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RESEARCH OF WATER- COAL FUEL PREPARATION BY THE METHOD OF RATIONAL LOADING OF BALL MILL

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Summary: The methodology for experimental studies of highly concentrated water-coal suspensions prepared with the necessary rheological characteristics in a ball mill by way of the rationalization of the granulometric composition of coal fines is described.

Key words: water-coal fuel, the ball loading, experimental design, dynamic viscosity, sedimentation stability.

INTRODUCTION

Producing the artificial composite ecologically cleaner water-coal fuel (WCF) is one of the trends of the search of alternative fuels to replace conventional oil and gas. Preparation of WCF is a complex process associated with the requirements for it, such as - a high concentration of coal up to 70% or more (by weight), relatively not a high dynamic viscosity up to 1 Pa.sec at a shear velocity gradient from 10 to 16 sec^{-1} and sedimentation stability for 15 days and more [17, 8, , 21, 22]. These parameters are achieved by adjusting the granulometric bimodal composition of coal and by the use of surfactants.

ANALYSIS OF PUBLICATIONS, MATERIALS AND METHODS

The technological schemes developed by the firms "Snamprogetti" (technology «Reocarb», Italy); «Fluidcarbon» (Sweden) [17]; Salzgitter Industriebau GmbA (technology "Denskoul" [8] "Karbogel"); "Coal," Young WCF (China) [25] have found the most wide application in the world practice. All these technologies are aimed at obtaining highly concentrated water-coal suspensions (65-75% solids) with ash content of fuel to 2-5% of WCF [4].

THE OBJECTIVE AND EXPERIMENTAL PROCEDURE

The investigations have shown, that at producing the water-coal fuel it is necessary to achieve the maximum possible concentration of coal and ability of WCF easily to be pumped through pipelines. Maximum package of WCF is achieved through the adoption of bimodal distribution by size of particles, that is, the combined system consisting of two discrete fractions by the size of the particles, the more coarse and fine fractions. The lowest viscosity and the highest concentration is achieved when the ratio “ more fine: more coarse fractions” makes 40:60 (in recalculation on an anhydrous mixture).

In connection with the necessity to obtain bimodal distribution of fractions of coal in the WCF, above mentioned technologies of WCF making have two- staged process of coal grinding. This complicates the technology of WCF preparation, increases its capital and operating costs. In addition, the loading technology and mode of operation of mills at the WCF preparation is the " know-how ".

With the aim of reducing the cost on producing the WCF we will consider the use of one-staged technology of preparation due to the rationalization of the ball loading and operation mode of the mills. The main tasks are: selection of rotational speed of the drum, determination of the size of the grinding bodies, determination of the grindability impact and grain size of the source material, grain size of grinded product and determination of the loading factor of drum of the mill. The correct solution of these problems depends on the technological and economic efficiency of the mill operation.

RESULTS AND ANALYSIS

Research has shown that to obtain a highly concentrated coal-water suspension with the desired rheology, sedimentation and thermal properties, the granulometric composition of coal particles must be bimodal, including the particles of size 80 $\div$ 250 μm (coarse grinding) and coal particle size 0 $\div$ 40 μm (fine milling) [15, 7].

When designing the experiment, the task was to load rationally the ball mill with three standard sizes of balls, charcoal and water, adequately describing the process of grinding.

The dynamic viscosity is chosen as the response function of the investigation.

The drum rotational speed, time of grinding and three diameters of balls are taken as varied factors (see Table 1).

The analysis of factors affecting the rational loading of the ball mill has allowed to identify five independent variables that determine this process, that is, the balls of three diameters: 42, 52, 62 mm, the drum rotational speed and time of grinding. Analysis of factors affecting the WCF preparation in ball mills had shown that the main factors are the rotational speeds of the mill drum n_{min}, n_{mid} and n_{max}; the granulometric composition and mass of loaded balls d_{min}, d_{mid} and d_{max}; grinding time. All these factors have a quantitative assessment, are measurable, manageable and compliant ones. Each of them has its own local area to carry out the experiment.

If we pass from the values of the factors in the natural scale to a code one, then independent variables D_1, D_2, D_3, n and t, varied in the experiment, will be as follows:

$$X_1 = \frac{D_1 - 9}{1}\ ;\ X_2 = \frac{D_2 - 9}{1}\ ;\ X_3 = \frac{D_3 - 9}{1}\ ;\ X_4 = \frac{n - 63}{5},$$

$$X_5 = \frac{t - 40}{20},$$

Preparation of the WCF compositions was produced with using the plasticizing additives manufactured in Ukraine, having the best characteristics of plasticizers considered in the analysis, in the quantitative ratio of 1% on the dry weight of coal. [8, 4, 12, 21, 22, 16].

The ball mill MLK-300 with a rotary axis is selected for the experiment. It has sizes D*L=300*190 mm. Volume of the mill V = 13dm^3. Drive of the mill consists of a electric motor with power 0.65 kWt and a control unit that allows to regulate the rotational speed of the drum.

Source coal of Donetsk coal basin, the "DG" brand, rich, crushed in a hammer crusher, PML-150, to a grain particle size of 0-3 mm. The mass of coal sample weight is calculated as follows:

$$P_i = 0{,}12 \cdot \delta_ø \cdot V, \tag{1}$$

where: V-volume mill, m^3;

$\delta_ш$ - bulk density of coal, it is taken on Handbook 0.8 t/m^3.

0,12- filling factor of the mill by coal in an amount of 12% from the volume of the mill.

Grinding is carried out wet under solid content 75% by weight with the use of a plasticizer in an amount of 1% on the dry weight of coal.

Filling factor of the mill by balls $\varphi_ш$ = 0.4-0.5. Grinding time - from 20 to 60 minutes. The rotational speed of the mill drum, the granulometric composition of loaded balls are determined by the analytical dependences, taking into account the effective work at the boundary and a some reduced layer of balls [19, 20]:

maximum ball size for a given diameter of the drum is in the range, mm:

$$d = \frac{D}{18} - \frac{D}{24}, \tag{2}$$

minimum size of the ball enough to destroy the most big pieces of coal is:

$$d_ш = d_m \sqrt[3]{\frac{\delta^2}{1.28\beta c \varepsilon \rho_ш D}}, sm. \tag{3}$$

Where: δ - ultimate compression strength, taking σ= 300 kg/sm^2,

ε - Young's modulus, ε = 300 000 kg/sm^2,

c - coefficient taking into account the variability of Young's modulus, c = 1,

β - coefficient taking into account the fraction of energy that goes directly to the grinding of the coal, in the fall of the ball at it, β = 0,5,

D - the size of coal particles,

$p_ш$ - density of the ball, $\rho_ш$ = 0.00786 kg/sm^3.

$$d_ш = 28\sqrt[3]{d}, \tag{4}$$

or

$$d_{ш} = id, \tag{5}$$

where: d - the average size of a piece of source material, mm,

i- factor depending on the hardness of the material.

Rotational speed of the mill drum, rev / min

for the effective operation of the boundary layer of balls:

$$n = \frac{32}{\sqrt{Df}}, \tag{6}$$

for the effective operation of the entire inner mass of the balls:

$$n = \frac{34.2}{\sqrt{Df}}, \tag{7}$$

for the effective operation of some reduced layer of balls:

$$n = \frac{37.2}{\sqrt{Df}}, \tag{8}$$

where: D - inner diameter of the drum, m,

f - coefficient of friction of the ball on the armor, f = 0,466 [14].

Maximum information in the study about the rational loading of the mill by five given components one can obtain using a full factorial experiment (FFE) of type 2^k. If the number of factors $k = 5$, planning matrix provides for 32 tests.

To produce the WCF with necessary dynamic viscosity of 1 Pa.sec at a shear velocity gradient from 10 to 16 sec^{-1}, the sedimentation stability for 15 days or more, we hold full factorial experiment of type 2^5, which provides for the planning matrix 32 tests.

The inspection of the homogeneity of variances, measured response functions at each point of experience by the criterion of Cochran, is satisfied for correct processing and use of the experimental results. When the experiment is carried out, the uniform duplication with five parallel experiments at each point of the design matrix is chosen. [1, 26]

We use the scales of measurement accuracy $\pm$ 5 g for weighing the balls. Maximum loading of the mill is 30 kg, drum rotational speed 58, 63 and 68 rev/ min. and grinding time of 20, 40 and 60 minutes. The resulting grinding are divided into 5 equal parts, water and plasticizer are added. The rotational speed is measured by speed tachometer. Then the viscosity of the suspension is measured by viscometer "Polymer" 1-M, at a shear velocity of 8 sec^{-1}.The order of the experiments is carried out in accordance with the table of random variables.

The number of measurements in each experiment is reduced to five, holding a total amount of 160 measurements and calculations. The mathematical model of the process is built on the results of measurements.

Table 1. **Matrix with coded and natural values of factors**

Area of Planning	№ of experience	The coefficients of the factor levels					Natural numbers				
		X_1 D_1	X_2 D_2	X_3 D_3	X_4 n_{min}	X_5 t_{min}	X_1 D_1, mm	X_2 D_2, mm	X_3 D_3, mm	X_4 n_{min}, ob/min	X_5 t_{min}, min
Fractional replica 2^{5-1} (core of plan)	1	-1	-1	-1	-1	+1	8	8	8	58	60
	2	+1	-1	-1	-1	-1	10	8	8	58	20
	3	-1	+1	-1	-1	-1	8	10	8	58	20
	4	+1	+1	-1	-1	+1	10	10	8	58	60
	5	-1	-1	+1	-1	-1	8	8	10	58	20
	6	+1	-1	+1	-1	+1	10	8	10	58	68
	7	-1	+1	+1	-1	+1	8	10	10	58	68
	8	+1	+1	+1	-1	-1	10	10	10	58	20
	9	-1	-1	-1	+1	-1	8	8	8	68	20
	10	+1	-1	-1	+1	+1	10	8	8	68	60
	11	-1	+1	-1	+1	-1	8	10	8	68	20
	12	+1	+1	-1	+1	-1	10	10	8	68	20
	13	-1	-1	+1	+1	+1	8	8	10	68	60
	14	+1	-1	+1	+1	-1	10	8	10	68	20
	15	-1	+1	+1	+1	-1	8	10	10	68	20
	16	+1	+1	+1	+1	+1	10	10	10	68	60
Star points	17	-2	0	0	0	0	7	9	9	63	40
	18	+2	0	0	0	0	11	9	9	63	40
	19	0	-2	0	0	0	9	7	9	63	40
	20	0	+2	0	0	0	9	11	9	63	40
	21	0	0	-2	0	0	9	9	7	63	40
	22	0	0	+2	0	0	9	9	11	63	40
	23	0	0	0	-2	0	9	9	9	53	40
	24	0	0	0	+2	0	9	9	9	73	40
	25	0	0	0	0	-2	9	9	9	63	40
	26	0	0	0	0	+2	9	9	9	63	80
Center of Plan	27	0	0	0	0	0	9	9	9	63	40
	28	0	0	0	0	0	9	9	9	63	40
	29	0	0	0	0	0	9	9	9	63	40
	30	0	0	0	0	0	9	9	9	63	40
	31	0	0	0	0	0	9	9	9	63	40
	32	0	0	0	0	0	9	9	9	63	40

Table 2. **The levels and variation intervals of factors listed in the table below**

Factors	Levels of variation		
	-1	0	+1
Loading weight of balls in the mill d_1=42mm	8	9	10
Loading weight of balls in the mill d_1=52mm	8	9	10
Loading weight of balls in the mill d_1=62 mm	8	9	10
Drum rotational speed, n, rev / min	58	63	68
Grinding time, t, min.	20	40	60

CONCLUSIONS

The basic factors, affecting the process under study and their calculation, are shown. The laboratory equipment and instrumentation are described. In order to study the process, the full factorial experiment such as 2^5 is selected, a matrix of its planning in coded and natural values is constructed. The implementation of the experimental investigations will improve the preparation of water-coal fuel with prescribed rheological and sedimentation characteristics.

REFERENCES

1. AdlerY.P., Markova E.V., Granovsky Y.V. 1976.: Planning an experiment in search of optimum conditions. M. 326 p.
2. Antonichev M.J. 1983.: The influence of the longitudinal movement of the slurry in a ball mill for grinding performance / / Enrichment useful. resources. -- № 33.- P. 19-23.
3. Antonichev M.Y., Brazhko A.D. 1983.: Dependence of the specific performance of a ball mill size of the initial and the final product. / / Mineral. - - № 32. From 40-44p.
4. Bragin B.F, Kolomiets A.S, Screamers A.P. Markuntovich F.D , Semin J.G. 1996.: Clean coal-water-fuel technology and systems. / / Visn. Shidnoukr. Derge. un-tu. - Yuvileyny vipusk. - P. 70-76.
5. Bragin B.F, Kolomiets A.S, 1995.: Pulps and slurries (technologies, equipment, calculations) - K: - IP and O – 464 p.
6. Bedran NG, Wisniewski M., Zemyansky A.M. 1989.: On a pattern of grinding in ball mills / / Izv. universities Horn. J. - № 2. - P.133-134.
7. Delyagin G.N., Kornilov V.V., Kuznetsov J.D. etc. 1993.: Improvement of water-coal fuel and the prospects for its use. App. Scientific-Technical to. Jour. "The economy and fuel and energy complex is Russia." M. VNIIOENG.
8. Highly concentrated coal-water slurry - Densecoul. Translation № 3/88-2, Institute "VNIPIGidrotruboprovod", Moscow, 1988. Source: BWKV. 39, 1987, № 5 P. 246-247.
9. Irokman R. 1978.: Fundamentals of grinding / assessment and review of the theory and practice of shredding / Tr. From Eng. Source: «Rock Products», № 6.
10. Karmazin V.N., Sergo E.E., Zhendrinsky A.P. and other. 1974.: Processes and machinery for mineral processing. Moscow. Nedra, - 560 p.
11. Kondrat'ev A.S, Ovsyannikov V.M, Olofinsky E.P. 1988.: Transportation and other water-coal suspensions, hydrodynamics and temperature. M.M, Mineral resources, - 213 p.
12. Khodakov G.S. 1972.: Physics grinding. Monograph. - M. - Science. -307 p.
13. Lebedev A.N. 1969.: Preparation and grinding of the fuel in power plants. Moscow, Publishing House, / / Energy, - 520 p.
14. Olofinsky H.E. 1985.: Research of hydromechanics pipeline transportation of suspensions // Proceedings: Study of hydrodynamics of suspensions in pipeline transport.. M. VNIIPI Gidrotruboprovod. – 320 p.
15. Physico-chemical basis for regulating the structural and rheological properties and stability of highly concentrated coal-water slurry during pipeline hydraulic transport. Collection of scientific papers. - Moscow: - NGO "Gidrotruboprovod." - 1989. -124 p.
16. Production of fuel liquid coal «Fluidcarbon» and use in Sweden / / Inst. Chem. lng. Symp. Ser., № 95, 1985, pp 325-331.
17. Portridj A.S. 1978.: Principles of crushing and grinding. Trans. from English. Source: Main and Kverk, № 7 8.t. 7. Krivoy Rog ONTI Mehanobrchermet.

18. Sergo E.E. 1975.: Crushing, grinding and screening of mineral resources. K, Highest School. - 240p.
19. Sergo E.E. 1985.: Crushing, grinding and screening of mineral resources. M, Nedra. - 285 p.
20. Uriev N.B., Potanin A.A. 1992.: Turnover of suspensions and powders. -M.: - Chemistry, - 256 p.
21. The study of hydrodynamics of suspensions in pipelines. Collection of scientific papers. - Moscow: - VNIIPIgidrotruboprovod. - 1985. – 103p.
22. Savin A.A. 1990.: Refined kinematic motion model boot a ball mill in waterfall mode. Tsement.- № 1. P. 6-8.
23. Uriev N.B. 1985.: Regularities of structure vysokokontsentrirovanih water-coal suspensions. - Sat scientific papers VNIIPIgidrotruboprovoda "Investigation of hydrodynamics of suspensions in the pipeline transportation." M. - P.8.
24. Vitoshin J.K., Karasik, V.M., V.F. Ocheretko. 1985.: Effect of dispersion of coal in the parameters of its gidrotransportirovaniya. - Sat scientific papers VNIIPIgidrotruboprovoda "Investigation of hydrodynamics of suspensions in the pipeline transportation." M. - P.36.
25. Wang Zu-Na, Zang-Rong-Zeng 1986.: Research and Development of coal-Water Fuel Technology in China, International seminars on Nuclear, War – 6th Session: International Cooperation: The Alternatives, August.

ИССЛЕДОВАНИЕ ПРИГОТОВЛЕНИЯ ВОДОУГОЛЬНОГО ТОПЛИВА МЕТОДОМ РАЦИОНАЛЬНОЙ ЗАГРУЗКИ ШАРОВОЙ МЕЛЬНИЦЫ

Татьяна Бондарь, Юрий Сёмин, Алина Сёмина

Аннотация. Приведена методика экспериментальных исследований приготовления высококонцентрированных водоугольных суспензий с необходимой реологической характеристикой в шаровой мельнице путем рационализации грансостава мелющих тел.

Ключевые слова: водоугольное топливо, шаровая загрузка, планирование эксперимента, динамическая вязкость, седиментационная устойчивость.

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RESEARCH OF MOVEMENT OF THE ABRASIVE SOLID PARTICLE IN SYSTEMS OF GIVING OF SAND OF LOCOMOTIVES

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Summary. Process of interaction of an abrasive solid particle with a transporting stream of air in devices of giving of sand of locomotives is considered. The mathematical model of interaction of a particle of sand with a transporting stream of air is made. In mathematical model difference of the form of a particle from the spherical form is considered. The accepted law of distribution of speed of a stream of air on cross-section section of the channel considers presence of an injected stream of air in the channel of giving of sand. The force of aerodynamic resistance operating on a particle of sand, is defined with the account of wave resistance which is shown at the big sizes of relative speed of a stream. The estimation of influence of wave resistance on size of speed of movement of a particle of sand in air stream is executed.

Key words: transporting stream of air, particle of sand, speed of movement, compressibility of air.

INTRODUCTION

For realisation of traction effort of the locomotive it is necessary to provide sufficient size of factor of coupling between a wheel of the locomotive and a rail.

The most widespread way of maintenance of necessary size of factor of coupling of a wheel of the locomotive with a rail on railways is giving of quartz sand in area of contact of a wheel of the locomotive with a rail. Pneumatic systems are the most widespread systems of giving of sand in area of contact of a wheel of the locomotive with a rail on railways presently. Sand giving in contact of a wheel to a rail occurs in the form of a two-componental stream which consists of transporting air and sand particles.

For maintenance of factor of coupling of a wheel of the locomotive with a rail at high level it is necessary to submit strictly certain quantity of sand to area of their contact. The decision of this problem depends on effective work of system of giving of sand.

OBJECTS AND PROBLEMS

For increase of an overall performance of system of giving of sand it is necessary to find out the mechanism of interaction of particles of sand and air stream.

At theoretical research of process of giving of sand in contact of a wheel to a rail the method of research of movement of a separate particle of sand in air stream is used. By the previous researches it is proved, that influence of firm particles on parametres of a transporting stream of air and interaction of particles among themselves can be neglected at volume concentration of particles no more than 3 % [1, 2, 3].

In systems of giving of sand existing on locomotives volume concentration of sand in air does not exceed 0,04 % [4].

Their sizes, the form and parametres of a transporting stream of air are defining factors which influence size and a direction of speed of particles of sand. At definition of parametres of movement of particles force of aerodynamic resistance, force of weight, the force caused by a gradient of speed of air (Safman force) have been considered. Other forces of an aerodynamic origin, at the relation of specific weight of a particle ρ_p to specific weight of air ρ $\rho_p / \rho >> 1$, it is possible to neglect [2, 5, 6, 7].

The behaviour of firm particles in air stream is influenced, also, by degree of turbulence of a stream of air. This influence depends on the sizes of a particle. At the sizes of particles $\delta > 0{,}1 \ldots 0{,}2$ mm, in air stream on character of movement of a particle it is possible to neglect influence of turbulent pulsations [5, 8, 9].

In systems of giving of sand of locomotives small particles of sand in the size $\delta < 0{,}2$ mm are not used, in connection with difficulties of their delivery in contact of a wheel to a rail [4]. At theoretical research of movement of particles of sand in systems of giving of sand of locomotives, movement of particles in the size $\delta > 0{,}4$ mm without taking into account pulsations components of speed of a stream of air has been considered. Movement of particles has been considered on an initial site of the channel of giving of sand. The axis of the channel of giving of sand is located under a corner α to a horizontal plane.

Movement was considered in the vertical plane which are passing through an axis of the channel (the axis x is directed along a channel axis).

$$\begin{aligned} m_P \cdot \frac{du_{PX}}{dt} &= f_{AX} + m_P g \sin\alpha, \\ m_P \cdot \frac{du_{PY}}{dt} &= -f_{AY} - m_P g \cos\alpha - f_{GR}, \end{aligned} \tag{1}$$

where: $m_P = \dfrac{\pi \cdot \delta^3 \cdot \rho_P}{6}$ – particle mass;

ρ_P – actual density of the material particle,

u_{PX} – projection velocity on the axis x,

f_{AX} – force projection of aerodynamic resistance on the axis x,

u_{PY} – particle velocity projection on the axis y,

f_{AY} – force projection of aerodynamic resistance on the axis y,

f_{GR} – the force stipulated by transverse velocity gradient in the air flow,

g – free fall acceleration.

The force of aerodynamic resistance with the particle motion is determined by the expression [4]:

$$\vec{f}_A = \psi \cdot \frac{\rho}{2} \cdot s \cdot \left|\vec{u} - \vec{u}_P\right| \cdot \left(\vec{u} - \vec{u}_P\right), \tag{2}$$

where: ψ– the coefficient of aerodynamic resistance of a particle with the account of its form;

ρ – density of air;

$s = \pi \dfrac{\delta^2}{4}$ – the area of particle midsection;

$\vec{u}$ – flow velocity;

$\vec{u}_P$ – particle velocity.

In a common case the coefficient of the aerodynamic resistance of the particle is a unique function of Reynolds number *Re*:

$$\mathrm{Re} = \left|\vec{u} - \vec{u}_P\right| \cdot \frac{\delta}{\upsilon}, \tag{3}$$

where: υ – kinematics air viscosity.

Sand particles have the suborbicular form . The factor of the form of particles of sand matters $k_g=1,15... 1,20$ [1, 3]. Factor of aerodynamic resistance of not spherical particle, at value of factor of the form $k_g=1,15... 1,20$ can be defined under formulas [1]:

$$\Psi = 4,36 \cdot Re^{-0,2}, \quad if \quad 20 \le Re < 800, \tag{4}$$

$$\Psi = 1,1, \quad if \quad Re > 800. \tag{5}$$

Force projection of aerodynamic resistance on the coordinate axis is determined by the equations:

$$f_{AX} = \psi \frac{\rho}{2} s \sqrt{u^2{}_{PY} + \left(u - u_{PX}\right)^2} \left(u - u_{PX}\right), \tag{6}$$

$$f_{AY} = \psi \frac{\rho}{2} s \sqrt{u^2{}_{PY} + \left(u - u_{PX}\right)^2} u_{PY}. \tag{7}$$

On a firm particle, moving in a stream, cross-section force operates also. This force can be caused rotation of a particle round an axis, perpendicular to a direction of longitudinal speed (Magnus force), presence of a cross-section gradient of longitudinal speed of a stream (Safman force) or joint action of these factors [5].

Conditions of input of a particle in a stream are that, that the effect of rotation of a particle during the initial moment of time is absent. Cross-section moving of a particle causes change of size of circulation of speed round a particle. Therefore the reasons for occurrence of the established rotary movement of a particle, in the absence of interaction with a channel wall, no.

Air stream in the target channel of system of giving of sand has a considerable cross-section gradient of speed. In this case the size of cross-section force can be defined under the formula Zhukovsky [10]

$$f_{GR} = \int_{-\frac{\delta}{2}}^{\frac{\delta}{2}} \rho(u - u_{PX})\Gamma(z)dz\,, \tag{8}$$

where: Γ(z) – velocity vector circulation along closed contour.

In each plane sphere section perpendicular to the axis z (the axis z is situated perpendicular to the plane of axis x, y) the radius value *r*:

$$r = \sqrt{\left(\frac{\delta}{2}\right)^2 - z^2}\,. \tag{9}$$

The circulation of velocity vector along the surface of each elementary part of the sphere with thickness *dz*:

$$\Gamma = 4 \cdot r^2(z) \cdot \frac{du}{dy}. \tag{10}$$

After integration of the expression (8) due to the expressions (9) and (10), we get the equation for transverse force value acting on the particle, stipulated by velocity gradient in the suspension flow:

$$f_{GR} = \frac{2}{3} \cdot \rho \cdot \delta^3 \cdot \frac{du}{dy} \cdot (u - u_{PX}). \tag{11}$$

In modern systems of giving of sand air with pressure 0,3...0,6 MPa is used. At such values of pressure, speed of a stream of air on an exit from a nozzle exceeds value of 300 m/s. The same value has speed of air concerning a sand particle during the initial moment of its interaction with a current of air. At such sizes of speed of movement of a stream of air concerning a particle of sand force of aerodynamic influence on it sharply increases owing to occurrence of wave resistance which is caused by compressibility of air. In this connection, at definition of parameters of movement of a particle, at its interaction with air stream, it is necessary to consider compressibility of air [11, 12, 13].

In [13] there is an experimental dependence of factor of aerodynamic resistance of a sphere ζ depending on Mah number, *M*. In a range of values $0,3 \le M \le 1,8$ experimental dependence has been approximated by function:

$$\zeta = \left(n \cdot (M - 0,3)^b \cdot e^{c(M - 0,3)} + A\right), \tag{12}$$

where: *n, b, c, A* - approximation factors.

The chosen area of values of Mah number is caused by that at $M < 0,3$ wave phenomena are absent, and at used in systems of giving of sand sizes of pressure of air of value $M > 1,8$ are impossible.

With the account of concrete values of factors of approximation function takes a form:

$$\zeta = \left(4,74 \cdot (M - 0,3)^{2,64} \cdot e^{-2,03(M - 0,3)} + 0,35\right). \tag{13}$$

On fig. 1 the schedule of approximating function $\zeta = f\,(M)$ is resulted and experimentally received values ζ are specified.

