \cdot f \cdot t)dt}{t_2 - t_1} \quad (9)$$

Since effective voltages of network and decreased frequencies must be equal, it is appropriate to switch over stom the correlation of equality of effective voltages to the correlation of areas equality of the half-period of decreased frequency:

$$S_1 = k \cdot \int_{t_\alpha}^{t_2} U_{m2} \cdot \sin(2 \cdot \pi \cdot f \cdot t)dt \quad (10)$$

$$S_2 = \int_0^{k \cdot t2} \frac{U_{m2}}{k} \cdot \sin(2 \cdot \pi \cdot \frac{f}{k} \cdot t)dt \quad (11)$$

where: S_1 –the total area which consists of k half-periods in the half-period of decreased frequency, S_2 - the area of half-period of decreased frequency.

After integration, the dependence (10) and (11) take the form:

$$S_1 = k \cdot U_{m2} \cdot \frac{\cos(2 \cdot \pi \cdot f \cdot t_\alpha) - \cos(2 \cdot \pi \cdot f \cdot t2)}{2 \cdot \pi \cdot f} \quad (12)$$

$$S_2 = \frac{U_{m2}}{k} \cdot \frac{\cos\left(2 \cdot \pi \cdot \frac{f}{k} \cdot 0\right) - \cos\left(2 \cdot \pi \cdot \frac{f}{k} \cdot t2\right)}{2 \cdot \pi \cdot \frac{f}{k}} \quad (13)$$

With the fulfillment of condition of areas S_1 and S_2 equality (see fig. 1.) obtain:

$$k \cdot U_{m2} \cdot \frac{\cos(2 \cdot \pi \cdot f \cdot t_\alpha) - \cos(2 \cdot \pi \cdot f \cdot t2)}{2 \cdot \pi \cdot f} = U_{m2} \cdot \frac{1 - \cos(2 \cdot \pi \cdot f \cdot t2)}{2 \cdot \pi \cdot f} \quad (14)$$

As a result of (14) gives the dependence of instant time of the phase angle t_α on network frequency and division factor of frequency:

$$t_\alpha = \frac{\arccos\left(1 - n - \cos\left(2 \cdot \pi \cdot t_2 \cdot \frac{f}{k}\right) \Big/ k\right)}{2 \cdot \pi \cdot f} \quad (15)$$

Parameter t_2 directly depends on network frequency f and can be defined as:

$$t_2 = \frac{k}{2f} \quad (16)$$

After the transformation (15) with (16) finally obtain the dependence of instant time of the phase angle t_α on network frequency and division factor of frequency:

$$t_\alpha = \frac{\arccos\left(\frac{2-k}{k}\right)}{2 \cdot \pi \cdot f} \tag{17}$$

The results of calculations with underfrequency in 2-6 times are tabulated in Table. 1

Table. 1. The dependence of the instant time of phase angle t_α on the division factor k of frequency at network frequency $f = 50\text{Hz}$

k	2	3	4	5	6
$t_{\alpha x}$, sec.	0,005	0,006082	0,006667	0,007048	0,007323

The received analytical dependence of instant time of phase angle t_α on network frequency f and division factor of underfrequency k, allows to calculate precisely instant time of phase angle t_α at which the ratio will be observed (4).

CONCLUSIONS

1. The proposed method quasifrequency-phase speed control of induction motors allows discretely control the speed with constant rigidity of mechanical characteristics of IM.

2. The analytical dependence of instant time of phase angle t_α on network frequency f and the frequency decrease factor k at which the observed correlation $U/f = \text{const}$ is obtained.

3. Proposed a method for decreasing of electrical losses in BP with quasifrequency-phase speed control of IM by changing the instant time of phase angle $t_{\alpha x}$ depending on sequence number of half-wave of supply voltage during half-period of decreased frequency.

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СПОСОБ КВАЗИЧАСТОТНОФАЗОВОГО РЕГУЛИРОВАНИЯ ЧАСТОТЫ ВРАЩЕНИЯ АСИНХРОННЫХ ДВИГАТЕЛЕЙ

Борис Невзлин, Дмитрий Половинка, Дмитрий Сергиенко

Аннотация. Предложен способ регулирования частоты вращения асинхронных двигателей вниз от номинальной, кратной целым числам, за счет переворачивания соответствующих полуволн синусоидального напряжения питания. За счет использования фазового метода регулирования напряжения этот способ позволяет выдерживать постоянным соотношение между частотой и напряжением. Разработана принципиальная электрическая схема, реализующая квазичастотнофазовый способ, и предложены расчетные формулы для определения момента времени фазового угла t_α от частоты вращения асинхронных двигателей. Рис. 4, ист. 20.

Ключевые слова. Квазичастотнофазовый способ, регулирование частоты вращения, понижение частоты, асинхронный двигатель.

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TECHNOLOGICAL PECULIARITIES OF FORMING OF AXISYMMETRIC UNREINFORCED CONCRETE PIPES

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Summary. The results of experimental theoretic investigations of properties of modified concrete for manufacturing of axisymmetric unreinforced products are introduced in this article. There have been proposed the ways of passage the main contradiction of technology of concrete with the aim to get special high quality concrete.

Key words: modified concrete, cement matrix, extraction, polyroll, liquid phase.

INTRODUCTION

The recovery of high effective artificial building conglomerates is possible by modifying the structure of cementing matrix and concrete [Ramachandran, Feldman, Boduen 1986, Batrakov 1998, Adylkhodzhaev, Solomatov 1993, Pilipenko 2010]. Thus, the modification of concrete's structure is destined to improve technologic and service properties of material. It's possible the change of kinetics of gain of physical characteristics and final values of concrete strength by modifying [Sviridov, Kovalenko, Chesnokov 1991, Babkov, Sahybgareev, Kolesnik and other 2006, Kaprielov, Travush, Karpenko and other 2006, Solomatov, Vyrovoi 1991, Paschenko 1991, Glukhovsky, Runova, Maxunov 1991, Rudenko 2010].

At present only separate attempts of physical modification of concrete, for example, at its vacuum processing are famous [Bazhenov 2005, Batrakov 1998, Glukhovsky, Runova, Maxunov 1991, Sakai, Sugita 1995]. In this case the limited quantity of water of mixing is spiked in concrete mix providing optimal response execution of hydration of cementitious agent. The subsequent vacuum dewatering changing the initial concrete composition leads to the deep modification of its structure formation. In particular, the density and strength of a material is considerably increasing. It should be marked that the physical modification of concrete leads to the change of character of fixation of particles of cementitious agent [Hewlett 1998, Glekel, Kopp, Akhmedov 1986, Adylkhodzhaev, Solomatov 1993, Tomosawa 1997].

OBJECTIVE AND SUBJECT OF RESEARCH

The objective of present research is the development of scientific and technical foundations of technology of modified concrete for the production of unreiforced axisymmetric goods.

The limited quantity of produced and applied unreinforced concrete pipes is explained by the circumstance that the resistance of concrete by intensity of tension is not considerable and makes up only 7…11 % of strength of concrete under compression [Gvozdev 1987, Ruben 1986, Trifonov, Dodonov, Kuznetsov 1998]. This problem is complicated by the main contradiction of technology of concrete:

- for the elevation of strength of concrete under tension is necessary the decrease of water-to-cement ratio (W / C) up to the values near to the normal density of cement-water paste at simultaneous fiscal cement restraint;
- for the elevation of placeability of concrete mix is necessary the contrary condition which – the elevation W / C, the increase of water content and, thus, the cement content.

The development of scientific foundations of technology of high quality concrete for the unreinforced pipes is possible by the complex solution of specified contradictions. For this is necessary to accept the following initial statements of developing technology of high quality concrete:

1. The properties of concrete mix must be defined by technological conditions of products' forming;
2. The concrete composition is defined by predesigned project properties of material in the product and, if necessary, it can differ from the initial concrete mix composition;
3. The process of vibro impact impulsive compression of concrete of forming product must provide the recovery of utmost compact structure of material, especially on coating surface of a product.

RESULTS OF EXPERIMENTAL RESEARCH

As the result of experimental theoretic research work there have been developed the scientific foundations of the recovery of extra high quality concrete, technological foundations of forming axisymmetric products, including the new installation for forming the concrete unreinforced pipes by vibro impact impulsive pressing. The installation is destined for forming pipes with little lift having a nominal inside diameter from 500 to 1500 mm and length up to 2000 mm. Forming of pipes can be done in plant and testing area conditions, on outdoor area, including temporary placing.

As it was supposed to achieve maximum strength and waterproofing of concrete by unwatering of concrete mix in the process of vibro impact impulse pressing, the great attention has been paid to the definition of optimal conditions of removal the surplus amount of water of mixing out of it [Pilipenko 2010].

Intensive unwatering of concrete mix by vibro impact impulse pressing can be achieved at optimal quantity of cement-water paste and mixture which is not only filling the gapes between grains of carcass, but also removes them from each other on the

minimum distance. Thus, the concrete composition and regime of vibro impact impulse pressing were defined under the condition of the recovery of concrete with the minimum remnant W / C and maximum strength. The criteria of full compression of concrete mix are the given level of extraction of surplus water of mixing and achievement of average density of molded concrete near to the theoretical ($Kc = \rho c / \rho theor \geq 0,97$).

Experimental investigations of voluminal state of stress have been made on the special laboratory installation. The special device gave the opportunity to realize pneumatically the impulsive air-feeding on cylinder piston. That has been imitating vibro impact impulse compression of concrete mix and concrete with the simultaneous modification in the developed technological process of production of axisymmetric products.

The concrete mix of the product between pressing clamping device and perforated timbering wall turns out to be in compressed state. Stress and strain state of concrete mix leads to the motion of filler raw staff, cement and water one from another under condition of the elevation of strain of ultimate strength to shearing. The great meaning for the process of compression of mixture has the cycling of application of stress from impulsive waves of compression and shuttle movements of moving form [Fedyaevsky, Ginevsky, Kolesnikov 1993, Shlikhting 1989].

The advantage of technology of vibro impact impulse compression of concrete of pipes is:

- the combination of laying, compression and modification of concrete mix and concrete in one process, including floating of inner cylindrical surface of a product;
- a high accuracy of geometrical dimensions of forming products;
- an increased degree of mechanization of production at minimal metal consumption of equipment;
- a high productivity at a low energy consumption;
- an immediate demoulding operation at products making metal saving of technology.

The installation is also equipped with measuring and registering apparatus for the analysis of the value of inner pressure and motions.

It was established by the research work that at physical modification of concrete mix with the usage of vibro impact, shearing and impulsive compression, the process of structure formation leads to the change of morphology of crystallohydrates in comparison with the usual vibrated concrete.

It was established by complex methods of chemical, X-ray phasic, submicroscopical, adsorptive, porometric analysis that the morphological structure of cementing matrix of concrete is characterized by the change of quantitative ratio of volumes of cryptocrystalline, needle-shaped fibrous and plate like prismatical ingredients at the end of structure formation, which is 1,5 times exceeding vibro compressed and vacuum treated concretes.

The analysis of hygrometric state and differential thermic analysis of concrete confirmed that the quantity of chemically connected water in cementing matrix of modified concrete exceeds on 23…39 % the analogical data of concrete subjected to vacuum treating and vibro compression.

Due to undertaken studies was obtained the system of regularities of vibro impact impulsive influence on concrete mix which revealed the considerable differences of the process of compression from the single impact and vibro compression. By this was proved the appearance of zones of high intensive compression and strain which alternatively change in time in the pyller of compressing mixture, there were also gained the quantitative characteristics for the definition of parameters of compression.

It was established that the physical modification of concrete is carried out by the extraction of surplus water which takes place in laminar, turbulent and non-continuous modes. There have been obtained formulas describing the regularities of movement of water-to-air phase depending on applied pressures and parameters of transmissibility of concrete mix and filtrational ports of form.

The developed technology is based on the combination of high intensive vibro impact impulsive compression and decrease of actual W / C in molded concrete up to the level equal to the normal density of cement-water paste. Thus, the optimal parameters of developed technology are provided due to the compression near to the theoretical level at simultaneous extraction of surplus water of mixing collectively with water-to-air phase of concrete mix.

There have been defined the technological parameters of proportional unwatering of concrete at the height of molded product due to the results of undertaken studies $(W / C)_{remn}$ = const.

The analysis of strength properties of concrete obtained by vibro impact impulsive method of compression has been carried out on the samples-cylinders and kerns of equal diameter drilled out of unreinforced pipes. The results of research work of strength properties of concrete are introduced in table 1.

The results of experimental investigations show that with the increase of the quantity of extracted water from 18 to 24 % the strength of concrete of vibro impact impulsive pressing is notably increased. The strength of the samples from which is extracted the equal quantity of surplus water of mixing at the equal regime of vibro impact impulsive pressing with the usage of different diameters and conicity of filter ports is nearly equal. But only with the increase of the thickness of the layer of compressing concrete mix is increasing the time of extraction and the necessary quantity of filter ports. It testifies that exactly the quantity of extracted water of mixing defines the structural strength of compressed concrete by vibro impact impulsive pressing.

As the criteria of evaluation of properties of filter ports proposed by us defining the efficacy of the process of vibro impact impulsive pressing of concrete mix and concrete was proposed the coefficient of effective compression (CEC), which shows the approaching of values (W / C)remn to the index of planned [W / C] = 0,253.

It was carried out the series of experiments to study the dependence of CEC on given quantity of extracting surplus of water of mixing. For the increase of accuracy of obtained values of CEC of filter was defined as simple average of the results of three observation values CEC at the quantity of extracting water of mix from 18 to 24 %.

It was marked that in the process of effective pressing of concrete mix at inlet part of filter ports of form the compacted layer can be formed. [Altshul 1990, Vulis, Kashkarov 1985].

Table 1. **Physical mechanical characteristics of modified concrete, drilled out of unreinforced pipes with the length 1500 mm**

№№	Sample of test concrete	Density, kg / m^3		Strength, MPa	
		in kerns	average index	in kerns	average index
Concrete, obtained by vibro impact impulsive method of compression					
1	Cylinder laboratory	2480	2480	91,3	91,3
2	Kerns, drilled out of pipes with diameter 500 mm	2498 2511 2516 2516 2517	2512	96,7 97,4 98,6 101,0 101,7	99,1
3	Kerns, drilled out of pipes with diameter 1000 mm	2527 2529 2531 2530 2531	2530	104,8 107,0 111,6 113,4 114,7	110,3
Concrete, obtained by traditional method					
1	Cylinder laboratory	2235	2235	45,8	45,8
2	Kerns, drilled out of pipes with diameter 500 mm	2273 2285 2302 2314 2316	2298	45,3 45,7 46,2 46,8 46,5	46,1
3	Kerns, drilled out of pipes with diameter 1000 mm	2300 2314 2329 2340 2354	2327	46,0 46,7 46,8 47,1 47,6	47,0

The results of experimental investigations show that with the increase of the quantity of extracted water from 18 to 24 % the strength of concrete of vibro impact impulsive pressing is notably increased. The strength of the samples from which is extracted the equal quantity of surplus water of mixing at the equal regime of vibro impact impulsive pressing with the usage of different diameters and conicity of filter ports is nearly equal. But only with the increase of the thickness of the layer of compressing concrete mix is increasing the time of extraction and the necessary quantity of filter ports. It testifies that exactly the quantity of extracted water of mixing defines the structural strength of compressed concrete by vibro impact impulsive pressing.

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In accordance with the conditions of investigations in case of pressing of concrete mix with the usage of concrete form with filter ports which size exceeds the sizes of particles of fine aggregate the firm ground copes out of particles of fine aggregate will be formed at inlet part of port. Intergranular pores of these copes will fulfill a function of filters preventing loss of cement. While using the filters with ports removed from each other on sufficient long distance it should be expected the forming not complete compacted layer in concrete mix but in separate compacted dome-shaped shells. Directly at inlet part of filter ports the rate of flow of extracting fluid is considerably higher than in separate sections near inlet part of filter ports. It can cause external wash out of cementing particles that is their carry-over from the surface of concrete sample on the surface of the form. Laying bare of some section of mineral carcass of cope near filter ports is limited as the rate of flow of extracting water of mix is decreasing proportionally to squared distance from the port. The formation of washed out zones should increase the rate of extracting surplus water of mix because of partial destruction of the shells with increased resistance to flow.

The truth of these statements has been checked by experiment. The main method of the study of structure of concrete compressed by vibro impact impulsive pressing with the usage of perforated concrete forms with diameter of filter ports 1 mm and 2 mm, it was accepted the definition of microhardness of cementing matrix of modified concrete on thin sections with the size 55×55 mm.

The selection of method of investigation is due that the definition of microhardness gives the opportunity to get the information of structural mechanical properties on limited sections of the sample [Moranville-Regourd 1999]. The microhardness depends not only on crystallized factors but also on mechanical ones: pinhole rating; the presence of internal stresses [Blais 1999]. The type and concentration of new formation, the peculiarity of capillary interspace, microdefects, and uniformity of microstructure influence the microhardness of cementing matrix.

In conducted experiments was used fine grained concrete of composition 1:2. It is due to the presence of coarse aggregate increases the variation of values of microhardness.

At the first stage was investigated the structure of concrete compressed with the usage of filter ports characterized by increased separation of ports to expel their interaction. As the perforated concrete form was used steel push barrel with the diameter and height of 150 mm, thickness of wall 6 mm, with conical filter ports of input diameter 1mm and 2 mm at outlet diameter 55 mm. The pressing of concrete mix has been made within 10 min. While using metal filter ports of the form on the surface of concrete sample washed out zones are formed introduced by copes of particles of fine aggregate. Washed out zones have the forms near to hemispheric with diameter from 14 to 2,5 mm at input diameter of filter ports 1 mm and 2 mm respectively. The obtained

data show that microhardness of cementing matrix on the distance of 1…5 mm from filter port 2,0…2,7 times higher than on the distance of 25 mm.

For each of tested filter ports the character of change of microhardness of cementing matrix at the removal from the center of the port in the direction perpendicular its plain is the same as at the removal in parallel direction. This gives the opportunity to make the conclusion that the shells of increased microhardness of cementing matrix at inlet part of filter ports have hemispheric form. The values of microhardness of the sample compressed with the usage of filter ports with input diameter 2 mm in all points exceed the microhardness of the sample compressed with the usage of filter ports with input diameter 1 mm. The increase of the size of input diameter of filter ports together with the increase of washed out zones also causes the increase of sizes of hemispheric shells of increased microhardness. This is explained by the fact that the increase of diameter of washed zone of areneceous cope takes place under the action of high resistance to flow. Considerable compressive impacts caused by the action of pressing of concrete mix spread over more remote sections and this causes the compression of larger section in size at input part of filter ports.

The analysis of experimental data show that the diameter of hemispheric shells with increased microhardness of cementing matrix in the place of input part of filter ports achieves 15…25 mm. At a filter port with separation 25×25 mm can be reached the formation of overlap single complete medium of increased microhardness.

CONCLUSION

It was proved that maximal compression of concrete mix ($K_c \rightarrow 1,0$) can be reached with the help of vibro impact impulsive influence describing by the system of analytical regularities revealed considerable differences of the process of compression by single impact including vibrocompaction. It was proved the appearance of compressed mixture of alternatively changing in time zones of high intensive pressure and strain in the pyller.

It was established that the high effect of physical modification of concrete can be made by the extraction of surplus water of mix which takes place in laminar, turbulent and broken regimes. The quantitative description of the process of extraction of water-to-air phase can be produced using classical laws of filtration taking into consideration the degree of gas content of fluid by air bells and final broken regime of extraction of water of mix.

There were established by the complex of fulfilled investigations the regularities of placing and configuration of filter fields of concrete form taking into consideration the form and diameter of ports preventing their fouling in the process of product's forming.

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ТЕХНОЛОГИЧЕСКИЕ ОСОБЕННОСТИ ФОРМОВАНИЯ ОСЕСИММЕТРИЧНЫХ НЕАРМИРОВАННЫХ БЕТОННЫХ ТРУБ

Владимир Пилипенко

Аннотация. В статье представлены результаты экспериментально-теоретических исследований свойств модифицированного бетона для изготовления осесимметричных неармированных изделий. Предложены пути преодоления основного противоречия технологии бетона с целью получения особо высокопрочного бетона.

Ключевые слова: модифицированный бетон, цементная матрица, отжим, уплотнение, жидкая фаза.

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THE USE OF IT-TECHNOLOGIES IN STUDENT EMPLOYMENT USING A COMPETENCE BASED APPROACH

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Summary. The main task of the present-day education is "the production of competent people who would be capable of applying their knowledge in a changing environment and whose primary competence is their ability to engage in constant self-education throughout their lives".

Key words: information and communication technologies, educational process, competence, key competencies, professional activity.

INTRODUCTION

The transfer from the industrial society and simple technological operations to the postindustrial type of economy requires a large number of people who can work with packages of modern technologies in a changing environment that makes a person assess the situation and take responsible decisions. A new type of economy makes new demands on graduates, among which an increasing priority is being given to demands of systematically organized intellectual, communicative moral principles that allow the successful organization of activities in broad social, economic and cultural contexts.

OBJECTS AND PROBLEMS

Recently job placement of graduates has become more complicated. In the present-day labour-market there is a gap between the goals of the education system and the real needs of graduates, employers and society [Artemenko V, Nozdrina L, Rudnitsky O. 2002].

The effectiveness of the interaction between employers and young specialists in the labour-market depends on the match of young graduates' competencies to the requirements of the labour-market. The following three key periods are very significant in the formation and development of such competencies:

- before a higher school: when choosing a profession (choice of the profession for which demand exceeds supply);
- when studying at a higher school: formation and development of the personal skills for which demand exceeds supply (through additional courses, community work, work experience, etc.);
- after a higher school: creation of tools which enable graduates to better position themselves advantageously in the labour-market and employers – to find graduates with the required competencies [Rakova L.N. 2000].

Competence is defined as an educational result expressed as the preparedness of a graduate in terms of knowledge, abilities and skills which will allow them to reach a set goal. Competence is "knowledge in action"; readiness for performing a practical activity.

Competence is a "basic characteristic" of a person which is connected causally with the criteria of effective and successful actions in professional or work situations. The "basic characteristic" means that the competence is a deep and stable part of a personality so that it is possible to foresee the behavior of a person in a wide range of situations, both professional and everyday. The causal relationship means that the competence conditions behavior or action [Chernilevsky D.V. 2002].

While working with employers, every higher school faces a prioritized list of qualities which a graduate has to have to be successfully employed. Traditionally, employers have considered that a young specialist should have the potential for good personal skills and competencies and a good professional training. Employers want to see a young specialists' active life, good motivation, self-development ability, efficiency, result focused, good communication skills, and a penchant for a healthy way of life. In fact employers list these as the main competencies which enhance the competitiveness of a graduate in the labour market.

Today educational establishments are gradually coming to the same point of view as employers – a graduate in demand is the one who wants, has the ability and knows how to work in their field. The quality of competence and knowledge is dependent on the higher school [Rakova L.N., Gass V. 2006].

Table 1. **Graduate Competencies**

Object and information competencies	**Action and communication competencies**	**Value oriented competencies**
•Ability to work with taught information; •Critical perception of the information; •Conversion of information from conceptual to verbal and vice versa.	•Ability of the subjects of the education process to cooperate and to create specific tasks; •Ability to manage, analyze and organize activities; •Ability to make reasoned decisions.	•Knowledge of norms, values and cultural traditions; •Relationship with the world, themselves, and society based on the personal needs, motives, emotions and values.

The maturity of these competencies is shown by the following personal characteristics:

•spirituality, humanism, tolerance;

• mobility, decision making independence, responsibility, and the ability to make a conscious choice

• communication, social activity, and the ability to cooperate;

• creativity and constructive thinking.

Besides fundamental, scientific and professional training, the following skills are required from higher school graduates:

- to find their bearings in related fields of knowledge;- to use unconventional approaches to solving different problems and to find competitive solutions of problems;- to have a command of modern communication methodologies, approaches to economic analysis and organization of marketing activities;- to promote the results of professional activities in relevant markets;- to maintain their professional competitiveness throughout their career.

Generally employers consider young higher school graduates as a source of action, dynamism and modern knowledge for the enterprise and as a dislocating combination of reduced responsibility and high ambitions. When making a decision about employment they basically take into account one of the two market advantages that the graduate has:

• specific expertise which is in high demand in the market and which cannot be replaced by any personal qualities; this specific knowledge makes graduates of certain specialties a priori competitive;

• special personal qualities needed in the market economy and which distinguish one graduate among many of his fellows; these qualities can make their owners competitive even if their specialty is not in demand in the market.

There is no universal model of competencies; competencies are always contextual. The gap (imbalance) between the content of the education and the application of that content can be problematic. In order to avoid this issue and to create effective higher schools activities which will assist in the development of students personalities and to develop their professional skills the formation of students professional self-dependence should be supported by the use of modern information educational technologies as a basis of professional training.

The growth of social media opens up hundreds of new communication channels allowing higher schools and organizations to cooperate in matters concerning the coordination of graduate competencies and to promote the effective employment of graduates by cultivating the networks of talent during their training.

An example of an application of a virtual environment is WebEx which allows web conferences, presentation viewing, video resume recording and playback and video lectures, etc.