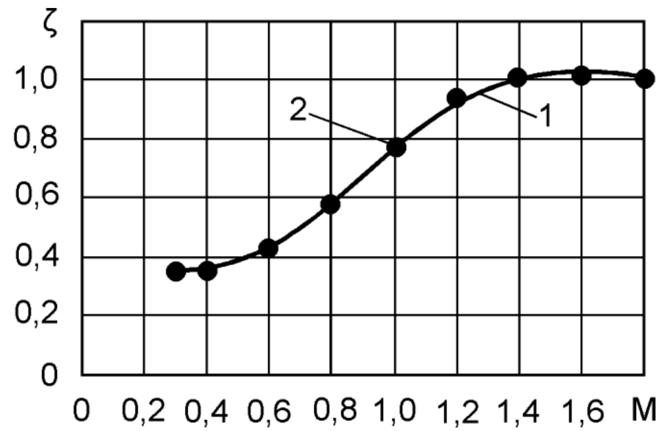

Fig. 1. Dependence of factor of aerodynamic resistance ζ from Mah number
(1 - the schedule of approximating function $\zeta = f\,(M)$, (2 - experimental values ζ)

For the account of influence of the form of a particle on factor of aerodynamic resistance it is necessary to enter into the formula (13) the form of factor correction k_f . which is equal to result of division of size of factor of aerodynamic resistance of a particle of not spherical form on size of factor of aerodynamic resistance of a particle of the spherical form:

$$k_f = \frac{\psi}{\zeta} \ . \qquad (14)$$

For sand particles, at value of factor of the form k_g*=1,15... 1,20,* k_f =3,*14*. The formula for definition of factor of aerodynamic resistance of particles of sand with the account of their form and compressibility of air in the field of *Re> 800* in a range of values of Mah number $0,3 \le M \le 1,8$ is given by:

$$\psi = 3{,}14 \cdot \left(4{,}74 \cdot (M - 0{,}3)^{2{,}64} \cdot e^{-2{,}03(M-0{,}3)} + 0{,}35\right). \qquad (15)$$

Taking into account speed of movement of a particle of sand, the size of Mah number is defined from the formula [14]:

$$M = \left(\frac{(u - u_{PX})^2 + (u_{PY})^2}{(a_o)^2 - \left((u - u_{PX})^2 + (u_{PY})^2\right)\frac{k-1}{2}} \right)^{0{,}5} , \qquad (16)$$

where: a_o - speed of a sound in air which is defined on values of parameters of braking of a transporting stream of air;

k - an equation exponent adiabatic process for air.

Speed of transporting air on an initial site of the channel of giving of sand was defined on laws for the flooded turbulent stream taking into account speed of an injected stream of air u_C [15, 16]:

$$u = \frac{(u_O - u_C)}{0{,}3 + 0{,}14 \cdot \dfrac{x}{do}} \cdot \left[1 - \left(\frac{|y|}{d_O / 2 + x \cdot tg(\varphi / 2)} \right)^{1{,}5} \right]^2 + u_C , \qquad (17)$$

where: u_O - speed of transporting air on an exit from a nozzle;

φ - a corner of disclosing of a stream of transporting air;

d_O - diameter of a nozzle;

x, y - coordinates of a particle of sand.

Taking into account resulted above dependences, the system of the equations for calculation of parameters of movement of a particle of sand on an initial site of the channel of giving of sand, taking into account compressibility of air and difference of the form of a particle from spherical, is given by:

$$\left. \begin{aligned} \frac{du_{PX}}{dt} &= \frac{3}{4}\psi \frac{\rho}{\rho_P \cdot \delta} \sqrt{(u_{PY})^2 + (u - u_{PX})^2} \cdot (u - u_{PX}) + g \sin\alpha , \\ \frac{du_{PY}}{dt} &= -\frac{3}{4}\psi \frac{\rho}{\rho_P \cdot \delta} \sqrt{(u_{PY})^2 + (u - u_{PX})^2} \cdot u_{PY} - g \cos\alpha + \frac{4}{\pi} \frac{\rho}{\rho_P} \cdot \frac{du}{dy} \cdot (u - u_{PX}) \cdot \operatorname{sgn} y . \end{aligned} \right\} \qquad (18)$$

On fig. 2 the settlement scheme to mathematical model is shown.

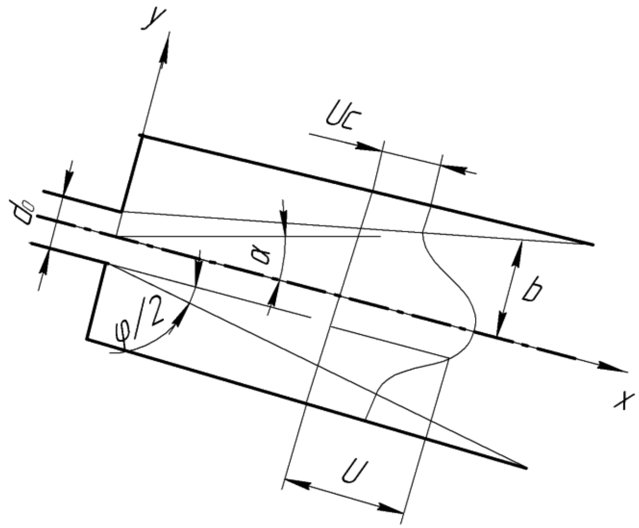

Fig. 2. The settlement scheme to mathematical model of movement of a particle of sand on an initial site of the channel of giving of sand of the locomotive

On fig. 3 results of calculation of speed of movement of a particle of sand in the size δ = 0,815 mm executed with the account and without the account of compressibility of air are resulted.

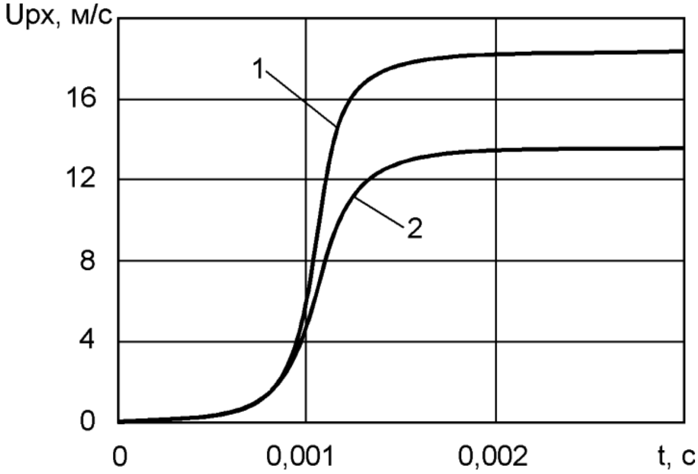

Fig. 3. Results of calculation of speed of a particle of sand in the size δ = 0,815 mm on an initial site of the channel of giving of sand (1 - with the account of compressibility of air, 2 - without the account of compressibility of air)

Calculations are executed at following sizes of initial data: speed on an exit from a nozzle u_O = 313,3 km/s, the speed of a sound calculated on parametres of braking of the transporting stream of air, a_O = 343,1 m/s, speeds of an injected stream of air u_C = 20 m/s.

Results of calculation show, that the account of compressibility of air allows to increase accuracy of calculation of speed of a particle by 35 %.

CONCLUSIONS

The received results show, that at calculations of movement of particles of sand in systems of giving of sand of locomotives at high speed of a stream of air, it is necessary to consider compressibility of air.

REFERENCES

1. Shrajber A.A., Milyutin V. N, Jacenko W.P., 1980.: Gidromehanika of two-componental streams with solid polydisperse substance. Kiev, Naukova dumka. - 250 s.
2. Sukomel A.S., 1977.: Heat exchange and hydraulic resistance at movement gazovzvesi in pipes / A.S.Sukomel. F.F.Tsvetkov, R.V.Kerimov. – M.: Energia. - 192 s.

3. Razumov I.M., 1979.: Pnevmo and hydrotransport in the chemical industry. (Processes and devices of chemical and petrochemical technology.) M.: "Chemistry". - 248 s.
4. Kamenev N.N., 1968.: Effective use of sand for draught of trains / N.N.Kamenev// Scientific trudy. Vsesouzn. n. -i. in-t g.d. transporta. M: Transport. Vyp. 366. - 86 s.
5. Mednikov E.P., 1980.: Turbulentnyj perenos i osazdenie aerozolej / E.P.Mednikov. - M: Nauka. - 176 s.
6. Fuks N.A., 1955.: Mechanics of aerosols /N.A. Fuks. – M.: Izd-vo AN of the USSR. - 352 s.
7. Shrajber A.A., Gavin L.B., Naumov V. A, Jacenko W.P., 1987.: Turbulentnyje techenije gazowzvesi. Kiev, Naukova dumka. - 240 s.
8. Sou S., 1971.: Gidrodinamika of multiphase systems / S.Sou. – M.: Mir. - 536 s.
9. Saks S.E., 1970.: Opredelenije kriticheskoj skorosti vzvesenesushego potoka. - IFG., T 18 № 5, 832 – 837 s.
10. Nigmatulin R. I., 1978.: Osnovy mechanici heterogennyh sred. – M.: Nauka. 336 s.
11. Fabricant N.J., 1964.: Aerodynamica /Fabricant N.J.. - M.:Nauka. - 814 c.
12. Povh I.L., 1969.: Technicheskaja hydromechanica / I.L.Povh. - L.:Mashinostroenie. – 520 s.
13. Deitch M. E., 1961.: Technicheskaja gazodinamika / M.E.Deitch. - M.-L.: Gosenergoizdat.- 671 s.
14. Bugaenko V.V., 2010.: Doslidzhennja efektivnosti dostavki abrasivnogo materiala v oblast contacta kolesa locomotiva s relsom / V.V. Bugaenko //Visn. Shidnoukr. nat. un. im. V. Dalja. - Lugansk, № 11 (153). T. 2, 277 – 286 s.
15. Abramovich G. N., 1976.: Prikladnaja gazovaja dinamika /G. N. Abramovich. - M.:Nauka. - 888 s.
16. Zalmanzon L.A., 1969.: Teoria elementov pnevmoniki / L.A.Zalmanzon. - M: Nauka. - 507 s.

ИССЛЕДОВАНИЕ ДВИЖЕНИЯ АБРАЗИВНОЙ ТВЕРДОЙ ЧАСТИЦЫ В СИСТЕМАХ ПОДАЧИ ПЕСКА ЛОКОМОТИВОВ

Виктор Бугаенко

Аннотация. Рассмотрен процесс взаимодействия абразивной твёрдой частицы с транспортирующим потоком воздуха в устройствах подачи песка локомотивов. Составлена математическая модель взаимодействия частицы песка с транспортирующим потоком воздуха. В математической модели учтено отличие формы частицы от сферической формы. Принятый закон распределения скорости потока воздуха по поперечному сечению канала учитывает наличие инжектируемого потока воздуха в канале подачи песка. Сила аэродинамического сопротивления, действующая на частицу песка, определена с учётом волнового сопротивления, которое проявляется при больших величинах относительной скорости потока. Выполнена оценка влияния волнового сопротивления на величину скорости движения частицы песка в потоке воздуха.

Ключевые слова: транспортирующий поток воздуха, частица песка, скорость движения, сжимаемость воздуха.

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ANALYTICAL INVESTIGATION INTO VELOCITY CHANGE OF THE TRANSPORTED MATERIAL IN A PIPELINE BEND

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Summary. The mathematical model of aerodisperse flow movement in bend is offered. The solution of this model is received under the conditions approached to the real ones. The experimental results are compared according to the given model and some simplifying hypotheses.

Keywords: pneumatic conveying of solids, flow velocity, differential equations.

THE MATHEMATICAL MODEL FOR THE MOVEMENT OF TRANSPORTED MATERIAL AT THE FLOW TURN

The main aim in the investigation of aerodisperse flow of solids is the mathematical description of their regularities depending on the characteristics of the particles and conditions of flow formation. Lack of knowledge about tension generation mechanisms being the difficult function of particles velocity puts obstacles in the way of working out of the adequate analytical description of regularities in pneumotransport flows. Besides, the high heterogeneity in solid phase concentration is typical for high velocities of pneumatic conveying of solids. All these problems worsen the experimental and analytical investigations of pneumatic conveying processes.

Additional difficulties arise at the mathematical modelling of pneumatic transportation in bend. This is due to the fact that centrifugal force influences the transported material in the perpendicular direction at the flow turn. The centrifugal force is many times more than the material weight [1]. The forces which cause hovering of the particles during the horizontal movement are in many times less than the centrifugal force. Therefore the overwhelming majority of fractions does not come back from an external bend wall into the flow of transporting gas, but settles on it.

The present bend calculation methods are based on the empirical dependences used for uniform flows [2, 3, 4, 5, 6]. Naturally, the calculations by these techniques give considerable errors because of ignoring the difficult physical nature of two-component flows transportation [7, 8]. Besides, in many scientific publications on this theme [4, 7, 9], the offer about the invariability of the cross-section area of deposited solids was accepted. However, the last experimental investigations with a transparent bend exposed the other structure of particles flow in a pipeline bend (fig. 1) [10, 8].

According to these sources the sliding speed of particles settled in the bend gradually decreases, and the thickness of a layer increases on the exit from the bend. This process is illustrated in fig. 1 and 2.

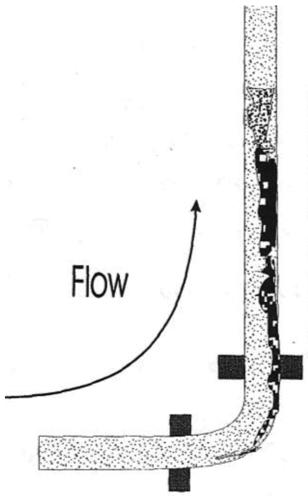

Fig. 1. Aerodisperse flow in a bend [10]

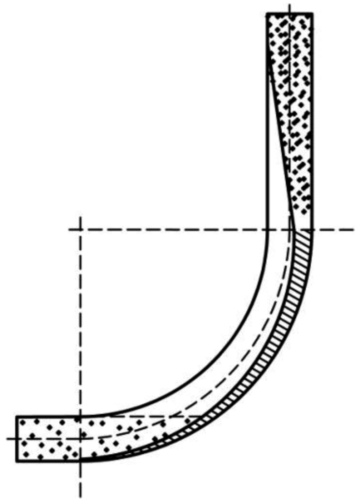

Fig. 2. The scheme of an aerodisperse flow in a bend according to [8]

The purpose of the work is to create the mathematical theory for the calculation of kinematic characteristics of the transported mass in a pipeline bend and to get formulas for the solids speed u_T on an exit from a bend.

The given mathematical model of the solids movement at the flow turn is based on the suggestion that the all material settles at the origin of a bend and changes the speed during the movement. It allows passing the law of mass change along a motion pass in a bend in the following form:

$$m(\varphi) = m_0 + m_1(\varphi), \tag{1}$$

where: φ – the polar angle counted from the beginning of flow turn for a square-wave bend; m_0 – mass of material at the origin of a bend $0 \le \varphi \le \frac{\pi}{2}$; $m_1(\varphi)$ – the function defined further and considered the change of material mass along a motion path.

It is necessary to consider that the friction force operates against the movement of material:

$$T = f \cdot N, \tag{2}$$

where: N – constraint force; f – the coefficient of material friction against a bend wall.

The scheme for the interaction of forces influencing material fractions in a bend is presented further. Gravitation *G*, centrifugal force *C*, constraint force *N* and friction force *T* belong to these forces (fig. 3).

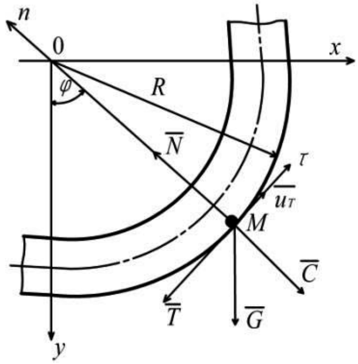

Fig. 3. The calculated scheme of a bend

THE ANALYSIS OF FORCE INTERACTION IN THE LAYER OF THE DEPOSITED PARTICLES

Let us project the vector equation of particles motion of the transported material of variable mass on an axis of Euler's coordinate system (fig. 3). We have:

$$\begin{cases} \dfrac{d}{dt}(mu_T) = -T - G\sin\varphi \\ m\dfrac{u_T^2}{R} = N - G\cos\varphi \,. \end{cases} \tag{3}$$

We determine reaction N from the second equation of system (3) and substitute in the first one. Further, taking into account the connection between a turning angle φ and velocity u_T, we can reduce system (3) to the differential equation relative to function $u_T\,(\varphi)$:

$$\frac{d}{d\varphi}\left(mu_T\right) = -m\left(f \cdot u_T + g\frac{R}{u_T}\left(f\cos\varphi + \sin\varphi\right)\right). \tag{4}$$

For the correct solution of this equation it is necessary to define dependence (1) and from physical reasons to determine function $m_1\left(\varphi\right)$.

Let us assume that the area occupied with a material at movement along a bend, occupies area *D* in bend longitudinal section represented in fig. 4.

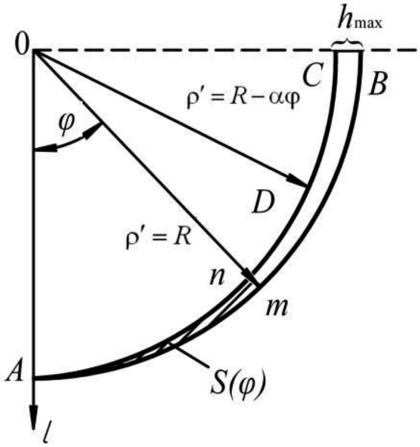

Fig. 4. The scheme of the deposited particles layer in a bend

Let us allow polar system of coordinates $(\rho'\varphi)$ with a pole O and a polar axis l. In this system of coordinates the equation of an external rim of bend AmB looks like $\rho' = R$, and the equation of internal border of area D – curve AnC – $\rho' = R - a\varphi$,

where: $$a = \frac{2h_{\max}}{\pi}. \tag{5}$$

We find by means of double integral the area of domain $AnOA$ defined by current value of an angle φ. Then required area $S(\varphi)$ of a domain $AmnA$ will be equal:

$$S(\varphi) = \frac{a\varphi^2}{6}(3R - a\varphi). \tag{6}$$

Designating through ρ mass of a layer of the transported material, corresponding to the fixed value $S(\varphi)$, we will define the change of its mass at a motion along a bend – function $m_1(\varphi)$ in formula (1):

$$m_1(\varphi) = \rho S(\varphi) = \frac{1}{6}\rho a\varphi^2(3R - a\varphi). \tag{7}$$

For parameter definition a in formula (8) we will consider that relative volume C_V of a material in a bend, as well as concentration of a flow, is defined as the proportion:

$$C_V = \frac{V_T(h_{\max})}{V_T}, \tag{8}$$

where: $V_T(h_{\max})$ – the volume occupied with a material at a motion in a bend of the pipeline; V_T – volume of the whole bend representing a part of a toroidal cover.

If it is possible to define the connection $V_T(h_{max})$ equation (8) can be considered as the equation for the definition $h_{\max}$, and consequently the parameter a.

THE DETERMINATION OF THE MATERIAL VOLUME IN A BEND

Let us consider the fourth part of a toroidal cover and assume that the material at transportation along a bend occupies a part of its volume *ABCNA* (fig. 5).

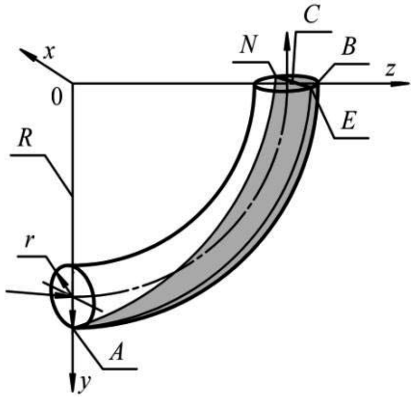

Fig. 5. To the determination of the deposited particles volume in a pipeline bend

Let us allow the Cartesian system of coordinates O_{XYZ} where the section equation tore in a plane $x0y$ will register as:

$$x^2 + \left(y - (R - r)\right)^2 = r^2 .$$

Then the surface equation tore as surfaces of rotation round axis $0x$, will be [11]:

$$x^2 + \left(\sqrt{z^2 + y^2} - (R - r)\right)^2 = r^2 .$$

Let us designate through D a longitudinal projection of an investigated surface to a plane $y0z$ (it is represented in Fig. 4). Then the required volume will be:

$$V_T(h_{\max}) = 2 \cdot \iint\limits_{(D)} dydz \int\limits_0^{\sqrt{r^2 - \left(\sqrt{z^2 + y^2} - (R - r)\right)^2}} dx \cdot$$

We pass in a plane $y0z$ to polar coordinates (ρ', φ) and use tabular integrals [12]. With their help find primitive function in internal integral and after some transformations we will receive:

$$V_T(h_{\max}) = \int\limits_0^{\frac{\pi}{2}} \left(\frac{\pi r^2 (R - r)}{2} + \frac{2}{3}\sqrt{\left(r^2 - (r - a\varphi)^2\right)^3} - \right. \qquad . \qquad (9)$$

$$\left. - (R - r)(r - a\varphi)\sqrt{r^2 - (r - a\varphi)^2} - (R - r) r^2 \arcsin\left(\frac{r - a\varphi}{r}\right) \right) d\varphi.$$

The first and the third items under integral in formula (9) are integrated elementary, for integration of the fourth item we apply an integration method in parts, and to the second – trigonometrical substitution. Collecting the received results, we will receive definitively:

$$
\begin{aligned}
V_T(h_{\max}) = {} & \frac{(R-r)r^2}{4}\Bigg(\pi^2 + \frac{\sqrt{(4ra\pi - a^2\pi^2)^3}}{6r^2 a} + \\
& + \frac{2}{a}\Big(\pi r - \sqrt{4ra\pi - a^2\pi^2} - (2r - a\pi)\arcsin\Big(\frac{2r-a\pi}{2r}\Big)\Big) + \\
& + \frac{r^4}{24a}\Big(3\pi - 6\arcsin\Big(\frac{2r-a\pi}{2r}\Big) - \frac{2r-a\pi}{r^4}\sqrt{4ra\pi - a^2\pi^2}\cdot\Big(3r^2 + 2ra\pi - \frac{1}{2}a^2\pi^2\Big)\Big)\Bigg).
\end{aligned} \tag{10}
$$

Thus, taking into account this expression and the expression for a quarter of torus volume with characteristics r and R [11]:

$$V_T = \frac{1}{2}\pi^2 r^2 (R-r),$$

it is possible to consider the transcendental equation (8) completely formed for the definition of $h_{\max}$. It should be mentioned that the roots of this equation are to be searched in limits $0 < h_{max} < r$ as experimental data show.

THE ANALYSIS OF THE TRANSPORTED MATERIAL VELOCITY IN A PIPELINE BEND

The problem of this subsection is to define the velocity of the material particles for any value of a polar angle φ (Fig. 3). For this purpose we have a problem of Koshi: differential equation (4) with the initial condition:

$$u_T\Big|_{\varphi=0} = u_{T0}, \tag{11}$$

where: u_{TO} – initial velocity of the transported flow particles on the entrance of a bend.

We substitute the law of mass change (1) considering dependence (7) in differential equation (4) and reduce it to the nonlinear differential equation of Bernoulli [13] of the following form:

$$\frac{du_T}{d\varphi} + P(\varphi)u_T = \frac{1}{u_T}Q(\varphi), \tag{12}$$

where:

$$P(\varphi) = f + \frac{(6R - 3a\varphi)\varphi}{6M_0 + (3R - a\varphi)\varphi^2};\ Q(\varphi) = -gR(f\cos\varphi + \sin\varphi);\ M_0 = \frac{m_0}{\rho a}. \tag{13}$$

We find the solution of equation (12) in a standard way:

$$y(\varphi) = u_T^2 = u(\varphi)\cdot e^{-2f\varphi - 2\overline{P}(\varphi)}, \tag{14}$$

where: $$\overline{P}(\varphi)=\int\frac{(6R-3a\varphi)\varphi}{6M_0+(3R-a\varphi)\varphi^2}d\varphi\,. \tag{15}$$

To find a primitive function in formula (15) it is necessary to determine denominator roots of the subintegral function, i.e. to solve the equation:

$$\varphi^3+a_1\varphi^2+b\varphi+c=0,$$

where: $a_1=-3Ra^{-1}=-3R_\delta;\, b=0;\, c=-6M_0a^{-1};\, R_\delta=R/a$.

Discriminant expressions are calculated [14, 15]:

$$\overline{Q}=\frac{a_1^2-3b}{9}=\frac{R^2}{a^2},\ \overline{R}=\frac{2a_1^3-9ab+27c}{54}=\frac{1}{a^3}\left(R^3+3\frac{m_0}{\rho}a\right),$$

and inequality $\overline{R}^2>\overline{Q}^3$ is obtained. So, equation (16) has one real root and two complex conjugate ones, evaluated using Cardano formulae (16):

$$\varphi_1=A+B-\frac{a_1}{3};\ \varphi_{2,3}=\frac{A+B}{2}-\frac{a_1}{3}\pm i\sqrt{3}\frac{A-B}{2},$$

where:

$$A=-sign\left(\overline{R}\right)\cdot\sqrt[3]{\left|\overline{R}\right|+\sqrt{\overline{R}^2-\overline{Q}^3}}=\sqrt[3]{\frac{R^3}{a^3}+3\frac{m_0}{\rho a^2}+\sqrt{6\frac{R^3m_0}{\rho a^5}+\frac{9m_0^2}{\rho^2a^4}}},$$

$$B=\frac{\overline{Q}}{A}=\frac{R^2}{a\cdot\sqrt[3]{R^3+3\frac{m_0}{\rho}a+a\sqrt{6\frac{R^3m_0}{\rho a}+9\frac{m_0^2}{a^2}}}}\,.$$

The subintegral expression in (15) is decomposed into a sum of simple fractions and the method of undetermined coefficients is used. After integration we obtain the function $\overline{P}(\varphi)$ in explicit form:

$$\overline{P}(\varphi)=-3\left(Dln\left|\varphi-\varphi_1\right|+\frac{1}{2}Eln\left(\varphi^2+p\varphi+q\right)+\frac{2F-Ep}{2q-0,5p^2}arctg\left(\frac{2\varphi+p}{2q-0,5p^2}\right)\right). \tag{16}$$

Here:

$$P=-\left(A+B+2R_\delta\right);\ q=\left(\frac{A+B}{2}\right)^2-3\left(\frac{A-B}{2}\right);$$

$$D=\frac{\left(2R_{\acute{a}}-\varphi_1\right)\varphi_1}{\varphi_1^2+p\varphi_1+q};\ \ E=-\frac{\left(2R_{\acute{a}}+p\right)\varphi_1+q}{\varphi_1^2+p\varphi_1+q};\ \ F=\frac{\left(2R_{\acute{a}}-\varphi_1\right)q}{\varphi_1^2+p\varphi_1+q}\,.$$

Thus, we have the equation for the function $u(\varphi)$ in (14):

$$\frac{du}{d\varphi}\cdot e^{-2f\varphi-2\overline{P}(\varphi)}=-2gR\left(f\cos\varphi+\sin\varphi\right),$$

solved elementary. After determining the integration constant from the starting condition(11) we obtain the desired dependence of the velocity on the angle φ as following:

$$u_T\left(\varphi\right)=\sqrt{u_{TO}^2\cdot e^{2\left(P(0)-f\varphi-\overline{P}(\varphi)\right)}-2gR\cdot e^{-2\left(f\varphi+2\overline{P}(\varphi)\right)}\cdot\Psi\left(\varphi\right)}, \tag{17}$$

where:

$$\Psi\left(\varphi\right)=\int_0^{\varphi}\left(f\cos\varphi+\sin\varphi\right)e^{2f\varphi-3\left[Dln\left|\varphi-\varphi_1\right|+0,5Eln\left(\varphi^2+p\varphi\right)+\frac{2F-Ep}{2q-0,5p^2}arctg\frac{2\varphi+p}{2q-0,5p^2}\right]}d\varphi . \tag{18}$$

If we put in (17), (18) $m_0=m;\ m_1\left(\varphi\right)=0$, then expression (17) becomes:

$$u_T\left(\varphi\right)=\sqrt{u_{T0}^2e^{-2f\varphi}-\frac{2gR}{4f^2+1}\left(\left(1-2f^2\right)e^{-2f\varphi}-\left(1-2f^2\right)\cos\varphi+3f\sin\varphi\right)}, \tag{19}$$

that is identical to the formula, obtained in [9] for the constancy of the material mass in the bend, located in vertical plane of «horizontal-vertical» type.

COMPARISON OF THE PRESSURE LOSS CALCULATION RESULTS IN THE PIPELINE BEND USING DIFFERENT METHODS

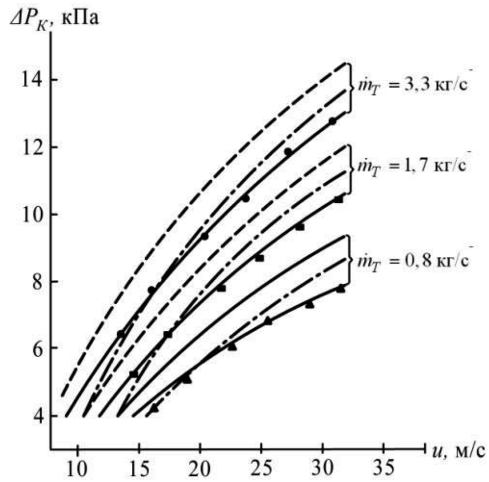

Fig. 6. Graphs of the pressure loss dependence in the pipeline bend

According to the given methods comparative calculations of the pressure loss in the pipeline bend with the rotation of the pipe at an angle $\varphi = 90^o$, bending radius R = 0,3 m, pipe diameter d = 0,05 m, located in the vertical plane with the material consumption 0,8; 1,7 и 3,3 kg/s are carried out. The velocity of the bulk material u_{TK} at the outlet of the bend fot the case of uniform distribution of deposited particles is detemined by formulae (17) and (18).

According to the calculation results we have graphs presented in fig. 6. Here the solid line indicates the experimental graphs obtained on the experimental stand of the Automobile and Highway Institute of the Donetsk State Technical University.

According to the graphs calculation accuracy by the method providing for the mass change of particles layer along the bend greatly improves the calculation accuracy on a simplified version.

CONCLUSIONS

1. It is shown that in the bend of the pneumotransport pipeline solids by centrifugal force are deposited on the wall of the bend, forming a layer of transported material, thickness of which is not constant, but changes along the bend according to the law, depending on the particle size, density of carrying and transported medium, bending radius.
2. A new analytical model of the bend, taking into account the variable height of deposited particles layer is developed; a nonlinear differential equation of the layer motion is composed; the law of the velocity change of the particle layer motion and the change of its specific gravity along the bend is obtained.
3. A design procedure of the pressure loss in the pipeline bend, consistent with the accepted analytical model is developed. The comparison of calculated and experimental data shows that their divergence does not exceed 15 %.

REFERENCES

1. Urban Ya. 1967.: Pneumatic transport / Ya. Urban. – M.: Mashinostroenie. – 253 p.
2. Malevich I.P. 1972.: Transportation and storage of powder-like building materials / I.P. Malevich, V.S. Seryakov, A.V. Mishin. – M.: Khimia. – 240 p.
3. Ulyanitzkii A.V. 1993.: Substantiation of minimal energy expenditure during horizontal pneumatic conveying of solids: thesis for cand. deg. in tech. sciences / A.V. Ulyanitzkii. – Odessa. – 182 p.
4. Uspenskii V.A. 1959.: Pneumatic transport / V.A. Uspenskii. – Sverdlovsk: Metallurgizdat. – 150 p.
5. Bradley M. 1990.: Pressure losses caused by bends in pneumatic conveying pipelines / M. Bradley // Powder handling and processing. – Vol. 2. – № 4. – pp. 315-321.
6. Chaltsev M.N. 2002.: Locking property of a pipeline bend and its practical use experiment / M.N. Chaltsev // Bulletin of National Technical University of Ukraine «Kiev polytechnic institute». Mashinostroenie. – Vol. 1. – Issue 42. – pp. 90-93.
7. Zuev F.G. 1976.: Pneumatic transportation at the grain-processing enterprises / F.G. Zuev. – M.: Kolos. – 344 p.

8. Solt P.E. 2006.: Bend location and pressure drop: An in-depth study / P.E. Solt // Powder and bulk engineering. – № 11. – pp. 3-6.
9. Chaltsev M.N. 2005.: Model of pneumotransport flow in a pipeline bend / M.N. Chaltsev // Industrial hydraulics and pneumatics. – Vinnitsa: VSAU. – № 2 (8). – pp. 104-108.
10. Klinzing G.E. 2000.: Solids flow behaviors in bends: assessing fine solids buildup / G.E. Klinzing // Powder technology. – № 113, pp. 124-131.
11. Aleksandrov P.S. 1979.: Course of analytic geometry and linear algebra / P.S. Aleksandrov. – M.: Nauka. – 512 p.
12. Gradstein I.S. 1963.: Tables of integrals, sums, lines and products / I.S. Gradstein, I.M. Ryzhik. – M.: Phyzmatgiz. – 1100 p.
13. Egorov A.I. 2005.: Ordinary differential equations with appendices / A.I. Egorov. – M.: Phyzmatlit. – 384 p.
14. Aleksandrova P.S. 1961.: Encyclopedia of elementary mathematics. Book II. Algebra / ed. Aleksandrova P.S., Markushevich A.I., Khinchina A.Ya. – M.: State publishing house of technical theoretical literature. – 424 p.
15. Kurosh A.G. 1975.: Algebraic equations of arbitrary powers / A.G. Kurosh. – M.: Nauka. – 33 p.
16. Fichtengoltz G.M. 2001.: Course of differential and integral calculus / G.M. Fichtengoltz. – M.: Phyzmatlit. – Vol. 3. – 622 p.

АНАЛИТИЧЕСКОЕ ИССЛЕДОВАНИЕ ИЗМЕНЕНИЯ СКОРОСТИ ТРАНСПОРТИРУЕМОГО МАТЕРИАЛА В КОЛЕНЕ ТРУБОПРОВОДА

Михаил Чальцев, Леонид Вовк

Аннотация. Обосновывается и предлагается математическая модель движения аэродисперсного потока в колене трубопровода. Получено решение этой модели при условиях, приближенных к реальным. Приведено сравнение результатов, полученных экспериментально, по данной модели и для некоторых упрощающих гипотез.

Ключевые слова: пневматическое транспортирование сыпучих материалов, скорость потока, дифференциальные уравнения

TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11B, 30-35

MATERIAL CHOOSING FOR POLYMER PARTS PRODUCTION BY MEANS OF MULTICOMPONENT MOLDING METHOD

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Summary. Main factors affecting the quality of the finished polymer product, produced by multicomponent molding are analyzed in the article.

Keywords: multicomponent molding, viscosity, shrinkage, polymer**.**

INTRODUCTION

Waste of polymeric materials, on the one hand, is an environmental contamination source, and on the other hand – cheap raw material for production of application wide range products. The most expedient from the ecology and energy conservation side is a polymeric waste recycling, that is the main environmental problem nowadays. Therefore creation of conditions for expansion of a raw-material base, reduction of raw material, fuel and energy resources losses, and also decrease of environmental contamination level are the major principles of industrial policy in our country [1].

Recycling method is most widespread, however on a way of its realization there are serious difficulties. Even if a polymeric waste is carefully separated from other garbage, they can't be overworked in polymeric recycling product with satisfactory properties because of a singularity inherent in polymers – inability to mix up with one another or, speaking strictly scientifically, their thermodynamic incompatibility. At mixing of polymers even the close chemical nature (for example, polyethylene and polypropylene) the two-phase disperse systems which properties are much worse, than properties of initial components more often are formed. Therefore before processing of a polymeric waste, for example packages, by fusion in granules, suitable for manufacture by molding of new polymeric products, the most careful sorting of a waste according to a chemical compound is necessary [15].

Molding methods were widely adopted in processes of new qualitative products obtaining from secondary polymeric materials. To such methods we can refer extrusion, co-extrusion, multicomponent molding etc. [2].

OBJECTS AND PROBLEMS

The choice of materials admissible combination for manufacture of new qualitative polymeric details by means of multicomponent molding method with usage of secondary polymeric materials plays a main role for the environmental contamination level reducing, and also for resource-saving and energy conservation. It is necessary to take the careful analysis for determination of their compatibility, chemical stability and wear resistance, and also maintenance possibility in environmental conditions and correspondences to other special requirements. Viscosity of melts and value of shrinkage should be relatives [11,17,20]. Various combinations of materials lead to wide range of adhesion strength of a basic material with put on it other polymer. It is possible to achieve adhesion from zero level to durability of a chemical bond when materials interact at molecular level and create heavy-duty adhesion which is characterized by long life in the conditions of aggressive chemical environment. As multicomponent molding includes adhesion of various materials in one complex product durability of materials adhesion plays a crucial role. To factors which influences on durability of adhesion it is possible to put compatibility, temperature of technological process, the area of contact surfaces, a texture, sequence of injections performance and construction of details concern at their mechanical adhesion [14].

Co-injection or Sandwich Molding gives the chance to reduce production costs owing to usage of cheaper secondary materials everywhere where there is no necessity for exclusive usage of high-quality material, for example, as capacity filler [7]. Thus, as base material it is possible to use secondary polymeric raw materials because in products made according to sandwich-molding technology this material is not visible and expensive materials are used only for creation of a thin decorative blanket.

By sandwich-molding technology it is possible to produce products of the difficult form with application wide range – from electrical and consumer goods to various special industries (table 1) [5,9].

Table 1. **Examples of the products made by sandwich-molding technology**

Automobile industry	**Other branches**
Lock casing	Tooth-brushes
Reflectors for headlights	Tool handles
Ventilating grid	Toys
Connectors for safety pillows	Buttons of various devices
Door gaskets	Accessories
The air duct dampfer	Garden furniture
Colorfull scatterers of back stop signal lights	Remote control units cases for TV sets

Sandwich molding allows using a wide range of polymeric materials. Though the majority of them are thermoplastics, there are some promising improvements thanks to which thermosetting materials are used with the thermoplastic. As two materials here are used, a property of melts and their compatibility has a great value. During material selection process the most important criteria are: a difference in viscosity and adhesion between surface and basic materials. As the basic material should penetrate in surface it is desirable that viscosity of the surface material was lower, than at basic. Usage of a material with low viscosity as the basic leads to that the front of this material melt flow is moved too quickly concerning surface that as a result is badly reflected in quality of a product surface. An experimental research of sandwich molding has been connected to check influence of viscosities ratio of the surface and basic materials on their space distribution in a product [3,12,13].

As in a finished product both materials are allocated by layers, for achievement of optimum characteristics of mold their reliable adhesion is necessary. In table 2 the basic information for a considerable number of various materials combinations is resulted [4,18,19]. It is necessary to mark that it can be used only for acquaintance. Real functional characteristics should be defined by finished product field of application as the final result depends on parameters of molding process. One more property of a material which should be considered is shrinkage. There is a thumb rule which demands that used materials had identical shrinkage at molding. It will allow to reduce pressure in adjoining layers [5,6,16].

Table 2. **Polymer materials adhesion**

	ABS	ASA	CA	PA 6	PA 6.6	PA-Blend	PBTP	PC	PC/ABS	PC/PBT	PC/PET	PE	PETP	PMMA	POM	PP	PPO	PS	SAN	TPE/TPU
ABS	△	▲	▲	▲	▲		▲	▲	▲	▲	▲	□	▲	▲	■		■		□	□
ASA	▲	△	▲		▲		▲	▲	▲	▲	▲	■	▲	▲	■	■	■	■	▲	□
CA	▲	▲	△				▲					■			■	■	■			
PA 6	▲			△	△	▲	▲	□	▲	▲	▲	□			■	□	■	■		□
PA 6.6	▲	▲		△	△	▲	□		▲	▲	▲	□			■	□	■	■		□
PA-Blend				▲	▲	△									□	□	■			□
PBTP	▲	▲	▲	▲	□		△	▲	▲	▲	▲	□	▲	□	□	□		□	▲	□
PC	▲	▲			▲		▲	△	▲	▲	▲	■	▲		□	■		■	▲	□
PC/ABS	▲	▲		▲	▲		▲	▲	△	▲		■			□	■		■		□
PC/PBN	▲	▲		▲	▲		▲	▲	▲	△	▲	■	▲	▲	□	■		■		□
PC/PET	▲	▲		▲	▲		▲	▲	▲	▲	△	■	▲	▲	□	■		■		□
PE	□	■	■	□	□		□					△				▲			□	▲
PETP	▲	▲					▲	▲		▲	▲	■	△							□
PMMA	▲	▲					□			▲	▲	■		△		■	■	■	▲	□
POM	□	■	■	■	■	□	□	□	□	□	□	■			△					□
PP		■	■	□	□	□	□	■	■	■	■	▲		■		△	□			
PPO	■	■	■	■	■	■								■		□	△			□
PS	■	■		■	■		□	■	■	■	■			■			▲	△		□
SAN	□	▲	▲				▲	▲	□	□	□	□		▲			■	□	△	▲
TPE/TPU	□	□		□	□	□	□	□	□	□	□	▲	□	□	□	□	□	□	▲	△

Designation	Ahhesion
■	no adhesion
□	limited
▲	normal
△	high

At sandwich molding following material combinations for a sheath and the core are possible:

• solid sheath – foam core,

• solid sheath – solid core

For walls in the thickness more than 4 mm are used the solid material in a combination to a core made from a foam secondary polymer (figure 1). It allows to avoid appearance of sections with shells that reduces internal pressure in a mold product. The details made on this method unite in themselves favorable structural properties of details from the foam polymeric material with a low roughness of solid details surface [8].

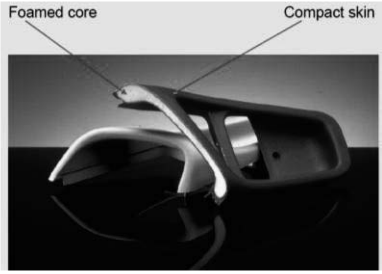

Fig. 1. Solid material in a combination to a core made from a foam secondary polymer

For walls in the thickness less than 4 mm a sheath and core materials are solid. In this case specific properties of a product are reached at the expense of raw materials correct selection for sheath and core (figure 2).

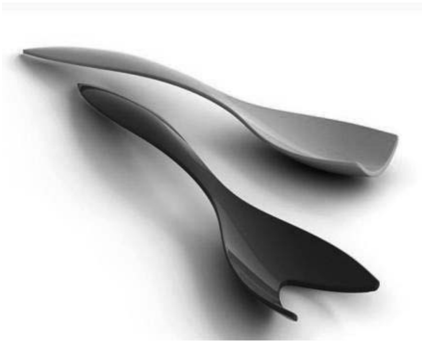

Fig. 2. Solid material in a combination to a solid core from a secondary polymer

High quality of a detail surface at low durability of an external material can be added with high strengthening properties of a core material [10].

For saving of resources as a core material it is necessary to use products of secondary plastic processing. In a combination to a sheath from a raw material such combination allows to receive products with high quality of a surface. Such approach has received the greatest propagation in the autoindustry where as a core material for brand new bumpers the overage processed plastic details of the cars are used. Insignificant impairment of polymeric material properties after secondary processing doesn't affect the general physical and mechanical properties of a completed product.

CONCLUSIONS

One of the main factors affecting the quality of the finished product, produced by multicomponent molding is the compatibility of polymers and the uniformity of the melt (thickness variation) in the mold. Compatibility is determined by the chemical nature of the material and can be improved through the introduction of additives or adhesives.

The analysis of materials for qualitative plastic parts production by means of multicomponent molding using raw materials as the core it is necessary to pay attention to following five pacing factors:

1. Adhesion of materials.
2. Polymers thickness.
3. Shrinkage of these materials.
4. Thermal extensions for both materials.
5. Polymer melts viscosity.

REFERENCES

1. Dyadychev V.V., Pugacheva H.A., Kildeychik A.A., 2010.: Co-injection molding as one of the most popular injection molding technologies for manufacture of polymeric details from secondary raw materials. - TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2010, 10C, pp. 88-93.
2. Люкс Ф., 1999.: Упаковка и экология: Пер. с англ. - М.: изд-во МГУП, 1999. – 220 с. Osswald, Tim A; Lih-Sheng Turng, Paul J.Gramamn, 2007. Injection Molding Handbook, 2nd Ed. Hanser Verlag., 2007 (pp. 288-289, pp. 337-338).
3. Avery J.A., 1996.: Innovation in Polymer Processing – Molding. Munich: Hanser, 1996 (pp. 331-365).
4. http://www.battenfeld-imt.com/en/anwendungstechnik/mehrkomponenten-spritzgiessen.html - Multicomponent technology.
5. Osswald, Tim A; Lih-Sheng Turng, Paul J.Gramamn, 2007.: Injection Molding Handbook, 2nd Ed. Hanser Verlag., 2007 (pp. 288-289, pp. 337-338).
6. Jack Avery, 1998.: Injection molding alternatives: a guide for designers and product engineers. Munich: Hanser, 1998. (pp, 34-48).
7. http://www.ticona.com/home_page/tech/processing/special_injection_molding/multi-component.htm - Multi-Component Molding
8. Multicomponent Molding. The World of Technics and Technologies, 2010, March #5(102) (pp.38-40).
9. http://terpconnect.umd.edu/~skgupta/M3T/MMMP.html - Multi-Material Molding Processes
10. http://www.ticona.com/home_page/tech/processing/special_injection_molding/multi-component.htm - Multi-Component Molding
11. Musa R. Kamal, Avram I. Isayev, S. Liu, 2009.: Injection Molding: Technology And Fundamentals (Hardcover) (pp. 3-5)
12. http://polimers.at.ua/publ/lite_plastmass_pod_davleniem/1-1-0-69 - Injection Molding of Plastics.
13. http://www.polytechnika.ru/?id=6372 – Demag BARS – German quality in Russia.
14. Joseph B Dym, 1987.: Injection molds and molding: a practical manual. New York: Van Nostrand Reinhold. (pp. 313-322)

15. Douglas M Bryce. Plastic injection molding: manufacturing process fundamentals. Dearborn, Mich.: Society of Manufacturing Engineers, 1996. (pp. 6-7)
16. Jay Shoemaker, 2006.: Moldflow design guide: a resource for plastics engineers. Munich: Hanser. (pp. 173-190).
17. John P. Beaumont, 2007.: Runner and Gating Design Handbook: Tools for Successful Injection Molding. Munich: Hunser (pp. 7-13).
18. Gerd Pötsch,Walter Michaeli, 2008.: Injection molding: an introduction. Munich: Hunser (pp. 15-46).
19. Herbert Rees, 2001.: Understanding injection mold design. Munich: Hunser (pp. 74-77).
20. Dominick V. Rosato,Donald V. Rosato,Marlene G. Rosato, 2000.: Injection molding handbook. Boston : Kluwer Academic (pp. 479-513)

ВЫБОР МАТЕРИАЛОВ ДЛЯ ПРОИЗВОДСТВА ПОЛИМЕРНЫХ МАТЕРИАЛОВ МЕТОДОМ МНОГОКОМПОНЕНТНОГО ЛИТЬЯ ПОД ДАВЛЕНИЕМ

Валерий Дядичев, Елена Пугачева, Алексей Кильдейчик

Аннотация. В статье произведен анализ факторов, влияющих на качество готового полимерного изделия, выполненного с использованием многокомпонентного литья под давлением.

Ключевые слова: литье под давлением, вязкость, усадка, полимер.

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COMPUTER SYSTEM NOTIFIES THE DRIVER ABOUT THE FACT OF FALLING ASLEEP

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Summary. Considered the problem of falling asleep driver. Proposed a method of detecting the fact of falling asleep, by finding and subsequent analysis of the face. Describes the basic principles of methods and approaches to pattern recognition for the implementation of an integrated system of voice control with the possibility of interactive communication, the function of preventing from falling asleep.

Key words: automobile, electronics, computer system, voice control, interactive communication, voice, speech dictionary**.**

INTRODUCTION

New technologies every in part of everyday life and allow you to improve the world, making life more compact and convenient Fortney. Taking the example of existing vehicles should be noted that not every vehicle is fully uses modern technology designed to enhance comfort and safety that does not require extra effort and attention.

Introduction to the vehicles computer system of interactive communication, as well as an additional set of warning the driver from falling asleep, substantially reduce the risk of accidents associated with the distraction of managing board of machine functions and alerts the driver falling asleep [1, 2] .

Recognition of voice commands is an issue of advanced technologies. Despite the fact that today's automotive industry reached the summit of progress, still very hard to find a vehicle equipped with voice recognition and controls with the help of on-board commands. Famous automobile concerns BMW, VOLVO, Mercedes striving to improve driver comfort and safety on the roads, so the latest models of their designs make it possible to control the on-board electronics using your voice ("turn on the radio, turn on the next station, call number, etc.") [3, 4].

OBJECTS AND PROBLEMS

The aim is to increase the degree of safety and ease of driving, as well as to prevent falling asleep while driving the driver. Tasked with developing a system to get rid of unnecessary manipulation of the driver, while watching his face, by analyzing the eye area and to identify the fact of falling asleep. The absence of the various buttons, and the need to push, substantially reduces the risk of danger to distract the driver while driving.

On the basis of the developed computer system voice control features on-board the vehicle [4], established control module driver falling asleep at the fact [5]. This system can be integrated into a normal car, and still provide, as well as comfort while driving, and safety (fig. 1). [7].

Fig. 1. Mounted in an upgraded computer front panel car

When it was creating software for the detection of the factor of sleep is necessary to put implementation of machine vision (IMV). Complex devices that are part of the system includes a specific set of technical tools. The main camera is, to capture the image, and image processing unit or controller. Additional devices, but no less important are the optics, which determines the boundaries of the camera, the light that illuminates the object of observation, and the display is required to display the information in real time and to configure the system[8-9].

Ability to perceive the external world in the form of images allows a certain authenticity to recognize an infinite number of objects on the basis of acquaintance with a finite number of them, but the objective nature of the basic property of the images allows the fashion-modulated process of their recognition. As a reflection of objective reality, the concept of image as objectively as reality itself, and therefore this concept may be in itself the object of special study [10,11].

But as it turned out to make vision systems to work is no easy task, so it became necessary to construct a mathematical model of camera and determine the values of all parameters in the model, using OpenCV[12,13]. This model is very useful when you need to perform measurements with a camera (fig. 2).

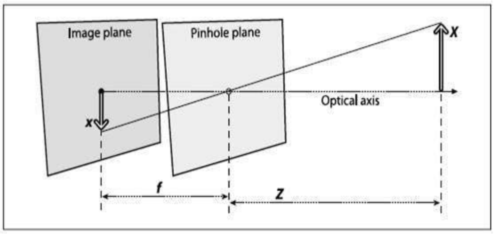

Fig. 2. The schematic model of the camera

Perspective projection equation looks as so:

$$-u = f \cdot \frac{X}{Z}. \tag{1}$$

Given the fact that usually the main optical axis, Skye does not pass through "charge-coupled device" (CCD) - a matrix with the coordinates (0, 0):

$$-u = f \cdot \frac{X}{Z} + c. \tag{2}$$

Here: *c* - coordinate of the point of intersection of the main optical axis of the CCD array[14]. Given the fact that because of technological manufacturing error matrix pixels are slightly rectangular in shape, were obtained equations for X and Y coordinates:

$$f_u = s_u \cdot f,$$
$$f_v = s_v \cdot f,$$
$$u = f_u \cdot \frac{X}{Z} + c_u,$$
$$v = f_v \cdot \frac{Y}{Z} + c_v, \tag{3}$$

where: s_u and s_v - the coefficients of the pixel.

To them it was more convenient to work, shall show the perspective projection equation in matrix form:

$$u_{corrected} = u \cdot (1 + k_1 + r^2 + k_2 \cdot r^4),$$
$$v_{corrected} = v \cdot (1 + k_1 + r^2 + k_2 \cdot r^4). \tag{4}$$

Here: r - distance from the intersection of the main optical axis of the CCD to the point of projection; k1, k2 - factors the radial distortion.

Introduce the function:

$$\lambda = 1 + k_1 \cdot r^2 + k_2 \cdot r^4). \tag{5}$$

Then the matrix equation perspective projection has the form:

$$q = \frac{1}{Z} \cdot \begin{pmatrix} \lambda & 0 & 0 \\ 0 & \lambda & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot M \cdot Q. \tag{6}$$

The orientation errors:

$$R_z(\theta) = \begin{pmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix};$$

$$R_x(\psi) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\psi) & \sin(\psi) \\ 0 & -\sin(\psi) & \cos(\psi) \end{pmatrix};$$

$$R_y(\varphi) = \begin{pmatrix} \cos(\varphi) & 0 & -\sin(\varphi) \\ 0 & 1 & 0 \\ \sin(\varphi) & 0 & \cos(\varphi) \end{pmatrix}. \tag{7}$$

The resulting matrix of camera rotation around the desired coordinate system:

$$R(\psi, \varphi, \theta) = R_x(\psi) \cdot R_y(\varphi) \cdot R_z(\theta). \tag{8}$$

Now the camera model, taking into account the radial distortion and errors in the installation looks as:

$$q = \frac{1}{Z} \cdot \begin{pmatrix} \lambda & 0 & 0 \\ 0 & \lambda & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot M \cdot R \cdot (Q + T). \tag{9}$$

We now turn to homogeneous coordinates:

$$\begin{pmatrix} u_i \\ v_i \\ 1 \end{pmatrix} = \frac{1}{Z} \cdot \begin{pmatrix} \lambda & 0 & 0 \\ 0 & \lambda & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot M \cdot \begin{pmatrix} r_{00} & r_{01} & r_{02} & t_x \\ r_{10} & r_{11} & r_{12} & t_y \\ r_{20} & r_{21} & r_{22} & t_z \end{pmatrix} \cdot \begin{pmatrix} X_i \\ Y_i \\ Z_i \\ 1 \end{pmatrix}, \tag{10}$$

where: r_{ij} – the relevant parts of the resulting matrix rotate the camera around the desired reference system;

t_x, t_y, t_z - the components of displacement-ka measure of the required coordinate system.