WebEx is an implementation of a Web conference, the general name for the technology and tools for online meetings and in real time collaboration. Web conferences allow online presentations, collaborative work on documents and applications and the ability to view sites, videos and pictures [Kalinenko N.A. 2009, 2010].

Web conferences are as a rule internet services that require installation of a client program on each participant’s computer. Some services provide access to web conferencing through a browser using flash, java or special plug-in.

Services for web conferencing can include the following features and tools: - Screen sharing - sharing the screen or individual applications; - Whiteboard - interactive whiteboard; - Web presentations; - Co-browsing - the possibility of simultaneous browsing;- annotation tools;- monitoring of participants' presence;- text chat;- integrated VoIP communication;- video communication;- Leadership management and delegation;- Shared mouse and keyboard management;- meeting moderation tools tools for collection of feedback (e.g. surveys);- tools for meeting planning and invitation of participants;- recording of web conferences.

A Whiteboard is an interactive board available to all the participants of the online meeting. This is a workspace where participants can draw diagrams, type text, make notes – this allows the meeting participants to understand one another better and not to spend their intellectual resources on understanding and memorizing what was said. An Interactive Video Lecture with synchronous slides (IBCC) simultaneously displays on the computer (or projector) window both the video of a lecturer and the slides of the presentation changing synchronously during the video playback.

The above platforms are an effective mechanism in the process of learning and allow us to solve the urgent issue of networking of students, higher schools and employers during a students' job seeking;, video interviewing and video resume organizing. The effective use of the above platforms by both higher schools and employers with an agreed upon model of competencies of specialists provides more employable graduates which will be in greater demand by employers.

Recently job seeking through the World Wide Web has become more and more popular and higher schools should respond to this challenge by active implementation and use of appropriate technologies. This we based networking of all the interested parties should be based on the innovations of these virtual environments.

Firstly it is information about the demand for specialists. The most appropriate resources for students are:- specialty job websites, - portals designed specifically for graduates, - industry portals with sections "Work" and "Employment", - Web pages of specialized periodicals, - social communities, - sections of available vacancies on sites of companies-employers, etc. To minimize costs and to optimize processes in recruitment, recruiters and internal HR services are already using modern digital technologies and Internet communications. The use of the following modern technologies in the employment process will help the educational services market meet business requirements.

Video resume: A video of approximately 30 seconds during which the applicant give a presentation about himself. After recording the video is digitized and attached to the applicant's CV in the Resume Bank and becomes available for viewing by employers, HR managers and recruiters.

A high quality Video resume allows the applicant:- to take a premier position among other applicants;- to attract more interest from potential employers;- to avoid trial interview and to open the door to the direct employer;- to show their personal and professional qualities to the potential employer;- to save time for job seeking and to explain the reason for their high salary expectations;- to present much more information than a traditional resume can contain;- to present themselves simultaneously as both a personality and a professional.

For some specialties (sales manager, salesman, secretary) experience and skills are not so important as personal qualities and communication skills which can be demonstrated by applicants in their video resume. The use of text resumes and video resumes combined allows the employer to get better acquainted with the personal and professional qualities of applicants. The use of video resumes reduces the number of applicants' interviews.

The innovative format of the video resume use in companies is most applicable when it comes to recruitment in different cities and countries. Employers invite applicants to be interviewed online and use specific software and equipment (web camera, headset) that allow interviewers and interviewees to see and hear each other. There is no need to go to another city and to go through multiple stages to be interviewed for employment. It is possible to present yourself and your professionalism in a comfortable environment sitting at your computer. The recruiting manager can ask to submit documents, references, resume and photo. It is necessary to prepare the complete package of required documents in electronic form as well as originals.

It is advisable to record your online video interview yourself. The advantages of undertaking this recording are as follows: a) managers will be able to view the video interview (if they were not present during the interview) at any time and to make a decision about the employment; b the applicants will be able to analyze their interview again to evaluate the advantages and objectives of the company that may become their employer in the near future [Sumtsov V.G., Rakova L.N. 2000].

Before the interview the interviewee must study the interview questions that the employer may ask.

Any company that is looking to hire personnel from other cities and countries and all recruitment agencies greatly increase their choices by using video interviews, overcoming distance and time limitations and reducing financial costs. Video interviewing is the know-how in the recruiting of personnel based on the use of the online format of the Internet.

Interactive broadcasting programs can be used to connect video, voice, online chat, online surveys, case studies, psychological and professional techniques, virtual whiteboard and video recording. Using these tools the interview is interesting, fast and efficient.

Key features and benefits of video interviews:

• A virtual interview is connected globally in less than one minute;

• Multiple representatives from one company located in different places (an office, a house, vacation, business trip, a car) can be connected each with the ability to ask questions by voice and by online chat and to see and hear the applicant;

• the ability to use test cases, tests, online surveys, live feedback;

• resumes, references, copies of diplomas and other documents submitted during the interview can be viewed by recruiters, HR-managers, company managers during the interview;

• A video record of the interview is available for further viewing, interpretation and analysis by recruiters, HR-managers, and the managers who have to make a decision about meeting the applicant in person;

• Only the following are needed: the rent of a virtual class, web-camera, headset with a microphone.

A Webinar or web seminar is an online event where one or more moderators can conduct presentations on behalf of an employer or an applicant with meetings for groups from several to thousands of participants on the Internet or a corporate network. During the webinar each of the participants is at his computer and the contact between them is supported by the Internet using a web application. To join the conference you simply enter the address of a particular webinar [Kalinenko NA, Kharkovskiy TO, 2010].

The following moderator facilities area available: to broadcast using a web-camera and a microphone (webinar participants both can hear and see the moderator); to show presentations or to draw on the whiteboard; to download and play video and audio files; to chat; to conduct surveys; to allow webinar participants to present (audio and video).

The following facilities are available for the participants: to see and hear the moderator in real time; to watch presentations; to ask questions to the moderator and to communicate with other webinar participants using chat; to take part in surveys; to present using audio and video with the moderator's permission.

There are many technical platforms and services available for organizing webinars. The minimum set of functions is audio broadcasting by voice and getting feedback in writing using chat. The maximum is the use of voice and video for the moderator, presentation using drawing and shared work, surveys of users and the possibility of presenting at the meeting by several participants simultaneously.

Webinars are the most convenient form of networking when it comes to virtual teams. Besides physical and financial convenience (you don't have to go anywhere), webinars provides the participants with psychological support.

This multimedia approach is much more effective than traditional uses of technology in employment. Webinars allows the use of all types of perception: visual, auditory and kinesthetic, so the participants understand information faster and remember the knowledge in their memory for a long time.

A virtual job fair is a unique event which enables companies and employers to establish direct contacts with applicants using modern Internet technologies with mediation by higher schools [Tikhomirov V., Rubin J., Samoilov V. 1999].

The advantages of job searching through the Internet are:

-simple and free access to thousands of vacancies (applicants don't have to spend time, money and energy visiting different personnel departments and agencies);- the ability to create an advertisement with resume about the applicants availability on a number of sites (employers visit these resources and so the applicant's advertisement will be seen by many people who are interested in recruiting).

Some sites provide guaranteed privacy to individuals.

Notification about open vacancies through e-mail (an email, unlike a phone call does not require an immediate answer from the employer). The virtual job fair enables applicants:- to place their video resumes on the site;- to have access to "conference halls" where video presentations about companies and master-classes by leading specialists take place in real time;- to get the desired job;- to get full review of information about employing companies.

The virtual job fair enables employers:- to conduct video interviews and to save time and money;- to choose qualified personnel;- to promote the company's brand

amongst applicants;- to receive immediate feedback;- to search for specialists over a wider geography.

The reasons for conducting virtual job market using mediation of higher schools:

-young people are the main part of the Internet users; they are the most vulnerable part of the labor market in Ukraine and so need additional support;

-the trust in higher schools websites among employing companies is greater than the trust in an individual person; leading companies are interested in attracting young specialists with a good education which is guaranteed by the higher schools.

The functions of higher schools in organizing a virtual fair of vacancies:

- involving employing companies in participation;

- involving highly-qualified and competent business trainers to conduct master-classes and lectures online;

- notification of higher school students and alumni about the requirements and terms of the virtual fair of vacancies.

CONCLUSIONS

For the effective implementation of the virtual fair of vacancies it is necessary: to find sponsors to conduct the event; to decide about the date and to place advertisements in mass media; to determine the exact conditions for participation in the fair; to create the base of resumes and vacancies; to create a web portal to show the process and results of the fair. The problem of adding personnel at enterprises is complicated by poor contacts between enterprises and higher schools, but regardless of this both business and education understand the advantages of interaction with one another which is why they consider it is necessary to expand and strengthen all forms of cooperation by creating and implementing effective models of cooperation using modern IT technologies.

Promising areas for improving the virtual fair of vacancies concept the creation of a system of assessment of resumes and notification of the applicant about areas for improvement (This will give the applicant ideas about the reasons for their denial of employment and about the direction of their self-improvement); enabling employers to create their advertising stand on the site of the virtual fair of vacancies; implementation of mailing of “hot” vacancies and information; expansion of the geography of the involved employing companies into a network.

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ИСПОЛЬЗОВАНИЕ IT-ТЕХНОЛОГИЙ В КОМПЕТЕНТНОСТНОМ ПОДХОДЕ К ТРУДОУСТРОЙСТВУ СТУДЕНТОВ

Султан Рамазанов, Наталья Калиненко, Лариса Ракова

Аннотация. Главной задачей современного образования является «производство компетентных людей, которые были бы способны применять свои знания в изменяющихся условиях, и чья основная компетенция заключалась бы в умении включиться в постоянное самообучение на протяжении всей своей жизни».

Ключевые слова: информационные и коммуникационный технологии, образовательный процесс, компетенция, ключевые компетентности, профессиональная деятельность.

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STRENGTH OF GLUEWELD SEALS MADE OF DISSIMILAR STEELS

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Summary. The results of experimental studies on technology trial and properties of glueweld seals, made with resistance spot welding on steels that are used to produce the rolling stock locomotives and wagons side sections and sections of the roof, including dissimilar joints are shown.

Key words: welding, glueweld seal, strength, corrosion resistance

INTRODUCTION

The rolling stock locomotives' and wagons' side sections and sections of the roof are constructed with the corrugated sheet siding, 1,5mm thick, and stiffness frame elements, that consist of bent skirts and Zeta Profile varying lengths, 2,0 mm.

To produce them different materials are used. For example, to produce the side wall of diesel train passenger car sheets of steel 10Х13Г18ДУ and sections of steel 09Г2С are used.

Sections are the building framings, working with buffing loadings. Therefore, during their manufacture there are special requirements to the technology of weld joints are including their density, because these sections protect rolling stock from the environment influence.

These designs have a lot of welds. They vary in their length, continuity and spatial position and are executed generally with semi-automatic welding gas-shielded atmosphere.

OBJECTS AND PROBLEMS

Presence in the construction a large number of welds causes an increase in its deformation during the welding process, and the residual strain exceeds the level permitted by the specifications [3]. It is hard to apply effectively in such construction existing activities to reduce the because of the complexity of their distribution [15].

In addition, intermittent welds do not have integrity. So after welding additional step of sealing the connection is made. When welding steel 10Х13Г18ДУ as electric arc, and by contact welding problems with its weldability [4,10,9,12].

While this constructions are produced the resistance spot welding may be implemented, but the compounds that are obtained in this way, also have some disadvantages [17]. One of them is the lack of tightness of the joint. There is a way of fastening sheet cladding to the frame by hydro impermeable rivets using putty Polyurethane-50FC. But this method also has some disadvantages[7].

To solve these problems spot welding by adhesives use is proposed. Glueweld seals have several advantages over joints, that are made with electric arc or by contact welding. The main are – impermeability of joints and lower level of residual strain.

In theory, glueweld joints on aluminum and its alloys are studied sufficiently and in practice are widely applied [1,2]. Glueweld seals on steels of especially the dissimilar joints are insufficiently studied.

Development of production bases of steel resistance spot welding by adhesives.

Prepare materials for welding. To perform glueweld joints of high quality it is very important to prepare materials' surface. There are a lot of ways to prepare surface of the same material. For research based on an analysis of published data and test results when developing welding mode [1,5,6,19] the following technique of surface preparation for welding is chosen and implemented.

For austenitic steel 10Х13Г18ДУ only degreasing with an organic solvent № 646 was used. The use of chemical method surface preparation of sheet steel in a production environment will be with difficult due to large sized sheets sheathing module framing of rolling stock.

For 09Г2С steel a chemical treatment etching in an aqueous solution of hydrochloric acid (200-220 g / l) with adding the katapina (5-7 g / l) was used. Etching time 20-30 minutes at solution temperature 18-30ºС followed by washing in cold water. Neutralization of residual hydrochloric acid with aqueous $NaCO_3$ (5 g / l). Solution temperature is 50-60 º C, soaking time 2-3 minutes followed by rinsing in cold water and drying.

Weld samples were performed on a point-phase machine AC-type MT-1614 with a nominal welding current 16 kA and compression force of the electrodes 6.3 kN.

Welding conditions, wherein sufficiently high quality weld on the samples is achieved are the followings [13,14,16]: Compression load 0,44 kN at the air pressure in the system 3,0 MPa, time compression, welding and forging respectively is 1,2, 1,6, 0,3 s. The diameter of the working part of the electrode used is 10 mm, diameter of the resulting indentation electrode is 8mm.

Selecting the type and brand of glue. The choice of adhesive to get glueweld seals of given design is difficult, because the large range of adhesives, but there is no universal.

When selecting adhesive the nature of the bonded materials is taken into account, glueweld seals operating conditions (operating temperature, current load, service time, environment etc.) technological application of the adhesive, the cost of adhesive.

Besides adhesive should not worsen the properties of glueweld seals, particularly corrosive. Therefore, the pH of the adhesives, recommended to connect the specified materials, should be close to 7 in accordance with ГОСТ 9.902-81.

Given the rolling stock sections temperature and operating environment, epoxy adhesives were selected to make the research. Epoxy adhesives are convenient and practical for use. They are available for use with environment temperature variation from 0 to 35 º C unpretentious to the preparation of the surface bonded materials, have low toxicity. Can be, both hot and cold hardening. Have a wide range of viscosity.

Despite the best properties of hot curing adhesives (longer-term viability of the glue and higher bond strength) to manufacture steel sheet plating of rolling stock the use of cold curing adhesives is appropriate, because they have more than a simple technology application. Due to the large size of welded sections hardening of the adhesive hot-curing at temperatures 110-180ºC additional and energy consuming equipment, is require; that will lead to higher production costs. Therefore, the cold curing adhesives produced by the industry at present were selected to study.

Table 1 shows the main characteristic of used adhesives - ultimate strength at shift of glued joints under described conditions.

Table 1. **Ultimate strength at shift of glued joints of some materials, Mpa**

Material	Test Temperature, ºC	Brend of Glue		
		UP-5-207	UP-5-207-1	UP-5-240-1
Oily steel 08кп	25	25	-	-
Degreased steel 3-sured		28	25	38
Steel 3 after 10 thermal cycles	-50 to + 150	25	22	36

You can make the following preliminary conclusions on the strength of adhesive stamps: the greatest strength has glue UP-5-240-1 at temperatures up to +50ºC; Glue UE-5-207 is most versatile and can operate at high temperatures. Also in studies we apply epoxy adhesive, consisting of a resin EPOXY-531 and hardener TELALIT-410. Its mechanical properties are unknown.

In compiling of cold curing adhesives the important point is the ratio between the adhesive and hardener. Adhesives were prepared in the same proportions, recommended by passport data [2].

Since the thickness of adhesive layer affect the weld strength, when preparing it for welding should seek to ensure adhesive layer within 0,05 - 0,16 mm. When applying glue in these studies thickness provides within 0,1-0,2 mm. Adhesive was applied to each side of connected surfaces. Preparation of adhesive and welding was performed at a temperature of 15-20 º C.

In compiling cold curing adhesives important point is the ratio between the adhesive and hardener. Lack of hardener leads to incomplete drying of the glue. The excess cause unwanted aggressive influence pasted on the materials. The content of curing agent affects the ultimate strength of the adhesive joint. Adhesives for this research are prepared in the following proportions, presented in table 2.

Table 2. **Ratio of resin, filler and hardener for making glue**

Component	Ratio of parts by weight of components for the preparation of the following brands of adhesives			
	UP-5-207	UP-5-207-1	UP-5-240-1	EPOXY-531
Resin	100	100	70	100
Filler	-	-	30	-
Hardener	25	25	10	20

Since the thickness of the adhesive layer affects the joint strength, when preparing it for welding we should strive to ensure the adhesive layer within 0,05-0,16 mm. When applying the glue in this research thickness was provided within 0,1-0,2 mm. Adhesive was applied to each side of the jointed surfaces. Preparation of adhesive and welding was performed at a temperature of 15-20 º C.

Research on glueweld seals' strengh. For these five groups of similar samples 4 in each group were welded from the investigated steels. These are the following groups: 1 - welded samples without glue; 2 - glueweld samples with the use of glue brand UP-5-240-1; 3 - glueweld samples with the use of glue brand EPOXY-531; 4- glueweld samples with the use of glue brand UP-5-207-1; 5 - glueweld samples with the use of glue brand UP-5-207.

Destruction of samples were carried out on tensile testing machine P-20 with a maximum load of 200 kN recording on tape the nature of the load changes.

The test results, as average for all groups of samples, shown in table 3 and figure 2.

Table 3. **The value of the breaking load (kN) samples with welded and glueweld seals under static tension**

Steel Brand	Glue Brand				
	Без клея	UP-5-240-1	EPOXY-531	UP-5-207-1	UP-5-207
09Г2С	23.2	33.4	36.2	36.3	34.5
10Х13Г18ДУ	27.3	32.6	39.7	37.6	35.1
10Х13Г18ДУ + 09Г2С	24.3	32.9	37.4	35.8	34.8

According to the results of destroyed samples investigation the following was subsisted.

1. Destruction of glueweld seal made of steel 09Г2С occurs at the welded point, and on the adhesive interlayer. Welded point is destroyed by shear without significant tearing of the base metal. The diameter of the destroyed contact detail – the welded and gluewelded seals have almost the same detail and come up to 6,5- 7mm. . Destruction of glueweld seal made of steel 10Х13Г18ДУ was more complex. None of the seals was destroyed at the weld points, and was destroyed by the heat-affected zone. The destruction of welded seal made of dissimilar steels occurs at the welded point with tearing of the base metal (only steel 09Г2С is tired out).

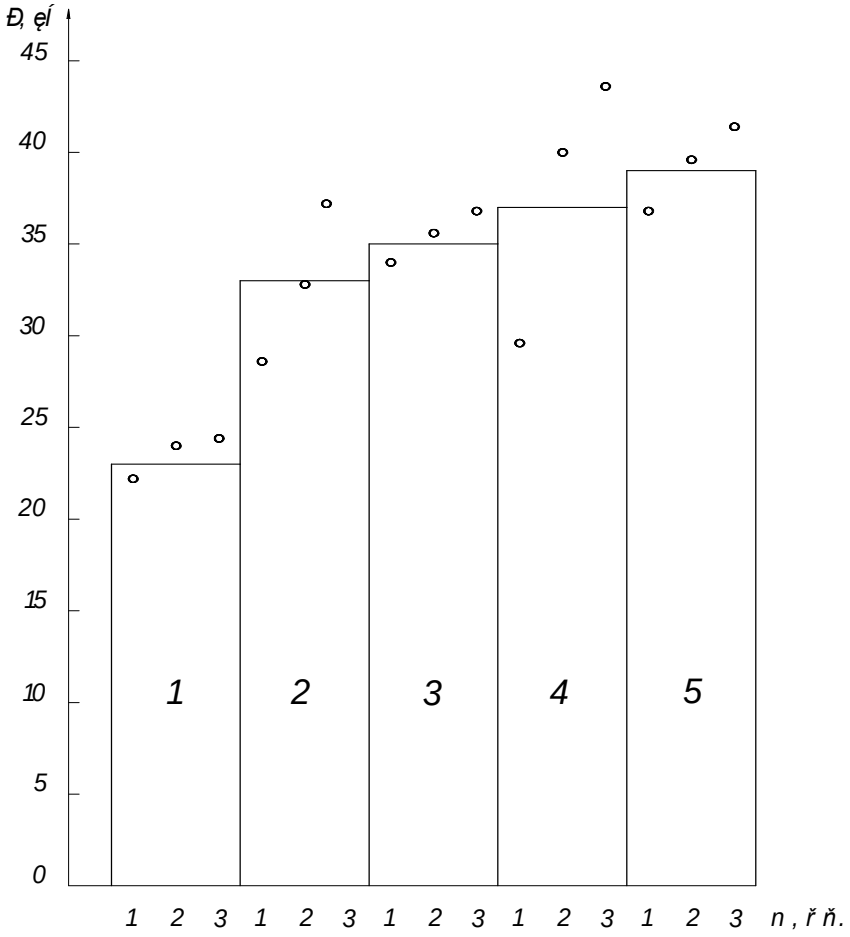

Fig. 1. The results of the samples destruction at stretching the steel 09G2S: 1 – Weld Seal; 2 – Glueweld seal with Glue UP-5-240-1; 3 – Glue UE-5-207; 4 – Glue UP-5-207 -1; 5 – Glue EPOXY-531

2. In the heating zone the glue is burnt out at the weld point. Diameter of glue burnout varies from 10 to 16mm. Each zone has a burning glue evaporating channel, through which the combustion products of glue get out. This phenomenon leads to deterioration of the adhesive layer and reduce seam leakage. This phenomenon is minimal (mostly absent) when applying the glue UE-5-240-1 EPOXY-531.

3. Molten core of glueweld seal when applying the glue UP-5-207 has on its perimeter splashes of metal.

4. When welding on the adhesive interlayer it is stated that the glue with hardener hardens within a few minutes after welding.

5. Glueweld seal on the researched joints under static stretching is stronger in 1,4-1,7 times than the same weld type. The greatest strength have seals, welded with the glues EPOXY-531 and UP-5-207-1. Welded and gluewelded seals on the 10Х13Г18ДУ steel have slight difference in strength while stretching. But glueweld seal shows more stable results in strength when testing.

Nature of the observed changes in the load is shown in Figure 2.

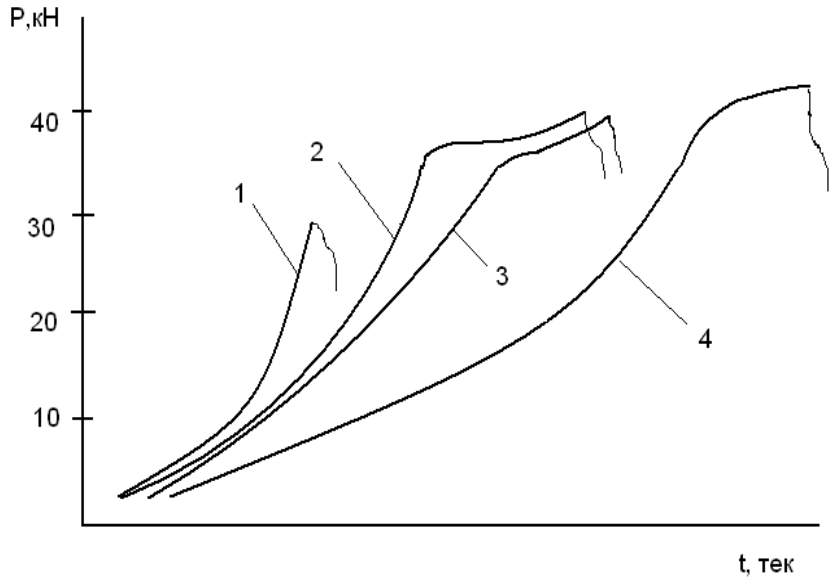

Fig. 2. The destructive nature of the force change under static stretching in the seals: 1 – Steel 10Х13Г18ДУ 1,5 mm thickness; 2 – Steel 10Х13Г18ДУ 1,5 mm with steel 09Г2С 2,5 mm; 3 – glueweld seal made of steel 10H13G18DU 1,5 mm; 4 – glueweld seal made of steel 10Х13Г18ДУ 1,5 mm with steel 09G2S 2,5 mm

The figure shows, that the variation in load at welded and gluewelded seals is different. Nature of the load changes of weld seal (presented in Figure 1) has a gradual increase of breaking force to complete destruction of the sample. Nature of the load changes of gluewelded seal (presented in Figure 2) has also a gradual increase of breaking force. The destruction speed increases until the loading to 30 kN and then begins to fall. In the area of markers 33-34 kN speed drops to almost zero. This fading of destruction force lasts about 5 seconds. Further speed of applied destruction force begins to gradually rise to a complete destruction of glueweld seal.

It can be assumed, that the breaking load "freeze" in this area could be caused by plastic deformation of the seal. The presence of the adhesive increases the yield plateau. This phenomenon confirms the higher resistance to the breaking load of glueweld seals compared with welded.

6. The nature of glueweld seals destruction depends on the thickness of the welded plates. Plate with 2,5 mm thickness under static stretching are not deformed, and

spotwelds are cut. Plate thickness 1,5 mm in the process of destruction have the plastic deformation and spotwelds are tired out from the basic metal;

7. Strenght of glueweld seal made of dissimilar steels (Steel 09Г2С + Steel 10Х13Г18ДУ) is determined by the strength of steel 09Г2С (less durable). The steel 09Г2С plate under static stretching is destroyed.

8. Epoxy adhesives provide a lasting seals of steels, used in the research, and are suitable for use at glueweld seals. The strength of adhesive joint depends on thickness of adhesive layer, it should be not more than 200 microns. The glue EPOXY-531 is able to penetrate under the overlap of the joint to a depth of more than 25mm, that enables its use to correct defects in the adhesive layer;

9. Glueweld seals, performed using the resistance spot welding, have a smaller area of the heat affected zone compared to the seals without adhesives. It follows that the construction, produced by this method, will have a smaller residual strain and stress, than in fusible welding.

All this makes the use of glueweld seals in the manufacture process of rolling stock sheet-sections preferable, than electric arc welding methods and welding without adhesives.

Glueweld Seals Corrosion Properties. To determine the corrosion properties accelerated 30 day tests of singletons glueweld seals were carried out in the hostile environment – 3% NaCl solution. Width of the lap joint – 20mm. After holding in hostile environment the weld points were drilled, and the samples were destroyed on the adhesive interlayer.

The examination of the samples showed of corrosion traces presence in the places of the combustion products of glue, where the porosity of the adhesive layer is formed. Under the adhesive layer in all the glueweld seals no traces of corrosion were found. Consequently, the presence of such a defect as porosity reduces the joint corrosion resistance.

Glueweld Seals Impermeability. Testing the glueweld seals on the impermeability of the joint was carried out on samples, welded using all four brands of glue. Weld points were affixed along the sample. Width of the joint lap – 25mm. On one side of lap of the welded samples purified kerosene was applied with the filling gun. On the other side of the lapping chalky solution was put with the brush and was let to dry before the test.

After some time where the chalk solution was deposited, in some samples there were spots of kerosene near the weld points. After the destruction of these samples porosity was found near a weld point. In other places of lapping, without the presence of this defect there was no penetration under the lapping. Consequently, the porosity reduces not only the corrosion resistance, but also the impermeability of the glueweld seal.

CONCLUSIONS

Depending on the materials to be welded strength of the glueweld point seals exceeds the strength of the appropriate welded joints in 1,4 - 1,5 times. The adhesive

layer in the welded joint increases the plastic flow of the seal before break and makes it more like plastic compared with welded joints without glue.

Weldability of resistance spot welding austenitic steel 10Х13Г18ДУ and dissimilar joints from this and low-carbon steels using adhesives is better in comparison with welding without adhesives.

Glueweld seals have a higher corrosion resistance in the case, if the impermeability of adhesive layer is not affected. Glueweld seals has full integrity weld under the circumstances the weld lapping is less than 25 mm.

The most technologically advanced to use in weld joints of sheet cladding and frame modules of rolling stock is a cold curing epoxy adhesive DP-5-240-1.

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ПРОЧНОСТЬ КЛЕЕСВАРНЫХ СОЕДИНЕНИЙ ИЗ РАЗНОРОДНЫХ СТАЛЕЙ

Александр Серебряков

Аннотация. Приводятся результаты экспериментальных исследований по отработке технологии и свойствам клеесварных соединений, выполненных контактной точечной сваркой на сталях, используемых для изготовления боковых секций и секций крыши кузовов локомотивов и вагонов подвижного состава, в том числе разнородных соединений.

Ключевые слова: сварка, соединение клеесварное, прочность, стойкость коррозионная

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URGENT PROBLEMS OF THE WORKING ENVIRONMENT IN THE FOUNDRY

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Summary. In the article implemented the research of the harmful factors of the working environment of machine building enterprises with various casting techniques.

Key words: casting, harmful and dangerous factors, intensity, dust, gases.

INTRODUCTION

In Ukraine, a quarter of employees work in conditions that do not meet sanitary-hygienic standards. The social insurance fund's statistics about compensation payment for the loss of efficiency from accidents and occupational diseases each year is 520 million UAH., nonrecurrent payments established by diagnosis "occupational disease" – about 160 million UAH., additional payments to pensions – about 150 mln. [Krishen, 2006].

The number of enterprises also increases, labor conditions on which are harmful to the health of the workers [Timoshina 2010]. In many foundry enterprises workers are under the influence of dangerous and harmful production factors, exceeding the maximum allowable concentration and maximum allowable levels in the working areas. The prolonged exposure of these factors on the labourer may lead to the lower efficiency and aggravation of health.

PUBLICATIONS ANALYSIS

The analysis of the literary sources showed that the respiratory organs diseases of the dust etiology prevalent in different countries: Ukraine, Russia and other CIS countries, Europe. In Ukraine, from 1992 to 2009 the number of diseases of respiratory organs is the highest in comparison with other diseases [Timoshina 2010]. The breakdown of respiratory diseases over the years shown in the fig. 1.

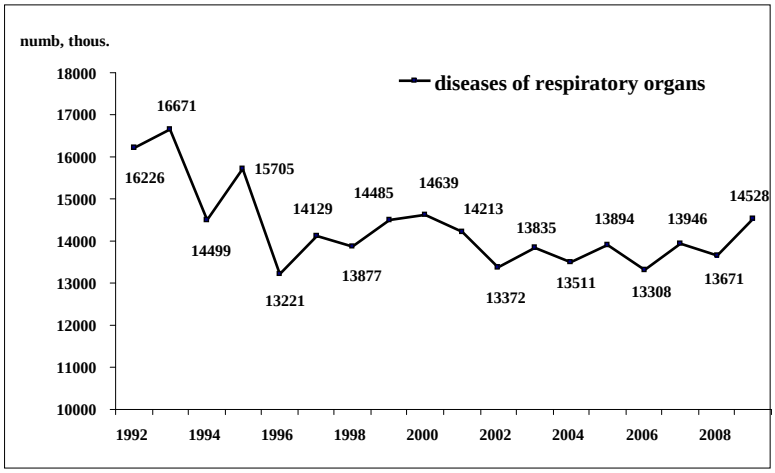

Fig.1. The number of diseases of respiratory organs on years

The reduction of the number of diseases occurred in 1996. Further, the number of cases varies within the limit from 13000 to 15000 cases, despite the economic crisis and the decrease in production. In 2009, the number of respiratory diseases is 14528 cases (in 2008 - 13671 cases), namely there was a trend of growth. Diseases of respiratory organs occupy a leading position in the structure of occupational diseases. The high risk of the dust diseases is proper to many industrial sectors (except coal-mining), including the foundry.

The occupational diseases is part of an overall morbidity of the population. The diseases of respiratory organs also prevalent in the structure of occupational diseases – 36,2%, the vibration diseases – 25,8%, the diseases of musculoskeletal system – 10,3%. With the help of researches and analysis of the causes of occupational morbidity in Ukraine established that working conditions are the major factor of occupational diseases, and mechanical engineering and metallurgy place the second largest number of cases [Kundiev 2007].

The problem of occupational diseases considered in the following papers. Rabenda Andrzej Stefan researched the patterns of influence of industrial harmful factors on the health of workers in Poland. He explored the risk of the dust diseases of electric welders, foundry workers and weavers.

In the work of Dmitry Pavlovich Pertsev was established the system of preventive measures in the production of castings in the permanent metal molds. The author considers that the principal harmful factor at the casting in permanent metal molds is heating microclimate against the background of the harmful influence of industrial noise. The additional production harmful factors are the dust and gas pollution of the working zone with substances whose content is many times higher than the maximum allowable concentration.

As of day, the working conditions of the modern foundry are not enough studied, as well as industrial harmful and danger factors at different ways of casting. The

prevention of the danger occurrence (the growth of occupational diseases, injuries) can be achieved through a comprehensive analysis of the working conditions at each workplace, each particular enterprise of any form of property that is problem of today.

PURPOSE AND RISING OF THE TASK OF RESEARCHES

The purpose of the work is to research both traditional and new casting technologies, analysis of harmful and danger factors of the production environment, the analysis of the harmful factors on the each jobsite.

BASIC DIVISION

At present, developed the following methods of casting: casting in sand-clay molds, casting on the gasified models, casting in the vacuum-film form, casting with the cold-thicken compounds (CTC), casting with the water-glass compounds (WGC), casting with the hot-thicken compounds (HTC), the die casting, the shell casting, the rotary casting, the pressure die casting, the freeze crystallization casting, the magnetic form casting, the die casting under controlled gas pressure, the graphite mold casting, the ceramic mold casting, the suspension casting, and others [Efimov 1991, Ivanov 1990, Speransky 1995, Golofaev 2001, Budanov 2006, Kechin 2002]. All processes are attended by various industrial harmful and danger factors.

The work executed experimentally based on laboratory researches [Bachovska 1966, Vershinin 1992, Leita 1980.], on the analysis of working conditions maps, on the results of jobsites review and literary data. It was made an integrated assessment of harmful and danger factors of the most common modern foundry technologies in iron-casting and steel-casting workshops, of the holding company “Luganskteplovoz”, Lugansk casting-mechanical plant and other enterprises.

The workers in the labor process, usually undergo to the influence of several harmful and danger factors of the surrounding production environment. The influence of each of them is different. The industrial harmful factor passing the maximum allowed level and the maximum allowed concentration, and prolonged action, can become the danger factor [Gandzyuk 2004]. Therefore, on the first stage identified and studied the harmful factors, which exceed the maximum allowed concentration and level. Also, there were identified the most typical danger factors for the foundry industry. The intensity of the factors determined on the exceeding the maximum allowed concentration and level. The research results presented as the characteristics of the intensity of the harmful and danger factors, which are contained in the author’s paper [Shinkareva 2010].

The paper presents the results of 24 methods of casting. It was set the percentage of the each method of casting in the mechanical engineering in Ukraine. The analysis of the intensity of the following industrial harmful factors: dust, gases, aerosols, excessive heat, noise, vibration, electromagnetic radiation, physical overload, neuropsychic stress. The most intensive danger factors were revealed: sparks, spatter, high voltage electrical circuits, moving machinery.

In the examined work [Shinkareva 2010] for each casting method can determine the amount of the intensive production factors. They create unfavorable conditions on the each jobsite. For example, while the casting in sand-clay molds arise 10 intensive factors, while the casting on the gasified models – 7, while the continuous casting – 2. During the continuous casting add 4 more moderate factors, and 8 minor factors. The use of the casting in sand-clay molds in Ukraine is 60%, and continuous casting – 0,9%, namely, the new technologies did not receive the wide development yet. The produced researches [Shinkareva 2010] confirm that the foundry – one of the most dangerous sectors of the mechanical engineering.

The use of the modern technology eliminates some of the intensive factors, but appear new harmful factors. For example, the electromagnetic radiation – while the casting in magnetic forms, the release of the hydrogen fluoride, the carbon monoxide and carbon dioxide – during the thermal decomposition of the synthetic sealing film with the vacuum-filming method of casting. The significant emission of the toxic gases occurs in the process of drying the rods and forms in the use of the organic binder, as well as by pouring the metal. The complex influence on the health of employee of the listed harmful factors requires a more careful study.

For the full characteristics of the danger of the foundry was conducted the research of appearance of the harmful and danger factors on the main technological jobsites. The results are presented in the authors' work “The research of the harmful factors of the foundry at various stages of the process” [Shinkareva 2010]. The analysis of the job hazards was conducted at the major jobsites in the technological lines for 24 methods of casting. In 18 of the 24 ways prevail the intensive harmful factor – the dust: while the casting in sand-clay molds, the dust is on the 11 jobsites, while the casting on the gasified models, the dust is on the 13 jobsites, while the investment casting is on the 12 jobsites, while the full-mold casting is on the 10 jobsites, and etc. The analysis of the harmful and danger factors at the various operations of the technological process [Shinkareva 2010] on the each workplace established that during the preparation of the molding materials from the 24 methods of casting in 17 is the basic harmful factor – the dust. They are such processes as the casting in sand-clay molds, the casting on the gasified models, the casting on the vacuum-filming forms, the casting with the use of the cold-thicken compounds, the water-glass compounds, the hot-thicken compounds, the shell and ceramic casting, the die casting under controlled gas pressure, etc. During the preparation of the molding sand in the 17 methods is the harmful factor – the dust (gases in the 15 ways), during the preparation of the core mixtures, the dust is in 18 methods (gas in the 17 methods) as well as the manufacture of the half-forms and rods, models and core boxes, during the shakeout of castings, the separation of the runners and rods, the cleaning, the main harmful factor is the dust. Consequently, the conducted analysis showed that the main intensive harmful factor of the foundry are dust, gases, heat. Most of the operations in the manufacture of the castings are accompanied by the dust concentration which is in several times higher than the maximum allowed concentration.

The examination of the air pollution state on the iron foundry of the holding company “Luganskteplovoz” showed that in the working area during the preparation of the molding and core sands, the content of the dust was 8,16 mg/ m^3, that exceeds the maximum allowed concentration which is equal to 2 mg/m^3, on the molding area, the

content of the dust equals 10,7 mg/m^3, during the castings shake-out – 10,3 mg/m^3, which is coordinate with the data of the works [Ivanov, 1990, Speransky 1995].

The long-term inhalation of such air may lead to the development of such occupational disease as pneumoconiosis [Basakov 2003, Artamonov, 2004]. The development of this disease directly depends from the extent of dispersion of the dust [Strizhko 1996, Demchenko, 2010], the qualitative structure of the dust and the degree of the dust content in the air, length of service, as well as the number of other factors, such as excessive heat, noise, weight and strength of the labor process, the presence of other harmful substances in the working area.

The analysis of the listed ways of casting on the isolation of harmful gases [Shinkareva TA, 2010] established that: while the casting in the sand-clay molds (gases isolated on 11 technological processes), on the gasified models (on 10), casting with the cold-thicken compounds (on 9), casting with the water-glass compounds (on 9), casting with the hot-thicken compounds (on 10), the chill casting (on 8), and the shell casting (on 11), and etc. The analysis of the jobsites in the 24 methods of casting revealed that the most dangerous from the point of isolation of gases are: on the molding sand jobsites (in the 14 from the 24 methods of casting) and on the core sand jobsites (in 16 from the 24 methods of casting), the manufacture of half-forms and rods (in 15 from the 24 methods), drying of half-forms and rods (in 12 out of 24), and the castings shakeout from the mold (in 23 methods).

During the melting and it's overheating, the casting into the molds, hardening and cooling it in the form also isolate the large amount of gases [B.S. Ivanov, 1990, B.S. Speransky, 1995], which depends on the choice of the casting method and the furnace. During the melting in the induction furnaces, the main harmful factors are the excessive heat, gases and electromagnetic radiation, during the melting in the cupolas, the main harmful factors are the dust, fumes, the excess heat, during the melting in the electroarc furnaces, the harmful factors are the graphite dust, the excessive heat, gases, noise.

Thus, from the study of the variety of harmful and danger factors, the most intensive, which are often found in all ways of casting are the dust, gases, the heat. Obviously, in the foundry on the jobsites occur the set of adverse factors, which have harmful effects on the health and the efficiency of the labourer. Hygienic standards are still the main tool for evaluating the safety of the health of the workers, and exceeding of such standards is considered as the breach of the health legislation. Measures to protect the employee nowadays is shorter working day, week, additional days to the vacation, early retirement, additional payments for the unhealthy working conditions, the assignment of preventive nutrition, insurance, and etc. However, the influence of the harmful and danger factors can cause the disturbance of the workers health, even if these factors satisfy the maximum allowed conditions and level. Unfortunately, in the foundry industry during the crisis, the compliance of the standards is impossible task for the most enterprises.

CONCLUSIONS

The fight with the dust and other harmful factors is in progress mainly just after their formation and their release into the air. To solve the problems of improving the working conditions on the foundry workers jobsites seems necessary the following:

• study of the physical and chemical content of the intensive harmful dust factor and the process of the dusting;

• study of the chemical content of the isolated gases;

• the conduct of the researches of other intensive factors;

• the development of the technical means intended for the creation of a hygienically safe working conditions.

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АКТУАЛЬНЫЕ ПРОБЛЕМЫ СОСТОЯНИЯ ПРОИЗВОДСТВЕННОЙ СРЕДЫ В ЛИТЕЙНОМ ПРОИЗВОДСТВЕ

Татьяна Шинкарева, Анатолий Гедрович, Анатолий Голофаев

Аннотация. В статье проведено исследование вредных факторов производственной среды машиностроительных предприятий при различных литейных технологиях.

Ключевые слова: литье, вредные и опасные факторы, интенсивность, пыль, газы.

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MODELLING OF A CONTROLLED TRACTIVE WHEELSET FOR A BOGIE OF A RAILWAY VEHICLE BASED ON NOISE SPECTRUM ANALYSIS

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Summary. This paper examines an intelligent railway vehicle system subjected to adjust and control a complex mechatronical system that includes controlled wheelsets. The dynamic and tractive characteristics of a railway vehicle are controlled based on noise spectrum analysis for the friction coefficient detection and railway wheel squeal. In this paper, we propose a combined control system with two stages of control strategies. The first control strategy is used for adhesion control and adjustment of railway vehicles based on an observer, which allows the determination of the maximum tractive torque based on the optimal adhesion force between the wheels of a railway vehicle and rails depending on weight load from a wheel to a rail, friction conditions in the contact zone, a lateral displacement of wheel set and wheel sleep. The second control strategy allows the adjustment of a wheel set's position on the track to be executed by means of actions from actuators to links of axle boxes depending on analysis of noise in the wheel-rail contact. The non-linear MBS software package called Simpack was used for the simulation model of the proposed mechanical system. The proposed control strategy was modeled in Matlab/Simulink. The Simpack model was linked with the control unit in Matlab/Simulink by means of a SIMAT-interface. The system was investigated using co-simulation.

Key words: dynamics of rail vehicles, mechatronic systems, fuzzy logic controller, bogie, adhesion model, actuator, stability control, guidance control, integrated control, rolling noise, microprocessor control system, simulation, locomotive model

INTRODUCTION

The realization of maximum adhesion forces for a rail vehicle in straight and curving parts of track is a very difficult process because it is connected with use of tractive efforts and depends on the contact characteristics in the zone between the wheels and rails.

Modern solutions in the field of the development of new control systems for mechatronic systems of running gears allows the possibility to improve the interaction between wheels and rails for different modes of the movement for rail vehicles. These systems can be tentatively divided into the following groups:

- traction control systems
- suspension control systems

- brake control systems
- combined control systems.

At the present time, there has been special research attention on the problem of reducing the wear of wheels and rails on the curving parts of a railway track. For this research, it is necessary to determine the exact parameters of the contact between a wheel and rail, and the displacement and position of a wheel set on straight and curving parts.

Usually for decreasing wear and the improvement of adhesion realization in the tractive mode, only two control systems are used from the above written classification. One of these systems is the adhesion control system; the second one is the active steering control system.

In our previous publications [Spiryagin M., Lee K.S., and Yoo, H.H., 2007, Spiryagin M., Lee K.S., and Yoo H.H., 2008] we presented control systems that allowed for the adjustment of traction efforts for different adhesion conditions. These systems were developed based on a method of steepest descent and fuzzy logic [Pupkov K.A., Egupov N.D., 2004].

Active steering control system of a rail vehicle is described in . [Spiryagin M., Lee K.S., Yoo, H.H., Spiryagin V., and Vivdenko Y., 2007]. That system was proposed for a two-axle bogie which uses constraints with radius links and one of the radius links of axlebox also functions as an actuator.

The systems described above have one common feature – information about contact characteristics for the system is obtained by means of noise analysis from the wheel-rail contact.

However, the system that allows doing combined control of characteristics of a wheelset's movement, is one of the most interesting examples to improve vehicle dynamics. This system [Perez J., Busturia J., Mei T.X., and Vinolas J., 2004] allows the control of traction efforts as well as the active steering control by means for mechatronic bogie vehicles with independently rotating wheels. From a practical point of view, mechanical components of this kind of systems need further improvement. The system has a good chance to find an application for new types of rail vehicles in the future.

At the present time, the modernization of existing electromechanical designs of running gears for rail vehicles is one of actual questions. In this article, we describe an improved mechatronic system that includes two subsystems. One of these subsystems is an adhesion control system (it is connected to the traction control). The second one is the active steering control system. The proposed decision was estimated by means of simulation. For the simulation, a complex model of a bogie of a rail vehicle, control system for traction motors and actuators were developed.

OBJECT AND PROBLEMS

Model Of Rail Vehicle

The evaluation of traction and dynamic characteristics of a rail vehicle requires an adequate representation of different modes of a vehicle's work and an interaction between running gear's elements and track [Masliev V.G., 2002, Iwnicki S. , 2006,

Himmelstein, 2004]. The solution of this task is possible to reach if the friction process, which present in the contact between wheel and rail, is described in the correct way.

The traction bogie of a rail vehicle DEL-02 manufactured by JSC "Holding company "Luganskteplovoz", was taken to conduct the simulation experiments. The bogie is shown in fig. 1 and has a two-stage spring suspension. This bogie and non-motor bogie of the same vehicle has unified parts such as the frame, brake, mounting-returning device. The traction bogie has two AC traction motors with supported-frame suspension and two torque gears. The traction from the wheel to the pivot is transmitted through the resilient axle box radius links, bogie frame and resilient traction rods.

We make an assumption that the bogie is equipped with wheels, which have a profile as shown in fig. 2, and the wheels move on the track with a rail profile plotted in fig. 3.

The value of the adhesion force is separately calculated for each wheel and depends on a rail vehicle's velocity, a slip velocity of contact bodies, wheel and rail profiles, a weight load from a wheel to a rail, friction condition in the contact zone and a position of a wheel relative to a rail.

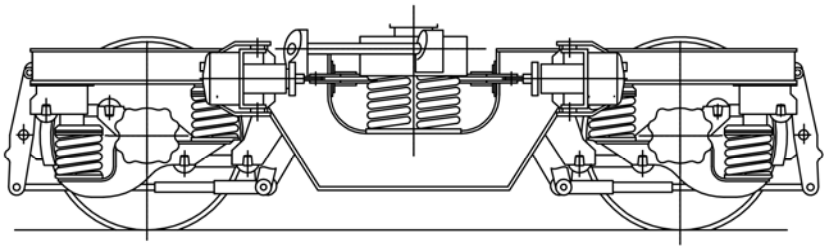

Fig. 1. Side view of front traction bogie of the rail vehicle DEL-02

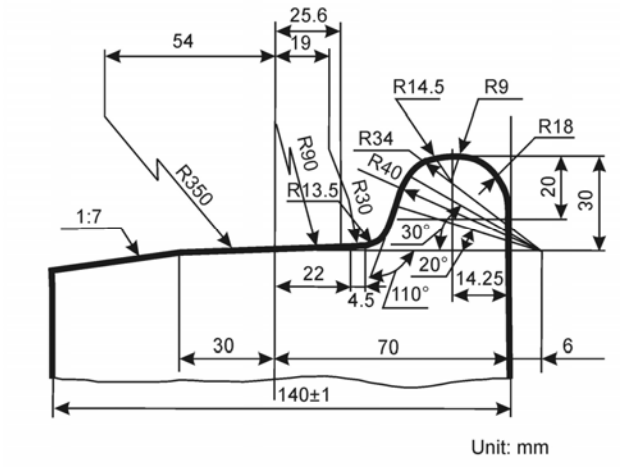

Fig. 2. Wear wheel profile, which is obtained by means of wear analysis for locomotives' wheels [Carev 1982]

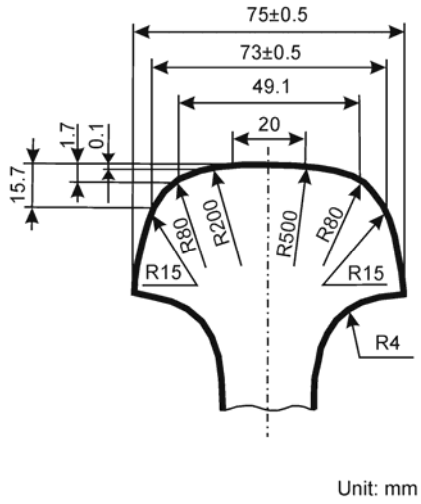

Fig. 3. New rail profile

For the simulation of adhesion process in the contact zone, the adhesion model [Spiryagin V., 2004, Spiryagin, M., Lee, K.S., Yoo, H.H., Kashura, O., and Kostjukevich, O., 2007] was applied. The adhesion force can be defined as

$$\vec{F}_a = N\frac{\vec{S}}{\left|\vec{S}\right|}/\left(A_1/\exp(\varepsilon\cdot B)+A_2\ln(\varepsilon\cdot B)+A_3/(\varepsilon\cdot B)+A_4(\varepsilon\cdot B)+A_5\right)T_2T_4T_9/T_7T_8 \quad (1)$$

Here: N – weight load from a wheel to a rail;
A1, A2, A3, A4, A5 – coefficients of relation;
$\vec{S}$ - vector of wheel slip;
ε - relative slip, [%];
B=T1T3T5T6;
T1, T2 – coefficients, which depends on friction conditions in rail-wheel contact;
T3, T4 – weight load coefficients;
T5 – velocity coefficient dependent on the velocity V of the locomotive;
T6, T7 – coefficients, which are dependent on cross motion y of a wheel relative to the rail;
T8 – coefficient of angle of attack of the wheel;
T9 – coefficients, which depends on traction of braking mode of a rail vehicle's movement.