The model includes internal camera: f_u, f_v - focal length; c_u, c_v - the position of the optical center and the external parameters: three Euler angles, the three components of the vector transmission[15,16].

The definition of these parameters on OpenCV, ie to calibrate the camera. The principle of calibration can be seen in the images of the chessboard. Knowing how to located the corners of the chessboard, numerically selected camera settings. OpenCV has a set of built-in support for this model calibration. For convenience, the preparation of such algorithms used Open Motion Planning Library, written in the platform specifically to boost planning trajectories of mobile robots and manipulators [17,18].

During the experiment, part of which was a distinction between open and closed eyes of the driver, the following results[19]. The camcorder was mounted on the windshield of the vehicle (fig.3).

Fig. 3. The camera position

In order to be recognized driver's face during the night used the camera with infrared vision LED. In identifying the recognition of sleep and driving, the system issues a warning signal and begins to communicate with the driver. To prevent subsequent sleep with the driver is a dialogue, a set of pre-recorded phrases that can be changed at will[20].

Figure 4 (a, b), made two imaging taken with the camcorder.

Fig. 4 a. The camera detect sleeping

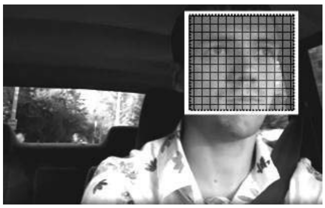

Fig. 4 b. The camera normal view

CONCLUSIONS

This system, which increases the degree of safety and ease of driving, preventing sleep a driver while driving. The system software is implemented to detect the factor sleep through the implementation of machine vision (IMV). A mathematical model of the camcorder and the values of all parameters in the model, using OpenCV. For the calculations used Open Motion Planning Library, written in a specialized platform boost for planning the trajectories of mobile robots and manipulators.

REFERENCES

1. Redzyuka A.M., 2005.: Road transport of Ukraine: status, problems and prospects: onograph / State Road Transport Research, p. 67-89.
2. Chelyabin P. N., 2004.: Horizons Transport: Good transport policy / Expert Council of the Federation Council Industrial Policy p. 13-49.
3. Anselm D., 2006.: Zwei Jahre elektronishe Wegfahrsperre. Electronik im Kraftfahrzeug, Tagung Baden-Baden, p. 110 - 123.
4. Schurmann J. F., Meier H. J., 2008.: TIRIS - Leader in Radio Frequency Identification Technology, Texas Instruments Technical Journal Vol. 10. No. 6, p. 30 - 71.
5. Rosenblatt V. F., 2005.: The problem of fatigue, "Nauka", p. 23- 45.
6. Abelson R., 1973. The Structure of Belief Systems, in "Computer Models of Thought and Language" in R. Shank K. Colby, San Francisco, p. 34-63.
7. Underwood S, Gates C., 1972.: Visual Learning and Recognition by Computer, TR-123, Elect. Res. Center University of Texas, p. 64-81.
8. Goldstein I.,2001.: Understanding Simple Picture Programs, Ph.D.Thesis, AI-TR-294, Artificial Intelligence Laboratory, MIT, Cambridge, p.67-89.
9. Gombrich E.,2006.: Art and Illusion, Pantheon Books, New York, p. 43-87.
10. Guzman A., 2001.: Some Aspects of Pattern Recognition by Computer, Thesis, MAC-TR-37, Project MAS, MIT, Cambridge, Mass, p. 21-53.
11. Koffka K., 2001.: Principles of Gestalt Psychology, Brace and World, New York, p. 23-63.
12. Lavoisier A., 1998.: Elements of Chemistry, Great Books of the Western World, v. 45, Encyclopedia Britannica, Chicago, p. 28-93.
13. Levin J.,1993.: Network Representation and Rotation of Letters, Dept. of Psychology, USCD, La Jolla, Calif., p. 24-43.
14. McDermott D., 1984. Assimilation of New Information by a Natural Language Understanding System, M.S.Thesis, MIT Artificial Intelligence Laboratory, Cambridge, Mass. , p. 117-163.
15. McDermott D., 1984. Assimilation of New Information by a Natural Language Understanding Syste, MIT Artificial Intelligence Laboratory, Cambridge, Mass. , p. 117-163.
16. Fillmore C.,2001.: The Case for Case, in "Universal in Linguistic Theory", Chicago, Bach E. Harms R. (eds.), N.Y., p. 45-55.
17. Freeman P., Newell A., 2003.: A Model for Functional Reasoning in Design, Proc. Second Intern. Conf. on Artificial Intelligence, London, p. 105-115.
18. Huffman D., 2007.: Impossible Objects as Nonsense Sentences, in "Machine Intelligence 6", Meltzer B., Michie D. (eds.), Edinburgh University Press, Edinburgh, p. 45-55.
19. Hogarth W., 2005.: Hogarth essays, Garden City, New York, p. 9-55.
20. Chomsky N., 2006.: Syntactic Structures of Voice recognition, The Hague, p. 75-105

КОМПЬЮТЕРНАЯ СИСТЕМА ПРЕДУПРЕЖДАЮЩАЯ ВОДИТЕЛЯ О ФАКТЕ ЗАСЫПАНИИ

Валерий Дядичев, Татьяна Терещенко, Игорь Морозов

Аннотация. Рассмотрена проблема засыпания водителя, предложен метод обнаружения факта засыпания, путём поиска и последующего анализа лица. Описаны основные принципы методов и подходов к распознаванию образов для реализации комплексной системы голосового управления с возможностью интерактивного общения, функцией предупреждения от засыпания.

Ключевые слова: автомобиль, электроника, компьютерная система, голосовое управление, интерактивное общение, голос, речевой словарь.

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THE EXPERIMENT PLANNING AND TECHNOLOGICAL PROCESS MODELLING OF THE DETAILS' MANUFACTURING BY HOT STAMPING

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Summary. The variable factors of technological process of detail manufacturing by hot stamping were defined; the matrix of experiments' planning was designed; the calculation of mathematical models of steepest ascent was made and the optimal index of detail manufacturing were achieved, which correspond to the requirements of technological process. The comparison of calculated and experimental data was also made.

Key words: work material, stamp, heating temperature, heating time, experiment, planning matrix, factors, mathematical model.

THE DEFINITION OF THE TASK

The search of optimal levels of parameters is one of the main tasks, which is being decided while making new technical schemes while production or technological processes control. Implementation of the optimization task, based on the theory of experiment planning, just as any task of experimental research, starts from the definition of the object of analysis, the aim of the research, studying of the essence of the observable process, the analysis of the existing resources, the possibility of making the experiment on the studied object in the needed diapason of changing factors. The planning of the experiment helps to increase the labour productivity, the reliability of the results, the minimization of the total number of experiments, simultaneous variation of all variables, that define the process, and also the choice of strict strategy, that permits to take reasonable decisions after each series of experiments .

THE ANALYSIS OF THE LATEST RESEARCHES AND PUBLICATIONS

Under the data, given in the article [1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22], there was made the experiment planning while manufacturing the detail by hot stamping.

THE AIM OF THE WORK

To synthesize the mathematical model and to define the optimal indices of detail manufacturing by hot stamping.

THE MAIN RESULTS OF THE RESEARCHES

To get the optimal parameters of the detail manufacturing (lifting screw) by hot stamping there was made the experiment planning [2, 4, 13, 19, 20, 21].

The factors that define the process were examined:

X_1 – heating temperature of the work material ^{0}C;
X_2 – heating time work material, min;
X_3 – heating temperature of the stamp ^{0}C;
X_4 – nominal mass of the falling parts of the hammer, kg;
X_5 – the number of hits of the hammer;
X_6 – air pressure of the hammer, MPa.

The chosen variable factors and their diapasons are:
$X_1 = 1000^0C \div 1200^0C$;
$X_2 = 5 \div 22$ min;
$X_3 = 150^0C \div 300^0C$.

The matrix of experiment planning to define thickness of the detail and the results of the experiment are given in the table1.

Table 1. **The matrix of planning and the results of the experiment**

№	X_1	X_2	X_3	$h_{\det}$	$h'_{\det}$	$\bar{h}_{\det}$	$\Delta h_{\det}$	$\Delta h^2{}_{\det}$	$S^2{}_{ad}$	$S^2_{i\ \det}$	y
1	-1	-1	-1	10,15	10,20	10,17	0,02	0,0006	0,0002	0,0006	10,5338
2	1	-1	-1	11,00	10,98	10,99	-0,01	0,0001	0,0001	0,0001	10,7378
3	-1	1	-1	11,03	11,10	11,06	0,03	0,0012	0,0003	0,0012	10,8673
4	1	1	-1	11,01	10,95	10,98	-0,03	0,0009	0,0002	0,0009	11,0713
5	-1	-1	1	10,08	11,00	10,54	0,46	0,2116	0,0529	0,2116	10,5178
6	1	-1	1	10,60	11,01	10,80	0,20	0,0424	0,0106	0,0424	10,7218
7	-1	1	1	11,02	10,96	10,99	-0,03	0,0009	0,0002	0,0009	10,8513
8	1	1	1	10,98	10,64	10,81	-0,17	0,0289	0,0072	0,0289	11,0553

PROCESSING OF RESULTS OF THE EXPERIMENT

The following experimental and calculating data was put in the table 1 while making the experiment:

$h_{\det}$ – thickness of the detail in first measuring, mm;

$h'_{\det}$ – thickness of the detail in second measuring, mm;

$\overline{h}_{\det}$ – arithmetic mean of thicknesses of the details on results of the experiments, mm;

$\Delta h_{\det}$ – difference between arithmetic mean of thicknesses of the details and thickness of the detail in first measuring, mm;

n – the number of the parallel experiments, *n* = 2;

$$S^2_{i_{\det}} = \frac{\sum_{i=1}^{N}\left(h_{\det i} - \overline{h}_{\det i}\right)}{n-1}$$ – dispersion of the arithmetic mean in each line of matrix;

$$S^2{}_y = \frac{\sum_{i=1}^{N} S^2_{i\det}}{8}$$ – dispersion of repeatability;

$$S^2_{ad} = \frac{\Delta h^2{}_{\det i}}{f}$$ – dispersion of adequacy;

where: $f = N - (k+1)$ – is the number degree of freedom; f = 4;

N – is the number of experiments;

k – is the number of factors;

$F_{\det}$ – is Fisher's criterion;

Y – is the parameter of optimization, calculated according to the equation of regression, mm.

Mathematical model for defining the thickness of the detail is presented as a polynomial:

$$h_{\det} = b_0 + b_1 \cdot X_1 + b_2 \cdot X_2 + b_3 \cdot X_3;$$

where: $b_0; b_1; b_2; b_3$ – are coefficients of mathematical model;

X_1, X_2, X_3 – are factors.

After calculation of the coefficients the mathematical model becomes like this:

$$h_{\det} = 10{,}7945 + 0{,}1020 \cdot X_1 + 0{,}1668 \cdot X_2 - 0{,}008 \cdot X_3.$$

The tabulated value of the criterion of Cochran is 0,679. As far as the experimental value of the criterion of Cochran (0,37) does not exceed the tabulated one (0,679), the hypothesis about the uniformity of dispersions is true.

The model is appropriate, because the experimental value of Fisher's criterion (6,4) does not exceed the tabulated one(6,8).

DECISION-MAKING AFTER MAKING THE MODEL

Synthesized linear model is appropriate and looks like polynomial of the first-degree. Coefficients of polynomial are partial derivatives of the function of response on appropriate variables. The signs of coefficients tell us about the character of the factors' influence. Plus sign means that with the increase of value of the factor the optimization parameters increase as well, and with the decrease the optimization parameters decrease. As all the coefficients are significant, we pass to the movement on gradient to reach the optimum area.

The conditions, the planning matrix, the results of the experiments series and the calculation of steepest ascent are given in the table 2.

Table 2. **Planning matrix, the results of the experiments series and the calculation of steepest ascent**

Levels	Factors			Response
	$\widetilde{X}_1$	$\widetilde{X}_2$	$\widetilde{X}_3$	
Main	1050	10	225	
Variability interval	150	5	75	
Superior	1200	15	300	
Inferior	900	5	150	
b_i	0,1020	0,1668	-0,008	
$b_i \times I_i$	15,3	0,8338	-0,6	
Step for X_i				
Truncation	15	0,8	-0,6	
9	1065	10,8	224,4	10,83
10	1080	11,6	223,8	10,87
11	1095	12,4	223,2	10,91
12	1110	13,2	222,6	10,94
13	1125	14	222	10,98
14	1140	14,8	221,4	11,02
15	1155	15,6	220,8	11,05
16	1170	16,4	220,2	11,09

CONCLUSIONS

In the experiment № 14 we achieved the optimal indices of the detail manufacturing, that correspond to the requirements of the technological process. When the heating temperature of the work material is 1140^0C , heating time of the work material is 14,8 mins and heating time of the stamp is 221,4^{0}C , the thickness of the detail is 11,02 mm and it is in the acceptable limit (11÷ 11,02).

Experimental and calculation data is given in the table 3.

Table 3. **Experimental and calculation data**

Parameters	Boundary indices of the technological process	Manufacturing indices of the technological process	Optimal indices after the calculation
Heating temperature of the work material, ^{0}C	1100…1200	1110	1140
Heating time of the work material, min	8…22	10	14,8
Heating temperature of the stamp, ^{0}C	150…300	150	221,4
Nominal mass of the falling parts of the hammer, kg	1000	1000	1000
The number of hits of the hammer per minute	80	80	80
Air pressure of the air-and-steam hammer, MPa	0,6…0,8	0,65	0,65

REFERENCES

1. Sytnik V.V. 2010.: The Research of the Technological Process of Hot Stamping while Details Manufacturing / V.V.Sytnik // Open information technologies and computer integrated technologies. – Kharkiv:National Aerospace University named after N.E. Zhukovskiy “KhAI”. – Number 46. – Pages 109 – 113.
2. Adler Yu.P. 1976.: Experiment Planning during the Search of Optimal Conditions / Yu.P. Adler, Markova Ye.V, Granovskiy Yu.V. – Moscow: Science. – 275 pages.
3. Sytnik V. 2010.: Isledovaniye tehnologicheskogo procesa pri izgotovlenii detaley / Sytnik V. // Otkritiye informacioniye tehnologii I kompyuterniye integrirovaniye tehnologii. – H.: NAKU «HAI». –Vip.46. – P.109 – 113.
4. Adler U.P., Markova E.V., Granovskiy U.V. 1976.: Planirovaniye experimenta pri poiske optimalnih usloviy / U.P. Adler, E.V. Markova, U.V. Granovskiy – M.: Nauka,– 275 p.
5. Rizhov E.V., Gorlenko O.A. 1990.: Matematicheskiye metodi v tehnologicheskih / Rizhov E.V., Gorlenko O.A.– Kiyev: Nauka,– 184 p.
6. Moiseyev N.N., Ivanilov U.P., Stolyarova E.M. 1978.: Metodi optimizacii / N.N. Moiseyev, U.P. Ivanilov, E.M. Stolyarova – M.: Nauka,– 352 p.
7. Polyak B.T. 1983.: Vvedeniye v optimizaciyu / B.T. Polyak – M.: Nauka,– 384 p.
8. Pontryagin L.S. i dr. 1983.: Matematicheskaya teoriya optimalnih procesov / L.S. Pontryagin i dr. – M.: Nauka,– 392 p.
9. Boltyanskiy V.G. 1969.: Matematicheskiye metodi optimalnogo upravleniya / V.G. Boltyanskiy –M.: Nauka,– 408 p.
10. De Grot M. 1974.: Optimalniye statisticheskiye resheniya / De M. Grot – M.: Mir,– 496 p.
11. Rekleytis G., Reyvindran A., Regsdel K. 1986.: Optimizaciya v tehnike / G. Rekleytis, A. Reyvindran, K. Regsdel – Tom 2. M.: Mir,– 320 p.

12. Adler U.P. 1968.: Vvedeniye v planirovaniye experimenta / U.P. Adler – M.: Metalurgiya,– 155 p.
13. Krasovskiy G.I., Filaretov G.F. 1982.: Planirovaniye experimenta / Krasovskiy G.I., Filaretov G.F. – Mn.: Izd. BGU,– 302 p.
14. Yermakov S.M., Mihaulov T.A. 1976.: Kurs statisticheskogo modelirovaniya / S.M. Yermakov, T.A. Mihaulov – M.:– 296 p.
15. Zemlyanskiy A.A., Mordovin G.M. 2004.: Planirovaniye experimenta I statisticheskaya obrabotka rezultatov / A.A. Zemlyanskiy, G.M. Mordovin – Balakovo: BITTU,– 32 p.
16. Gabasov R.F., Kirilov F.M. 1981.: Metodi optimizacii / R.F. Gabasov, F.M. Kirilov – Mn.: Izd. bel. gos. un.,– 350 p.
17. Kolemayev V.A., Kalinina V.N. 2001.: Teoriya veroyatnostey I matematicheskaya statistika / V.A. Kolemayev, V.N. Kalinina – M.: INFRA,– 302 p.
18. Rastrigin L.A. 1968.: Statisticheskiye metodi poiska / L.A. Rastrigin – M.: Nauka,– 376 p.
19. Nalimov V.V. 1971.: Teoriya experimenta / V.V. Nalimov – M.: Nauka,– 207 p.
20. Fini D. 1970.: Vvedeniye v teoriyu planirovaniya experimenta / D. Fini – M.: Nauka,– 288 p.
21. Hiks C. 1967.: Osnovniye principi planirovaniya experimenta / C. Hiks – M.: Mir,– 408 p.
22. Yanoshi L. 1968.: Teoriya I prektika obrabotki rezultatov izmereniy / L. Yanoshi– 462 p.

ПЛАНИРОВАНИЕ ЭКСПЕРИМЕНТА И МОДЕЛИРОВАНИЕ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ИЗГОТОВЛЕНИЯ ДЕТАЛЕЙ ГОРЯЧЕЙ ШТАМПОВКОЙ

Ирина Кириченко, Николай Кошевой, Виктория Сытник

Аннотация. В статье выполнен расчет математической модели, крутого восхождения и достигнуты оптимальные показатели изготовления детали, которые соответствуют требованиям технологического процесса. А также выполнено сравнение расчетных и полученных экспериментальным путем данных.

Ключевые слова: температура нагрева, время нагрева, эксперимент, матрица планирования, факторы, математическая модель.

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CREATING A SOFTWARE SYSTEM FOR CONSTRUCTION OF THE DAILY SCHEDULE FOR RAILWAY INDUSTRIAL ENTERPRISE

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Summary. This article contains the description of the structure of software which is now under development and will be used for planning cargo operations and maneuvering on the industrial rail transport. Data representation in the program considered. The functional features of the program units are described.

Keywords: automation, daily schedule, locomotive, cargo fronts.

INTRODUCTION

One of the main country transport system's elements is industrial enterprises' transport where the bulk of traffic volume is born and redeemed. On the enterprise wagons undergo significant transport and technological processing consisting of cargo, maneuverable and technological operations. Therefore the question of optimal planning of railway traffic complex stays actual for a long time. The important topic for operational planning automation is the creation of program product (traffic controller's automated working station (WKS) which will allow to reduce operating costs and increase the effectiveness of traffic controller's work, as well as to fulfill rating, planning and control over the executing of technological operations functions on the enterprise[3,4,10].

Traditionally the daily schedule is used to solve the present day planning problems. But building a daily schedule is a quite labor intensive process which requires considerable efforts from the scheduler. It is possible to solve this problem with the help of computerization, particularly by automation of building daily schedule. That's why it was decided to create programming tool set which will allow to fulfill building at a high rate and to avoid mistakes during this process[1,2].

OBJECTS AND PROBLEMS

The analysis of scientific achievements on this topic indicates, first of all, big actuality of the considered task. Projects of traffic controller's automated working station (WKS) can be seen among foreign and Ukrainian specialists' publications but this research is notable for searching for methods of problem solving support for development system[6,7,8,9,11,12].

Let us look at the development system's structure. It consists of several separate units that interact with each other, thus making the system work. Each unit is separated from others thus change of separate system part do not affect its integrity and other units work[14].

The program consists of separate units each of which carries out its part of work. We allocated following units: *database information processing unit; wagons and trains revision unit; stations and cargo fronts' revision unit; locomotive revision unit; logic of program work unit; graphic display unit; program interface.* On the fig. 1 we depicted interaction between mentioned units, user and database.

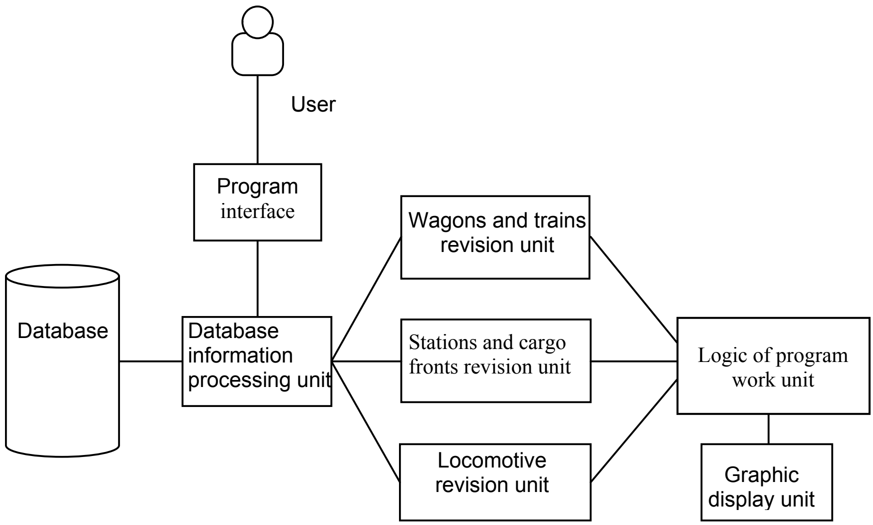

Fig. 1. Scheme of program units interaction

Database information processing unit (DB) is responsible for downloading and presentation of the information from the database in the program. The database is a link that connects components of the future WKS one element of which is developing in this research system for building daily schedule. Database information processing unit must maintain constant connection with a database and to control input and output information in the real-time mode. It also has to provide updated information for operative reflection of changes in the database in the system graphic interface. Any changes in the logical structure of the daily schedule should also be stored immediately in the database with the purpose to use them with other elements of railway company WKS. This approach will make it easy to combine daily schedule editor with any WKS systems and will provide overall system stability.

Wagons and trains revision unit allows to edit, add and look through existing trains and wagons. All the necessary information for the unit work about available wagons and trains can be either downloaded from the database (with the help of appropriate unit) or entered directly by the user. This unit interacts closely with the database information processing unit as the data entered by the user must be operatively saved to the database and be downloaded from it in the future. Information about the train is given in such way:

$$T_i = \{N, C_a, t_a, t_w, L\}, L = \{L_1, L_2, ..., L_{Ca}\}, \quad (1)$$

where: N – train number; C_a – the wagons quantity; t_a – time of the train arrival at the connecting station; t_w – time of the train technological processing beginning; L – the list of wagons in the train[10].

Stations and cargo fronts' revision unit is responsible for presenting stations and cargo fronts, downloaded from the database, in the program as well as for possibility to edit and add new ones. Information about the cargo front is given in such way:

$$F_i = \{N, T_c, C\}, \quad (2)$$

where: N – cargo front number; T_c – cargo front at the given front; C – maximal cargo quantity at the given cargo front[6,15].

Locomotive revision unit is responsible for editing the information about available locomotives. Information on the locomotives is also stored in the database, and can be downloaded and stored there at any time of the program work. Information about locomotives may be presented in such way:

$$L_i = \{N, C, n_c\}, \quad (3)$$

where: N – locomotive number, C – the cost of one hour of locomotive work, n_c – locomotive power measured in the quantity of wagons it can move simultaneously[5,13].

Logic of program work unit performs checks on the possibility of existence of data entered to the program, protection against user's errors and determines the sequence of the program execution. Logic unit provides the control over the sequence of user's actions and performs checks on the validity of entered data which is related to the technological operations. Operation concerning work logic unit has the following look:

$$O_i = \{N_f, T, C_a, t_b, D, C_l, L\}, C_l = \{C_1, C_2, ..., C_{Ca}\}, \quad (4)$$

where: N_f – number of the cargo front where the operation is executed; T – cargo operation type; C_a – the quantity of wagons which take part in the operation; t_b – the time of the operation start; D – the operation duration; C_l – the list of wagons which take part in the operation; L – locomotive which maintains the given operation.

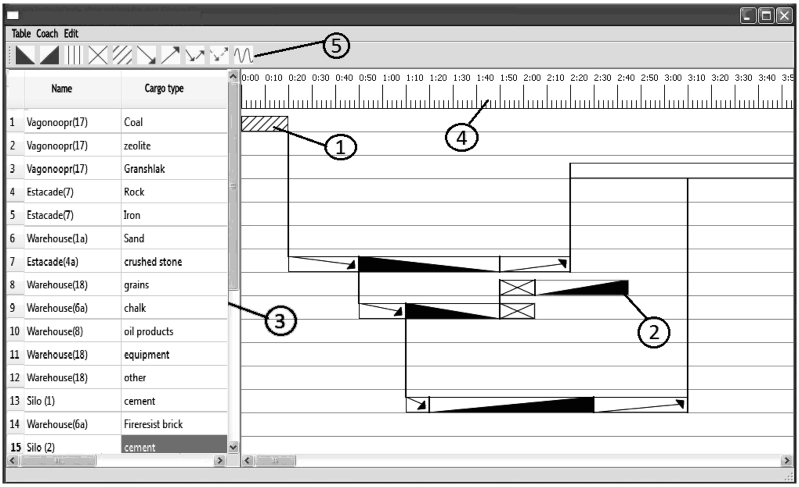

Fig. 2. The main window of the program with the part of ready-built daily schedule
1 – graphical display of the individual transaction (display unit); 2 –visual message about disarranged wagons (work logic unit); 3 – the list of enterprise cargo fronts (station revision unit); 4 – the bar which transfers date and time into screen coordinates (work logic unit); 5 – types of transactions, acceptable for the station (database information processing unit)

Also internal logic of program unit checks locomotive occupancy and cargo front employment at the moment of some transaction; allows the user to receive the information about any wagon state at any moment of time; and also it displays transactions after which there are crude wagons or a free locomotive.

Graphic display unit is responsible for displaying the results of interaction between the user and the program, particularly in the form of daily schedule. It is used for visualization of the work of all previous units and also it implements user's graphic interface (fig. 2).