Coefficient T9 should provide a safety in the braking mode. Furthermore, the process, which has a place in a suspension and is called a suspension lock, has a big influence on vehicle dynamics. In this case, the dynamics start worsening and, as a result, the adhesion coefficient between the wheel and rail decreases. Based on this, the coefficient T9 can be equal to 1 in the traction mode and equal to 0.5 in the braking mode.

The values of coefficients for equation (1) for the wheel and rail profiles, shown in fig. 2 and fig. 3, are listed in Table 1. Furthermore, in this table, μ is the maximum friction coefficient of concrete friction condition for two contact bodies.

In the next section, the possibility of obtaining information about friction contact characteristics such as the maximum friction coefficient and the angle of attack by means of noise analysis will be discussed.

Noise In Wheel-Rail Contact

A review of investigations on the possibility of detecting friction conditions in the contact zone with the help of the method of using of noise analysis was published by [Spiryagin M., Lee K.S., and Yoo H.H., 2008]. It allows making a preliminary conclusion that the detection of the maximum adhesion coefficient is possible by means of noise analysis.

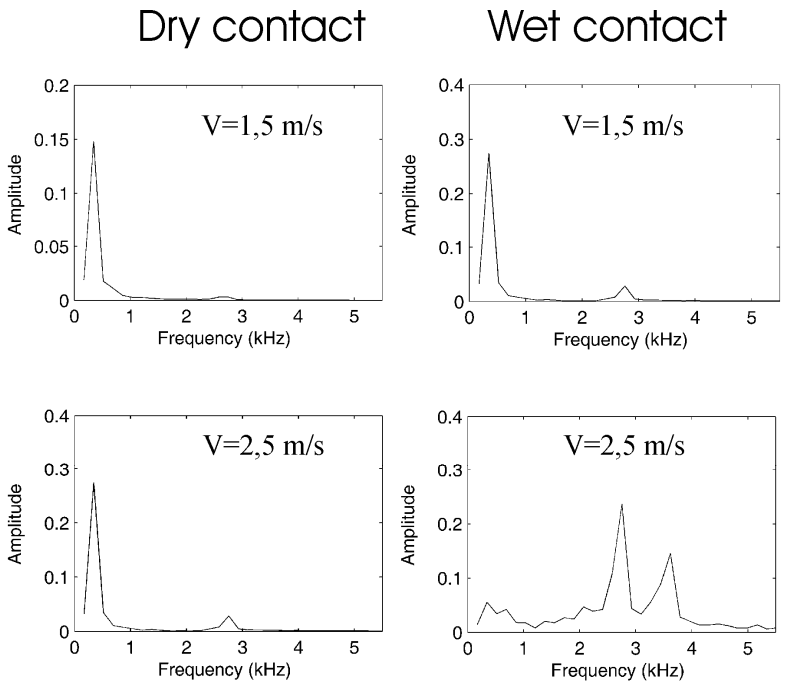

Fig. 4. Results of noise analysis in the contact with the permanent slip and the angle of attack ψ=0

The problem of the dependence of the angle of attack on noise characteristics has been studied in works published by [Hsu, S.S., Huang, Z., Iwnicki, S., Thompson, D.J., Jones, C.J.C., Xie, G., and Allen, P. D., 2007, and Koch, M., Hentschel, F., Himmelstein, G., and Krouzilek, R., 2003]. The obtained results for the measurements,

made on special test rigs, show the possibility of getting information about the angle of attack based on an analysis of the power spectral density and the sound pressure level. Fig. 5 shows the investigation results obtained by [Hsu, S.S., Huang, Z., Iwnicki, S., Thompson, D.J., Jones, C.J.C., Xie, G., and Allen, P. D., 2007].

For the further confirmation of the proposed method, a series of experiments on a specially developed test bench were made by [Spiryagin M.I., Spiryagin V.I., Klyuev A.S., Klyuev S.A., Ulshin V.A., 2008, Spiryagin M., Lee K.S., Yoo H.H., Spiryagin V., and Vivdenko Y., 2008]. The obtained results show that the detection of the contact characteristics only by noise sound pressure analysis is not possible. However, the study on acoustical signal allows the possibility to get this information. The example of analysis is shown in fig. 4. However, a more detailed investigation in this field is still required.

Table 1. **Coefficients for equation (1) for the definition of the value of adhesion force in the wheel-rail contact**

A_1	1
A_2	-0.1419381
A_3	0.026201
A_4	4.3642
A_5	2.0729
T_1	$0.026+2.38\mu$
T_2	$\mu/0.40907$
T_3	0.00635+0.0000368N, N[kN]
T_4	$0.9713+0.0003454N-0.0000005674N^2$, N[kN]
T_5	$(0.10108v-0.108)^{0,5}$, v[m/s]
T_6	$1.0002+0.1026y+0.002419y^2-0.000728y^3$, y[m]
T_7	$0.99976+0.0059684y-0.00006288y^2+ +0.0000577856y^3$, y[m]
T_8	$1-0.0056\|\psi\|(0.1057+0.087y+0.01156y^2)$, ψ [rad]

Based on these results, it is possible to make a conclusion that the use of noise analysis to get the friction characteristics in the contact zone as well as the angle of attack is a possible variant. However, it is necessary to remember that for each concrete case of interaction between wheels and rails, the same noise can be identified only for the same models of rail vehicles with specified design characteristics, such as wheel and rail profiles, suspension systems and etc.

Proposed Control System

For our proposed system, we need to use the algorithms for control systems described in works published by [Spiryagin M., Lee K.S., and Yoo H.H., 2008, Spiryagin M., Lee K.S., Yoo, H.H., Spiryagin V., and Vivdenko Y., 2007]. In this paper, we investigate combined work of control subsystems for the complex control of

wheelset's dynamics. Fig. 6 shows the proposed microprocessor systems for one wheelset.

For the correct work of adhesion control subsystem, it is necessary to make a comparison of optimal and estimated adhesion forces.

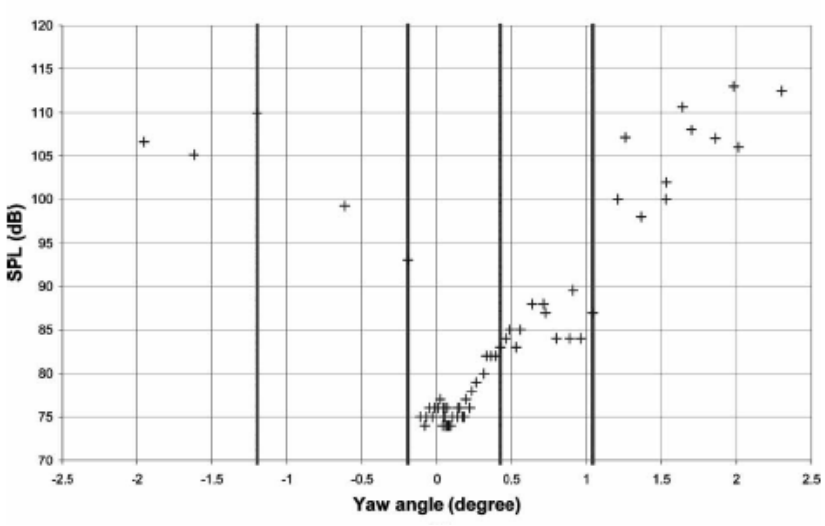

Fig. 5. Dependence between sound pressure level of the dominant frequency and yaw angle for rail-wheel contact [Hsu, S.S., Huang, Z., Iwnicki, S., Thompson, D.J., Jones, C.J.C., Xie, G., and Allen, P. D., 2007]

Optimal adhesion force can be computed according to Equation (1). In this case, the slip value should approximately be equal to 3 percents because this slip provides a stable work in the wheel-rail contact [Engel B., Beck H.-P., Alders J., 1998].

The detection of the adhesion coefficient, which is also used in Eq. (1), is possible by means of noise spectrum analysis in the wheel-rail contact and using GPRS and GPS technologies. A GPS satellite system is used for obtaining the position of a railway vehicle at a specific moment of time. After receiving the current position on the curve, the track characteristics for the current position can be obtained by means of the GPRS from the station computer. The obtained noises are processed by a special algorithm to obtain the noise characteristics for certain frequency bands. By looking up a special database data, received from experimental and theoretical research, the dependence of the adhesion coefficient on noise and track characteristics, vehicle velocity, relative slip, the lateral displacement and the angle of attack can be obtained.

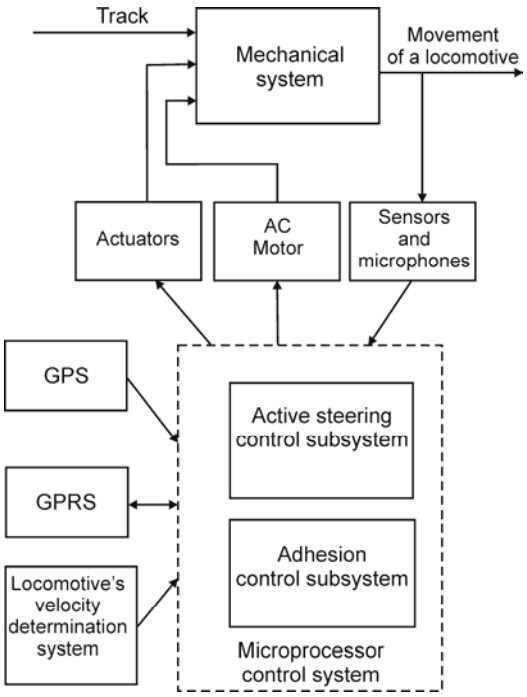

Fig. 6. Microprocessor control system

The estimated adhesion force can be defined based on Laplace transformation and adapt primary order low-pass filter by the following equation

$$F_{est} = \frac{T_{wheels}}{r} - \frac{J}{r^2}\frac{1}{\tau_0}\left(1 - \frac{1}{\tau_0 s + 1}\right) \cdot V(s) \tag{2}$$

Here: T_{wheels} is the tractive torque applied to a wheelset, r is a radius of wheel, J is an inertia of wheelset, τ_0 is a time constant of the observer, and V is the locomotive velocity.

Based on a comparison of the obtained results of the values of the optimal and estimated adhesion forces, the adjustment of the required torque of the AC traction motor for a wheelset is provided by means of a controller, which has been developed with the use of fuzzy logic. More detailed information on this controller used for our proposed system can be found in [Spiryagin M., Lee K.S., Yoo, H.H., Spiryagin V., and Vivdenko Y., 2007].

For the second subsystem for active steering of the wheelset, it is necessary to change one of radius links of axlebox by a link-actuator in the mechanical system. This decision does not require any change in the bogie's design. The algorithm is based on a comparison of values for optimal and estimated steering angles (the steering angle is a yaw angle of wheelset relative to a bogie's frame).

The optimal angle can be obtained with the following equation:

$$\gamma_{opt} = \arcsin\left(b / 2R\right) \tag{3}$$

Here: b is the distance between the leading ant trailing axles of bogie, R is the track curvature, which can be defined by means of using GPS/GPRS technologies.

The estimated steering angle γ_{est} can be defined as

$$\gamma_{est} = \psi - (y_1 - y_2) / b + i^* \cdot (b / 2R) \tag{4}$$

Where: ψ is the angle of attack (this angle can be obtained from noise analysis as described in Sec. 3), y_1 and y_2 are the lateral displacements of wheelsets; $i^* = 2i - 3$ (for the leading wheelset i=1 and for the trailing one i=2).

The controller for the active steering control system, based on the simple proportional control law, is described by [Spiryagin M., Lee K.S., Yoo, H.H., Spiryagin V., and Vivdenko Y., 2007].

Design And Simulation Model

The evolution of the proposed system was performed by means of a simulation on a traction bogie of a railway vehicle DEL-02. The weight of a half carbody was connected unmoveable as weight forces to the supports. For the development of the simulation model, the non-linear MBS software package called Simpack was used. The proposed control strategy was modelled in Matlab/Simulink. The Simpack model of the bogie was linked with the control unit in Matlab/Simulink by means of the SIMAT-interface. Based on the software packages described above the system was investigated by using co-simulation.

Fig. 7 presents the dependence between the maximum adhesion coefficient and the distance along the track. This allows the simulation of different adhesion conditions between wheels and rails.

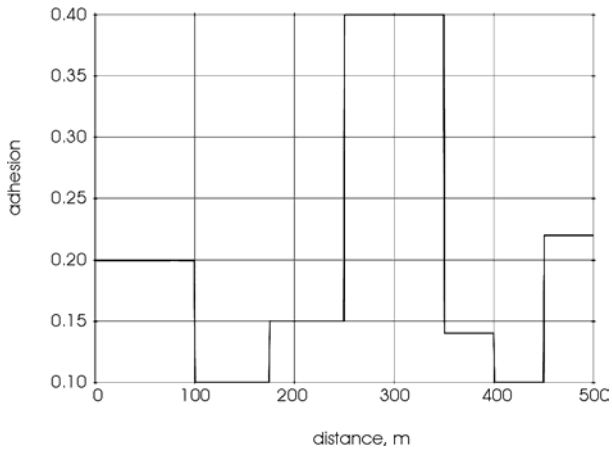

Fig. 7. Dependence of the maximum adhesion coefficient on distance along the track inputted in Simpack

The estimated rail curvature is plotted on fig. 8. For this simulation, the curvature radius was obtained from the following equation [Koch, M., Hentschel, F., Himmelstein, G., and Krouzilek, R., 2003]

$$1/R = \Omega / V \tag{5}$$

fig. 9 shows the calculated results as a function of the time. The obtained results confirm the satisfactory work of the proposed system.

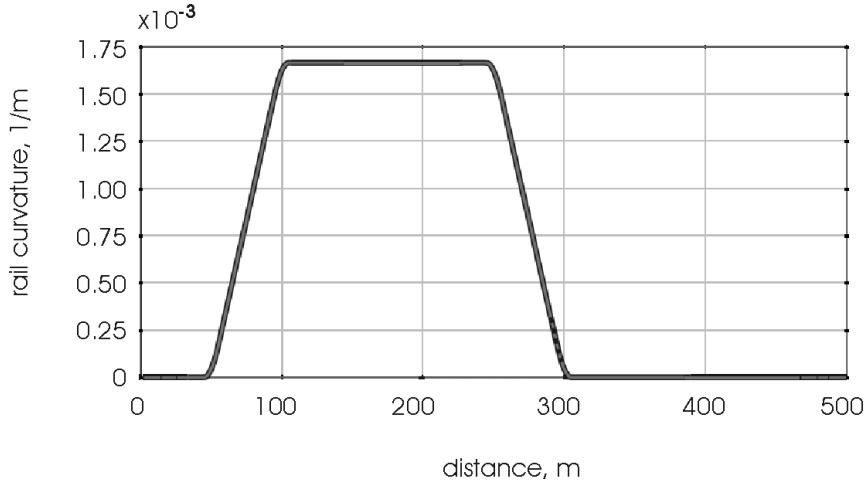

Fig. 8. Estimated rail curvature

CONCLUSIONS

This paper presents the design of a mechatronic wheelset for a bogie of a railway vehicle. Co-work of the adhesion control system and the active steering control system were used to improve vehicle dynamics in curved parts of track. The work of the proposed control subsystems is based on noise analysis.

The system performance was checked with co-simulation in Simpack and Matlab/Simulink software. As a result, we achieved a satisfactory control system.

In conclusion, for the correct work of the system in real conditions more detailed theoretical and experimental investigation needs to be performed on the dependence of the adhesion coefficient and the angle of attack from noise in rail-wheel contact for different working and friction conditions.

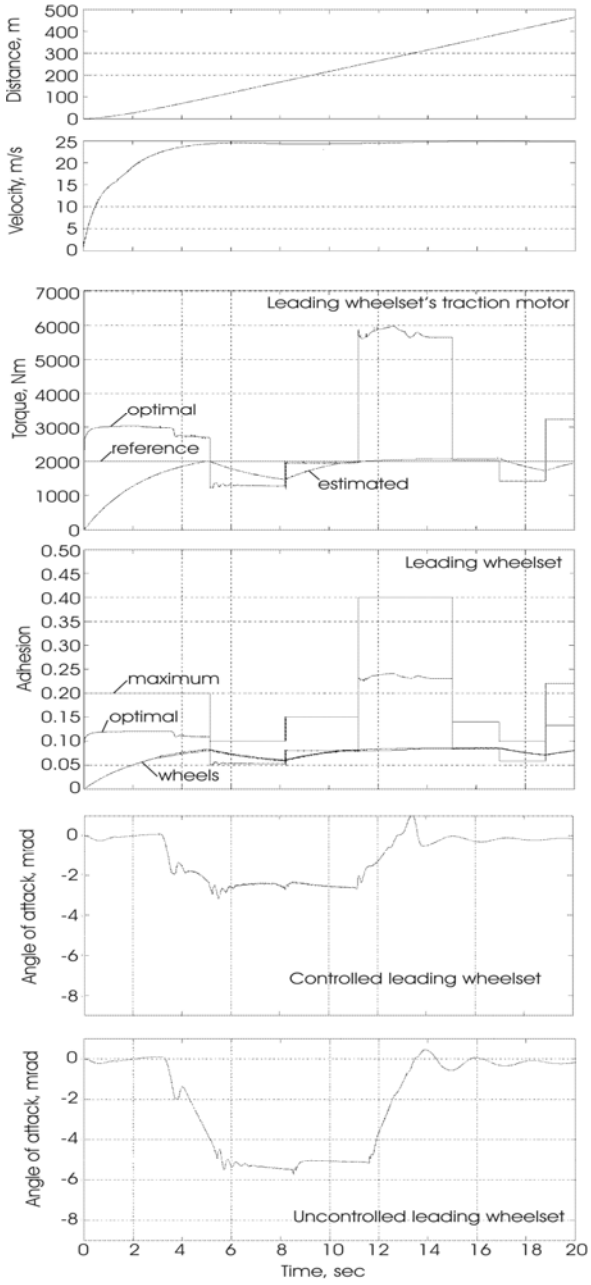

Fig. 9. The results obtained for a railway vehicle under different adhesion conditions from Simpack and MATLAB/Simulink co-simulation

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МОДЕЛИРОВАНИЕ УПРАВЛЯЕМОГО КОЛЕСНО-МОТОРНОГО БЛОКА ДЛЯ ТЕЛЕЖКИ РЕЛЬСОВОГО ТРАНСПОРТНОГО СРЕДСТВА, ОСНОВАННОГО НА СПЕКТРАЛЬНОМ АНАЛИЗЕ ШУМА

Максим Спирягин, Валентин Спирягин, Ирина Костенко

Аннотация. В этой работе исследуется система управления железнодорожного транспортного средства объектом регулирования и управления являестя комплекс мехатронных систем управляющих колесномоторным блоком.Управление динамическими и тяговыми характеристики железнодорожного транспортного средства основываются на анализе спектра шумовом контакта колеса и рельса для содействующего фрикционнгого состояния. В статье, мы предлагаем комбинируемую управляющую систему с двумя стратегиями управления. Первая стратегия управления использует контроль и управление сцеплением колеса и рельса, позволяет определить максимальный тяговый вращающющий момент, основанная на оптимальной силе сцепления между колесами железнодорожного транспортного средства и рельсами в зависимости от вертикальной нагрузки передаваемой от колеса к рельсу,фрикционных условий в контактной зоне, боковое смещения колеса относительно рельса и скорости скольжения. Вторая стратегия управления позволяет регулировать положение колесной пары относительно пути, посредством действий актуаторов установленных в буксовой ступени подвешивания в зависимости от анализа шума в контакте колеса и рельса. Для имитационной модели предложенной механической системы был использован пакет программ нелинейного моделирования Simpack . Предложенная стратегия управления моделировалась в Matlab/Simulink. Модель Simpack связывлась с устройством управления в Matlab/Simulink посредством SIMAT-interface. В результате чего иследовалась совмесная работа двух стратегий управления транспорнтным средством.

Ключевые слова: Динамика рельсового транспортного средства, мехатронная система, конроллер нечеткой логики, тележка, модель силы сцепления, актуатор, устойчивость, система упраления направлением движения, интегральный контроллер, шум качения, микропроцессорная управляющая система, моделирование, модель локомотива

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DYNAMIC NON – AXIS – SYMMETRICAL SUM ABOUT THE TORSION OF THE ELASTIC HALF-SPACE WITH THE PUNCH

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Summary. In the work the sum about the joint oscillation of the elastic isotropic half-space and rigid while stretching (compression) of the punch of an arbitrary shape in the plan to which the rotational moment changing according to the harmonic law in time is applied. The asymptotic formulas for defining contact shearing stresses under the punch, the angle of lagging and module of complex amplitude of the punch oscillation.

Keywords: elastic half-space, integral transformations, frequency of oscillations, contact shearing stresses, complex amplitude of oscillations.

INTRODUCTION

Nowadays the mechanics of contact interactions of solid deformable bodies represents a big and actively developing branch of mechanics of continuums. Static contact sums are quite well researched. A big problem is created by the solutions of dynamic contact sums which have a scientific and practical value.

The main publications on the given problem are given in the works [Galin 1980, Vorovich, Alexandrov, Babeshko 1974, Vorovich, Babeshko 1979, Seymov 1976, Novatskiy 1970, 1975, Kilchevskiy 1976, Cherepanov 1974, Alexandrov, Kovalenko 1986, Goryacheva, Dobychin 1988, Alexandrov, Pozharskiy 1998, Alexandrov, Chebakov 2005, Grinchenko, Meleshko 1981] which contain the review of main scientific results dedicated to the solution of contact static dynamic and thermoelastic sums for elastic and viscoelastic bodies. Mathematical methods of solution flat and spatial sums while different boundary conditions on the contact squares are set out. The main correlations of mechanics of continuums and theory of elasticity are given.

OBJECT AND PROBLEMS

The aim of the given work is the research of dynamic non-axis-symmetrical sum about the torsion of the elastic half-space (fig. 1) with the punch and determination of

contact shearing stresses under the punch the angle of lagging and module of complex amplitude of the oscillation punch. Henceforth for shortness speaking about stresses transferences lagging their amplitude values are meant. True values are received with the multiplication by the multiplier e^{iwt} . As far as it is known to the authors the similar sum wasn't earlier considered.

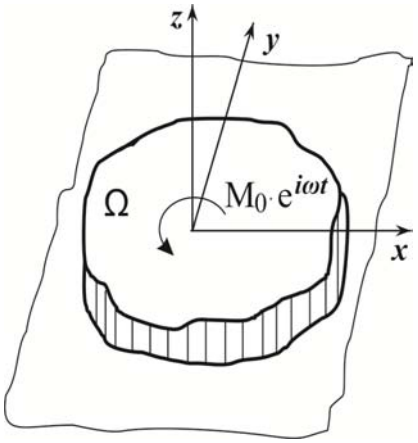

Fig. 1. The loading diagram

1. Постановка задачи. Putting the sum. From a mathematical point of view the sum comes to the solution of Lame's [Mushelishvili 1966] equation while the absence of body forces with the boundary conditions

$$\left.\begin{aligned} u &= f_1(x,y,o) \\ \nu &= f_2(x,y,o) \end{aligned}\right\} \qquad (x,y)\in\Omega, \qquad (1)$$

$$\sigma_z(x,y,o)=0,\ \ \tau_{xz}(x,y,o)=\tau_{yz}(x,y,o)=0,$$
$$(x,y)\notin\Omega.$$

Here u and ν are elastic transferences on the axes x and y, and $\sigma_z,\tau_{xz},\tau_{yz}$ tension on the square with the normal z.

The use of the principle of saturable absorption [Vorovich, Babeshko 1979, Tihonov, Samarskiy 1972, Starchenko 2005, Starchenko, Buryak 2005] and twofold Fourier transform [Uflyand 1968], the given mixed sum will be led to the system of two twofold integral equations of the first type

$$\begin{aligned} &\iint_\Omega \tau_1(\xi,\eta)K_{11}(x-\xi,y-\eta)d\xi d\eta+\iint_\Omega \tau_2(\xi,\eta)K_{12}(x-\xi,y-\eta)d\xi d\eta= \\ &\qquad =4\pi^2\mu\, f_1(x,y),\quad (x,y)\in\Omega, \\ &\iint_\Omega \tau_1(\xi,\eta)K_{12}(x-\xi,y-\eta)d\xi d\eta+\iint_\Omega \tau_2(\xi,\eta)K_{22}(x-\xi,y-\eta)d\xi d\eta= \\ &\qquad =4\pi^2\mu\, f_2(x,y),\quad (x,y)\in\Omega, \end{aligned} \qquad (2)$$

Here: $\tau_1(x,y)=\tau_{xz}(x,y)=\tau_{11}(x,y)+i\tau_{12}(x,y),\ \tau_2(x,y)=\tau_{yz}(x,y)=$
$=\tau_{21}(x,y)+i\tau_{22}(x,y)$ – is shearing stresses in the area of the contact,

$$K_{11}(p,s)=\int_{-\infty}^{\infty}\int F_1(\beta,\gamma,k)[F(\gamma,k)]^{-1}e^{i(\alpha p+\beta s)}d\alpha d\beta,$$

$$K_{12}(p,s)=\int_{-\infty}^{\infty}\int F_2(\alpha,\beta,\gamma,k)[F(\gamma,k)]^{-1}e^{i(\alpha p+\beta s)}d\alpha d\beta,$$

$$K_{22}(p,s)=\int_{-\infty}^{\infty}\int F_1(\alpha,\gamma,k)[F(\gamma,k)]^{-1}e^{i(\alpha p+\beta s)}d\alpha d\beta,$$

$$F_1(\beta,\gamma,k)=-4\beta^2\gamma^2+\left(3\beta^2+\gamma^2-k^2\right)k^2+4\beta^2\sqrt{\gamma^2-k^2}\sqrt{\gamma^2-b_0^2k^2},$$

$$F_2(\alpha,\beta,\gamma,k)=\alpha\beta\left(4\gamma^2-3k^2-4\sqrt{\gamma^2-k^2}\sqrt{\gamma^2-b_0^2k^2}\right),$$

$$F(\gamma,k)=\sqrt{\gamma^2-k^2}\left[4\gamma^2\sqrt{\gamma^2-k^2}\sqrt{\gamma^2-b_0^2k^2}-\left(2\gamma^2-k^2\right)^2\right],$$

$$F_1(\alpha,\gamma,k)=F_1(\beta,\gamma,k)\big|_{\beta=\alpha},\ \gamma^2=\alpha^2+\beta^2,$$

$$k^2=p\omega^2\mu^{-1}(1-i\varepsilon),\ b_0^2=(1-2\nu/2(1-\nu)).$$

ρ,μ – is the density and module of lagging of elastic half-space;

ε – is the coefficient of proportionality which characterizes the internal friction;

ν – is Puassona coefficient.

For big values of the parameter $|k|$ and bandpass area of the contact the system of equations (2) to the members of the order of values $\frac{1}{|k|^2}$ is disintegrated into two independent equations:

$$\int_{-a}^{a}d\xi\int_{-\infty}^{\infty}\tau_j(\xi,\eta)d\eta\int\int_{-\infty}^{\infty}\frac{1}{\sqrt{\tau^2-k^2}}e^{i[\alpha(x-\xi)+\beta(y-\eta)]}d\alpha d\beta=4\pi^2\mu f_j(x,y), \tag{3}$$

$$(j=1,\ 2).$$

Taking into consideration that $f_1(x,y)=-\theta y,\ f_1(x,y)=\theta x$ and searching for the solution of the equations (3) accordingly in the form of

$$\tau_1(x,y)=-y\tau_1^*(x),\quad \tau_2(x,y)=\tau_2^*(x), \tag{4}$$

with the regard of the equalities

$$\frac{1}{2\pi}\int\int_{-\infty}^{\infty}\eta e^{i\beta(y-\eta)}d\eta d\beta=y,\quad \frac{1}{2\pi}\int\int_{-\infty}^{\infty}e^{i\beta(y-\eta)}d\eta d\beta=1.$$

understood in the sense of the theory of general functions [Vladimirov 1976] we will persuade that $\tau_1^*(x)$ and $\tau_2^*(x)$ must be found from one-dimensional integral equations of the first type which in dimensionless variables will have the look.

$$\int_{-1}^{1}\tau_j(\xi)k_\varepsilon[\chi(x-\xi)]d\xi=\pi\Delta f_j^*(x),\quad (|x|\le 1,\ j=1,2). \tag{5}$$

$$k_\varepsilon[\chi(x-\xi)]=\int_0^\infty\frac{\cos[\chi(x-\xi)]m|dm}{\sqrt{m^2-(1-i\varepsilon)^2}}. \tag{6}$$

Here: $\Delta=\mu a^{-1},\ 2a$ – is the width of the plus punch,

$f_1^*(x)=0,\ f_2^*(x)=\theta x,\ \theta=\theta_i+i\theta_2$ – is the amplitude of the angle of the turn of the punch, $\chi=\omega a(\rho/\mu)^{1/2}$ – is the relative frequency of the oscillations.

Using the method of work [Nobl 1962], we'll get the main member of asymptotics of solution of equations (5) for big χ. With the regard to indications (4) while $\varepsilon \to 0$ we'll have

$$\tau_1(x,y) = -\Delta\theta\chi i\left[e^{-i\chi(1+x)}\Big/\sqrt{i\pi\chi(1+x)} + erf\sqrt{i\chi(1+x)} + \right.$$
$$\left. + e^{-i\chi(1-x)}\Big/\sqrt{i\pi\chi(1-x)} + erf\sqrt{i\chi(1-x)} - 1\right]y, \tag{7}$$

$$\tau_2(x,y) = \Delta\theta\chi i\left[\left(x - \frac{1}{2}i\chi\right)e^{-1\chi(1+x)}\Big/\sqrt{i\pi\chi(1+x)} + \right.$$
$$+ x\,erf\sqrt{i\chi(1+x)} + \left(1 + \frac{1}{2}i\chi\right)e^{-i\chi(1-x)}\Big/\sqrt{i\pi\chi(1-x)} +$$
$$\left. + x\,erf\sqrt{i\chi(1-x)} - x - \right], \qquad \left(erf\ x = \frac{2}{\sqrt{\pi}}\int_0^x e^{-s^2}ds\right).$$

Further we'll define the reactive moment which acts on the punch from the side of the half-space referred to the unit of length

$$M_z^{/} = \frac{1}{2b}\int_{-1}^{1} dx \int_{-b}^{b}\left[x\tau_2(x,y) - y\tau_1(x,y)\right]dy = M_1^{`} + iM_2^{`}. \tag{8}$$

Substituting (7) and (8) we'll get

$$M_z^{/} = \Delta\theta\left[(1+4xi)erf\sqrt{2xi} + \sqrt{2xi}e^{-2xi}\Big/\sqrt{\pi} - 2xi\right]\Big/3, \tag{9}$$
$$\left(M_z = M_z^{`}/b^2, \quad M_z = M_1 + iM_2\right).$$

In the formulas (8) and (9) it's known that the punch isn't endlessly long but has the final but quite big length.

2. We'll get the formulas for counting the angle of lagging φ and module of complex amplitude of the oscillation of the punch θ_0. We'll write down the equation of the rotating movement of the punch relative to the ax z.

$$J_z \cdot \frac{d^2}{dt^2}\left(\theta e^{i\omega t}\right) = M_0 e^{i\omega t} - M_z e^{i\omega t}, \tag{10}$$

where:

$$JmM_0 = 0,\ J_z = J_z^{/`}/b^2,\ M_0 = M_0^{`}/b^2,$$

$J_z^{`}$ – is the moment of the inertia of the punch relative to the ax z.

Having done the differentiation in (10) and the division of real and imaginary parts we'll get taking into consideration (9)

$$M_0 = \theta_1\left(A_{11} - J_z\omega^2\right) + A_{12}\theta_2, \quad 0 = \theta_1 A_{21} + \theta_2\left(A_{22} - J_z\omega^2\right). \tag{11}$$

Solving the system (11) relative to θ_1 and θ_2, we'll find

$$tg(-\varphi) = \theta_2/\theta_1 = A_{21}^*\left(\chi^2 J_z^* - A_{22}^*\right)^{-1},$$
$$\theta_0^* = \left[\left(\chi^2 J_z^* - A_{11}^*\right)^2 + \left(A_{12}^*\right)2\right]^{-1/2}. \tag{12}$$

Here:

$$J_z^* = J_z(a\rho)^{-1},\ A_{nj}^* = A_{nj}/\Delta,\ (n,\ j = 1,2),$$
$$M_1 = (A_{11}\theta_1 + A_{12}\theta_2)\Delta,\ M_2 = (A_{21}\theta + A_{22}\theta_2)\Delta, \qquad (13)$$
$$A_{22} = A_{11},\quad A_{21} = -A_{12},\quad \theta_0^* = \theta_0\Delta/M_0,\ \theta_0 = \left(\theta_1^2 + \theta_2^2\right)^{1/2}.$$

The results of the calculation of values done according to the formulas (12), (13) are given in table 1.

Table1. **«The results of the calculation of the module of complex amplitude of the oscillation of the punch and the angle of lagging»**

$\chi \setminus J_z^*$	θ_0^*			$\varphi(pad)$		
	5	10	20	5	10	20
0,125	3,785	4,476	4,623	0,890	1,165	1,891
0,250	3,635	2,421	1,028	1,555	2,413	2,855
0,375	2,074	0,907	0,403	2,378	2,835	3,007
0,500	1,043	0,463	0,215	2,722	2,960	3,058
0,625	0,612	0,282	0,134	2,862	3,014	3,081
0,750	0,403	0,190	0,092	2,933	3,044	0,094
1,000	0,214	0,104	0,051	3,002	3,074	3,109
1,250	0,133	0,065	0,032	3,034	3,089	3,116
1,500	0,091	0,045	0,022	3,053	3,098	3,120
2,000	0,051	0,025	0,012	3,075	3,109	3,125

From table 1 the dependences of values φ and θ_0^* on the non-dimensional frequency χ while different values of the non-dimensional moment of the inertia J_z^*. can be seen.

It's seen that for values $\chi \geq 0{,}25$ the module of complex amplitude decreases with the increase χ and J_z^* but the angle of lagging φ increases with the increase χ and J_z^* that quiet corresponds to the physical meaning of the sum.

CONCLUSIONS

The strict conclusion of integral equations with taking the principle of the limited absorption into consideration is received. The asymptotic formulas for defining contact shearing stresses in dependence on the amplitude of the angle of the turn of the punch which can be used for specified calculations on the durability and rigidity in transport and general machine-building are given.

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ДИНАМИЧЕСКАЯ НЕОСЕСИМЕТРИЧНАЯ ЗАДАЧА О КРУЧЕНИИ ШТАМПОМ УПРУГОГО ПОЛУПРОСТРАНСТВА

Валерий Старченко, Вячеслав Буряк

Аннотация. В работе рассматривается задача о совместном колебании упругого изотропного полупространства и жесткой на растяжение (сжатие) пластинки (штампа) произвольной формы в плане, к которой приложен крутящий момент, изменяющийся по гармоническому закону во времени. Получены асимптотические формулы для определения контактных касательных напряжений под штампом, угла сдвига фаз и модуля комплексной амплитуды колебания штампа.

Ключевые слова: упругое полупространство, интегральные преобразования, частота колебаний, контактные касательные напряжения, комплексная амплитуда колебаний..

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THE RESEARCH OF FRICTIONAL CHARACTERISTICS OF MODIFIED CARBON – CARBON COMPOSITES

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Summary. The results of experimental researches of the modified frictional C-C composites of a new generation.

Keywords: a frictional material, a disk brake, friction coefficient, C-C composites.

INTRODUCTION

Providing with the unconditional safety under the conditions of continuous growth of the traffic speed of vehicles is considerably defined by the effectiveness of the action of brakes. One of the main problems of brake mechanisms is the essential dependence of physical and mechanical and tribological characteristics of frictional materials of brakes on the multitude of accidental factors especially including the influence of the temperature factor is singled out as in the braking process the work of frictional forces is transformed into the heat energy. The temperature of the surface of frictional interaction of the tribological situation in the brakes can reach 400, 600 and even 1000^{o}C.

Thereupon some actual researches are the all-round researches of frictional materials of a new generation which differ from serial materials with more stable wide-ranging characteristics of the change of working temperatures in the braking process.

OBJECT AND PROBLEMS

For the last decades the science of our country, engaged with the research of frictional materials and the increase of vehicles operation safety, has received a significant development in the works of Chichinadze A., Alexandrov M., Kragelskiy I., Volchenko A., Gurin V., Hebda M., Gudz G.

One of the directions of braking efficiency increase is the application of the modified frictional C-C composites of a new generation, allowing to stabilize the friction coefficient [Bruneton 1997, Starchenko 2005, 2006, 2010, Fitzer 1987].

The experimental researches of the tribological characteristics of different frictional materials such as carbon-carbon composite materials (C-CCM) with the fabric-lined breaching structure of the reinforcement modified C-C composites and hybrid C-C composites were conducted on the serial friction machine (SFM-2) in the brake laboratory in Volodymyr Dal East-Ukrainian national university [Starchenko 2010]. All the trials are performed under the conditions of dry friction (Coulomb friction) and "wet" friction under the equal conditions of weighting (as a rider the brake discs made of hardened steel and C-C composites are used.

For the trial of carbonic materials with the fabric-lined breaching structure of the reinforcement the first examples of shoes were made of fine-grained industrial graphite (FIG-7). According to the results of conducted tests the apparent density of examples made of graphite (FIG-7) made up 1,77g/cm^3, open porosity-17,2% and densimetric density-1,7g/cm^3. The trials were conducted together with the rider made of steel 45 (HB=580…620) while having the equal speed of the rotation of the disc 1000 turns/per minute (2,62m/c) and different specific pressure - 2,0 and 3,35 MPa (fig.1).The results showed that while increasing the specific pressure from 2 up to 3,35 MPa the value of the friction coefficient of the graphite along the steel is decreased approximately in 2-3 times that is in accordance with the classical theory of tribology and the results of earlier conducted works with the graphites of different types.

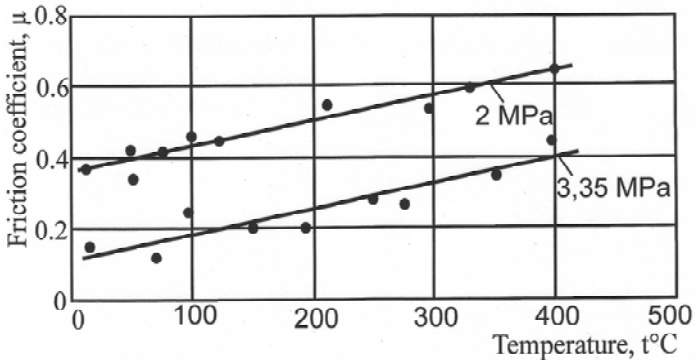

Fig. 1. The dependence of the constant of friction
of graphite (FIG-7) on the temperature

For the further trials with the help of the fabric-lined method some development types were produced-shoes with the reinforcing framework on the basis of carbonic fabric URAL-TM4 with the pyrocarbonic matrix the billets were also sewn with the carbonic thread URAL NSH in two combinations with the pitch-15mm (fig. 2). Testing development types showed that apparent density of the material makes up 1,37g/cm^3, open porosity-14,92% and densimetric density-1,61g/cm^3. The trials showed that while the friction of the shoe made of C-CCM along the hardened steel the friction coefficient

practically linearly is increased up to the temperature of 300°C and then becomes stabilized according to the value on the level-0,9 that might be conditioned by the change of the character of the friction process from the elastic one up to the viscoelastic one.

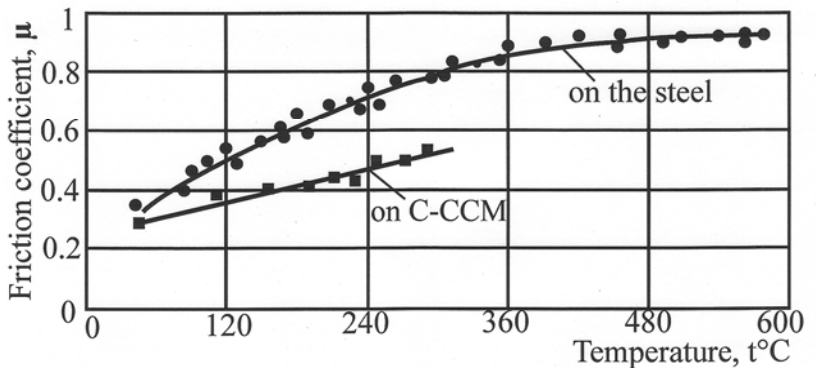

Fig. 2. The dependence of the constant of friction on the temperature; C-CCM, pressure-1,34 MPa

The confirmation of that is the evident decrease of the solidity of the steel disc while measuring after the trials with the temperature of the surface of more than 300C.

So if the initial steel solidity made up HB=580…20, then after the trials while the the temperature of more than 300°C the solidity decreases up to the values - HB=160…200. While using the disc and shoe from the same material - C-CCM under absolutely identical conditions the temperature of the surface didn't exceed 280°C that is evidently connected with a higher heat conductivity of carbonic composites in comparison with steel (in 20….40%) and lesser values of the value of the friction coefficient. For researching peculiarities of "wet" friction of the pair C-CCM - steel onto the surface of the friction some water was supplied with the continuous flow. The results of the trials are given in table 1.

It was established that while having equal conditions the constant of "wet" friction is less than while dry friction approximately in 2 times, while having the equal pressure - 1,34 MPa the friction constant accordingly makes up 0,15 and 0,34. While "wet" friction the same tendency of decreasing the friction constant with the growth of the pressure is observed.

Table 1. **The dependence of the constant of "wet" friction of carbon-carbonic composite material along the steel on the pressure**

Pressure, MPa	0,67	1,34	2,68	4,02	5,36	6,7	10,1	13,4	16,7
The maximum temperature,°C	17	17	19	20	23	25	26	30	32
The friction coefficient	0,20	0,15	0,11	0,11	0,10	0,10	0,09	0,09	0,08

The conclusion must be made that while dry friction of shoes made of "pure" C-C composites along the steel or along the disc made of the same material (a composite along a composite) under the conditions of small temperatures of the friction surface the value of the constant of friction isn't high but with the growth of the temperature of the contact surface it has a steady tendency for the considerable increase.

The trials of modified C-C composites. For the increase of the friction coefficient at a small temperature of the friction surface and its stabilization of its wide-ranging change the technological scheme of production of new modified frictional C-C composites on the basis of pyrocarbonic matrix is offered. The distinctive peculiarity of which is the introduction of the friction modifiers into the structure: abrasive fine-dyspersated particles of alumina boron carbide and amorphous boron.

The development types are produced on the basis of the pyrocarbonic matrix [Gurin 2001, Starchenko 2008, 2004] with the reinforcing framework and carbonic tissue URAL-T22 and addition of amorphous boron or boron carbide. As a rider a rotating disc made of hardened steel was used. The trials were conducted under the conditions of dry and "wet" friction while the speed of the disc rotation 1000 turns, per minute and the pressure in the range 6,7…20.1 MPa (fig. 3). As it is evident from the received results the use of modified composites allows to solve the problem put by: to increase the constant of the friction at small temperatures(up to 200^{o}C) and increase its stability at high temperatures of the working range it being known that the stabilization is shifted into the sides of lower temperatures. The trials while "wet" friction showed that the value of the constant of friction is decreased and lies within the limits 0.24…0.27 at pressure 0,67 MPa and 0.12 ..0.20 at pressure 1,67 MPa in the temperature range up to 50^{o} C. In modified C-C composites the value of the friction coefficient is higher that is conditioned by the interaction of the abrasive particles of modifiers with the metallic disc surface even while continuous water supply.

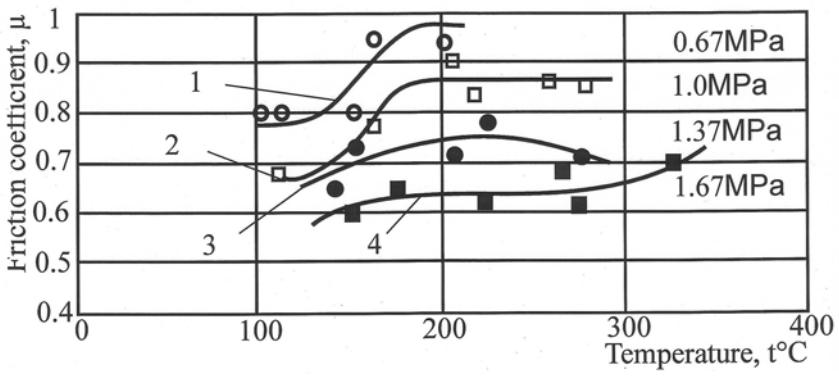

Fig. 3. The dependence of the friction coefficient
on the temperature of the friction surface

While the trials of hybrid C-C composites for the increase of their thermalphysic properties the method of using of different according to the structure fibres (hybridization) in the reinforcing framework and providing their spatial location in the

stuff was chosen. Thereupon for the decrease of the temperature tensity of the contact friction surface tension the shoe material is needed which would possess high thermal capacity and heat conductivity that would contribute to the heat abstraction which is formed as a result of the work of frictional forces on the contact friction surface. The development types are produced on the basis of the reinforcing framework which is made of carbonic fibres in the form of a carbonic tissue URAL-T22 and copper wire (d=0.15mm) moreover the layers of the carbonic tissue were alternated with the layers of the net from copper wire. The compression of the matrix with the pyrocarbon was conducted with the thermogradient gas-core method with the use of radially moving zone of the pyrolysis. While dry friction of the shoe from the hybrid composite along the hardened steel the constant of friction practically doesn't depend on the value of the pressure on the surface of the friction.

The temperature on the contact didn't exceed 109^{o}C and the temperature of the disc made up 150…200^{o}C that testifies to quite high thermophysical characteristics of a new hybrid composite and must be referred to the positive properties of the reinforcement at the expense of the use of the copper wire.

Table 2. **The dependence of the constant of "dry" friction on the pressure**

Pressure, MPa	0,48	0,71	0,98	1,19
The friction coefficient	0,42	0,40	0,46	0,46
Temperature, ^{o}C	47	68	97	109

As it had to be expected the constant of "wet" friction is less than while dry friction and is smoothly decreased as the pressure increases (table 3).

Table 3. **The dependence of the constant of "wet" friction on the pressure**

Pressure, MPa	0,48	0,98	1,43	1,91	2,39	4,79	7,18
The friction coefficient	0,24	0,18	0,16	0,14	0,14	0,12	0,12
Temperature, ^{o}C	27	22	24	40	40	40	45

The important fact is the fact that the use of the net made of copper wire in the structure of the reinforcing framework of hybrid C-C composites considerably allows to decrease the thermal tension of the contact surface of the friction and increase the stability of the constant of the friction in the wide temperature range (table 2). Received results allow to prognose that brake shoes from hybrid composites with the copper wire will work effectively and safely and even under the conditions of the increased humidity.

CONCLUSIONS

As a result of some experimental researches it is defined that the frictional materials for the brakes of vehicles in the form of modified C-C composites have better tribological indices and substantially increase the effectiveness of the brake process

that provides the minimization of the brake way and the time of braking thereby contributing to the increase of the traffic safety of vehicles.

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ИССЛЕДОВАНИЕ ФРИКЦИОННЫХ ХАРАКТЕРИСТИК УГЛЕРОД-УГЛЕРОДНЫХ КОМПОЗИТОВ

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Аннотация. Приведены результаты экспериментальных исследований модифицированных фрикционных С-С композитов нового поколения.

Ключевые слова: материал фрикционный, тормоз дисковый, коэффициент трения, С-С композиты.

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APPICATION OF COMPLEX POWER FUEL MADE OF COAL-ENTERPRISES WASTES PRODUCTION TECHNOOGY USING NEW BINDING MATERIALS

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Summary: In conditions of ecological state worsening the necessity in raw materials and wastes, particularly coal wastes, recycling and fuel briquettes production becomes urgent. The article investigates technology of complex power briquettes production using lingo-sulphanates as ecologically clean binders.

Key words: fuel briquette, binding materials, technical lingo-sulphanates, power value.

ANALYSIS OF PROBLEM STATE

Coal-mining production is technologically accompanied by formation of considerable quantities of different anthropogenic wastes, reaching 37% of coal extraction [1]. With transition to collection of ecological taxes proportionally to volumes of factual production discharge including wastes disposal to technological dumping grounds, the most effective managers of enterprises began to realize that it is cheaper to exclude or reduce quantity of wastes at places of their formation than to pay out ecological tax. Such source-saving approach is the most actual nowadays [2, 3, 4, 15, 22].

AIM AND TASKS OF INVESTIGATIONS

Coal wastes fine-fraction and finely dispersed component briquettes are the most rational way of raw material secondary use. One of the major difficulties of briquettes production is the necessity of cheap, non-scare and ecologically safe binding material application. In connection with this, the use of modified technical lingo-sulphanates having better strength characteristics has been proposed.

PRESENTATION OF INVESTIGATION RESULTS

Culm and slime utilization is mainly performed on accumulators. Only preliminary specially prepared wastes can be used for the second time. Major technological difficulty in culm and slime recycling is their dehydration to 10-12% humidity. In connection with this, development of small- and middle-power compact productions engaged in culm and slime recycling into briquettes corresponding modern power processes requirements becomes very actual. Agglomeration is one of actual tasks in preparation coal wastes for use as an power fuel. To obtain sellable product fit for realization in the recoverable raw materials market, briquette should meet a number of requirements:

- should not contain harmful impurities exceeding permissible level;
- possess strength sufficient for its further transportation;
- retain strength while being humidified in transportation;
- possess strength at high temperatures;
- possess homogeneous chemical structure;
- possess homogeneous linear sizes of pieces;
- have comparable with traditional cost.