Thus not only the effective program work is achieved but also, what is more important, the possibility to expand the program for new needs which may appear during the practical use arises.

CONCLUSIONS

The developed suite of tools is able to facilitate greatly the railway station controller's work by excluding from his work not only the necessity to measure and draw graphic elements (with the risk to make a slight mistake in the detail which will entails entirely wrong daily schedule), and also the need to follow the logical transaction sequence and the order of data constantly. It will allow building a daily schedule quicker, more efficiently and with fewer mistakes. The system will also allow correcting mistakes without rebuilding of the daily schedule from the very beginning.

Structural system of work will allow easily expanding the system if it is required and will supply with compatibility of the tool set with other systems of parallel allocation, for example, it will allow to combine the program with earlier developed visualizer unit which allow to enhance facilities of the railway enterprise operator's WKS.

Also perspectives of the program enhancement include numerous possibilities to automate the process of the building and clearing transactions of the logical plan such as the priority of removal and feed of wagons to cargo fronts, the calculation unit for maneuver operations etc.

REFERENCES

1. Akulinichev V.M., 1979.: The organization of the car traffic volume on the railway transport. Moscow: Transport.
2. Akulinichev V.M., 1983.: The organization of shipping operations by industrial transport: Student's book. – Moscow: Transport
3. Bobrovs'kij V.I., Kozachenko D.M., Vernigora R.V., 2004.: Basic track development model in simulation models of railway stations. // Edited volume UkrDAZT: Series "Improving cargo and commercial work on Ukrainian railway stations". – # 62. – Harkiv: UkrDAZT. – p. 20-25.
4. Bobrovs'kij V.I., Kozachenko D.M., Vernigora R.V., 2004.: Technical and economic administration of railway stations on the basis of ergative models // Information and control systems on the railway transport. – № 6. – p. 17-21.
5. Goncharov N.E., Kazantsev V.P, 1978.: Maneuvering work on a railroad: the scientific publication. - Moscow: Transport.
6. Kolodiy L.P., Mishchenko N.G., Sidyakov V.A., 1986.: Railway stations and industrial junction of transport: - Moscow: Transport.
7. Korop G.V., 2008.: Logistic approach in the planning of maneuvering work with a sufficient number of paths / The reporter of ENU im.V.Dalya. - Lugansk. - № 7 (125). - p. 164-172.
8. Korop G.V., Ovcharenko A.O., Titakov S.O., 2009.: Improving existing methods of planning maneuvering work / / The reporter of ENU im.V.Dalya. - Lugansk. - № 5 (135).
9. Kozachenko D.M., Vernygora R.V., Korobyova R.G., 2008.: Software system for simulation of railway stations on the basis of daily schedule / D.M. Kozachenko, R.V. Vernygora, R.G. Korobyova / / Rail transport in Ukraine. - № 4. - p. 18-20
10. Kozlov I. T., 1985.: The capacity of transport systems / Kozlov T. - M.: Transport.
11. Levickij I. E., Korob'eva R.G., 2008.: Improving the processing of local car traffic volume in rail junctions // The reporter of Dnipropetrovsk national university of railway transport. – Dnipropetrovsk: Dnipropetrovsk national university of railway transport Press, # 23. – p. 104-107.
12. Nechaev G.I., Korop G.V., Slobodyanyuk M., 2009.: Automation of classification work planning at rail mode // Transport problems 2009. Conference materials. – p. 283-287.
13. Odintsov L.V., 1947.: Reviews of maneuvering work. - Moscow. Transzheldorizdat,.
14. Prata S.,2007.: C++ Primer Plus, 5th Edition. Lectures and exercises. Translated into Russian. – Moscow: I. D. Williams Ltd.
15. Sotnikov I.B., 1976.: Interaction of stations and sections of roads. Moscow: Transport.

СОЗДАНИЕ ПРОГРАММНОГО ПРОДУКТА ДЛЯ ПОСТРОЕНИЯ СУТОЧНОГО ПЛАНА-ГРАФИКА ЖЕЛЕЗНОДОРОЖНОГО ПРОМЫШЛЕННОГО ПРЕДПРИЯТИЯ

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Аннотация: В статье представлена структура разрабатываемого программного комплекса для планирования грузовой и маневровой работе на промышленном железнодорожном транспорте. Описаны функциональные особенности блоков программы.

Ключевые слова: суточный план-график, автоматизация, локомотив, грузовые фронты, вагонопоток.

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MODEL FOR TRANSPORT FLOW OPTIMISATION IN FLEXIBLE MANUFACTURING SYSTEM

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Summary. The articles describes a set of mathematical models to find the structure of transport flows in flexible manufacturing systems. It is shown that the suggested models can significantly increase performance of industrial systems. Fig. 3, Table. 4. sources 20.

Key words: flexible manufacturing system, transport flow, palettes, machine tools, assembly center, industrial robot, flexible assembly systems.

INTRODUCTION

The effectiveness of modern automated production systems (APS) is mostly determined by the efficiency of the transport system. The functioning process of APS is exposed to many influences that have a random nature. Furthermore, the degree of mutual influence of various subsystems APS is very high. These causes make little use to describe the functioning of the APS existing analytical methods [Krushevski, 1982,]. Unlike analytical models, simulation models allow to describe the work of APS more adequately. The use of simulation models allows the development of methods for assessing the impact assessment of the structure of transport flows on the effectiveness of APS work under the influence of numerous random factors that are random in nature. An increasing number of organizations are implementing Flexible Manufacturing Systems (FMS) to achieve competitive advantage [Talavage, 1999].

ANALYSIS OF PUBLICATIONS

Problems streamlining traffic flows were considered in many papers [Krushevski, 1982, Valkov, 1978]. There are many paper suggested different analytical method for defining optimal parameter of FMS. In [Solot, 2003] surveys the analytical methods that have been developed for optimizing the design of flexible manufacturing systems. A rough-cut analysis tool that quickly determines a few potential cost-effective designs at the initial design stage of FMS was presented in [Heungsoon, 2001]. The state-of-the-art research on flexible manufacturing systems (FMS) design and planning was described in [Kouvelis, 2001]. In [Vide, 1986] method for work flow optimization in an FMS to decrease requirements of secondary resources based on using a combination of static analysis and computer simulation, dynamic analysis have been developed. Set of mathematical models for solving vehicle routing problem was suggested in [Toth, 2002]. Different multi-criterion approaches to FMS scheduling problems have been described in [Gupta, 1991]. In [Pinot, 2007] was developed different solutions for jobs scheduling problem in flexible manufacturing systems. Set of problem concerning the operations aspect of FMS was reviwed in [Basneta, 1994]. In the process of operational management of APS is necessary to solve the problem, significantly different from the traditional, covered in papers [Lu, 2001, Qiao, 2002, Qiao, 2003]. The difference lies in the fact that APS is allowed simultaneous processing of products of various kinds. Problems for creating simulation models of FMS was discribed in [Felix, 2000, Ozdena, 1988, Park, 2005].

THE GOAL OF RESEACH

In here we propose the methods of searching a rational structure of transport flows APS.

In the basis of the developed method is a hybrid approach that combines simulation and analytical modeling. The effectiveness of the proposed approach is shown in the example of optimizing traffic flows in automated flexible assembly system. Proposed in this paper, the method allows to consider the influence of random factors on the functioning of the APS.

MAIN PART

Consider the functioning process of automated flexible assembly system (AFAS). Such systems are often used in the assembly of various instruments (pressure gauges, ammeters, etc.) [Heungsoon, 2001]. AFAS is a collection of units of main process device, combined into a single non-synchronous transporter system. As the main process device often use assembly centers (AC), built on the basis of industrial robots (IR), control-measuring machines. Non-synchronous transporter operates independently of the cycle of the major items of process device. Palettes (P), to which assembled appliances are being attached, are transported with the help of this transporter. Technological process of unit assembling starts with the installation of the unit case to the free P. Then in accordance with the established technological assembly routes the P is transported from one AC to another. Route of each P in the AFAS is defined by assembly process installed on the device. When choosing the route of a few ACs that can perform the requested operation, the AC which has the smallest load factor is selected. P is suited to the selected AC, and loaded on it with help of IR. If the AC is busy, the P stays on the transporter. In this case every next P stops when approaches the first, forming the line of P.

If the number of (P) caught in queue is more than the transporter can fit, then AC before which this queue was formed, will be blocked by this queue. It can not be loaded or unloaded until the clog is removed. As soon as the first P from a queue is loaded on the AC, the line disappears or moves up to the next P on the AC.

The functioning process of the AFAS is characterized by the following indicators: productivity, utilization level of basic technological equipment, loading diagram non-synchronous transporter, the average queue length of each AC, the average time P spends in each queue, the average time locked status of each AC, the matrix of the intensity of the traffic flows between different AC.

The formation of P queues reduces productivity of AFAS and utilization level of equipment. These numbers depend on many factors: the accidental loss of the equipment operability and its recovery; potential rerouting of P due to the changed situation in the operational process of the AFAS, the duration of technological operations.

A rational strategy for traffic flows management is to minimize losses from bursts of P's and AC's downtime. In order to search for a rational strategy of traffic flows management, AFAS are encouraged to use the method that combines advantages of analytical and simulation modeling. Analytical model of the functioning process of the AFAS is formulated in terms of integer linear programming problem [Kuznecov, 1980, Katta, 1983, Gartner, 2007]. At the present time, we have effective methods and standard software packages for computers developed for such tasks.

Simulation model of the AFAS (fig. 1) consists of software modules that simulate the interaction of real equipment. Initial data for the simulation is the number of AC (N), the nomenclature of K collected devices and technological processes of their assembly, the duration of technological operations and their distribution among the AC, the number of Ps, placement of the equipment along the non- synchronous transporter. The developed model allows the monitor to observe the process of functioning of the AFAS (P movement, the mechanism of P queues and blocking situations for each AC). At the request of the researcher information that characterizes the functioning of the AFAS in time is given in the form of tables, charts or diagrams.

One of the main indicators characterizing the operation of the AFAS, is a matrix of traffic between the AC:

$$\omega_{i,j} \ , \ i, j = 1,2 \ldots N, \quad i \neq j,$$

where: N - the number of AC in the AFAS.

Under a stream of P is the average number of P sent from the i-th AC on the j-th unit time. Experiments with simulation model showed that at constant input data streams $\omega_{i,j}$ do not change. One of the main factors reducing productivity AFAS are the formation of P queues and blocking AC. On length of stay in P queues is significantly affected by the alignment along the AC non-synchronous transporter.

We introduce the variables $x_{i,j}$ $i,j=1,2..N$, $i \neq j$. $x_{i,j}$ is interpreted as the number of intermediate AC between the i-th and j-th AC in the direction of motion of non-synchronous transporter. These variables can take any integer values in the range from 0 to $N-2$.

The optimality criterion of traffic flows in the AFAS is proposed to use the losses associated with potential downtime P in the queues. In this case, the objective function can be written as follows:

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\omega_{i,J}x_{i,j} \tag{1}$$

To ensure the effective functioning of the AFAS is required to find such $x_{i,j}$,for which the function (1) reaches a minimum . In this case, should be performed a number of limitations:

1. P with the i-th AC routed to any of the (*N-1*) AC;
2. The j-th AC P comes with any of *(N-1*) machines;
3. If the direction of movement of the conveyor between the i-th and j-th AC distribution relies *L* AC, then in the opposite direction (from the j-th AC to the i-th) should be placed (*N-L-2*) AC.

These restrictions can be written as follows:

$$\sum_{j=1}^{n}x_{i,j}=(N-1), \qquad i=1..N,\ i\neq j,$$

$$\sum_{i=1}^{N}x_{i,j}=(N-1), \qquad j=1..N,\ j\neq i.$$

$$x_{i,j}+x_{j,i}=(N-2), \qquad i=1..N,\ j=1..N,\ i\neq j.$$

To obtain the diagram we divide the last load transporter-making at a fixed number of M cells and for each cell we define the ratio of its use:

$$\eta_q=\frac{t_q}{T_ц}.100, \qquad q=1..M, \tag{2}$$

where: t_q - the total time during which the q-th cell transporter was P; T - time simulation of the AFAS.

The obtained values η_q, drawn on a graph is a diagram of the transporter loading (fig. 2). This diagram has a characteristic sawtooth shape. On the chart we can identify a number of specific fragments (fig. 2c), each of which η_q increases with the number cell *q*. The number of such fragments in the diagram load equal to the number of AC in the AFAS. H_i height of each peak is characterized by the total flow to the i-P to the AC, and the value of h_i - the average time of the blocked state of the *i*-th AC.

Experiments conducted with a simulation model of AC, showed that $h_1=h_2=\ldots=h_N=h$ increases overall system performance. Such equality is achieved by varying the distance between the loading positions of neighboring AC at constant values of H_i.

To achieve this equality, each fragment of the diagram is approximated by straight lines. Then, using the least squares method we obtain the equations of these lines. For a fixed length transporter obtain a system of *N +1* equations. Solving this system, we define a cell transporter, which should accommodate the loading position for each AC, the mean time, they blocked the state was roughly equal.

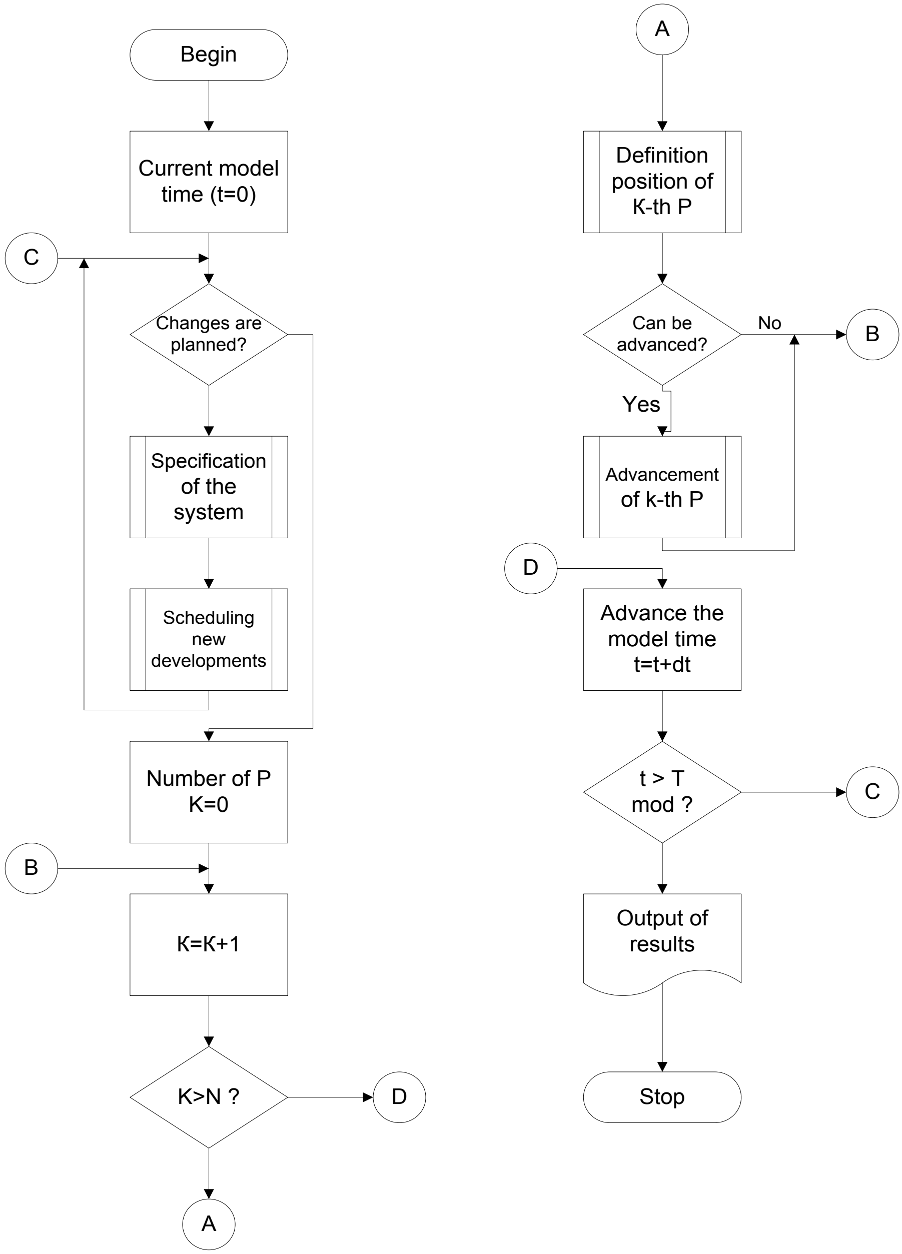

Fig.1. Block diagram of algorithm of simulation model AFAS

Example. In accordance with the following procedure is required to determine the placement of equipment in the AFAS assembly devices (fig. 3). In these production systems, the main technological equipment are AC that are based on highly functional industrial robots (IR). In consideration of the AFAS includes 4 AC, each of which carries four manufacturing operations. A total of AFAS runs 16 different manufacturing operations. In a production system produced 3 types of devices. Technological processes of assembly devices include 12 different types of manufacturing operations. From industrial experience it is known that the duration of each manufacturing operation can be regarded as a random variable distributed normally with mathematical forward 3 seconds and standard deviation - 1.5 sec. Table 1 shows the technological processes for assembly units.

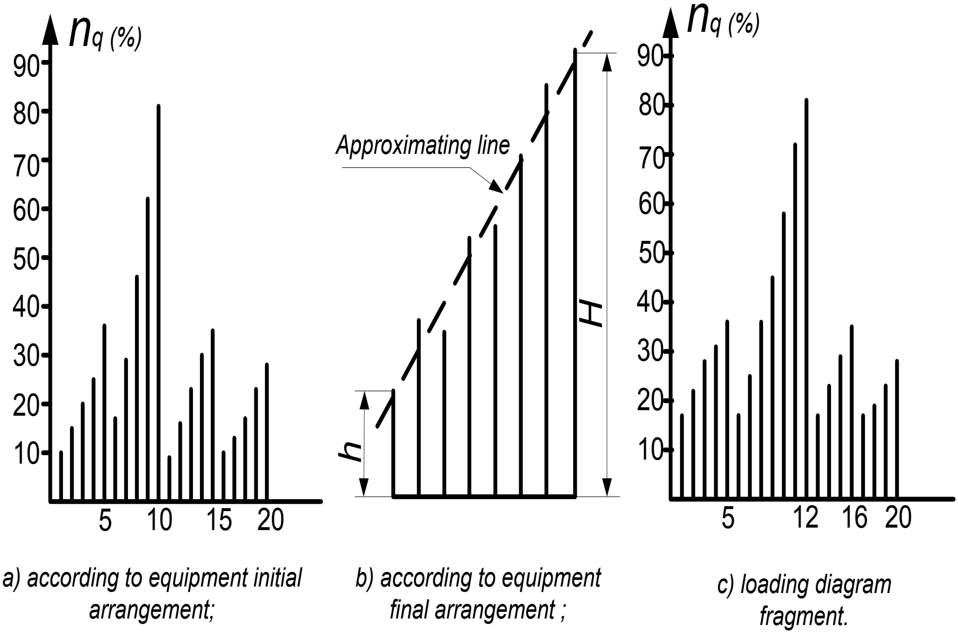

Fig.2. Variants of transporter loading diagram

Table 1. **Technological processes of assembly device.**

Unit	**Technological operations**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	2	11	6	2	4	2	5	12	10	4	2	6	7
2	10	4	2	7	11	8	10	12	9	3	6	3	-	-
3	5	12	4	11	3	10	5	7	9	3	8	12	6	5

As for the assembly of devices of various types need 12 different types of transactions, all the AC in the AFAS can be configured to perform 16 types of manufacturing operations, the most common types of manufacturing operations are duplicated on multiple AC. Table 2 shows the distribution of manufacturing operations between the AC.

Table 2. **Distribution of manufacturing operations between the AC**

AC	**Technological operations**			
1	1	2	11	6
2	4	2	3	7
3	10	8	4	5
4	2	9	5	12

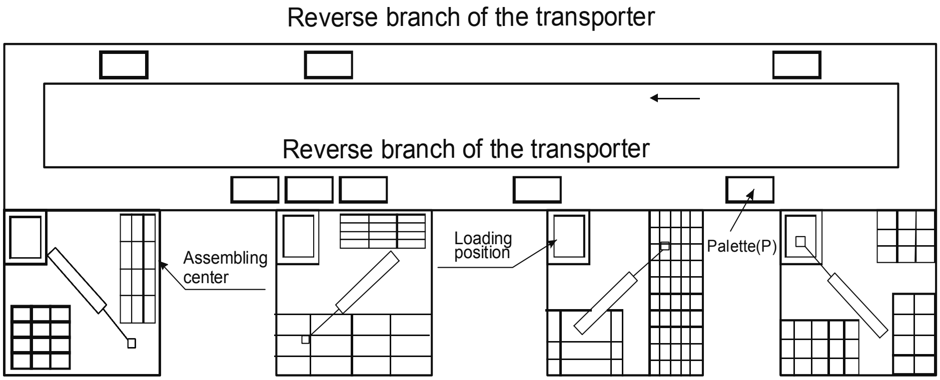

Fig. 3. Scheme of automated flexible assembly system (SSIA)

As a result of the experiments with simulation model AFAS we obtained matrix of flows Ps between the ACs (table 3).

Table 3. **Flows Ps between ACs in the AFAS**

		AC			
		1	2	3	4
AC	1	0	54	21	65
	2	78	0	66	174
	3	0	129	0	12
	4	54	139	54	0

From the analysis of the matrix flows implies that the initial placement of ACs along the transporter is not rational. The worst situation is dumping on a pair of ACs (i, j), which corresponds to the maximum term function (1). In this example, this applies to the AC № 3 and № 2, for which $\omega_{3,2}$= 129. When moving from AC № 3 to AC № 2, P can get into the two intermediate stages in AC № 4 and № 1.

We define rational arrangement of the equipment by minimizing adopted restrictions on expression:

$$54x_{1,2}+21x_{1,3}+65x_{1,4}+78x_{2,1}+66x_{2,3}+174x_{2,4}+$$
$$129x_{3,2}+12x_{3,4}+54x_{4,1}+139x_{4,2}+54x_{4,3}.$$

As a result of solving this problem by Gomory [Kuznecov, 1980], we obtain:

$$x_{1,2} = x_{2,4} = x_{3,1} = x_{4,3} = 0,$$
$$x_{1,4} = x_{2,3} = x_{3,2} = x_{4,1} = 1,$$
$$x_{1,3} = x_{2,1} = x_{3,4} = x_{4,2} = 2.$$

These variables correspond to the following arrangement AC 1-2-4-3. Retesting of simulation experiments yields the following matrix flows of the AC between P.

In our AFAS ACs are located only along the forward portion of the transporter (see fig. 3). To obtain the loading diagram this branch of the transporter is divided into 20 cells. Originally loading position AC were located in the cells 5, 10, 15 and 20. Under this option of AC arrangement the distance between the loading positions are the same and equal to 5 cells each. Since before the first AC there is the reverse branch of the transporter, then last, fourth AC can not be blocked by P queue. It is therefore necessary to determine the distance of the first and second, second and third, third and fourth AC. For this reason, counting should be carried out from the sixth cell (M = 12).

Table 4. **P flows between AC in the AFAS**

		AC			
		1	2	3	4
AC	1	0	119	72	48
	2	0	0	174	112
	3	143	69	0	54
	4	96	97	21	0

In our AFAS ACs are located only along the forward portion of the transporter (see fig. 3). To obtain the loading diagram this branch of the transporter is divided into 20 cells. Originally loading position AC were located in the cells 5, 10, 15 and 20. Under this option of AC arrangement the distance between the loading positions are the same and equal to 5 cells each. Since before the first AC there is the reverse branch of the transporter, then last, fourth AC can not be blocked by P queue. It is therefore necessary to determine the distance of the first and second, second and third, third and fourth AC. For this reason, counting should be carried out from the sixth cell (M = 12).

From the diagram loading transporter (fig. 2) follows that the AC № 1 was in a blocked state in average 2 times longer than the AC № 2 and № 3, because h_1 two times greater than h_2, and h_3 .. Using the method of least squares, we obtain the equations of the lines for the second, third and fourth fragments of diagram loading transporter, and then presented as in the above method of system of linear equations:

$$8.79y_1 + 65.1h = 0.3,$$
$$3.75(y_3 - y_2) + 23.5h = 0.4,$$
$$32(y_4 - y_3) + 26.3h = 0,$$
$$y_4 = 15$$

By solving this system of equations we received following results y_2 = 7, y_3 = 11, y_4 = 15 (relative to the first cell, y_2 = 12, y_3 = 16, y_4 = 20) h = 12,2.

To reduce the blocked state of AC loading position should be placed in a cell № 5, 12, 16, 20. Simulation experiments with the developed model show that the performance of the AFAS was increased by 12% under the new arrangement of the loading position. The loading diagram of the transporter for this equipment arrangement option is shown in fig. 2.b.

CONCLUSIONS

Problems of optimization transport flow in flexible manufacturing systems were described. Mathematical model for defining arrangement of assembly center along the transporter was developed. This model has effective solution method based on mathematical programming. Suggested algorithm can significantly improve performance of flexible assembly system. New kind of diagram for estimating of quality management transport system in FMS has been suggested. Such diagrams can be used for finding optimal strategy of transport system control. Numerical experiments were conducted on a real flexible assembly system to compare the performances of suggested models. The results show very good performance of developed models.

REFERENCES

1. Krushevski A.V., 1982.: Handbook on economic-mathematical model and methods(in Russian), Kiev: Technika, 1982.-207 p.
2. Valkov A.V., 1978.: Optimal machine-tools arrangement (in Russian).- Manufacturing Mechanisation and Automation , 1978, № 2, p.6-8.
3. Kuznecov J.N., Kuzubov V.I., Voloshenko A.B., 1980.: Mathematical Programming (in Russian).- M.: Vysshaja shkola, 1980. – 300 p.
4. Basneta C., Mizeb J. H. 1994.: Scheduling and control of flexible manufacturing systems: a critical review.- International Journal of Computer Integrated Manufacturing vol.7, pp 340 – 355.
5. Felix T. S., 2000.: The development of intelligent decision support tools to aid the design of flexible manufacturing systems.- International Journal of Production Economics.- vol. 65, num. 1, pp. 73-84.
6. Gartner B., 2007.: Understanding and Using Linear Programming.- Springer, 2007.- 226 p.
7. Gupta Y.P., Evans G. W., Gupta M. C., 1991.: A review of multi-criterion approaches to FMS scheduling problems.- International Journal of Production Economics vol. 22, pp. 13-31
8. Heungsoon F. L., Johnson R. V., 2001.: A line-balancing strategy for designing flexible assembly systems.- International Journal of Flexible Manufacturing Systems, 2001, vol. 2, num. 2, pp. 91-120.
9. Katta G. M., 1983.: Linear Programming.- N.Y., John Wiley & Sons, 1983.- 457 p.
10. Kouvelis P., 2001.: Design and planning problems in flexible manufacturing systems: a critical review.- International Journal of Flexible Manufacturing Systems, 2001, vol. 2, number 2, 75-90,
11. Lu R., Gross L., 2001.: Simulation Modeling of a Pull and Push Assemble-to-order System, The European Operational Research Conference, Rotterdam, The Netherlands

12. Ozdena M., 1988.: A simulation study of multiple-load-carrying automated guided vehicles in a flexible manufacturing system.- International Journal of Production Research, 1988, vol.26 , num. 8, 1988, pp. 1353 – 1366.
13. Park S.C., 2005.: A methodology for creating a virtual model for a flexible manufacturing system.- Computers in Industry, vol. 56, num 7, 2005, pp. 734-746.
14. Pinot G., Cardin, O., Mebarki, N., 2007.: Jobs scheduling problem in flexible manufacturing systems.- Man and Cybernetics. ISIC. IEEE International Conference: 7-10 Oct. 2007.- pp. 151 - 156
15. Qiao G., Lu R., Riddick F, 2003.: Flexible Modeling and Simulation for Mass Customization Manufacturing, Proceedings of the 2003 IIE Annual Conference, Portland, OR
16. Qiao G., McLean C., Riddick F., 2002.: Simulation System Modeling for Mass Customization Manufacturing, Proceedings of the 2002 Winter Simulation Conference, San Diego, California
17. Solot P., van Vliet M., 2003.:Analytical models for FMS design optimization: A survey.- International Journal of Flexible Manufacturing Systems, 2003, Volume 6, Number 3, pp.209-233,
18. Talavage J., Hannam R.G., 1999.: Flexible manufacturing systems in practice: application, design and simulation, Marcel Dekker Inc., New York, 358.
19. Toth P., Vigo D., 2002.: The vehicle routing problem, Society for industrial and applied mathematics. Philadelphia.
20. Vide J. J., Cyr T. P. 1986.: FMS work flow optimization.- Summer Computer Simulation Conference; Reno; NV (USA); 28-30 July 1986. pp. 705-710.

МОДЕЛЬ ДЛЯ ОПТИМИЗАЦИИ ТРАНСПОРТНЫХ ПОТОКОВ В ГИБКИХ ТРАНСПОРТНЫХ СИСТЕМАХ

Олег Малахов, Марина Матвеева, Сергей Стоянченко

Аннотация. В статье предлагается ряд математических моделей для определения оптимальной структуры транспортных потоков в гибких производственных системах. Показано, что использование разработанных моделей в реальных условиях может значительно увеличить показатели производственных систем. Фиг. 3, таблиц. 4. источников 20.

Ключевые слова: гибкие производственные системы, транспортные потоки, палетты, металлорежущие станки, сборочные центры, промышленные роботы, гибкие сборочные системы.

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TRANSACTIONAL ACTIVITIES OF CONTEMPORARY ORGANIZATION

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Summary. The essence of the transactional activities of an organization is considered. Author analyses the role of implicit and explicit contracts, complete and incomplete agreements. The efficiency of transactional activities of the organization strongly depends on the situation with contract enforcement.

Key words: transaction, agreement, contract enforcement, complete contract, incomplete contract, implicit agreement.

INTRODUCTION

A transaction can be defined as a contract. Accordingly, the transactional activity of the organization includes the preparation, conclusion, monitoring of various contracts. Broadly speaking, transactional activities of the organization includes not only the conclusion, monitoring of contracts with partners across, but also tracking the various commitments to state.

Law as a discipline pays great attention to legal aspects of transactions and transactional activities. Economists, starting with the famous work of Ronald Coase [Coase 1960] focused on the study of transaction costs [Battigalli, Maggi, 2002];, transactional sector of the economy [Chasanov, 2009]. However, it makes sense to pay attention on the problem of transactional activity of a single organization. This activity predetermines in many ways successes and failures of the organization.

Transactional activities of the organization is carried out in relation to agreements with employees; clients; suppliers of material resources etc. These activities can take place in the domestic markets of the country-based organization, or in the foreign markets.

Transactional activities of the organization are as important as its transformational activities, i.e activities connected with transformation of inputs into finished product. Quality of the transformational activities of a company depends on the quality of contracts which she concludes on the markets of finished goods and production factors.

RESEARCH OBJECT

All the units of the organization are involved in transactional activity one way or another. Personnel division recruits staff, signs agreements with the recruited personnel. The Marketing service studies changes in demand for the company's products and prepares information on agreements with existing and potential customers. Finance and Accounting services are engaged in the calculations of various indicators of the company, which characterize implementation of the agreements. Legal department prepares and concludes contracts.

Most of the staff of any organization is involved in transactional activity. First of all, this applies to senior management, functional and line managers who constantly monitor and evaluate the performance of their subordinates of their job duties, quality of products and purchased inputs.

There are organizations for which the transactional activity is the main or even sole area of work, they do this work for others. Those are various intermediaries. For other organizations transactional activity is also important, but it accompanies a major, transformational activity. Some organizations serve their transaction operations themselves. Others apply to third party for doing these operations.

The scale of transactional activities of the organization depends on: the number of markets on which it operates; complexity of contracts (volume of the responsibilities which the organization exchanges in the course of each transaction); the number of areas of responsibility that must be monitored.

Transactional nature of the organization is due to: a focus on those or other markets; focus on particular areas of responsibility of the parties, the nature of interactions with customers, suppliers and government agencies. Each organization should prioritize its transactional activities. In one case this could be an analysis of wages and benefits in certain segment of the labor market. In another case - monitoring the quality of a particular product of a supplier.

No less important is the identification of key institutions and the factors influencing the transactional activities of the organization. Among them: changes in the standards of the factors of production, finished goods; the organization of markets, changes in the level of market competition; macroeconomic ups and downs; activities of chamber of commerce, advertising agencies, intermediary organizations; natural disasters.

RESERCH RESULTS

Implicit and explicit agreements in the activity of organization. One aspect of transactional activities of the modern organization is the definition of the relation between explicit and implicit parts in the contracts it concludes. As is known, an explicit agreement usually recorded on paper. Implicit contract may take the form of an oral agreement. Implicit agreement can be considered as an adherence to some kind of unwritten rules, norms [Baker , Gibbons , Murphy, 2002].

In what cases implicit contracts are suitable for the organization? It makes sense to resort to the implicit agreements, where there are difficulties in concluding explicit agreements; or preparation, conclusion and monitoring of the latter are costly. In addition, by the implicit agreement businesses fill legal voids that are formed in the current legislation.

Implicit agreements are more flexible and less inertial than explicit agreements, because they are concluded, in particular, in cases where it is necessary to quickly and flexibly respond to changing market conditions.

Implicit agreements are usually practiced when it is not required to make significant investments in specific assets from the organization and its contractor, i.e investments in assets that can not be in case of failure of the transaction be refocused on other tasks. It happens that the agreement provides for investment in specific assets from one side only. In this case, mixed implicit-explicit version of the agreement of the parties is possible. The party in whose favour the investment is implemented, can take on liabilities denominated explicitly. A party who carries out such an investment - the implicit obligations.

In most contracts exists an explicit part as well as an implicit part. Certain provisions of the agreement can make explicit part, and others - an implicit part.

Share of an implicit component can vary depending on: a) the intentions of contracting parties, the actual situation; b) the legislative framework in the field, c) the operating environment of the parties. In an unstable environment an organization may choose to increase the explicit part of their relationship and to reduce the implicit part.

One of the factors influencing the relationship between implicit and explicit agreements can be an external shock. In a crisis situation in Ukraine barter transactions (especially in engineering) became widespread many of which are wholly or partly implicit.

In practice, transitions from contracts with a significant implicit component to contracts with small implicit component and vice versa are possible. In other words, in the course of their business relationship the parties may regulate the level of the implicit part. For example, the strengthening of trust between them will be accompanied by an increase in this part. A complication of the contractual relationship - can be accompanied by an increase in explicit part. Initially, the lease of equipment owned by the organization may stipulate in writing only the size of the monthly payment. But the tenant is very carelessly handled the equipment and at the conclusion of an agreement for a new term explicit part of the agreement is supplemented by new items, governing the use of equipment.

The entry into an implicit agreement involves risk. It makes sense to resort to implicit agreement in cases where confidence in the pursuit by the opposite party to the agreement exists. For example, when it is unlikely that a customer refuses to buy the product if the organization has already invested in the creation of capacities for its production.

If the managers of organization are not inclined to take risks, then they will enter into implicit agreement only in a situation of complete transparency and confidence in counterparty. If managers are neutral or even risk-averse, they will be more likely to practice implicit agreement.

Implicit agreement prevail in cases of long-term relationships with contractors which organization knows well. In contrast, explicit agreement practiced in case of short-term contacts with the organizations which reputation is in doubt.

The next situation is possible. Initially, the agreement is implicit, based on good knowledge of the organization of the counterparty. But then, the organization finds opportunistic behaviour of the counterparty, and an implicit agreement change on an explicit one. However, an implicit agreement may be beneficial to our organization, because it allows to: a) to hide her opportunistic behaviour, and b) to close eyes to non implementation or incomplete implementation of its obligations by the opposite side.

In general, other things being equal the conclusion of the implicit agreement puts the organization at greater risk than the conclusion of the explicit one. And the higher the proportion of implicit part in the rights and obligations of the organization, the higher the risk it is subjected. In some cases, the high proportion of implicit component in agreement is objective, and can not be avoided. In other cases, the organization unreasonably comes to risk and uncertainty by entering into an implicit agreement where it could easily be replaced by explicit one.

Widespread are implicit agreements in the modern marketing: a) between wholesalers and retailers, retailers and customers, in the process of the organization of trade networks, and b) on the market of the government agencies, c) in advertising, and d) in the network marketing and in the organization of “sales pyramids". The objects of such agreements may include: quality, durability of goods, delivery dates, quantities and quality of after sales service, number of attracted clients.

Client is "taught" to use certain products of the company. An implicit agreement is concluded between the respective company and its customers. Customer: "I buy your products because I know your company and that she cares about a fair price and quality." Company: "I hope for your loyalty to our products, so I will not fail you with its quality and price." It should be noted that this kind of implicit agreement is concluded largely with the help of explicit tools: a written assurances, the assurances in advertising displays; free samples of products.

Virtually all transactions have implicit component when: a) the good is paid first, and only then is consumed; b) uniquely determine the quality of consumption good is not possible, then there exists information asymmetry between buyer and seller.

Modern organization: complete and incomplete agreements. As we know, one of the characteristics of the agreement is the degree of completeness. According to the common opinion incomplete contract is a contract with a minimum specification of the rights, responsibilities of the parties. Incomplete contract differs from the complete contract by the level of specifications in such aspects:

- the level of investment by each of the parties;
- the conditions of termination;
- conduct of the parties (industrial, labour etc.);
- payment arrangements;
- the rights of the parties;
- duties, responsibilities of the parties;
- description of changes in the environment (laws, rules, behaviour of competitors, NGOs), which can lead to change of contractor’s positions.

It should be highlighted a few main reasons for concluding incomplete contracts. Some aspects of the behaviour of environment, the behaviour of the contractants themselves may be unforeseen, that is, these aspects can not be specified in the agreement in advance. In the case where the means of labour, more or less unchanged, the worker performs the day-to-day standard functions, there are conditions for the conclusion, renewal of a complete labour agreement. If the means of production and labour results vary due to various unanticipated events occurring in the environment of operation of the business, the more appropriate is incomplete contract.

Detailed specification of the agreement may be objectively impossible. Excessively high transaction costs of drawing up and implementing the full agreement may become the reason explaining the incompleteness of the contract.

The agreement may not be enough specified by mistake and deliberately. "Gaps" in such an agreement make possible to interpret its provisions to a certain degree of freedom and derive by organization benefit from this.

It is, above all, of the benefits due to lack of awareness of the counterparty of the seller. The latter may deliberately withhold some information about the defects, the possibility of failure in the operation of equipment sold. Informed party - the vendor may not want to formulate in the contract that event B can occur in case of an event A due to a reluctance to draw the attention of the buyer to this possibility.

Incomplete contract can also be used for future blackmail one party by another. Implicit and explicit contracts may be incomplete. Specification of rights, responsibilities in the agreement can be achieved on paper, but can - in the course of an oral agreement.

The problem of implementation of contracts. Enforcement of contracts which organization concludes is very important for her. The problem of contract enforcement was particularly acute in Ukraine after collapse of the Soviet Union. Administrative levers of the realization of contracts have not been replaced by new ones: the legislative, economic instruments. A vacuum was created: the country has entered a market economy almost exclusively with one real working mechanism of contracts enforcement - implicit mechanism, which is based on personal connections of contractors. But this mechanism was often glitched, evidence of that was the desire of suppliers to insure themselves demanding full payment for products shipped.

The contract can not be realised when:

- in the course of the contract realization it becomes clear that the costs of its implementation exceed the benefits. Such a situation may arise, for example, if legal, technical, technological, financial difficulties appear on the way to contract realization;
- realization of the contract, as well as failure of this realization bring benefits to its sides, but the failure is more economically attractive;
- the parties of the contract have the ability and desire not to implement the contract and effective enforcement is expensive;
- enforcement is possible and paid off, but for the contractors it is not advantageous for some reasons;
- one or both parties of the agreement are forced to conclude it by the law, unwritten rules, norms;
- party / parties of the contract from the outset do not intend to perform the contract, but voluntarily come to his conclusion, due to various reasons.

Quite often, the failure of various obligations of economic actors is a consequence of external factors, such as financial and economic crisis. The action of a third party can facilitate or hinder enforcement of agreements. Recipients of externalities may resist or encourage the enforcement. Managers of the resort, near which is a farm for breeding pigs is situated, may prevent the conclusion and then implementation of contracts for the supply of pork by the farm.

Sometimes it happens that if one party does not comply with a provision of a contract, the other party does not raise his break, but begins to answer the same manner: does not perform its obligations. Further developments may evolve under different scenarios: a) a mutual escalation of non fulfillment of obligations ; b) the party which initiates failure of commitment after observing the same reaction of the other side, begins to treat its obligations responsibly.

In modern literature [Bull 1987, Dixit 2003, Radygin, Entov 2003] attention draws to the different instruments of contract enforcement: legal procedures, accompanied by monetary losses by violators of agreement; informal arbitration, the social sanctions in the form of loss of trust and reputation, etc. All the tools of enforcement can be grouped into three types: economic, legal and social. At the same time a clear division between different groups of instruments to ensure the contract realization in most cases does not exist. Such tools as the deposit, bank guarantee, insurance, etc. can be referred to both legal, and economic instruments.

Contract has the most effective enforcement if all instruments are at work. However, in practice, the implementation of contract is based usually on one or several efficient tools, which are supported by the less powerful ones. In particular, possible options include:

- the basis of enforcement are legal instruments, but they are complemented by economic ones;
- the basis of enforcement are the economic levers, which are supplemented by legal instruments;
- execution of the contract is based on economic instruments, which are complemented by social norms (reputation, trust);
- in the early stages of the contract implementation only legal instruments may be used but then such instruments, as reputation, economic incentives, sanctions enter in action.

Enforcement of agreements depends mostly on the interaction of legal and economic instruments. For example, such legal means of ensuring the implementation of contracts as mortgage securities, goods in turnover successfully complemented the economic benefits derived from the agreement between the parties.

Several provisions that "overlap" each other may appear in the contract: one is a prerequisite for another, "tied" to the fulfillment of other provisions. For example: a) the employee must keep technological discipline; b) he must constantly worry about raising his qualifications. But in order to keep discipline, specialist must constantly improve his professional abilities .

If the implementation of one agreement is in danger, parallel agreement is concluded, which strengthens enforcement of the first agreement. For example, in contracts for supplying goods, works and services the weakest point is to get money from the recipient of products and services. So a letter of credit agreement that guarantees payment to the supplier is concluded along with the delivery contract.

To strengthen the implementation mechanism of the agreements some kind of escalating liability for breach of its obligations can be used in relation to violator. Here is a typical example of a Ukrainian company. The employee violates the discipline (come to work drunk, do not follow the instructions of supervisor) and he loses monthly premium, and the day of the appearance in drunken form is considered as absence from work. If this continues, the employee is fired by Art. 40, paragraph 7 of the Labour Code of Ukraine [Labour Code of Ukraine 2010].

In general, the task of the modern organization, consists in determining the strength of enforcement of its contracts and the development of economic instruments that would: a) strengthen the legal and social mechanisms of the implementation of these contracts; b) supplement the economic part of contract by the new provisions (new awards, bonuses, allowances).

One tool for ensuring fulfillment of the contract is: a) the possession by one of the contractors of specific assets, b) ownership of specific assets by both parties. The organization "A" in some cases forced to comply with the terms of the contract with organization “B” since the "B" has a monopoly on specific asset that of vital importance to the "A". "B" is able to blackmail the "A" by threat to exit a contract.

Effective stimulus for implementation of the agreement is its short-term nature, the need for their renewal for another term. If one party does not fulfil the conditions of the leasing contract, the opposite party can not renew their relations to a new term. Of particular importance is the term of the lease. Additional items can enter with its renegotiation, for example, increasing penalties for the safety of movable and immovable property. Or, alternatively, in order to encourage the contractor, the opposite party introduces less stringent conditions of the lease. These instruments contribute to enforcement of the contract.

The modern organization concludes simple contracts and complex contracts, with the exchange of a considerable number of different powers, responsibilities. In a complex contract some of its points, items can be implemented, and some - no, or not completely. For example, the supplier fully implements agreement on the quality of the delivered product, but does not adhere to the terms of the contract on delivery time and provision of additional services. In other cases, products may not meet the specified standards of quality, were made with violation of technology. However, the volume, timing of delivery (an agreed schedule) of the contract is performed.

One practiced in the modern world agreement is an agreement governing the cooperative behavior. In the saturated markets of this type of agreement is highly relevant to organizations. When a few big companies controlling the market, agree on quotas and prices, much depends on compliance with the agreements of each party. What mechanisms will ensure compliance with these agreements? Implementation of the agreement by the parties depends on the ratio of benefits / costs of compliance with the agreement and the benefits / costs from its breach. Non-cooperative behavior of the organization may be due to the fact that the net benefits of breach of an agreement substantially exceed the net gain from its implementation.

One of the manifestation of the weak contract enforcement between buyers and sellers is a discrepancy to the standards of products.

The problem of implementation of agreements exists not only in the interaction of independent economic contractants, but also between the actors within the organization, in the system of internal transactions. Any hierarchical structure is a system of agreements, built on the directives of superiors to their subordinates, on co-operation of workers. If the agreements are regulated by effective horizontal relations, there is no need for a strong "vertical". But failures in horizontal contacts within organization require effective administrative arrangements.

Sometimes, if enforcement of agreement between independent economic agents leads to problems, their union may occur within horizontally or vertically integrated structures. But in some cases due to difficulties with enforcement it could be more appropriate the disintegration of the organization when its divisions receive independent status.

In assessing the effectiveness of enforcement arrangements through the court one must consider that such enforcement is associated not only with the direct costs and loss of time by the organization of the claimant, but also with costs that are associated with rupture of relations with a partner. With increasing degree of specificity of the asset - the subject of the contract, this rupture can result in significant costs to find a new contractant.

CONCLUSIONS

Each organization, one way or another, is involved in the construction and periodic changes in its contractual relations. Owners and managers of firms adhere to some rational considerations in these construction and changes.

To optimize transactional activities of the organization is to optimize its agreements, in particular, on the following characteristics: the level of specification, the ratio of explicit and implicit parts, the mechanism of implementation.

Optimization of transactional activity can involve: a change in its volume, change the emphasis and resources devoted to different directions of this activity. In some cases the organization may find it expedient to reduce the number of interactions with market agents, in others the opposite - increase the amount of such interactions.

To optimize its transactional activities organization can move from internal transactions within its boundaries to external transactions and vice versa. Here are examples of such transitions:

- in order not to rent space (external transaction), the organization acquires the corresponding property and its interaction associated with use of space assumes the character of domestic transaction;
- the company sells a repair unit, and then works with it on contract basis;
- the organization comes to the need to move from using its own expertise in computer technologies to work with relevant staff of specialized computer firms;
- to implement the project organization chooses not to use their own funds, but instead concludes a contract with bank and receives a bank loan;
- at a certain stage of its development organization moves from the use of their own guards to outside security service.

The basis of such transitions is a comprehensive economic analysis, which each organization has to conduct on a regular basis.

REFERENCES

1. Ayres I., Schwab S., 1999.: The employment contract. Kansas Journal of Law & Public Policy. N8, p.71-89.
2. Baker G., Gibbons R., Murphy K.J., 2002.: Relational contracts and the theory of the firm. Quarterly journal of Economics. N117, p.39-84.
3. Battigalli P., Maggi G., 2002.: Rigidity, discretion and costs of writing contracts. American Economic Review. N92, p798-817.
4. Bull C. 1987.: The existence of self-enforcing implicit contracts. The Quarterly Journal of Economics. N102, p.147-159.
5. Coase R. The Problem of Social Cost. – Journal of Law and Economics, 1960, 3(1), pp.1-44.
6. Chasanov I., 2009.: Transactional sector of economic system: national accounting of social reproduction. Avtoreferat of dissertation. Chelyabinsk..
7. Dixit A., 2003.: Trade expansion and contract enforcement. Journal of Political Economy. N111(6), p.1293-1317.
8. Hart O., Moore J., 1988.: Incomplete contracts and renegotiation. Econometrica. N56, p.755-785.
9. Hart O., Moore J., 1999.: Foundation of incomplete contracts. Review of Economic Studies. N66, p.115-138.
10. Johnson S., McMillan J., Woodruff C., 2002.: Courts and relational contracts. Journal of Law, Economics and Organization. N18, p.221-277
11. Klein B., 1996.: Why hold-ups occur: the self-enforcing range of contractual relationships. Economic Inquiry. N34, p.444-463.
12. Labour Code of Ukraine. Kyiv. 2010.
13. Maskin E., Tirole J., 1999.: Unforseen contingencies and incomplete contracts. Review of Economic Studies. N66, p.83-114.
14. Nosal Ed. 2001.: Optimal at will labour contracts. Economica. N68, p.187-201.
15. Pittman R. Specific Investment, Contracts, and Opportunism: The Evolution of Railroad Sidetrack Agreements. – Journal of Law and Economics, 34, October 1992, p.565-589.
16. Radygin A., Entov R., 2003.: Enforcement of ownership rights and contract obligations. Problems of economy. N5.
17. Segal I., 1999.: Complexity and renegotiation: a foundation for incomplete contracts. Review of Economic Studies. N66, p.57-82

ТРАНСАКЦИОННАЯ ДЕЯТЕЛЬНОСТЬ СОВРЕМЕННОЙ ОРГАНИЗАЦИИ

Виталий Мортиков

Аннотация. Рассматривается сущность трансакционной деятельности организации. Автор анализирует роль явных и имплицитных контрактов, полных и неполных соглашений. Эффективность трансакционной деятельности организации находится в сильной зависимости от ситуации с осуществлением
соглашений.

Ключевые слова: трансакция, соглашение, инфорсмент контракта, полный контракт, неполный контракт, имплицитное соглашение.

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INFLUENCE OF VEHICLES ON POLLUTION OF ATMOSPHERIC AIR OF SEASIDE TOWNS

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Summary. The way the microclimatic features of the Crimean seaside towns influences the dispersion of “weightless” admixture from vehicles has been analysed in the article. The received results of the calculation of contaminants concentration along the different motorways have been estimated and calculated according to the existed methods. The calculation results demonstrate imperfection of these methods application in the conditions of the foothills and mountain relief, they don’t take into account the following climatic conditions: reverse temperature inversion, atmospheric air temperature gradient, geomorphologic features of relief, anthropogenic landscape and others. The aim of the present work was to improve the existing methods on calculation of disperse of “weightless” admixture in the boundary layer of the atmosphere in the conditions of the mountain relief by introduction of the additional coefficients.

Key words: vehicles, dispersion, “weightless” admixture, mountain relief, microclimate of territories.

INTRODUCTION

Quality of atmospheric air is one of the basic vital elements of the environment. To provide a safe person’s activity and prevent harmful influence on the environment it’s necessary to keep favorable state of atmospheric air, to renew and improve it.

The main source of the atmospheric pollution in modern towns and settlements is motor transport – up to 85-90%. Pollution caused by vehicles is of linear – vector character [Lukanin 2001].

The main pollution substances entering the atmospheric air and the wayside territory are oxide of carbon (CO), dioxides of sulfur (SO_2), nitrogen (NO_2), hydrocarbons (C_nH_m), phenol (C_6H_6O), formaldehyde (CH_2O), petrol, technical oil, fuel oil and others [Jakubovsky 1979].

In Ukraine for calculation of pollution caused by vehicles, the existing methods are used. [Method of calculation of pollution 1985, 1995, 2000]. The calculation is done according to the specific emissions, mileage and product of coefficients of a number of factors.

According to the other two methods [1995, 2000], the calculation of the atmospheric emission is done with the amount of emission and the fuel used with the consideration of the type of movement, coefficients, technical state of the vehicle.

In the EC countries the method used is close to the one described above, the difference is in the classification of vehicles and the emission of pollutants into the atmosphere.

The methods mentioned are aimed at calculation of the disposed quantify per second, hour, month, they are used to calculate the amount of the money paid for ecological services, but they don't allow us to estimate the atmospheric air pollution.

The methods of calculation of concentration of harmful substances in the atmospheric air have been worked out for 30 years (from 1970-s till 1990-s) and were summarized in the method [Method of calculation 1987] where calculation of harmful substances concentration have been given. While district planning and road construction great attention was paid to the regulation of the atmospheric emissions in the unfavorable meteorological conditions [Methodical pointing 1986]. However, all the described methods don't show the amount of "weightless" admixture on the territory along the motorways in the conditions of foothills and mountain relief that is characteristic of the most seaside towns in Ukraine.

The main aim of this work is improvement of the present method on calculation of disperse of "weightless" admixture along motorways of different functions located in various geomorphologic relief forms.

MATERIALS AND METHODS

To solve the set problem the territories of the following resort towns in the Crimea have been chosen: Simferopol, Yalta, Feodosiya, since there are motorways in them. On the selected territories, the model measuring of quantitative and qualitative characteristics of transport streams on motorways has been done. Fig. 1 demonstrates the results of the observation.