Piecing of finely dispersed culms and slimes provides enterprises not only with additional power resources of iron-containing materials but reduces ecological impact on environment and stabilizes the work of main stages - accumulation, raw material preparation, and recycling. Briquetting is the process of obtaining pieces (briquettes) with and without additive binding materials with further mixture compaction into briquettes of necessary size and form. The aim of small materials structural formation is not only to obtain pieces of definite size but to create complex specified physical and chemical characteristics in artificial structures. Thus, there is an appropriate cause-result relation of technical parameters of structure forming processes with qualitative characteristics of prepared materials [13]. Fine-fraction materials with 0-10 mm fractures have low gas permeability which limits their further application without preliminary preparation. Briquetting of fine grain and finely dispersed materials with binders is the most universal way of attracting valuable fuel, mineral raw components as well as some anthropogenic wastes not suitable for immediate use in technical processes and apparatus because of their aggregate state into recycling. Distinctive peculiarity of briquetting process is possibility to produce briquettes from charge mixture effective for main types of power complex units. Materials which can be briquetting and the sphere of their application are presented in table 1. It is necessary to point out that not only anthropogenic wastes but original fine fracture and finely dispersed raw materials may be briquetted.

Let’s consider technological process of coal briquettes production. “Cold” briquetting is the most economically profitable and ecologically safe method. Having analyzed operational qualities of briquettes with different binders and technology of their production use we consider the application of lingo-sulphonite binders the most economically profitable one. It is useful to analyze this method in more details because this problem is the weakest one in technology of briquette production.

Table 1. **Characteristics of technology and sphere of briquetting application**

Source of raw material	Materials being briquetted	Sphere of briquettes application
Coal production anthropogenic wastes: - «old» rock spoil heaps (with 30-40% content of coal crumb); - «tailing dumps» of central concentrating mills; - culm.	-coal, coal crumb for municipal and domestic needs according to ТУУ 10.1-33333494-005; -coal, grade К and Ж for dust-like burning according to ТУУ 10.1-23472138-158; - coal for dust-like burning according to ТУУ 10.1-32186934-003; - finely dispersed coal cock duct-like crumb.	Population domestic needs. Industrial enterprises boiler houses. Municipal enterprises boiler houses. Rail-road car boilers Heat power stations

One of the main reasons limiting spheres of application of lingo-sulphanates (LST) as a binding materials is their instable characteristics and low binding ability while this material is the cheapest, non-scare and ecologically clean of all nomenclature of binding materials. Works [5, 6, 7] provide ways to increase level of achieved results allow to speak about development of principally new binders based on LST.

In development of binders intended for technology of coal briquettes production the highest effectiveness has been observed when using complex modifiers containing components action of which has strictly defined functional orientation. In the process of working, one part of the complex initiates and speeds out the beginning of structure formation in charge mix while the other one undergoes a chemical reaction with oligo-dimensional LST molecules and coal dust particles which results in creation of tree-dimensional mesh polymer. Finally, this causes the increase of binding ability and decrease of hardening length and stabilizes binder characteristics thus allowing to use it effectively in the given technology.

It was stated that it is advisable to use binding complexes combining non-ionogeneous surface active materials (NISAM) with some mineral acids. In such cases we observed binding ability increase from 0.37-0. 51 МПа to 2.84-3.00 МПа and even higher, while hardening of developed binder composition in combined use of thermal activation (380-400^{0}C), decreased from 12-15 min, to 1–3 min. Normal hardening regime took place at temperature equal to 200-220 ^{0}C. A new binding material based on LST content of which changes depending on coal briquettes configuration and mass has been developed on presented investigations and offered for application.

The given paper may be used at present on the enterprises of Lugansk and Donetsk region having large massifs of anthropogenic wastes of coal mines and on concentrating mills. Expenses, caused by the process of original lingo-sulphonate binders modification, are not significant. The advantages are as follows:

- possibility of quick achievement of required operational strength;
- charge mixture compositions adaptability to manufacture;
- insignificant power-consumption for speeding up the process of getting briquette strength (temperature control up 220 C).

Characteristics of briquettes containing binders based on modified LST (LSTm) made of coke powder have been investigated and stated (see table 2). They contain twice as little binding material as compared with their analogues [18, 19, 20].

When developing technology of briquette production the following tasks are of priority [13, 21]:

- production of briquette with prescribed characteristics meeting client's requirements (suggested technology allows to produce a briquette with prescribed geometric sizes, configuration and physical characteristics);
- briquette component structure which defines its power value has been developed with the assistance of coal-mining enterprises' specialists and briquette consumers;
- provision of briquette production and application effectiveness got at expense of briquette producing installation placement close to sources of wastes generating and usually located on one and the same site;
- provision of high productivity, low equipment cost, minimal number of servicing personnel.

Table 2. **Briquettes quality indices**

Composition of carbon materials mixture , %	Consumption of binder (LST, m), %	Compaction pressuser, MPa	Briquet size		Strength of dried briquettes		Heat resistance %
			Diameter, mm	mass, g	For release, %	For compression, MPa	
Coal dust, screenings	4	30	50	80	94,5	8,53	97,1
Coal dust, screenings	3,8	100	50	80	97,9	12,02	98,9
Fractured cock briquette fines - 100	5,5	40	80	275	97,4	8,59	97,1
Fractured cock briquette fines - 85; anthracite - 15	5,5	40	80	275	96,8	8,6	94,9
Fractured cock briquette fines - 70; anthracite - 30	5,5	40	80	275	91,7	4,99	93,8
Fractured semi-cock screenings - 100	4,5	30	50	50	95,8	7,18	85,9

Technology of coal briquettes production includes the following process stages:

- delivery of raw material components to the production site;
- raw material components storage;
- raw material components measuring for charge mix preparation;
- preparation of raw material mixture in forced action mixer;
- charge mix transportation to the formation station;
- formation of briquettes on the roller presses;
- transportation of formed production to the drying furnace;
- drying and achieving strength;
- finished products packaging(when needed);
- transportation to the finished products ware-house (or loading to the means of transportation).

Technical solutions to selection of configuration of such measuring and mixing equipment providing exact measuring of linked materials within 1% and allowing to perform heir mixing regulating stirring intensity thus controlling maximally possible rate of charge mix homogenization are well known [8, 9,1 0]. High rate of homogenization favours decrease of binder consumption not less than by 1.5% compared to analogue binder consumption when traditional types of mixing equipment are used [11, 14]. Decrease of water consumption when preparing charge mix is usually provided by introduction of specific chemical additives (types of used additives depend on a specific briquette structural contents), which allowed to decrease the length of heat exposure on a briquette [12]. Besides, compact technological scheme of briquettes drying in continuous furnace aimed at the most effective use of heat-transfer agent heat value ability has been developed. Developments of technological schemes of finished briquettes unloading allowing to bring the briquettes accumulation at the intermediate industrial sites to minimum (or to eliminate this stage at all) are known. Instead of it these developments allow to load finished products into rail-way car or motor transport immediately from a conveyor. Carried procedures give reasons to state that at present there is a small-scale produced industrial equipment and technological schemes of its configuration allowing to process 50 thousand tons ÷ 500 thousand tons of wastes and more a year [14, 15, 16, 17].

Different requirements are made to the coal charge mix components such as: ability for softening, porosity, flaking off, mechanical strength, abrading, restorability etc. Obtained briquettes should meet requirements and specifics of technological process of their supposed use as to their raw material (chemical) contents, size (grain size) and strength. As briquettes chemical structure and size are defined prior to briquetting, one of the most important characteristics of briquette quality and briquetting technological process in general are indices of their mechanical strength. Knowledge of these indices allows to estimate briquettes ability to stand without destruction certain impact-rubbing, impact and crushing loads which they will undergo in operation. These are mechanical strength indices that largely determine their consumption value, and in general, the possibility of their use at different enterprises with their specific infrastructure.

On the basis of conducted investigations it was found out that briquettes in the process of operation first of all undergo impact loads at drop structures in loading of bins or other apparatus or in shipping briquettes to consumers and in the process of unloading. Briquettes undergo crushing loads in case of their accumulation in bins or in piles at warehouses and when transported in rail-way cars.

When the column height equals ~ 40 m (close to bins maximum height) load to the lower sample will reach ~ 3,1 kg/cm^2. The same picture may be observed when piece materials are in the shaft type metallurgical furnaces. For example, it was stated that even in a high-shaft blast furnace the pressure of layers placed higher on the coke do not exceed 3-5 kg/cm^2. Thus, briquettes destruction is mainly caused by impact loads exposure. To define the impact strength different methods are used. According to these methods briquettes batches are thrown on a metal plate with 1.5-2 m height. The strength is defined by input of obtained piece (grade class less than 5, 10 or 25 mm depending on the briquettes size). Large briquettes (maximum size ~100 mm) are thrown only 1-2 times, small size briquettes (~25-30 mm) - not less than 4-5 times. However, in all cases briquettes are considered to meet the strength to throw conditions

if quantity of small pieces does not exceed 5-10 %. It means that large briquettes should not undergo multiple transshipment and technological scheme of the process should be consistent with it.

Presently, there is no state normative and technical base regulating requirements to briquettes as an element of power charge mix. That is why enterprises producing and consuming briquettes are forced to develop technical conditions for each concrete briquette type.

Among obvious advantages of a briquette one may mention the following:

- briquettes have regular and alike predetermined form and fixed weigh;
- they posses higher strength and better transportation ability;
- they posses higher density;
- posses ecological safety due to waste-free character of manufacturing and absence of high temperatures in production;
- different components (culm, slime, filings, husk etc.) may be used in briquette in any relationship;
- all types of finely dispersed materials may be used in briquettes.

MAIN CONCLUSIONS AND RESULTS OF INVESTIGATIONS

On the basis of the abovementioned conclusions about technological possibility to implement described method of anthropogenic wastes or its perspective use for development of separate regions of Ukraine may be done with certain degree of reliability [15], and experience accumulated in this sphere may be successfully used on the enterprises of Poland and Russia.

From technological point of view the following should be stressed:

- sufficiently high mechanical strength of coal briquette, particularly crumbling 1.1%, with the norm equal to not more than 10 % has been stated. Following 20 times throw down on the cast-iron plate, the main piece (50% of the original weight) preserved compressive strength at the level 25 kg/cm^2;
- compressive strength equaled 8,7-9,3 MPa;
- impact strength and attrition meet the claimed requirements;
- heat of combustion, Q, kcal/kg - averaged not less than 4000…5346, which meets the generally accepted norms.

Further introduction of briquetting technology is advisable on the enterprises of industrial regions of Ukraine (Lugansk, Donetsk regions) to solve the problem of accumulated and current wastes utilization, having in mind the following aims:

- to decrease considerably and eliminate pollution of environment with industrial production wastes within 10-15 years by essential decrease of slime fields and different “burials”, thus clearing vast territories of useful lands and improving ecology of industrial regions;
- to practice economy of natural and power resources of the country at the expense of maximum use of industrial wastes into economic turnover;
- to use new ecologically clean and effective binding materials based on products of vegetation raw materials recycling - lingo-sulphonate materials.

From practical point of view, the following should be mentioned:

- coal briquettes are new slime material changing coal to some degree;

- briquettes have regular form and weight, possess high strength and good transportation ability;

- briquettes have necessary heat of combustion.

Analysis of data allowed to formulate the task which may be solved in two ways.

On the one hand, recycling and utilization of wastes, their usage as a relatively cheap raw material for power fuel, increase of their quality competitiveness, and which is more important, decrease of finished product cost for industrial enterprises as well as for municipal and domestic needs of population. On the other hand, there is solution of ecological problem connected with cleaning of regions where vast anthropogenic wastes deposits have accumulated as well as utilization of current wastes accumulations produced by the abovementioned enterprises. Thus, ecological problem of coal mining regions of Ukraine transforms into the task of practical development of anthropogenic wastes aimed at their inclusion into resource and power potential of the country.

Such approach allows to solve not only economic and ecological problems but social tasks connected with employment of population and creation of additional working places. Existing technologies of coal production wastes secondary use are not perfect and claim for further investigations and development.

CONCLUSIONS

As the result of present investigation a coal briquette has been produced with the use of untraditional binder based on lingo-sulphanate material for power fuel, that is, principally new composite charge mix the use of which may return industrial wastes as coal briquettes, and as a raw material having sufficiently high profitability.

Production of such briquettes will allow essentially improve technical and economic indices of enterprise production cost, thus improving ecological state of regions.

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ПРИМЕНЕНИЕ ТЕХНОЛОГИИ ПОЛУЧЕНИЯ КОМПЛЕКСНОГО ЭНЕРГЕТИЧЕСКОГО ТОПЛИВА ИЗ ОТХОДОВ УГОЛЬНЫХ ПРЕДПРИЯТИЙ С ПРИМЕНЕНИЕМ НОВЫХ СВЯЗУЮЩИХ МАТЕРИАЛОВ

Юрий Свинороев, Владимир Коструб

Аннотация: В условиях ухудшающейся экологической обстановки возникает необходимость вторичной переработки сырья и отходов, в частности угольных отходов и получение топливных брикетов. В статье рассматривается технология получения комплексных энергетических брикетов с использованием в качестве экологически чистого связующего лигносульфонатов.

Ключевые слова: топливный брикет, связующие материалы, технические лигносульфонаты, энергетическая ценность.

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CASE-BASED REASONING METHOD FOR DIAGNOSTIC DECISION SUPPORT SYSTEM OF BRIDGE CRANES

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Summary. The elements of diagnosic system of bridge cranes is analysed. The stages in diagnosing faults is considered. The decomposition of bridge cranes faults retrieval and modified case-based reasoning cycle are offered. Diagnostic decision support system of bridge cranes has been developed.

Keywords: case, case-based reasoning, diagnosis, bridge crane, decision support system.

INTRODUCTION

When human beings diagnose systems and troubleshoot problems, they use their experiences with similar, previously solved problems extensively. Rather than deriving new solutions from scratch every time a problem is observed, they prefer to reuse existing experience and adapt it to the new circumstances [1]. As such, diagnosis and troubleshooting are excellent application areas for the development of case-based systems [2-3].

Reusing problem solving experiences to diagnose and troubleshoot new failures allows one to fix faults much faster and more consistently. Since case-based reasoning (CBR) is a learning process, the system fills the gaps in its knowledge over time and enables companies to retain and share experiences across the entire organization. Case-based diagnostic and troubleshooting applications are also very useful for training new, inexperienced personnel and ensure that the collective knowledge of the experts is instantaneously accessible to whoever needs it.

CONCEPT OF CBR

In most CBR systems, the case-based reasoning mechanism has an internal structure divided into two major parts: the case retriever and the case reasoner (fig. 1). The case retriever's task is to find the appropriate cases in the case base, while the case reasoner uses the cases retrieved to find a solution to the problem description given.

Case-based reasoning has been formalized for purposes of computer reasoning as a fourstep process [4]:

1. Retrieve: Given a target problem, retrieve cases from memory that is relevant for solving it. A case consists of a problem, its solution, and, typically, annotations about how the solution was derived.

2. Reuse: Map the solution from the previous case to the target problem. This may involve adapting the solution as needed to fit the new situation.

3. Revise: Having mapped the previous solution to the target situation, test the new solution in the real world (or a simulation) and, if necessary, revise.

4. Retain: After the solution has been successfully adapted to the target problem, store the resulting experience as a new case in memory.

These steps are part of the CBR cycle, which represents the process-oriented view of the descriptive framework presented by Aamodt and Plaza. The process is supported by supplying the cases with general knowledge about bridge cranes.

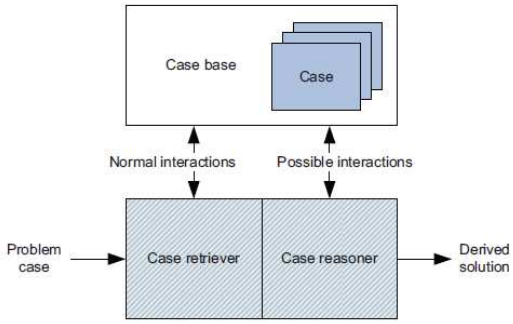

Fig. 1. Two major components of a CBR system

ELEMENTS OF A CASE-BASED DIAGNOSIS APPLICATION

Diagnosing and troubleshooting of bridge cranes typically involves three stages [5]:

1. Gathering information about the status of the system (i.e., the symptoms, signs or manifestations of the problem, the specifications and the current condition of the system to be diagnosed, and the characteristics of the operating environment);

2. Generating the diagnosis, which describes the root cause of the problem;

3. Suggesting the remedy, or steps necessary to rectify the fault.

Diagnosis and troubleshooting systems can acquire information regarding the system to be diagnosed directly from the device (on-line) or through human or electronic intermediaries (off-line). In the case of an on-line or condition monitoring system, the symptoms and system state are derived,without continuous user intervention, from interfaces and sensors monitoring the system. In the case of an off-line diagnostic system, the descriptions of the symptoms and the system are obtained from a user (e.g., a technician or knowledgeable user) or, after a failure is reported, downloaded electronically. Applications that fall in this category can provide web self-

service to end-users, support field technicians and medical personnel, or assist help-desk personnel while they are conversing with the end-users [6, 7].

While the process-oriented view provides a global and external view of the CBR process, the task-oriented view [8] decompose and describe the four top-level steps, where each step is viewed as a task that the CBR reasoner has to achieve (fig. 2). In the figure, tasks are named in bold letters, while methods are written in italics. The links between task nodes appears as plain lines and indicates task decompositions. The top-level task is problem solving and learning from experience and the method to accomplish this task is case-based reasoning (indicated in a special way by the stippled rectangle). The top-level task is split into the four major CBR tasks corresponding to the four processes: retrieve, reuse, revise, and retain. All the four tasks are necessary in order to perform the top-level task.

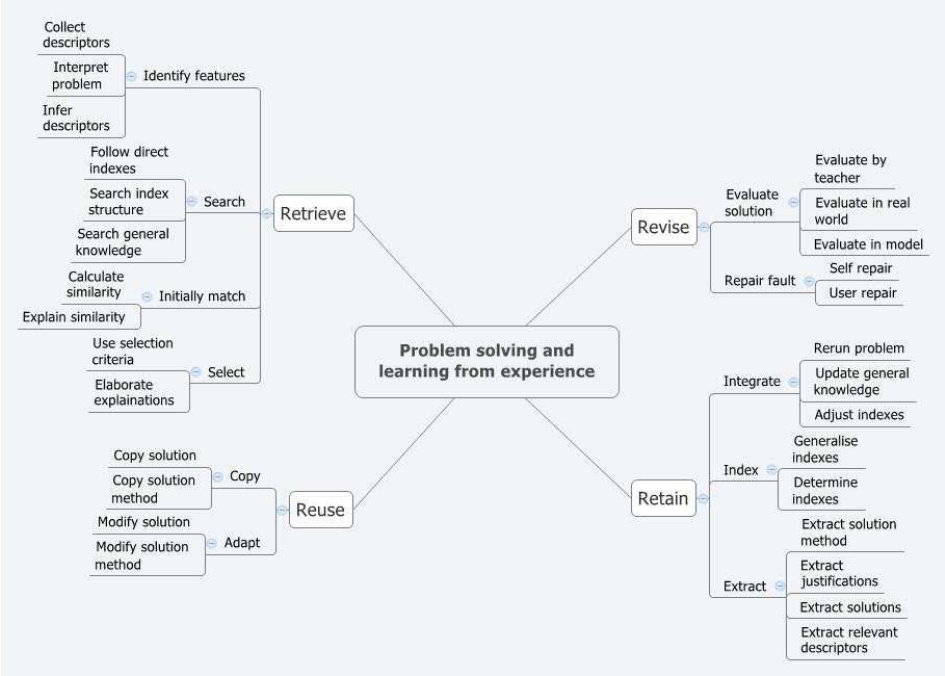

Fig. 2. Task-method decomposition of CBR (adopted from [5])

Diagnosis and troubleshooting experience can be stored in case-based systems in multiple ways (Bergmann et al.). The choice of representation has an impact on the maintainability of the system in the long term and the interaction modalities the system supports [9].While structural CBR systems require an up-front effort to create a vocabulary or domainmodel, they allow individual cases to be entered without having an impact on existing cases (Kriegsmann & Barletta, 1993; Goker & Roth-Berghofer, 1999). Some conversational CBR systems store the questions and their respective answers in the cases and do not require a domain model (Acorn & Walden, 1992). This

approach allows faster initial deployment, but maintenance of the application becomes cumbersome with a growing number or cases. Textual CBR systems use existing text files as cases and index these to perform retrieval (Lenz, 1996; Lenz et al., 1999). Depending on the complexity of the vocabulary used to index the text files, the initial effort to set up the domainmodel for these systems can become comparable with structural CBR systems [10]. On the other hand, since they will allow for reuse of existing documentation, initial set-up of the case base itself is typically very easy. However, the quality of the content in existing documentation and its suitability for use in a CBR system needs to be verified.

Diagnosis and troubleshooting systems do not exist in a vacuum [11]. Typically, they are provided or utilized in a larger organization and contain solutions for a specific system type and for a specific operating environment. Changes in the system, the operating environment or the organization will require the application and the knowledge containers (cases, vocabulary, similarity metrics, adaptation knowledge) to be maintained [12]. The processes for case acquisition, utilization and maintenance have to be put in place in an organization to ensure an application can be successful in the long term (Bergmann et al., 2003).

The initial knowledge in a diagnosis and troubleshooting application can be acquired through interviews with experts, or converted fromexisting documentation. Documents that are suitable for conversion include FAQ's, troubleshooting and diagnosis manuals, technical service bulletins and the like [13]. Depending on the application area, case-based diagnosis and troubleshooting systems will utilize a combination of reasoning methods. While some systems will only use cases to generate solutions, especially in situations where adapting an existing solution to a new problem is required, systems will use a combination of CBR and model-based reasoning (Simoudis & Miller, 1991; Portinale & Torasso, 1995), rule-based reasoning, induction, planning, or a mixture of these methods.

REFINING THE CBR CYCLE

Then the system must be able to execute the learning task more or less independently from its actual tasks. Such a learning functionality is often called introspective reasoning (Fox and Leake, 1995) or introspective learning (Zhang and Yang, 1999), respectively.

To integrate the desired learning functionality into the traditional CBR cycle consisting of the four well-known phases - retrieve, reuse, revise, retain - two basic possibilities can be distinguished [14]:

1. The extension of the existing process model by introducing an additional phase.

2. The refinement of one or several phases to integrate the new functionality into the already established phases.

When reviewing the original interpretation of the traditional CBR cycle it becomes clear that the second possibility seems to be more accurate. Aamodt and Plaza [4] have already discussed that the retain phase could be used to update general knowledge of the CBR system. Concerning the update of similarity measures the

possibility to refine case indexes has been mentioned. This can be interpreted, for example, as an adjustment of feature weights.

Basically, the retain phase is not the only phase of the CBR cycle responsible for the capability to learn new knowledge [15-17]. Before memorising a new case, the correctness of this new knowledge item has to be validated during the revise phase. So, the revise phase has a significant influence when learning new case knowledge, because it selects cases considered to be candidates for extending the knowledge base. In the following we show that this holds as well when learning similarity measures.

Fig. 3 illustrates how the traditional CBR cycle can be modified to integrate the possibility to learn similarity measures [18]. These modifications are discussed in more detail in the following sections.

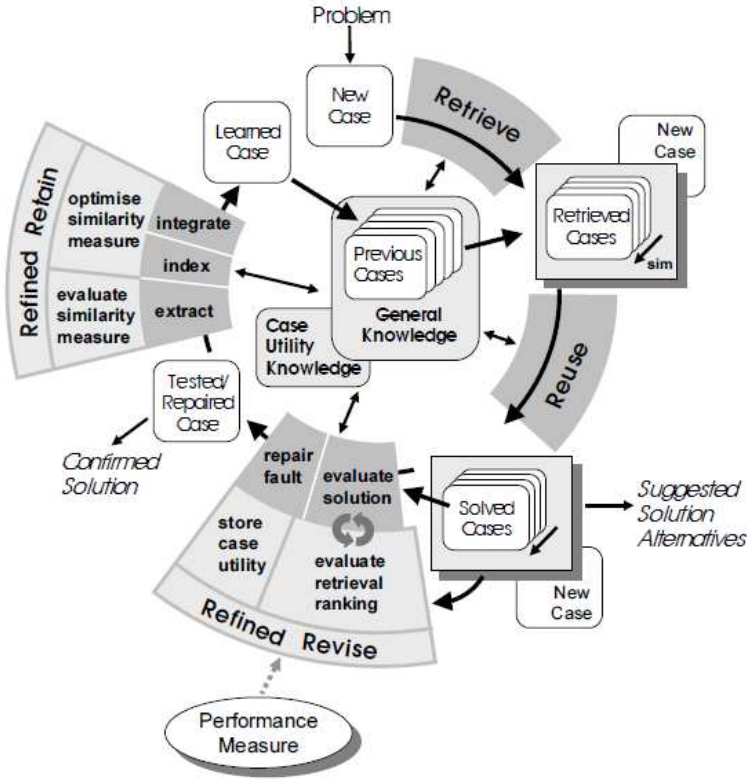

Fig. 3. Refining the CBR cycle for learning similarity measures

EXTENDED USE OF RETRIEVED CASES

In the traditional view of CBR, the retrieve phase provides one or several cases used to generate exactly one solution during the reuse phase. This solution is then proposed for solving the current problem and has to be evaluated during the revise

phase. However, in many application domains where CBR has been employed successfully this traditional view is not always suitable. Here, it is not desired that the CBR system generates exactly one solution, but several independent alternatives for solving the given problem.