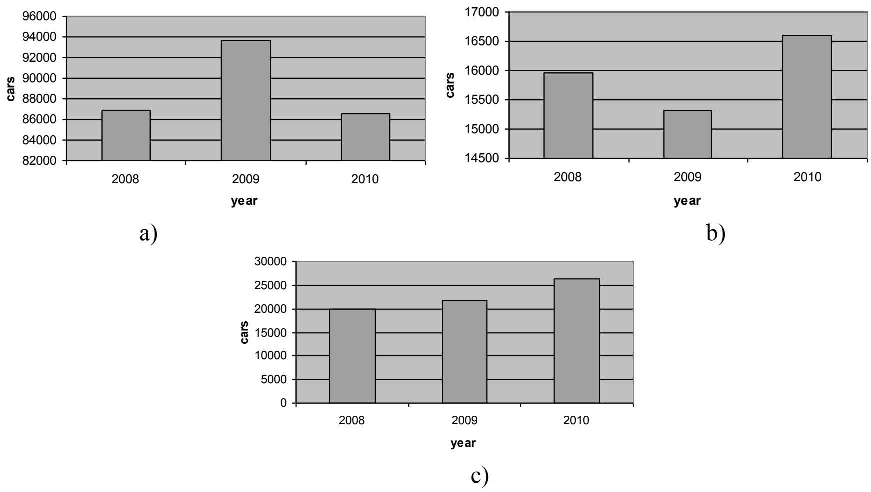

Fig. 1. Quantitative characteristics of motor transport streams on the selected motorway of cities: a) Simferopol, b) Yalta, c) Feodosiya

Table 1. **Annual mass of extras of pollutants for the selected highways of cities of Crimea**

City	Mass of extras of pollutants, ton/year		
	Year of supervision		
	2008	2009	2010
Simferopol	22850	24650	22774
Yalta	4199	4034	4367
Feodosiya	5214	5750	6928

The received results allow us to mark total pollution, but we can't have the concentration of emissions along the motorways that is thought to be more important. Therefore, these data can't be used for the estimation of the atmospheric air quality along the motorways.

To solve that problem on estimation of the emission concentration along the selected motorways, the authors used the methods existing in Ukraine [Method of calculation of pollution 1995, Berland 1985].

RESULTS

Table 2 demonstrates the results of the atmospheric emission concentration related to intensity of an average transport stream where the methods of model measuring along the selected motorways in Simferopol were used [Method of calculation of pollution 1995, Berland 1985].

Table 2. **Dependence of n·LPC on CO on the side of a road of motorway route from intensity of an average transport stream in Simferopol (2008 year)**

Types of motorways	Motorway	Intensive, car/hour	n·LPC CO, measured	n·LPC CO, calculation on [Method of calculation 1995]	n·LPC CO, calculation on [Berland 1985]
Motorway intercity	Kievskaya str.	3600	5,17	6,38	11,52
	Sevastopolskaya str.	3400	3,78	5,84	10,88
Inside city motorways	Pavlenko str.	2200	1,65	3,39	7,04
	Kechkemetskaya str.	2100	1,49	3,24	6,72
	Vorovskogo str.	2100	2,51	3,68	6,72
	Lugovaya str.	1150	2,09	1,77	3,68
	Frunze str.	1300	3,35	1,91	4,16
	Tolstogo str.	1200	2,78	1,85	3,84

According to tab. 2, we can say about the links between n·LPC and the atmospheric emissions along the motorways.

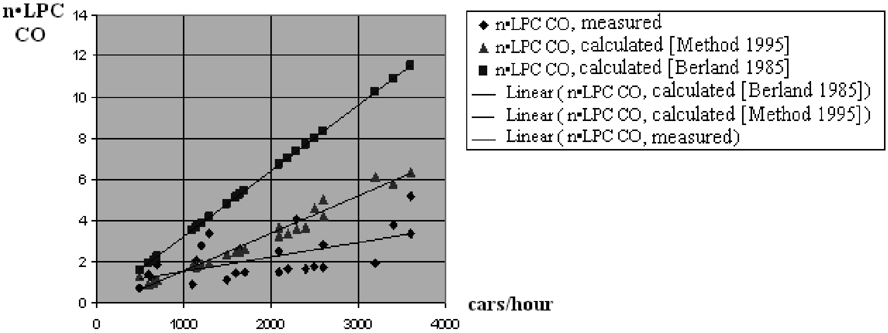

Fig. 2. Graphic dependence of the measured and calculation values of n·LPC on CO from intensity of a average transport stream

The received mark differences are significant, therefore, to regulate the atmospheric emission from vehicles it's necessary to take into account the additional characteristic: the wind speed, the amount of emission from the source, exchange coefficient. Thus, the application of the existing mathematical models without taking into consideration the meteorological conditions, the relief of the region can lead to results of calculation distortion and doesn't meet the demands as for the forecast quality, especially in the conditions of the foothills and mountain relief.

While calculating the admixture concentration from a linear source q(x), the authors used the modified formula of Lihtman [Bizova 1973], the formula takes into account the missing parameters:

$$q(x) = \frac{Q \cdot e^{-\frac{R}{x}}}{\Gamma(1+\rho) \cdot \mathrm{U} \cdot \mathrm{H}} \left(\frac{R}{x}\right)^{\rho}, \tag{1}$$

where: q(x) – concentration of admixture from a linear source;
Q – amount of the produced admixture;
R – dimensionless auxiliary parameter for the calculation of vertical dispersion;
ρ – dimensionless auxiliary parameter for the calculation of vertical dispersion;
U – middle in a layer from 0 to H the wind speed;
H – height of a source;
x – coordinate along the ax of x;
Γ(1+ρ) – gamma-function.

It is assumed for a weightless admixture that a laying surface does not take an admixture in and isn't influenced by it.

A linear source is assumed to be long enough. For a linear source the followings parameters are estimated:

- maximal value of concentration - $q_0 = D_1 \frac{QB}{UH^2}$, (2)

where: B – basic parameter of vertical dispersion;

• coordinate along the ax of x - $x_0 = A_1 \frac{H}{B}$, (3)

where: A_1 – dimensionless parameter for the calculation of x_0;

• parameter for the calculation of vertical dispersion - $R = \frac{CH}{B}$, (4)

where: C – dimensionless parameter for the calculation of R.

While calculating it's necessary to define the parameters of the source and admixture, meteorological data and the type of laying surface. In order to use the common results in the meteorological network, a number of classifications of the ground layer stability is introduced. According to [Berland 1985], there are six classes of stability of the ground atmospheric layer: n = 1, 2, 3 (corresponding to strong, moderate and weak instability); n = 4 (corresponding to equally weight or indifferent state); n = 5, 6 (corresponding to weak and moderate stability). Each class corresponds to the certain of wind speed, insolation degree and the time of a day [Bizova 1972]. The seventh, additional class is introduced in the work, it is used in the specific conditions (calm and weak winds, anomalous types of the wind, temperature inversion, transitional time of a day).

The value of the parameters forming part in the formulas 2 – 4, are used for the plain territory, therefore, they are not used in the conditions of foothills and mountain relief and additional coefficient for the mountainous conditions is needed.

The value of laying surface roughness z_0 influences the distribution of admixture in the boundary layer of atmosphere. For the towns located in the foothills and mountain relief z_0 = 80, 100, 120.

The value of the vertical dispersion parameter B*(the parameter of the authors) for z_0 = 80, 100, 120 and n = 4, 5, 6, 7, 8 at H < 25 m that is missing in [Bizova 1973] has been estimated by the method of extrapolation of the existing information with preliminary degree approximation (Fig. 3), that is B* = f (z_0, n).

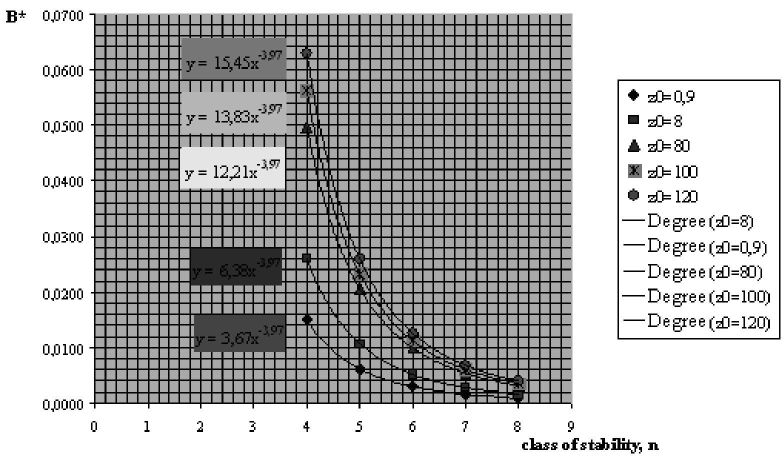

Fig. 3. Chart of degree approximation of dependence of B* from n and z_0

The given degree approximation formulas allows us to estimate the vertical dispersion parameters B* at the different value of z_0 and give possibility to transit from one class of stability to another one.

Vertical dispersion of admixture is influenced by the slope shape, the bottom width, the sides exceeding height, azimuth of extension and the position of the sun above horizon. With these factors having been taken into consideration, the authors set a number of the coefficients taking into account the vertical dispersion parameter (R) and the admixture parameter for the marked motorways of Simferopol (Tab. 3).

Table 3. **Values of correction coefficient *α** for the calculation of *R*, taking into *Δh* and *i* [Murovskiy 2005]**

Angle of slope of sides of valley, *i*	Absolute exceeding of sides, *Δh*, m		
	15-30	30-50	50-80
	*α**		
10-20	0,30	0,28	0,25
20-30	0,27	0,25	0,23
30-50	0,24	0,23	0,22
50-80	0,19	0,18	0,17

Tab. 4 demonstrates the estimation results of the parameters of the contamination zone from motor transport streams on the marked motorways of Simferopol with the consideration of the correction coefficients.

Table 4. **Calculated parameters of "weightless" admixture dispersion in Simferopol**

	Parameter					
	B (B*)	z_0, cm	R, m	x_0, m	q_0, mg/m^3	Δ, %
Experiment Results	-	80	20,0	120,0	16,2	-
Calculation according to [Bizova 1973]	0,0030	80	266,7	266,7	9,8	35
Calculation with the consideration of the correction coefficient	0,0054	80	22,0	137,0	19,2	18

The method approved by the authors was tested in the seaside towns of Yalta and Feodosiya located in different geomorphological zones at the most unfavorable meteorological conditions (calm). The results of the calculation were compared to data of the experiments (Tab. 5).

The error of estimated data according to the method of the authors with the consideration of the correction coefficients shown in Tab. 5 is withing the limits for the forecast of pollution of the ground layer of the atmospheric air along the motorways located in different geomorphological conditions.

The calculations give right to forecast pollution of the ground layer of the atmospheric air along the motorways. While making up general plans of towns or while reconstructing the existing motorways located in the conditions of the foothills and mountainous relief it is necessary to do calculations of the pollution of the ground layer of the atmospheric air to provide safe, vital activity of a man in the specific zones around the motorways.

Table 5. **Comparison of the results of the calculation of CO concentration from vehicles to the results of the experiments in Yalta and Feodosiya**

Street	Geomorphological location	Transport stream intensity, car/hour	Results of experiments q_0, mg/m^3	Roughness, z_0	Calculation with correction coefficient q_0, mg/m^3	Δ, %
Yalta						
K. Marksa str.	street (canyon)	1522	10,30	80	14,17	27
Moscow str. – Kievskaya str.	valley of the river	1805	15,42	120	17,22	11
Sevastopol motorway	south slope of mountain ridge	2145	14,52	100	18,06	20
Feodosiya						
Fed'ko str. – Gen. Gorbacheva str.	street (canyon)	977	6,98	80	8,51	18
Kuybysheva str. – Ukrainian str.	street (canyon)	1203	9,26	100	10,53	12
Kerch motorway	valley of the river	1013	5,38	80	7,26	26

CONCLUSIONS

1. The use of the methods [Method of calculation 1995, Berland 1985, Bizova 1973] for the calculations of the parameters of “weightless” admixture dispersion in the foothill and mountainous conditions leads to great mistakes.
2. Evaluation of the error of the calculated parameters of the pollution zone with consideration of correction coefficients is within the limits of permissible error for forecast of pollution of the ground layer of the atmospheric air.
3. The calculation results with the correction coefficients being used allow us to explain the norm exceeding (“smog”) in the lower ground layer (h = 20 – 25 m) in mountainous vallies inversion when reverse temperature inversion takes place.

REFERENCRS

1. Adrias A. Associated with the CORINAIR/COPET Methodology for Estimating / A. Adrias, Z. Samaras, T.-H. Zachariadis and K.-H. Zierok.- Document of the European Commission ISBN 92-826-5573, 1993.- Vol. 2-A.- 498.
2. Berlyand M.E. Prognosis and adjusting of contamination of atmosphere: ed. [for the stud. of high. educat. establ.] / M.E. Berlyand.- L.: Gidrometeoizdat.- 1985.- 273 p.
3. Bormann F., 1982.: The effects of air pollution on the New England landscape. Vol. 11. ¹ 6. Ambio. P. 338–346.

4. Byzova N.L. Meteorological descriptions for the calculation of diffusion in the boundary layer of atmosphere / N.L. Byzova of // IEM.- 1972.- № 27.- P. 56-63.
5. Byzova N.L. Methodical manual upon settlement of dispersion of admixtures in the boundary layer of atmosphere / L.N. Byzova.- M.: Gidrometeoizdat, 1973.- 70 p.
6. Eggleston S. Data on evaporative emissions of gasoline passenger cars submitted to the CORINAIR / S. Eggleston // Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Brussel 7- 8 okt. 1991.- Brussel.- 1991.- Vol.À: SNAP: 040611.- P. 126-135.
7. Eggleston S. CORINAIR Working Group on Emissions Factors for Calculating 1990 Emissions from Road Traffic / S. Eggleston, D. Gaudioso, N. Gorissen, R. Joumard, R.C. Rijkeboer, Z. Samaras and K.-H. Zierock.- Methodology and Emission Factors. Final Report, Document of the European Commission ISBN 92-826-5571-X: SNAP: 070100 – 070500, 1993.- Vol.- 1.- 324.
8. Jakubovskiy U. Motor transport and defense of environment. - M.: Transport.- 1979.- 198 p.
9. Lobl W. Spatially Disaggregated Emission Inventory for Anthropogenesis NMVOC in Austria / W. Lobl, R. Orthofer and W. Winiwarter // Atmospheric Environment.- 1993.-Vol. 27-A, ¹ 16.- 2575-2590.
10. Lukanin V.N., Trofimenko U.V. Industrial Transportation ecology.- M.: Higher School.- 2001.- 273 p.
11. Methodical pointing upon settlement of the troop landing of harmful matters a motor transport / State committee of the USSR on meteorology and control of natural environment.- M.: Gidrometeoizdat, 1985.- 24 p.
12. Method of calculation of extras of pollution substance from a motor transport / Mins Guards of natural environment and nuclear safety.- K.,1995.- 23 p.
13. Method of calculation of extrass of pollution substance from a motor transport / Mines. Guard of natural environment.- K.:, 2000.- 31c.
14. Method of calculation of concentrations in atmospheric air of harmful matters, contained in the extras of enterprises: OND-86.- [operating].- L.: Gidrometeoizdat, 1987.- 94 p.
15. Methodical pointing of adjusting of extras at unfavorable meteor condition: PD52.04.52-85.- [operating].- Novosibirsk: Zap. Sib. RVC, 1986.- 34 p.
16. Murovskiy S.P. Features of contamination of atmosphere the extras of motor transport in the conditions of mountain relief / S.P. Murovskiy // Building and technogenic safety.- 2005.- № 11.- P. 149-156.
17. Recommendation on the guard of environment in the district planning (CNII of town-planning).- M.: Stroyizdat, 1986.- 160 p.
18. Seiffert U. The Future for Automotive Technology / U. Seiffert, P. Walzer. - London: Frances Pinter, 1984.- 140.
19. U.S. Environmental Protection Agency. Regional Interim Emission Inventories (1987-1991): Vol. 2 / «Emission Summaries» EPA-454/R-93-021b. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, 1993.- Vol. 1.- 586.
20. Murovskiy S.P. Features of dispersion of «weightless» admixture in the ground layer of atmosphere in the conditions of mountain relief / S.P. Murovskiy // «Motrol», Lublin.- 2009.- Volume 11A.- 265-271.

ВОЗДЕЙСТВИЕ ПЕРЕДВИЖНЫХ ИСТОЧНИКОВ НА ЗАГРЯЗНЕНИЕ АТМОСФЕРНОГО ВОЗДУХА ПРИМОРСКИХ ГОРОДОВ

Анна Муровская, Зинаида Сапронова, Сергей Муровский

Анотация. В работе проведен анализ влияния микроклиматических особенностей территорий приморских городов Крыма на рассеивание «невесомой» примеси от передвижных источников (автотранспорта). Проведена оценка полученных результатов расчета концентрации загрязняющих веществ вдоль автомагистралей различного функционального назначения, рассчитанных по действующим методикам. Результаты расчета показывают несовершенство применения данных методик в условиях предгорного и горного рельефа, они не учитывают микроклиматические условия: обратную температурную инверсию, градиент температуры атмосферного воздуха, геоморфологические особенности рельефа, антропогенный ландшафт и др. Целью данной работы явилось усовершенствование существующей методики по расчету рассеивания «невесомой» примеси в пограничном слое атмосферы в условиях предгорного и горного рельефа путем введения дополнительных коэффициентов.

Ключевые слова: автотранспорт, рассеивание, «невесомая» примесь, горный рельеф, микроклимат территорий**.**

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FORMALIZATION OF PROCESSES OF SEAPORT COOPERATION NETWORK MANAGEMENT

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Summary. The smart control of the port communication network management presumes development and introduction of new IT for communication control in real time, it is evident that the main problem is the problem of development and implementation of the database for the network automation control. The article outlines the basic aspects which need to be resolved in order to create and implement the mentioned database.

Key words: formalization of processes, cooperation network of sea port, smart control, database.

PROBLEM'S STATEMENT

The global territorial disunity of natural recourses, production forces and consumers require the development of highly organized transportation technological process (TTP). One of the major instruments for creation of such TTP is its informational and logistical support. Marine TTP being one of the components of the world TTP demands – for providing its own activity development and use of the single information space.

ANALYS OF LAST RESEARCHING AND PUBLICATIONS

Nowadays it is important to receive not the giant information content but the necessary und sufficient quantity of reliable information, handled and prepared in such a way to make possible its on-line using for on-time decision making, adequate for completing task. Therefore, the point is not to provide fast traffic of giant message content but to ensure the on-time traffic of pre-handled (saved) information just in such content, which is necessary for decision making of concrete person within his time limits. Globalization, personalization and integration of infocomms define the common target development of SIS [Doroshenko, Ilyin, Iskanderov 2009, Kulgin 1999, Shybanov, Lychagin, Seregin 1990, Kruglov, Dli, Golunov 2001].

GOAL OF RESEARCHING

The efficiency of MTTP greatly depends on quality of control of this process. For efficiency enhancement of control of MTTP automatic control systems are being created (ACS). Depending on range of activity they can implement the control both of the whole area and its certain elements, in particular of the seaport.

MATERIALS AND RESULTS OF RESEARCHING

The modern seaport being the key element of TTP represents the large enterprise on which territory there is the full complex of different services providing intermodal transport. Under these circumstances the major logistical task is cooperativeness of production and consumption modes (performances) with service performance of transfer of vehicles, frontier and customs processing, storage, reprocessing and distribution of goods. To resolve indicated task without having any relevant information infrastructure is impossible. Therefore the most important direction of providing the efficient functioning of seaport is reasonable control of cooperation network. It is also necessary to take into account the particularities of marine, automotive, railway, river and air transportation technological processes and their infocomms.

Nowadays in all infocomms different information, commutation, network and telecommunication technologies are being used. This sharply complicates their using and further improvement, which requires the system approach and acquisition of knowledge in related fields: programming, informatics, logistics, large technical systems and network technologies [Haykin 2006, INTERCARGO 2010, INTERCARGO 2005, IMO 1996, IACS Common Rules for Bulk Carriers and for Double Hull Oil Tankers 2004].

The main function of seaport cooperation network, as well as any other, is the traffic of information from the message quarry to recipient. As the communication channels wire lines (ground, underground cables, and underwater cables), fiber-optic communication lines, on-air communication lines, radio channel, wireless network of communication of various frequency bands, including satellite, are used. Automatic control of such networks requires their technical, programming, information, organization, linguistic compatibility.

To achieve the efficient functioning of the network, it means providing the functions of transfer of messages with set-up parameters at least costs(material, financial, human)in order to meet the communication service requirements of users perfectly, it is necessary to complete a lot of application tasks, including the matters of organization of the optimal path of message transfer, rational use of the resources during operational processes, reconstruction and development of networks, providing the quality of communication services. Completing these tasks is carried out by the network control system by means of monitoring and observation the network parameters, its resources and their change in accordance with set-up algorithms and programs [IMO 2004, Lloyd's List 2007, Lloyd's List 2008, Lloyd's List 2010, The joint Accident Investigation Commission of Estonia, Finland and Sweden 1997, Proceedings of the International Ship and Offshore Structures Congress 1991].

Network control system is understood to be the complex of technical and program tools, aimed to provide the fulfilling of transport functions of network in the best way.

Control system has its own internal architecture and consists of the range of subsystems. In control system there can be marked two basic parts: decision-making system and a system of execution of a decision. The first one figuratively speaking is a brain of a system, its intellectual framework, which is implemented in the form of operating system; the second one is locomotor tool, implemented in the form of programming and technical tools of technical maintenance. In its turn, in the technical maintenance there can be marked the subsystems of control, measuring and reserving, calculations etc.

At the level of the organization control the analysis of a network condition and generation of decision variants at the stages of on-line control and planning, including expansion, reconstruction and increasing of network, redistribution of communication channels and information flows etc is implemented. The tasks of technological control are tasks of compilation and primary conversion of information about delayed messages, condition of communication lines, channel s and tools, bringing and realization of the control actions towards the communication tools. Completing indicated tasks, except requirements concerning operativeness, reliability and truthfulness, there are some tough requirements to the process of automatic control of the network, taking into account such particularities of the network, as complicity, large sizes, territorial distribution, and dynamics of the structure.

Nowadays in the different transport departments the various kinds and forms of communication, as well as various telecommunication, commutation, network and information technologies are being used.

Consequently, in the current context the all-round automation of cooperation network control is the perspective and economic direction of its development, where the knowledge intellectualization takes on more significance, that is why it is necessary to formalize the processes which are the subsystems of the network.

The strategy of the smart control of the cooperation network presumes development and introduction the new efficient information technologies, providing on-line cycle circularity of organization and technological network control, essentially increasing feasibility and concurrency of taking decisions.

The key element, providing the smart ACS by the network, is IS. Based on achievements of researches in the area of engineering, programming and micro process system knowledge, IS will greatly influence the opportunities of network control. However nowadays there is a negative influence of the range of factors on the development and implementation of IS and ACS. The main of them are:

– organization principles, hard and software of automatic control, using in the systems of the seaport, are not unified, what threatens the breakdown of control cycles;

– the modern automation tools for cooperation network control are almost absent or introduced with the insufficient capacity;

– application domain of network ACS as the sphere providing the functioning of the port, requires for its description the development of the adequate methods and tools of the knowledge intellectualization, as it possesses the certain characteristics.

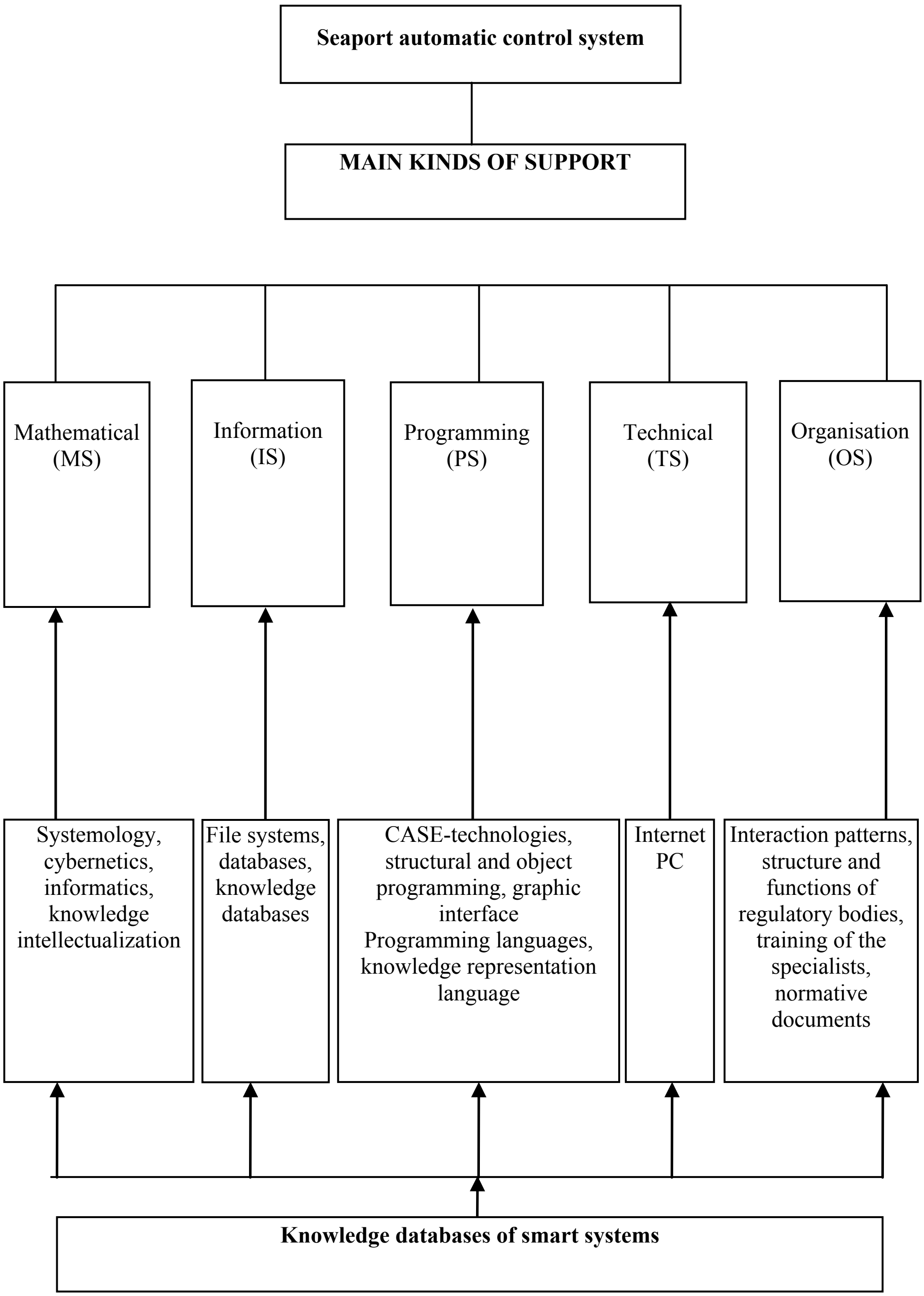

Fig. 1. Main kinds of smart system

The structure of TTP of the seaport should include in a smooth way the ACS of the cooperation network, which includes the database, which must comprehend the main subsystems of this ACS, including the various kinds of automation system support (fig. 1) [Shigemi, Zhu 2003, Zhu, Shigemi 2003, Jankowski, Bogdaniuk 2007, Vesely, Golberg, Roberts, Haasl 1981, IMO 2006].