The retrieval phase always should provide a list of retrieved cases ordered by the computed similarities [19]. If case adaptation is supported, this list is processed during the reuse phase where several solution proposals might be generated by adapting several retrieved solutions independently from each other. Basically, two ways to generate solution alternatives can be distinguished:

- Ad hoc: If it is feasible with respect to computation time, the reuse phase might perform adaptation for a fixed number of cases immediately. The resulting list of solution proposals, still ordered as determined in the retrieval phase, is then directly passed to the revise phase.
- On demand: If case adaptation is computational expensive, only the most similar case may be adapted first. The generated solution is then passed to the revise phase where it has to be evaluated. If the evaluation fails, because the solution cannot be applied to solve the current problem or due to poor solution quality, two ways for proceeding are possible. On the one hand, the faulty solution might be repaired during the revise phase. On the other hand, the revise phase could trigger the adaptation of the next similar case in anew execution of the reuse phase to obtain an alternative solution proposal.

Both approaches lead to the suggestion of several solution alternatives - when applying the on demand approach, at least if the most similar case could not be reused successfully - after the reuse phase [20]. In the following we only assume the possible existence of such a list of suggested solution alternatives but we do not care about the approach used to generate it. It is only assumed that solution alternatives are ordered according to the similarity of the underlying cases.

REFINING THE REVISE PHASE

According to the original process model that assumes the existence of only one solved case after the reuse phase, the revise phase can be subdivided into two subsequent tasks [14]:

1. Solution evaluation: In a first step the proposed solution, i.e. the outcome of the reuse phase has to be evaluated. This evaluation might be based on feedback from a teacher, on the results obtained through application in the real world, or on the outcome of a model-based simulation.

2. Fault repair: When recognising faults in the suggested solution during evaluation, the solution has to be repaired to obtain a valid solution. Basically, it might be repaired manually by the user or it might be repaired by the system based on additional general knowledge.

To enable a CBR system to learn similarity measures we propose a refinement of the revise phase. Besides the two described traditional tasks that ensure the generation of a valid solution, we introduce two additional tasks [21]:

1. Evaluate retrieval ranking: This task can be characterised as a superior control process for the common solution evaluation task. It initiates the evaluation of several solution alternatives and processes the obtained evaluation results. The foundation of the evaluation might be internal general knowledge or an external performance measure in form of a teacher, the real world, or a model.

2. Store case utility: This task is responsible for storing the results of the retrieval ranking evaluation for further processing. Basically, these results represent knowledge about the utility of cases with respect to the given query.

Generally, one could also argue that storing of evaluation results belongs more to the retain phase of the CBR cycle. However, we decided to assign this task to the revise phase. On the one hand, the decision whether to store particular results or not might be influenced by the performance measure, for example, by a human teacher. On the other hand, the retained knowledge is not directly used by the phases of the CBR cycle that are relevant for problem-solving. It is more an intermediate knowledge buffer that collects knowledge to be used only during the retain phase and thus it does not directly contribute to solving problems.

Basically, the refined revise phase consists of two parallel processes. On the one hand, the traditional revision process that only evaluates and repairs a single solution. On the other hand, a parallel process that evaluates the outcome of the retrieval phase based on the results obtained during several solution evaluations. While the evaluation of the retrieval ranking relies on the solution evaluation process, the traditional revision of a single solution can be initiated independently. This means, the retrieval evaluation can be interpreted as an optional process to be performed if desired.

REFINING THE RETAIN PHASE

The aim of the retain phase is to select knowledge entities to be integrated into the knowledge resources of the CBR system in order to improve its problem-solving competence and/or efficiency during future usage. Therefore, the traditional retain phase identifies the following three tasks:

1. Extract: This task is responsible for the extraction of relevant knowledge entities from the current problem-solving episode to be retained for future usage. Such knowledge entities might be represented by found solutions, solution methods, justifications, etc.

2. Index: The objective of this task is to determine indexes to be used for retrieving the learned case. This may be interpreted as the selection of an accurate vocabulary used to characterise the case but it might also be interpreted as the determination of accurate attribute weights.

3. Integrate: During the final task the extracted knowledge has to be integrated into the knowledge base of the system. This process might comprehend an update of the case base, the index structure, and of other general knowledge.

Although this traditional interpretation of the retain phase, in principle, already considers the modification of general knowledge and even an adjustment of attribute weights, it seems to be necessary to introduce two additional tasks [14]:

1. Evaluate similarity measure: Here, the quality of the currently used similarity measure is estimated based on the case utility knowledge acquired in the previous revise phase.

2. Optimise similarity measure: This task can be seen as a specialisation of the index and integrate task of the traditional retain phase but with focus on learning similarity measures. During this task, machine learning or optimisation methods, respectively, are being used to optimise the current similarity measure regarding the available case utility knowledge. This optimisation might be triggered by the outcome of the prior evaluation of the current similarity measure.

Similar to the refined revise phase, the tasks additionally introduced in the refined retain phase have not necessarily to be executed during every pass of the cycle. Instead, in certain application scenarios all described extensions of the traditional CBR cycle might only be relevant during explicit knowledge acquisition or maintenance phases [22]. For example, if the performance measure is supplied by a human domain expert playing the role of a teacher, the refined revision phase can only be executed in situations where this expert is available. During problem-solving situations where the system is used by a “standard user” who does not possess the required expertise, the introduced retrieval ranking evaluation might be skipped.

CBR SYSTEM FOR DIAGNOSIS OF BRIDGE CRANES

The bridge cranes diagnosis DSS has been delevoped. The main window of this system is shown on a fig. 4. As an initial set of cases the data of observations of bridge cranes made by the reports of technical diagnostics "The Engineering center of industrial safety" LLC (Lugansk, Ukraine) and Expert-diagnostic research laboratory "Lifting machines and industrial building" of Volodymyr Dal East-Ukrainian National University (Lugansk, Ukraine) is used.

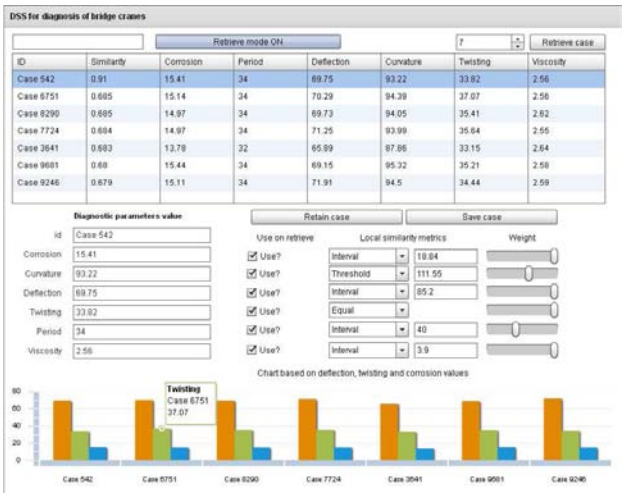

Fig. 4. The CBR DSS main window

The DSS allows to set the local similarity for every diagnostic parameter, weight of parameters and global similarity for a whole case. After setting of all necessary of similarity parameters the search of cases and their conclusion are carried out in order of diminishing of relevance with pointing of degree of similarity of every case is made.

Since a corresponding case is selected, its adaptation can be executed is modification of present in it decision with the purpose of its accordance to the parameters of current situation. In the case of absence of necessity for adaptation maintenance of the chosen case is executed without the change of diagnostic parameters.

CONCLUSION

The research described above, along with many other operational case-based diagnostic systems, demonstrate the applicability of case-based reasoning to diagnosis and troubleshooting of bridge cranes.

The conducted research show that diagnostics on the basis of cases allows to decide the weak formalized tasks of diagnostics of bridge cranes, simplify the aquisition knowledge from experts, shorten time of search of decision and implement self-training.

The bridge cranes diagnosis decision support system is developed. Using of this DSS assists diminishing of the informative loading on decision-making person in the process of troubleshooting, decline of influence of factors of subjectivity at the analysis of current situation, reduction of time, necessary for a decision-making.

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МЕТОД ДИАГНОСТИКИ КРАНОВ МОСТОВОГО ТИПА НА ОСНОВЕ ПРЕЦЕДЕНТОВ ДЛЯ СИСТЕМЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ

Ульшин В.А., Климчук С.А.

Аннотация. Проанализированы элементы системы технической диагностики мостовых кранов. Рассмотрены этапы диагностики неисправностей. Предложена декомпозиция поиска неисправностей мостовых кранов и модифицированный цикл вывода на основе прецедентов. Разработана СППР диагностирования мостовых кранов.

Ключевые слова: прецедент, рассуждение на основе прецедентов, диагностика, кран мостового типа, система поддержки принятия решений.

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AUTOMATED MANAGEMENT BY DESIGNER PREPARATION OF PRODUCTION OF ELECTRONIC VEHICLES

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Summary. A case frame by designer preparation of production of electronic vehicles is offered in the article. The corteges of managing influences generate by the method of group account of argument for achievement of the proper index of efficiency of management, analysis of hierarchies estimated by a method.

Key words: friction modifier, slip velocity, pneumatic drive**,** friction coefficient**.**

INTRODUCTION

For the decision of task of development of the system of support of decision-making designer preparation of production of electronic vehicles taking into account an application, properties and arrangement of producible objects domain it is necessary to select the groups of influences on the object of management, to make their classification and to select from them parameters the states and managing influences. On the basis of managing influences it is necessary to synthesize the frame model of knowledge's representation and to develop the structure of the system of support of decision-making, able to realize the stopped algorithms up. There is a not unimportant task also research of efficiency of the use of the offered system of support of decision-making [2]. On results the similar sort of correction it is necessary to watch and eliminate the managements uninvolved in corteges influencing factors, to define the constituents of management corteges directly, to provide the concordance of the last with optimum parameters and arrangement of producible objects [4].

OBJECTS AND PROBLEMS

Development of the system of support of decision-making implies classification of parameters of the state, external indignation and managing influences for the same object, but on different stages (constructing of block, achievement of the required resonance stability, preparation of production [3] and other), it is therefore necessary by

means of statistical tests to classify these influences, to identify dependences and to select managing influences with the purpose of determination of instruments of influence on interesting parameters and arrangement of object of designer preparation of production. On the basis of the identified managers of influences it is necessary to form the system of support of decision-making and to estimate its stability and efficiency of application [5, 17].

Direction-finding designer preparation of production problems consist in that probability of task of one or another type of managing influence is different for the electronic vehicles of different purpose and external environments, that in the turn is determined by the specific of arrangement, to the produced requirements and, consequently, by the different methods of achievement of the required properties [6]. For each of the considered types of electronic vehicles takes place the value of coefficients of meaningfulness of managing influence. Further on the set of types of managing influences and the database of coefficients of meaningfulness of each of them must define the criterion of quality of management by designer preparation of production of electronic vehicle directly (management efficiency) [9, 11]. At the hit of the got value in the application domain of the examined automated management by designer preparation of production of electronic vehicle, the transmission to the statement (working forms of the developed system of support of decision-making) of sequence and maintenance of managing influences is carried out on the optimized parameters, arrangement and properties of object of designer preparation of production, certain by the criteria of arrangement and optimized by the method of group account of argument.

Analyzing statistical selections, we get, that for functional dependence of criterion of quality of management by designer preparation of production of electronic vehicles characteristically presence of selection from the N supervisions

$$\begin{matrix} \{X(1);Y(1)\} \\ \{X(2);Y(2)\} \\ \dots \\ \{X(N);Y(N)\} \end{matrix}, \qquad (1)$$

where : X(i)=(x_1^i, x_2^i, … x_n^i) - values of initial factors at i - supervision; Y(i)=(y_1^i, y_2^i, … y_n^i) - values of out parameter i - supervision.

Functional dependence of F between entrances X(i) and by the out Y(i) parameters of case frame unknown, thus unknown neither dependence nor supposed its kind.

Therefore in accordance with the method of group account of argument, most complete dependence between the entrances X(i) and returns of Y(i) can be represented by the generalized polynomial of Kolmogorova – Gabora [1].

$$Y = a_0 + \sum_{i=1}^{N} a_i \cdot x_i + \sum_{i=1}^{N} \sum_{i \le j} a_{ij} \cdot x_i \cdot x_j + \sum_{i=1}^{N} \sum_{i \le j} \sum_{k \le j} a_{ijk} \cdot x_i \cdot x_j \cdot x_k + \dots \quad . \qquad (2)$$

where : a_i - unknown coefficients.

At construction of model, for determination of values of coefficients, as a criterion the criterion of regularity is used (exactnesses):

$$\overline{\varepsilon^2} = \frac{1}{N} \cdot \sum_{i=1}^{N} \left(y_i - f\left(x_i\right) \right)^2 . \quad (3)$$

It is thus necessary to find such values of parameters of model of a_i in (3), at which

$$\overline{\varepsilon^2} \to \min . \quad (4)$$

Principle of multiplicity of models for the examined case consists in that exists great number of models on this selection, providing a zeroing error (it is enough to promote the degree of model polynomial). That if is present the N sites of interpolation, it is possible to build whole family of models, each of which at passing through experimental points will give a zeroing error

$$\overline{\varepsilon^2} = 0 . \quad (5)$$

At a different noises level dependence $\overline{\varepsilon^2}$ will change on complication of S, saving here a general orientation I.e. it at first will diminish with growth of complication, and then - to increase. At the increase of noises level a size $\min\limits_{S} \overline{\varepsilon^2}$ will grow.

Exceptional situations at functioning of the examined system of support of decision-making are related to the possible «fall» of necessity of application of identical managers of influences for production of different objects, but treatment such exceptional situations is taken to extraction from the database of different scales of meaningfulness of choice of type of influence, it is therefore impossible to get identical results at identical managing influences [7, 12]. And, vice versa, different sets of managing influences for different electronic vehicles after treatment in the offered system of support of decision-making give, within the limits of the set exactness, unique value of efficiency of management by designer preparation of production of electronic vehicle [8, 18].

Teaching of the developed system of support of decision-making designer preparation of production of electronic vehicles is executed in order that after determination of efficiency of management by designer preparation of production of electronic vehicle of the explored classification group, the developed system offered the optimum scenario of achievement of properties, parameters, arrangement, vibration and resonance stability of electronic vehicle [10, 14]. Six neuron perseptron, the neurons of which have an activating function as a single jump, comes forward as the structure of the developed system of support of decision-making designer preparation of production of electronic vehicles [13].

On thirty one entrance of neuron network entrances signals [15], acting further on synaps on six neurons which form an unique layer, are given. On the returns of network signals are formed:

$$y_j = f\left(\sum_{i=1}^{31} x_i \cdot w_{ij} \right), \quad (6)$$

where: j = 1…6 - amount of classes of electronic vehicles; f - function of activating; x_i - component of vector of managing influences; w_{ij} - synapses weight.

Process what is going on in a neuron network, in a matrix form looks like:

$$\boldsymbol{Y} = \boldsymbol{F}\left(\boldsymbol{X} \cdot \boldsymbol{W}\right), \tag{7}$$

where: $\boldsymbol{X}$, $\boldsymbol{Y}$ - accordingly entrance and output vectors; $\boldsymbol{F(S)}$ - activating function applied memberwise to the components of vector $\boldsymbol{S}$; $\boldsymbol{W}$ - synaps Matrix.

For teaching of neuron network a teaching algorithm was applied with a teacher [16]. As a result of functioning of designing softwares package were got following synapses weight of neuron network of the developed system of support of decision-making, resulted in tabl. 1.

Table 1. **Synapses weight for neuron network**

Object 1	Object 2	Object 3	Object 4	Object 5	Object 6
$w_{41} = 5.943*10^{-2}$	$w_{12} = 2.878*10^{-3}$	$w_{33} = 4.683*10^{-2}$	$w_{24} = 4.953*10^{-2}$	$w_{55} = 5.558*10^{-2}$	$w_{56} = 6.843*10^{-2}$
$w_{51} = 9.138*10^{-3}$	$w_{32} = 7.348*10^{-3}$	$w_{133} = 4.822*10^{-2}$	$w_{94} = 6.394*10^{-3}$	$w_{85} = 2.033*10^{-2}$	$w_{66} = 2.556*10^{-2}$
$w_{81} = 8.151*10^{-2}$	$w_{102} = 5.263*10^{-3}$	$w_{163} = 0.223*10^{-2}$	$w_{174} = 6.904*10^{-3}$	$w_{95} = 3.904*10^{-3}$	$w_{116} = 3.943*10^{-2}$
$w_{101} = 1.81*10^{-2}$	$w_{112} = 2.843*10^{-3}$	$w_{213} = 1.242*10^{-2}$	$w_{184} = 6.394*10^{-2}$	$w_{145} = 8.037*10^{-2}$	$w_{126} = 2.374*10^{-2}$
$w_{201} = 9.66*10^{-3}$	$w_{192} = 9.239*10^{-2}$		$w_{304} = 3.230*10^{-3}$	$w_{155} = 5.035*10^{-3}$	$w_{156} = 5.495*10^{-2}$
	$w_{212} = 3.092*10^{-3}$			$w_{225} = 6.753*10^{-3}$	$w_{216} = 7.823*10^{-2}$
	$w_{242} = 6.932*10^{-3}$			$w_{235} = 2.645*10^{-4}$	
	$w_{272} = 5.633*10^{-3}$			$w_{265} = 0.549*10^{-3}$	
	$w_{292} = 9.293*10^{-3}$			$w_{295} = 3.934*10^{-3}$	

Testing of the trained network was conducted on tests selections not intersecting with teaching. Tests selections were built for each of types of electronic vehicles.

Thus, teaching of the system of support of decision-making designer preparation of production of electronic vehicles was made, testing and preliminary approbation of application of the developed system is made in designer preparation of production of electronic vehicles.

As a result of teaching of the developed system of support of decision-making designer preparation of production of electronic vehicles the list of recommendations on the management by arrangement of electronic vehicle is produced, providing the optimum scenarios of achievement of necessary properties, parameters, arrangement, vibration and resonance stability of electronic vehicle.

CONCLUSIONS

Thus, scientific and technical the issue of the day of increase of efficiency of management by designer preparation of production of electronic vehicles is decided by development of the system of support of decision-making, arrangement of electronic vehicle, operative management by designer preparation of production and control by the resources of enterprise system allowing to reduce expenses and prime price of pre-production model of electronic vehicle, functioning in single informative space; to reduce the terms of release of new electronic vehicles; to promote the competitiveness of enterprise at upgrading electronic vehicles, reliability, vibration and resonance stability.

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АВТОМАТИЗИРОВАННОЕ УПРАВЛЕНИЕ КОНСТРУКТОРСКОЙ ПОДГОТОВКОЙ ПРОИЗВОДСТВА ЭЛЕКТРОННЫХ АППАРАТОВ

Виталий Ульшин, Виктория Смолий

Аннотация. В работе обосновывается и предлагается модель управления конструкторской подготовкой производства электронных аппаратов, опирающаяся на исследование единого информационного пространства подготовки производства, оперативного управления предприятием и ресурсами предприятия, которая позволяет исследовать эффективность процесса управления.

Ключевые слова: управление, конструкторская подготовка производства, электронный аппарат, эффективность управления, единое информационное пространство, оперативное управление, управление ресурсами предприятия

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IMPROVING THE STABILITY OF ROTATION RING ROTOR WITHOUT MECHANICAL SUPPORTS

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Summary. The ways to improve the stability of rotation of the rotor ring without mechanical bearings by using no radial groove disk stator induction motor are developed. Considered three designs of slots of the stator: inclined, combined and break. Method for compensation of the errors of manufacturing of the structural components of the electric machine is proposed.

Keywords: synergy, rotor, stabilizing force, destabilizing force.

INTRODUCTION

Currently, there are many devices and machines that have working units in the form of the flat ring, rotating around the axis of symmetry. Examples might serve gyros rotors, working wheels of dynamic pumps and circular saws in the processable machines. Traditionally, ring-working body set in rotation, held in a space and accepts a payload and the resistance through spindle hub or shaft. The shaft receives the rotation from a separate electric motor and, in most cases, through an intermediate gear.

Reserve for increasing the efficiency of such machines is a synergetic association working body functions and secondary elements of the electrical machines, such as a disk induction motor (DIM) [4, 7]. This principle is realized by transferring torque to the rotor and held it in space by magnetic force that rotates. In that case mechanical connection completely exclude from the energy value chain. The basic idea of creating machines with direct drive without mechanical bearings described in the works [16, 2, 15].

In [15, 17] found that the stability of rotor rotation takes place at the vanishing of the tangential component of the main vector of forces, i.e. $F_\tau = 0$. It was shown that this condition is achieved by changing in wide range geometrical parameters of DIM and magnetic induction in the working gap. However, it should be noted that if the angle of elementary electromagnetic force $d\overline{F}$ along the groove does not change (for example, groove performed on a Archimedes spiral) [10], and provided $F_\tau = 0$, the

stabilizing radial force F_r equals zero. At the same time rotor will be in a state of indifferent equilibrium, and therefore wouldn't resist external radial forces.

The condition of stationary work of the device which is developed on the basis of DIM is the creation of such a system of forces in what the shift of the rotor from the center should not result to the emergence of destabilizing force $\overline{F}_\tau$, and caused only a stabilizing force $\overline{F}_r$ that returns it to the center [17, 18].

This condition can be achieved if the law of change of force $\overline{F}_\tau$ along the radius does not coincide with the law of change of the force $\overline{F}_r$. In this case, angle of inclination of stator slots ψ must functionally depend on the radius, that in general, reached by production of a curved groove, eliminating the Archimedean spiral.

As was shown in [17, 18], that at a bias e of the rotor into the engine working area formed the outer and inner asymmetric areas, and central area, that has axial symmetry. The width of the outer area is e_H, and the inner – e_B. The central part of the DIM working zone only involved in the creation of torque $M_{o\tau}$, and does not affect on the stability of the rotor. Stability of the last one depends on the value and the correlation of forces F_r and F_τ, which greatly simplifies the problem, since it suffices fulfillment of the condition $F_\tau = 0$ only in the peripheral regions.

The purpose of this study is to develop ways to ensure the stable rotation of the rotor ring without mechanical bearings. In acting on the rotor of technological load, which shifts its center of mass, the rotor must, by means of electromagnetic forces resist this load, and when removing it - to return to equilibrium.

Below we consider the constructive variants of DIM providing stable rotation of the rotor.

APPLICATION OF AN INCLINED SLOT OF STATOR

Great influence on the stability provided the angle ψ that determines the slope of the normal of stator slots in DIM in relation to the radius. In [13, 9, 14] showed that for the inclined slots the main vector has a radial $\overline{F}_r$ and tangential $\overline{F}_\tau$ components.

Assume that the three-phase stator winding [13, 5, 6], which has an outer R_{CH} and inner R_{CB} radiuses, formed by straight grooves, the direction of which does not coincide with the directions of the radiuses [19]. In Fig. 1 groove within the working area created by the rotor with internal R_{PH} and external R_{PB} radiuses and the stator, has a length *BC*, and the *AC* - the axis of the groove. We assume that the magnetic induction, which operates along the groove, is permanent ($B_H = B_B = B = const$).The groove *BC* at different points makes with the radius vector different angles and at the ends taking specific values ψ_H and ψ_B at that $\psi_H \neq \psi_B$. Moreover, from Fig. 1 follows that $\psi_B < \psi_H$. Tangential component of the electromagnetic force $dF_{\tau H}$ on the outer contour of the rotor is greater than the force $dF_{\tau B}$ acting on the internal circuit.

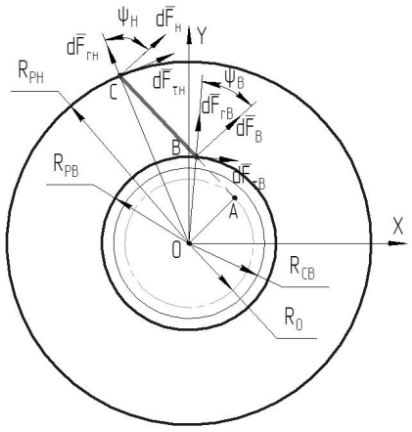

Fig. 1. The scheme of constructing of stator slot

Fulfillment of the conditions $F_\tau = 0$ is possible under $R_{CH} = R_{PH}$ and $R_{PB} - R_{CB} > e$ [17]. In this case, for the external and the internal areas following relation holds $e_B = 2e_H = 2e$, then the condition of stabilization is presented in the following form [18, 19]:

$$\sin\psi_H = 2\alpha_0^2 \sin\psi_B, \tag{1}$$

where: $\alpha_0 = R_{PB}/R_{CH}$.

Since the grooves *BC* on the stator are symmetrical center, the axis *AC* will have one point near the center. These points lie on a circle called base circle.

Axis of slots *AC* are tangents to this circle. In this case, there are always right-angled triangles *ΔOAC* and *ΔOAB*, built on a common leg R_0 , of which we find:

$$R_0 = R_{CH}\sqrt{(4\alpha_0^4 - 1)/(4\alpha_0^2 - 1)} \tag{2}$$

Condition of zero destabilizing force, is not running for any size ratio of the rotor and of stator. From (2) follows that if $R_0 \geq 0$ it $\alpha_0 \geq 1/\sqrt{2}$. Suppose that $R_0 = R_{CB}$, then $\alpha_0 = 1$. So to ensure a steady rotation when $B_B = B_H$ the parameter α_0 should be chosen within the $1/\sqrt{2} < \alpha_0 < 1$.

APPLICATION OF THE COMBINED SLOT OF STATOR

Electromagnetic forces acting on the rotor, directed perpendicular to the groove. If the groove is oblique, these forces have the tangential $d\bar{F}_\tau$ and radial $d\bar{F}_r$ components [9]. In [18] showed that at a bias of the rotor into the working area of the electric motor axially symmetric and two asymmetric crescent-shaped areas are formed. In axisymmetric areas sum of the projections of the electromagnetic forces on the

coordinate axes is zero, and therefore $d\overline{F}_\tau$ create only torque $M_{o\tau}$, and $d\overline{F}_r$ is counterbalanced. [18, 12, 11]. With increasing angle of inclination of the groove $d\overline{F}_\tau$ decreases, which leads to a decrease of the $M_{o\tau}$.

If in the peripheral areas provide $F_\tau = 0$ and $F_r \neq 0$ the rotor rotates stably. To do this slots near the external and internal contours of the stator must be tilted relatively to the radius. Thus, the groove is combined of three parts. The design of the groove is illustrated by pattern in Fig. 2

The groove is marked by a broken line $ABCD$. Part of the groove AB (located between the circles R_{CB} and R_{C1}), as well as part CD CD (located between the circles R_{C2} and R_{CH}) run at an angle to the radius. The purpose of the slope – the creation of a stabilizing force F_r. The central part of the groove BD creates only torque.

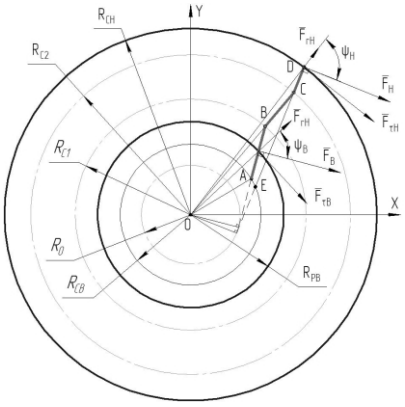

Fig. 2. Scheme of the combined slot of stator

Because of the small magnitude of the shift e assume that angles ψ_H and ψ_B have constant value. In such case for $B_H = B_B = B = const$, the condition $F_\tau = 0$ will correspond to (1)

APPLICATION OF A BROKEN SLOT OF STATOR

Fig. 2 shows that the increase of inclination angles groove ψ_H and combined groove ψ_B leads to an increase of the moment $M_{o\tau}$ [12]. When $\psi_H = \psi_B = 90°$, the moment $M_{o\tau}$ takes its maximum value, but the force $F_r = 0$. The force F_r increases with decreasing ψ_H or increasing ψ_B [18]. Consequently, for the simultaneous growth of the $M_{o\tau}$ and F_r it is necessary to increase the angle ψ_B.

Consider the extreme case when the angle ψ_B is equal to its maximum value $90°$ and $\psi_H < 90°$. This groove is called the broken one, its scheme is shown in Fig. 3 [20].

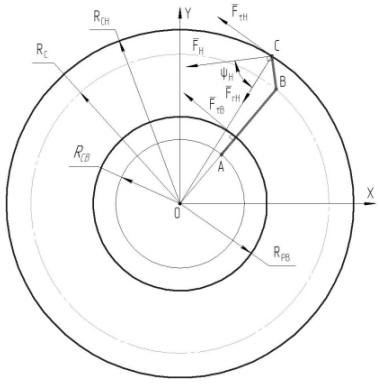

Fig. 3. Arrangement of a broken groove

Circle R_C divides the stator with an outer radius R_{CH} and inner radius R_{CB} in two regions: the outer bounded by the circles R_{CH} and R_C, and the inner one defined by the radiuses R_C and R_{CB}. Radius $R_{PH} = R_{CH}$ and $R_{PH} - R_C = e$.

Radial part of the groove AB is the source of the tangential forces $d\overline{F}_{\tau B}$, and creates only a torque. Part of the inclined of the groove BC, located in the outer areas of stator forms a forces $d\overline{F}_H$. Their tangential projection $d\overline{F}_{\tau H}$ increases the moment on the rotor of the motor and the radial projection $\overline{F}_{rH}$ provides stabilization of the rotor in radial direction.

The main condition for the stabilization of the rotor is the implementation of the equation (1). When $\psi_B = 90°$ equality (1) will be:

$$\sin\psi_H = 2\alpha_0^2 . \tag{3}$$

The angle of the groove and the dimensions of the rotor and stator can be chosen from the condition $0 < \alpha_0 < 1/\sqrt{2}$. Consequently, the use of broken groove ensures stable rotation of rotors larger area than with the two previously discussed methods, ceteris paribus increases the torque.

COMPENSATION OF ERRORS BY UNEVEN DISTRIBUTION OF MAGNETIC INDUCTION IN THE WORKING GAP

Discussed above methods of creating stable circular rotation of the rotor are based on strict observance of geometry DIM. Since in the production always have place the

size errors [8, 3], the real fulfillment of the condition $F_\tau = 0$ is problematic. Therefore, the DIM should be possible to compensate for inaccuracies of the parameters affecting the stability of the rotor. In similar cases in machine and instrument manufacture used movable and regulated compensators.

Compensation of errors of geometrical parameters can be accomplished by abandoning conditions $B = const$. In contrast to the geometric dimensions the magnetic induction can be regulated in the final product. Its value can be changed, both due to electrical and mechanical parameters, such as changing the current in the respective windings, or by changing the value of the working gap [9, 1].

Let the magnetic induction in the internal circuit B_B is not equal to stator magnetic induction in the external circuit B_H .When $R_{CH} = R_{PH}$ and $R_{PB} - R_{CB} > e$ the condition of asymptotic stability ($F_\tau = 0$) takes the form [18]:

$$B_H^2 R_{PH}^2 \sin\psi_H = 2B_B^2 R_{PB}^2 \sin\psi_B . \quad (4)$$

Thus, the left side of the equality (8) can always be aligned with the right one, by adjusting the magnetic induction on the external and (or) on the internal circuits of stator.

One way of changing the distribution of magnetic induction in the working area of the electric motor is to use magnetic core located over the internal area of stator. The working gap determines the magnetic induction B_B .

By changing size of working gap can be offset not only the error performance of the radial dimensions of the rotor and stator, but also, according to (8), inaccuracies in the slope of the grooves $\psi_H \neq \psi_B$.

CONCLUSIONS

1. Analyzed the influence of the slope of slots in DIM's stator on the stability of rotation of the rotor without mechanical supports. Stability of rotation is increased when the stators with sloping slots. Determined the conditions under which a stabilizing force F_r takes the maximum value.

2. Proved that the presence of the radial section of the groove in the central region of the stators increases the torque on the rotor of the motor and does not affect on its stability. Sloping groove sections provide a presence of a stabilizing force, and are also involved in the creation of the moment.

3. Proved that eliminate influence of an error of production in DIM on the stability of the rotor can be achieved by changing the magnetic induction on internal or external contour of stators. Why is proposed motor design with an adjustable magnetic core in which the distribution of magnetic induction given by the radial dimensions of the magnetic circuit and the magnitude of the working gap.

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ПОВЫШЕНИЕ УСТОЙЧИВОСТИ ВРАЩЕНИЯ КОЛЬЦЕВОГО РОТОРА БЕЗ МЕХАНИЧЕСКИХ ОПОР

Сергей Ерошин, Сергей Мирошник

Аннотация. Разработаны способы повышения устойчивости вращения кольцевого ротора без механических опор за счет применения не радиального паза статора дискового асинхронного двигателя. Рассмотрены три конструкции паза статора: наклонный, комбинированный и ломанный. Предложен способ компенсации погрешностей изготовления конструктивных элементов электрической машины.

Ключевые слова: синергетика, ротор, стабилизирующая сила, дестабилизирующая сила.

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OPERATING MODES POWER SUPPLY MOTOR-FAN ON DIESEL LOCOMOTIVES FROM TRACTION SYNCHRONOUS GENERATOR

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Summary. The analysis of the power modes of asynchronous motor fans traction from the synchronous generator, which working the locomotive in service.

Keywords: asynchronous motor fans, synchronous generator, locomotive.

INTRODUCTION

On diesel locomotives type 2TE116 power asynchronous motor fan (AMF) of cooling devices is carried out by the traction of a synchronous generator (TSG), which is also a load of traction rectifier unit (RU) and the traction motors (TD). TSG voltage at each position of the controller driver varies depending on the current generator according to the external characteristics of TSG + RU [Zakharchuk 1998]. Current TSG is determined by the profile path, weight, train speed. Thus, the condition of the train eventually determine the voltage and frequency on the stator AMF. Fig. 1 shows the range of values of phase voltage U_p TSG ГС-501А of the frequency f (a,b,c,d) and the voltage ml required for the optimal values of efficiency asynchronous drive with ventilatory load, according to law $U/U_r = (f/f_r)^2$.

OBJECT OF RESEARCH

Objects of researching are asynchronous motor-fans installed on cooling devices the locomotive 2TE116, with changing phase voltage and frequency of the traction generator.

PURPOSE OF RESEARCH

The purpose of research was to determine the relationships between the outer and the rated power of asynchronous motor-fan in operating modes. Objects of study are.

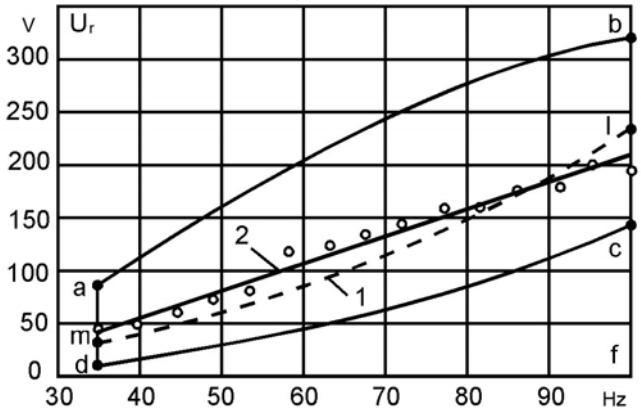

Fig. 1. Range of phase voltage U_p of the traction generator ГС-501А (a, b, c, d) of the frequency f : 1 – of the frequency optimal law of supply for the AMF; 2 – average operational values U_p

RESULTS OF RESEARCH

Experience in operating diesel-powered 2TE116 AMF from TSG proves that if a motor with fan load stands at bench trial power modes corresponding to points ***b*** and ***c*** (fig. 1), the electric reliability in operation is ensured. In this case, to ensure efficiency in the AMF point 10 requires an unsaturated magnetic system in the rated mode ($f_r = 100$ Hz, $U_r = 400\ V$), induction in the air gap must not exceed 0.65 Tesla. To validate AMB at ***b*** to inflate the bounding power of conventional short-circuited AMF 1.5 times. Hence the linear current load in the rated mode should be selected in 1.5 times less. With the overall power of serial motor-fan AMF37 equal to 37 kW on the locomotive 2TE116 allowable load on the shaft at rated speed 24 kW, i.e., at 1.54 times smaller.

Fig. 2 shows the histogram of power modes serial AMF in the operation of the locomotive 2TE116 № 400 in the South-Eastern Railway (depo registry Elets) within 60 hours (phase voltage, frequency, power).

According to the results of operational tests are constructed average operational values of phase voltage at the AMF (fig. 1, line 2) and histograms of frequency distribution voltage (fig. 3 a) and relative power $P'_2 = P_2 / P_{2n}$ in the fan shaft (fig. 3, b). According to the analysis of operating conditions power AMF (fig. 1-3) are defined

average operational values of supply frequency $f_{aop} = 60\,Hz$, voltage $U_{aop} = 110V$, power at the shaft motor-fan $P'_2 = 0{,}32P_{2r}$, which suggests that the AMF work with power mode and significantly below rated load ($f_r = 100\,Hz$, $U_r = 230V$).

When TD powered from the TSG via the RU voltage curve, the supply AMF differs significantly from the sinusoid, which results in the appearance of higher harmonics in the voltage curve TSG [Kolesnik 1978].

Determine the impact of higher voltage harmonics on the characteristics of TSG AMF in operating conditions of the locomotive. This is possible only after analysis of all possible modes of operation RU.

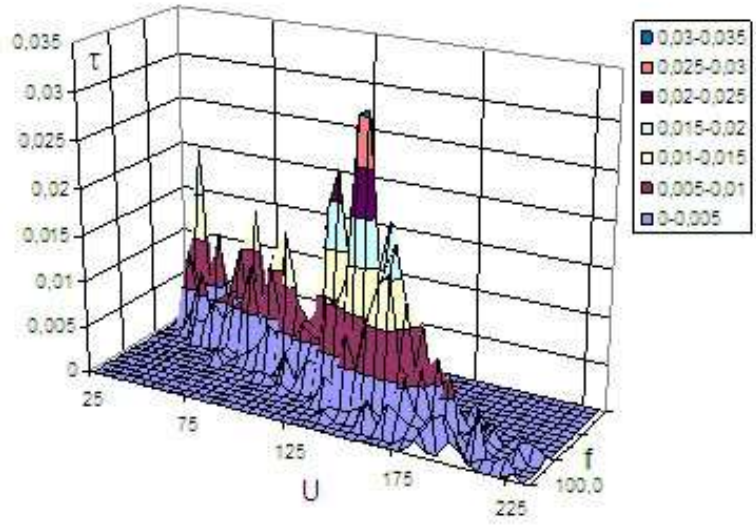

Fig. 2. Histogram of power modes
AMF in the operation of the locomotive 2TE116

In the six-phase system of TSG- RU work gates each three-phase rectifier bridge is determined by the same laws as in the work of an independent bridge.

Consider the operation of the rectifier load as a TD serial excitation with the inductive reactance comprising inductances of armature winding, extension and the main poles, which are assumed to be infinitely large.

There are three basic modes of operation of the bridge rectifier, which are characterized by different values of switching angles and delays.

Table 1 shows: the rectified voltage U_d from the e.m.f. phase $E_p = U_{1P} + j \cdot I_1 \cdot X$, rectified current I_d and switching reactance X; switching angles γ and delay α of E_p, I_d, X.

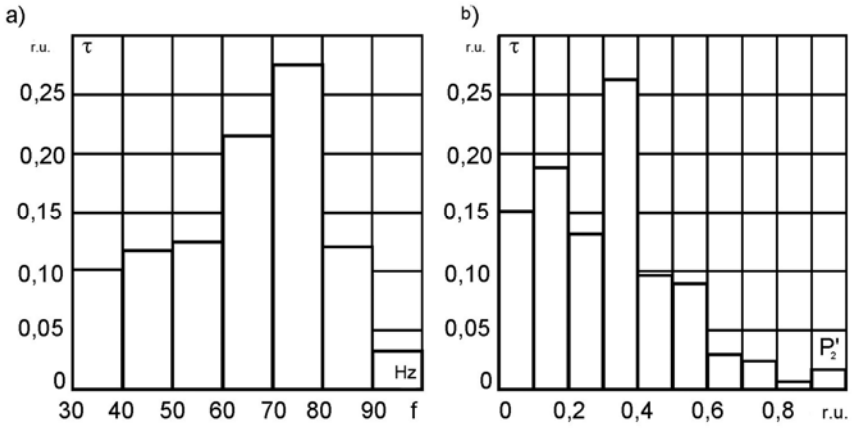

Fig. 3. Histograms of the distribution relative power P'_2 and frequency f AMF power, which operating the locomotive 2TE116

Expression table 1 on the external characteristics of fig. 4 define the modes of TSG–RU–TD for locomotive 2TE116. From fig. 4 that in operation the predominant mode of operation is the first RU $I_d < I = 4320\text{A}$ in the $\gamma < 50°$, the second mode is possible only briefly to disperse the train.

Phase power supply for TSG AMF $U_p = U_d / 2{,}4$ [Tolstov 1983].

Table 1. **Basic dependence characterizing the modes of operation rectifier in the TSG –RU–TD**

Modes of the rectifier	Formulas external characteristics and attitudes $\frac{U_d}{E_p} = f(\gamma, \alpha)$	The formulas for the angles and switching delay $\gamma, \alpha = \varphi(I_d, E_p)$
The first mode $\gamma \le 60°$ *P1*	$U_d = 2.34 \cdot E_p - 0.955 \cdot I_d \cdot X$; $\frac{U_d}{E_p} = 2.34 \frac{1+\cos\gamma}{2}$	$\cos\gamma = 1 - \frac{0.818 \cdot I_d \cdot X}{E_p}$
The second mode $\gamma = 60°$ $0 < \alpha < 30°$ *P2*	$U_d = \sqrt{4.12 \cdot E_p^2 - 2.74 I_d^2 X^2}$; $\frac{U_d}{E_p} = 2.03[1 - \sin(\gamma - 30°)]$	$\sin(\gamma - 30°) = 1.41 \frac{I_d \cdot X}{E_p} - 1$
Third mode $\alpha = 30°$ $60° < \gamma < 120°$ *P3*	$U_d = 4.05 \cdot E_p - 2.87 \cdot I_d \cdot X$; $\frac{U_d}{E_p} = 2.03[1 - \sin(\gamma - 30°)]$	$\sin(\gamma - 30°) = 1.41 \frac{I_d \cdot X}{E_p} - 1$

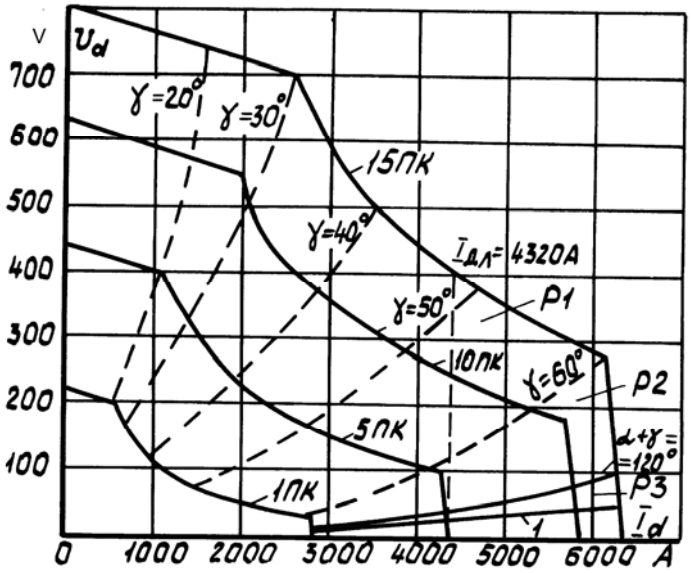

Fig. 4. Modes of TSG-RU-TD: 1 – limitation on chaining

In the voltage curve TSG working on a symmetrical load, no harmonics are multiples of three [Kostenko 1973]. Also, do not contain higher harmonics of even order, because TSG voltage curve is symmetric about the horizontal axis.

Determination of the 5-th and 7-th harmonics for voltage TSG possible by the Chebyshev method.

Results of the analysis of higher harmonic 5-th and 7-th order are shown in fig. 5, which implies that the operation at $\gamma < 50°$ 5-th and 7-th harmonic voltage TSG does not exceed 20, and 10% (respectively) the first harmonic.

AMF is calculated, as we know, a certain amount of the rated voltage at rated frequency. Are determined by the rated current, the dimensions and parameters of AMF. When connected to a machine sinusoidal voltage of its characteristics with sufficient accuracy are consistent with the calculation. Nonsinusoidal voltage at each of harmonics has to AMF its influence in accordance with its amplitude, a frequency of and the corresponding parameters of the AMF.

Determine the influence of higher harmonic voltage on the parameters of AMF

Electromagnetic moment from the higher voltage harmonics defined with respect to the rated point:

$$\frac{M_v}{M_r} = \frac{K_v^2}{v^4} \cdot \frac{K_{1S}}{\sqrt{v \pm 1}}. \tag{1}$$

where: K_v – coefficient characterizing the content of v-th harmonic voltage is determined for $v = 5, 7$ AMF of fig. 5, K_{1S} – the multiplicity of starting moment AMF.

From (1) it follows that with increasing harmonic order v, generated moment is significantly reduced under other equal conditions.

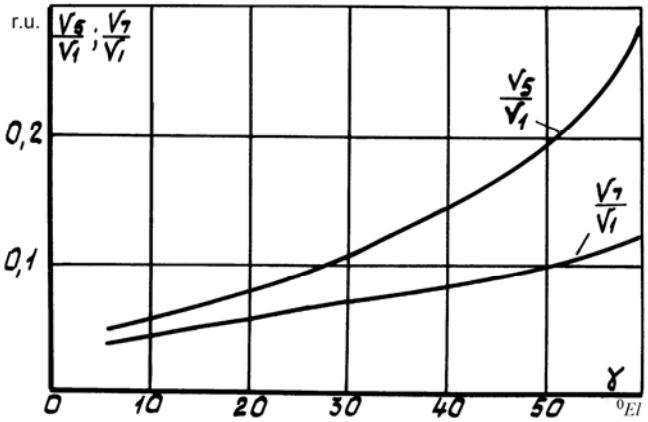

Fig. 5. The dependence of the harmonic 5-th and 7-th order voltage TSG from angle commutation RU

The ratio of total losses in the steel $\sum P_{st}$ to losses in the steel from the first harmonic P_{st1}

$$\overline{P}_{ST} = \frac{\sum P_{st}}{P_{st1}} = 1 + \frac{V}{V - V_2} \sum_{v=5,7...} \left(K' \cdot \frac{K_v}{v} \right)^2. \quad (2)$$

The ratio of losses in the stator windings $\sum P_{1el}$ and rotor $\sum P_{2el}$ in relation to the losses of the first harmonic of AMF, when powered nonsinusoidal voltage:

$$\overline{P}_{1EL} = \frac{\sum P_{1el}}{P_{1el1}} = 1 + \sum_{v=5,7...} \frac{K_v^2}{v^4}; \quad (3)$$

$$\overline{P}_{2EL} = \frac{\sum P_{2el}}{P_{2el1}} = 1 + \sum_{v=5,7...} \frac{K_v^2}{v^4 \sqrt{v \pm 1}}. \quad (4)$$

From the expressions (2) - (4) it follows that losses in the AMF significantly decreases are in increasing order harmonics under other equal conditions.

If you do not take into account the effect of the magnetization loop, the power factor of AMF for the higher harmonics [Kostenko 1973]

$$\cos \varphi_v = \frac{r_1 + \frac{v r_2'}{v \mp 1}}{\sqrt{\left(r_1 + \frac{v r_2'}{v \mp 1} \right)^2 + v^2 \left(x_1 + x_2' \right)^2}}. \quad (5)$$

This formula shows that the $\cos\varphi$ is very low, i.e. currents produced by the higher voltage harmonics are almost purely inductive. Correspondingly, one can assume that the influence of higher harmonic voltages on AMF, which powered by TSG is equivalent to an increase in the inductances x_1 and x_2' with all its consequences - a decrease in $\cos\varphi$, η and $M_{\max}$. Moreover, the influence of non-sinusoidal voltage effect is relatively small, even with a significant distortion of the voltage curve. For example, if the amplitude of the fifth and seventh harmonic voltages on the AMF is 29% and 12% of the amplitude of the fundamental harmonic (fig. 5), which powered by TSG, which corresponds to short-term operation of the locomotive (fig. 4), while $\cos\varphi$ decreased is estimated at 2%, compared with $\cos\varphi$ at sinusoidal voltage, coefficient of efficiency η 1%, which is unimportant, which powered by AMF TSG.

CONCLUSIONS

1. Which powered by the traction synchronous generator bounding units, overall power must be increased in 1.5-1.6 times in comparison with a rated capacity.

2. The actual operating power modes differ significantly from the rated modes: average operating the frequency $f_{aov} = 0.6\,f_r$, voltage $U_{aov} = 0.48U_r$, power on the shaft of the motor-fan $P'_2 = 0.32P_{2r}$, therefore, for optimizing the design parameters of AMF is necessary to consider the operational modes of supply and AMF.

3. The influence of higher harmonic voltages on the AMF when powered by TSG decreases $\cos\varphi$ by 2%, coefficient of efficiency η 1%, which is unimportant which powered by AMF TSG.

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ЭКСПЛУАТАЦИОННЫЕ РЕЖИМЫ ПИТАНИЯ МОТОР-ВЕНТИЛЯТОРОВ НА ТЕПЛОВОЗАХ ОТ ТЯГОВОГО СИНХРОННОГО ГЕНЕРАТОРА

Александр Захарчук, Игорь Бухтияров

Аннотация. Проведен анализ режимов питания асинхронных мотор-вентиляторов от тягового синхронного генератора при работе тепловоза в эксплуатации.

Ключевые слова: тяговый синхронный генератор, асинхронный мотор-вентилятор, тепловоз в эксплуатации.

CONTENT