Consequently one of the main problems of creature of the automatic control system for the seaport network is the problem direct of the development and constructing the databases for ACS. One of the approaches can be approximisation of all the components of the system with polynoms and the consistent use of them for the development of the control algorithm. However this approach cannot be called all purpose, because the use of several polynoms increases the time of calculations and influences the dynamic characteristics of the whole system in general and on the end error of determination. Another approach can be the use of the mechanism of artificial neural networks with the linear function of activation, flowchart of which is given below.

At the entrance of the linear network is given the vector, components of which are the dimensions, which characterize the subsystem:

$$W_{вх}^{T} = \{w_1, w_2, \ldots, w_n\}. \tag{1}$$

Before entering the network the vector is rated:

$$\overline{W}_{вх}^{T} = \frac{W_{вх}^{T}}{\left\| W_{вх}^{T} \right\|}. \tag{2}$$

Therefore the network has the input layer, consisting of N neurons, which have to implement weighted total of components of input vector and output layer, which consists of one neuron, which forms the outlet of the system. Selector of the control circuit is shown in the fig. 2.

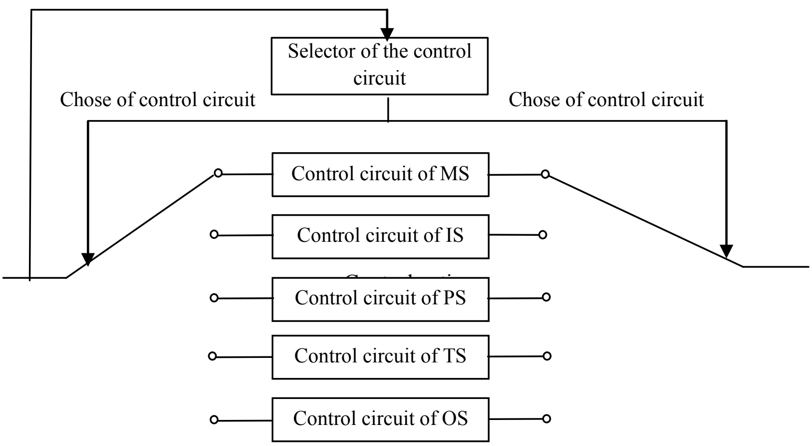

Fig. 2. Selector of the control circuit

CONCLUSIONS

The creature of the smart database for cooperation network cannot be realized without the appropriate tools. For such application domains there is no the proven technology and the long-present complex of means of development. In this case appears the necessity of search for such an approach, which would primarily provide the opportunity of the reasonable network control and would realize the possibility of generation of the true variant of decision based on the formalized control subsystems and possibilities of system self-learning.

REFERENCES

1. Doroshenko V.I., Ilyin A.A., Iskanderov Y.M., 2009.: Problems of control utomation of seaport cooperation communication network. Marine transportation operations. SMA named after adm. S.O. Makarov.
2. Kulgin M., 1999.: Technologies of cooperation networks: encyclopedia. SPb, S. Petersburg.
3. Shybanov V.S., Lychagin N.I., Seregin A.V., 1990.: Means of automatic control in communications systems. M., Radio and communication.
4. Kruglov V.V., Dli M.I., Golunov R.Y., 2001.: Fuzzy logic and artificial neural networks. M., Physmathlit, 224 p.
5. Haykin S., 2006.: Neural networks: full course. M., Williams, 1104 p.
6. Benchmarking Bulk Carriers 2009 - 10, 2010.: INTERCARGO.
7. Bulk Carrier Casualty Report, 2005.: INTERCARGO.
8. IMO, 1996.: Agreement concerning stability requirements for ro-ro passenger ships undertaking regular scheduled international voyages between or from designated ports in North West Europe and the Baltic Sea, SLF40/INF.14.
9. IACS Common Rules for Bulk Carriers and for Double Hull Oil Tankers, 2004.: Draft for Comments.
10. IMO Document MSC 78/26, 2004.: Report of Maritime Safety Committee on its seventy eight's session, item 6.
11. Lloyd's List, 2007.: 9 of May.
12. Lloyd's List, 2008.: 10 of March.
13. Lloyd's List, 2010.: May 17.
14. The joint Accident Investigation Commission of Estonia, Finland and Sweden, Final report on the capsizing on 28 September 1994 in the Baltic Sea of the Ro-Ro passenger vessel m/v Estonia, 1997.
15. Proceedings of the International Ship and Offshore Structures Congress 1991.: Volume 3, China.
16. Shigemi T., Zhu T., 2003.: Practical Methods of the design loads for primary structural members of tankers, Marine Structures 16, pp. 275-321.
17. Zhu T., Shigemi T., 2003.: Practical Estimation Method of the Design Loads for Primary Structural Members of Bulk Carriers, Marine Structures, 16, pp. 489-515.
18. Jankowski J., Bogdaniuk M., 2007.: Risk Model Used to Develop Goal – Based Standards for Ship Structures of Single Bulk Carrier, The Royal Institution of Naval Architects, London.
19. Vesely W.E., Golberg F.F., Roberts N.H., Haasl D.F., 1981.: Fault tree handbook, US Nuclear Regulatory Commission.
20. Document MSC 81/6/14 submitted by Germany, 2006.: IMO.

ФОРМАЛИЗАЦИЯ ПРОЦЕССОВ УПРАВЛЕНИЯ КОРПОРАТИВНОЙ СЕТЬЮ МОРСКОГО ПОРТА

Григорий Нечаев, Галина Гаркуша, Кристина Ходарина, Людмила Белкина

Аннотация. Интеллектуализация процессов управления морским портом заключается в разработке и внедрении новых информационных технологий, обеспечивающих управление всеми процессами в реальном масштабе времени. Рассмотрена основная проблема – разработка и внедрение базы знаний для автоматизации системы управления корпоративной сетью порта. Обозначены основные аспекты, требующие решения на пути создания и реализации такой базы знаний.

Ключевые слова: формализация процессов, корпоративная сеть морского порта, интеллектуализация управления, база знаний.

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THE METHOD OF BIOFUEL MIXTURES PRODUCTION AND THE DETERMINATION OF THE PRODUCTION PLACE IN LOGISTIC CHAIN OF THE CONSUMPTION

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Summary. In this article is represented the method of biofuel mixtures production with using chemically pure hydrocarbon components. The method of choice of possible biofuel production place in logistic chain is also represented in it.

Key words: biofuel, component, consumption, motor car transport, production place.

INTRODUCTION

The problem of alternative environmentally pure motor-car fuel production is very important in all the world and the developed countries pay great attention to the solving of this problem.

Nowadays the motor car transport is the mass source of an environmental pollution in most of countries, its part of pollution is from 50% up to 60% in total amount of harmful dumps, and in big cities this amount rises more than 80% - 90% [1].

Nowadays there is no industrial production of biofuel in Ukraine, there is only its handicraft production. The building of specialized plants for producing Ukrainian biofuel is planned by the government. According to the Cabinet of Ministers order from 28.12. №576-r «About the affirming of the conception of governmental program of the biofuel production development until the year 2020» the production of more than 520 thousand tonnes of biofuel every year has been planned in Ukraine since the year 2010.

The main aim of that document is «increasing of Ukrainian eco-power safety level and decreasing of national economy depending on the import of oil-products, providing the biofuel to agrarian sector of economy and transport », but the ways of its production and economically profitable field of its production are not marked.

RESEARCH OBJECT

The analysis of the biofuel using, as an alternative fuel for combustion engines, and the determination of efficiency in its using is considered in [1]. This question becomes more actual because of prompt rise in prices for power resources.

The problem of affordable fuel is acute throughout the world. Its cost is determined not only by the expenses on raw materials, but also by the expenses on its transportation to the place of consumption. The raw material potential, production and using of fuel, mainly alternative environmentally clean motor-car fuel, should take place as close as possible to each other.

Along with the introduction of secondary petroleum refining processes (alkylation, isomerization, etc.) in order to improve the quality of motor fuels, considerable attention is paid to the development of various additives and supplements, giving the motor fuels such properties, including environmental, which in principle can be achieved by technological processes of production fuels.

At the same time such factors, as the necessity of oil resources economy and the improvement of operating, and especially ecological properties of fuels, stipulate the searches of new effective methods of production and using the substitutes of oil fuels for cars.

The research purpose is a choice of method for the production of the motor–car fuel mixtures and the analysis of a possible place of biofuel production in the logistic chain of consumption.

The formulation of the task is to develop a new method of ecologically clean motor-car fuel mixtures production with using chemically clean compound hydrocarbon components and to determine the economically effective place of biofuel production in logistic chain.

RESULTS OF EXPERMENTAL RESEARCH

The logical continuation of trends in production of complex fuels is getting the fuel of plant origin (biofuel) with necessary physical and chemical properties for combustion in an engine by selection and genetic changes of the raw material. Since the use of methanol for producing biofuel complicates measures for accident prevention and environmental protection, and its use causes raised wear of engine details, then the alternative is to use more expensive alcohol as ethanol for production biofuels [8].

The production includes processes, beginning from rape seeds processing and finishing by storaging the products. The main processes during production PEE are the following: pressing, filtration, etherification, cleaning, distillation, conditioning (optionally), quality analysis of the made products. Pressing is a process of making oil from the rape seeds. It includes such sub processes: seeds purification, calibration, frying. Filtration is a process of deleting or separation of different types of admixtures from oil, which got in it during pressing. This process is of great value, because of inseparated admixture the fuel will be with unsatisfactory physical and chemical properties in the eventual result. Etherification - is a thermal process of glycerin deleting as a result of addition ethanol and catalyst to rape oil. Purification - is a process of deleting catalyst and possible admixtures. Quality analysis of made product is a final process. It includes verification and possibility of biofuel using [2].

Basic and responsible part of biofuel production process is etherification, for which it is important to provide the necessary amount of ethane and catalyst, as well as to provide the necessary temperature at which it passes, providing the excretion of glycerin.

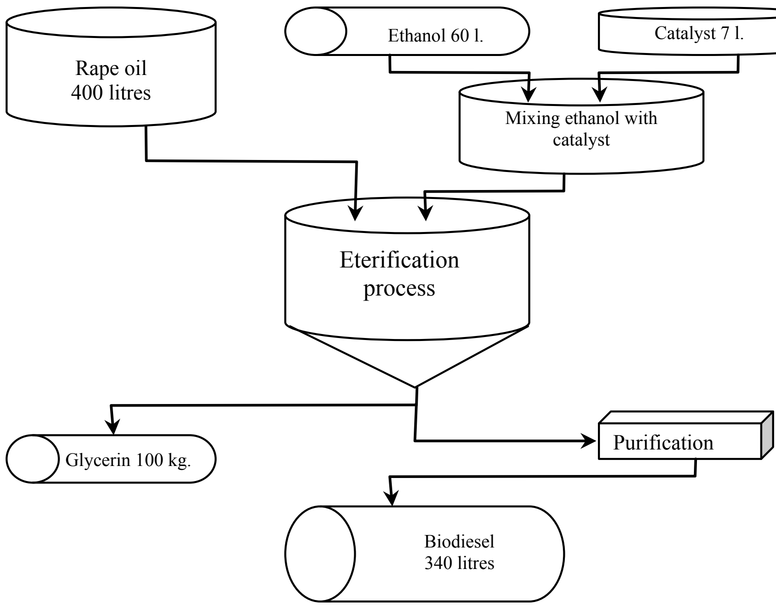

Fig.1. Elements of biodiesel production

The features of biodiesel production consist of the following task. The biofuel is made of rape oil by the schema shown on the Fig. 2.

At the estimation of basic indexes of biodiesel it is set, that the mixture of biodiesel steams with air, unlike a diesel fuel, does not create explosive mixtures. It is set that the warmth of biofuel combustion (34,3-41,7 MJl/t) is less, than diesel, and temperature of inflammation of such essential oil in 1,5 time higher than diesel fuel. Application of this type of fuel [3] practically does not provide the changing of power and torque of engine. However, there is about 5-7% of fuel expenses increase that is compensated by biofuel power reducing. The mechanical and thermal loading of engine remains almost at the same level, and the temperature of exhaust gases goes down on 3-10%.

Basic oil raw material for making biodiesel is traditionally technical rape. Although there are other kinds of agricultural products, suitable for its production, for example sunflower. Expedience of growing rape or other agricultural products as raw material for making biofuel for engines is stipulated by the level of expenses on its production.

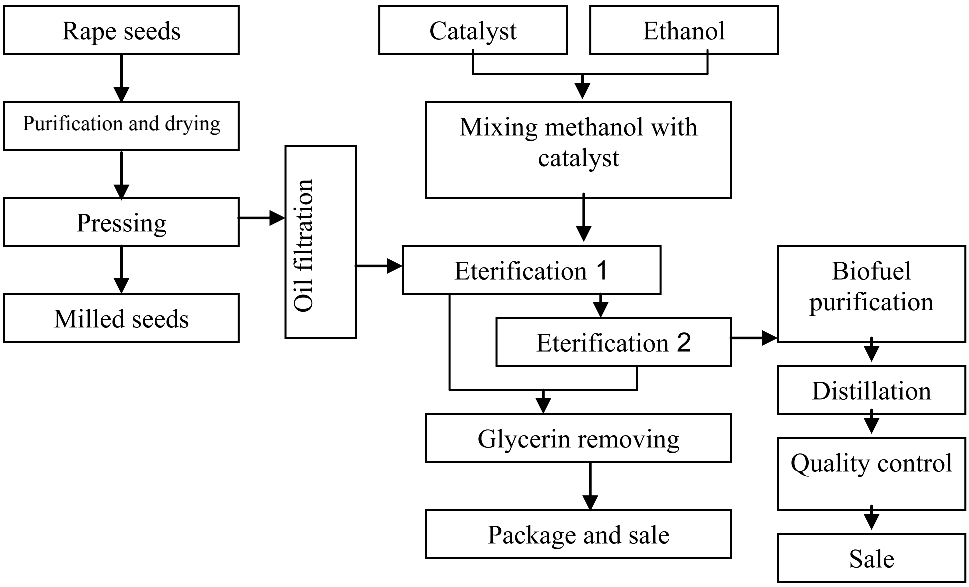

Fig.2. Full schema of biofuel production

Providing the economic efficiency of using biodiesel in Ukraine requires the complex account of all direct expenses and facilities from realization by-products during its production.

While building the plant for biofuel production in the logistic chain of consumption the building place should be chosen so, that expenses on realization of future transportations were minimum. The potential value of expenses in logistic chain “raw-transportation-production-transportation-consumption” is defined as «vial». This value takes into account the distance of the served sources (flows), and transport meaningfulness and it can be expressed in such a way:

$$\min \sum_{i=1}^{n} g_i \cdot l_i = V, \tag{1}$$

where: g_i - is a transport meaningfulness (for example, amount of the transported freight) of i-th source; l_i - is distance from this source to the economic-geographical centre of production.

To find the coordinates of economic-geographical centre, which serves objects (suppliers of raw material and users) with the least transport expenses, designate the sources (flows) P_1, P_2 … P_n with known coordinates, accordingly, X_1 and Y_1; X_2 and Y_2 … X_n and Y_n with known transport meaningfulness g_1, g_2 … g_n, and also unknown centre P, located between the known points P_1, P_2 …. P_n with hypothetical coordinates X and Y.

The coordinates of general economic-geographical centre let's define as:

$$X = \frac{\sum_{i=1}^{n} g_{pi} \cdot X_{pi} + \sum_{j=1}^{m} g_{cj} \cdot X_{cj}}{\sum_{i=1}^{n} g_{pi} + \sum_{j=1}^{m} g_{cj}}, \quad Y = \frac{\sum_{i=1}^{n} g_{pi} \cdot Y_{pi} + \sum_{j=1}^{m} g_{cj} \cdot Y_{cj}}{\sum_{i=1}^{n} g_{pi} + \sum_{j=1}^{m} g_{cj}}, \tag{2}$$

where: X_{pi} and Y_{pi}; i = 1….n ; and X_{cj} and Y_{cj} , j = 1…m - coordinates of conveyance and collection points, g_{pi} … g_{pn}; g_{cj} …. g_{cm} - transport meaningfulness of conveyance and collection points.

In this case collection points are agricultural enterprises, growing rape, sunflower and other oil plants. The conveyance points are consumers of biofuel, for example, filling stations or transport enterprises.

At the same time, in spite of certain advantages and seeming simplicity, for industrial production of biofuel in Ukraine it is necessary to solve great number of problems. Among them are: creation of areas for growing rape and sunflower, improving the structure of agricultural lands, creating new technologies, providing the assured markets of sale, creation state standards in the field of production and using the alternative types of energy.

CONCLUSIONS

In connection with diminishing of oil supplies it is actual to use alternative types of complex fuels for combustion engines, using of which all owes to save rare mineral fuel and substantially to reduce the content of harmful substances in exhaust gases. For attaining the value of physical and chemical properties of biofuel, which could respond to the set standards of fuels and which would allow using biofuel in combustion engines without the re-equipment of their fuel-pumping systems– it is possible, by the choice of optimum correlation of component parts and modes of biofuel production processes.

REFERENCES

1. Emeliyanov V.E., Krilov I.F. 2004.: Alternative ecological clean types fuel for cars. The Characteristic, varieties, using.- Moscow.; Astreli, - 68p.
2. B. Karpinski, B. Makuh. 1998.: Transport system Ukraine in context euro integration. Economic Ukraine. №7.
3. Girin V., Luchko M., Girin V. 2007.: Sistem's control i metod snigenia rashoda topliva transportnih sredstv I spectehniki. Visnik KTU – Krivorogski technical University – Krivoi Rog, - № 8. P. 101-107.
4. Luchko M. 2009.: Opredelenie mesta proizvodstva biotoplivnih smesei v logisticheskoi cepochke potreblenia. Visnik EUNU after V. Dal – East Ukraine National University after V. Dal - Lugansk,. – №. 4 (134). c. 152-155

5. Luchko M. 2004.: Analis rezultatov modelirovania raboti kariernogo transporta. Visnik EUNU after V. Dal – East Ukraine National University after V. Dal - Lugansk, — №10(68). P1. – P. 151-156.
6. Luchko M. 2008.: Analysis of the using bio-fuel, as alternative type fuel for engines of internal combustion. - Visnik KTU – Krivorogski technical University – Krivoi Rog, – № 11. – P.83-88.
7. V. Dubrovin, M. Korchemnyy. 2004.: "Biofuel. Technologies" machines and equipment. - Kiev. – 256p.
8. Selimov I.K., Abrosimov A.A. 1991.: Ecologi-economic aspects of the development production motor fuel in USA. Overview information. The Series "Guard surrounding ambiences".- №5.- Moscow; CPIITE.- Neftehim, - 64 p.
9. The Patent 11013. The Ukraine. Si OL 1/04. SSH 01.1/18, VO1 GZ/08. The Image of the reception fuel mixture and device for its realization/ Udovik V.S., Udovik S.S. Zayavl. 93005450, 1993. It Is Published 25.12.96. Byuliteni 4.
10. Verevka M.L. 2002.: Physico - Chemical characteristic alternative combustible on base vegetable masel. // Mechanization and electrification rural economy - . 86.- R.290-294.
11. Global Logistics Research Team at Michigan State University, World Class Logistics: The Challenge of Managing Continuous Change (Oak Brook, IL: Council of Logistics Management, 1995).
12. Malevich I.P. 1972.: Transportation and storage of powder-like building materials / I.P. Malevich, V.S. Seryakov, A.V. Mishin. – M.: Khimia. – 240 p.
13. Gradstein I.S. 1963.: Tables of integrals, sums, lines and products / I.S. Gradstein, I.M. Ryzhik. – M.: Phyzmatgiz. – 1100 p.
14. Caren W. Currie 1996.: Electronic Commerce and the Internet: Resources for Logisticians. Annual Conference Proceedings of the Council of Logistics Management, p. 339-54.
15. IACS Common Rules for Bulk Carriers and for Double Hull Oil Tankers , Draft for Comments, 2004.
16. Luchko M. 2002.: Estimation of conditions of exploitation of an industrial technological autotransport in conditions of quarry. Visnik EUNU after V. Dal – East Ukraine National University after V. Dal – Lugansk, № 12(58) – P. 111-117.
17. Govorushenko N., Turenko A.. Sistemotehnika transporta. P1. – Kharkov: RIO HGADTU, 1998. – 255p.
18. Douglas C. Long, Donald F. Wood 1995.: The Logistics of Famine Relief. Journal of Business Logistics, p. 213-229.
19. IACS Common Rules for Bulk Carriers and for Double Hull Oil Tankers , Draft for Comments, 2004.
20. Document MSC 81/6/14 submitted by Germany, IMO, 2006.

СПОСОБ ПОЛУЧЕНИЯ БИОТОПЛИВНЫХ СМЕСЕЙ И ОПРЕДЕЛЕНИЕ МЕСТА ПОИЗВОДСТВА В ЛОГИСТИЧЕСКОЙ ЦЕПОЧКЕ ПОТРЕБЛЕНИЯ

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Аннотация. Представлен способ получения биотопливных смесей с использованием химически чистых углеводородных компонентов. Представлена методика выбора возможного места производства биотоплива в логистической цепочке

Ключевые слова: биотопливо, компонент, автотранспорт, производство, логистическая цепочка

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DEVELOPMENT OF TRANSPORT INFRASTRUCTURE IN EASTERN UKRAINE AND ITS INTERACTION WITH THE INTERNATIONAL TRANSPORT CORRIDORS

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Summary. In the article considered conditions and facilities of development of transport infrastructure in eastern Ukraine and its interaction with the international transport corridors.

Key words: transport corridors, logistics, transportation technologies, transport, Lugansk region.

INTRODUCTION

The development of transport and logistics systems receives increasing consideration with the development of international cooperation, more intensive integration processes in the global economy and their globalization. At the same time the intergovernmental, economic, cultural and other connections providing is agreed on the desirability of creating an effective international transport infrastructure, which has certain technical parameters and provides consistent application of transportation technologies that can ensure the integration of national transport systems into the world transport system [Nechaev 2009, Nechaev 2010, Burkinsky 2009, Slobodyanyuk 2010, Primachev 2006].

RESEARCH

Up to 2010 year the Government of Ukraine had been repeatedly formulating tasks, the solution of which had to provide the measures for reconstruction of transport routes of the country, including them into the system of international transport corridors (ITC).

Among the documents adopted by the Government [Nechaev 2010, Rabotnev 2010, Izotov 2010]:

The network of national roads and constructions, which formed the structure of ITC and required some reconstruction and modernization was set by the program. It was indicated that there were three transport corridors (№ 3, 5, 9) which passed through the territory of Ukraine and the other four corridors of the Black Sea Economic Commonwealth (BSEC), Europe – Asia; the Baltic Sea – the Black Sea; Eurasian.

7,2 billions of UAH were assigned for their construction and operation, integration into the national network of international transport, which would allow to bring 1200 km of operating roads into the system. The Program proposed the construction of new and the reconstruction of existing roads, which coincided with the direction of ITC № 3, 5, 9. The Program implementation would provide a radical reconstruction of many road sections of the country and include them in the international communication network. It was also proposed to continue the reconstruction of national roads and to construct 270 km of new main roads. However the appropriate organizations didn't launch the implementation of the Program tasks.

As a result of many years systemic faults in governmental organs the weakening of the transit potential is not the only factor in Ukraine's internal politics nowadays. Bad quality of main roads, lack of necessary logistics services force shippers of neighboring states to drive our country around.

The analysis of the transit potential of Ukraine has shown that it is the largest by its volume of turnover in Europe. It is based in the Concept of the Government program of transboundary cooperation development in 2011-2015 years, and approved by the Cabinet of Ministers of Ukraine on 28.09.2010, 15:12.

According to the experts estimations, this potential is used only for 55-60%. Incomes from transit and set of services connected with it are about 5-7% of GDP. For comparison: in the Baltic countries this index reaches 30%. Ukraine doesn't receive about $ 2,5 billions into the budget because of the unbalanced use of transit potential annually.

It is also important to note that the transit cargoes following the reverse direction, passing through the Lugansk region (Chervona Mogila – Sverdlovsk – Rovenky) and then through Debaltsevo by the territory of Donetsk and Dnipropetrovsk regions in the direction of European countries go on the most loaded section of Dnieper and Donetsk railways, where the parameters of motion are 60-70 million t-km/km in one direction. This affects the overall movement of railway transport negatively and does not permit to increase the speed over 120 km/h, that confirms the necessity of urgent reconstruction and development of main roads included in the international transport corridors within the country [Nechaev 2005, Nechaev 2006, Nechaev 2010, Slobodyanyuk 2009].

Thus it is necessary to note that international roads in Ukraine are equipped, their communication facilities are driven to European standards, it provides the optimal characteristics of traffic flow. The direction of international roads coincides with the main freight traffic, including the transit one, by the following areas: West Ukraine – Kharkiv – Lugansk; Lvov-Kiev-Belarus; sea ports of Ukraine – Dnipropetrovsk – Russia; the Caucasus; Moldova – Russia, etc. **It is obvious that the Lugansk region has only two sections of roads of this type.** Their direction is – Debaltsevo – Lugansk – Krasnodon – Izvarino; Debaltsevo – Antracit – Dovzhansky. These are M-03 and M-04, which coincide with the roads of European routes E-50, E-40 (the total length is 182 km). And this is when the border infrastructure of the region consists of 12 international and interstate border checkpoints.

International transport corridors functioning happens due to the integration connections of railway transport. And it isn't accidental. Initiating the development project of transport corridors since 1980th, in order to optimize traffic flows, the European Commission has been paying special attention to ensuring the increasing volume of transit cargoes between Europe and Southeast Asia. For this purpose use of ports in Bulgaria, Romania and Ukraine will unload roads from the vehicles, especially in Western Europe. But the common EU strategy is also directed for the purposes of improving ecological standards and increasing proportion of the most ecological rail and water transport [Nechaev 2005, Nechaev 2006, Nechaev 2007]. The analysis shows that cargo transportation by vehicle is 44% of traffic volume in EU countries, by sea transport – 41%, by rail transport – 8%, by inland water transport – 4%. Meanwhile in Ukraine during the last years, the share of the rail transport is 50-55%, the sea – about 25%, the vehicle – 20-25%.

In some reasons Belarus has been successfully competing with Ukraine in cargo transportation by rail transport. For example, according to the Ministry of Transport of Belarus Republic, in 2008-2009 there were 992,3 thousands of transit trips of foreign carriers done through the territory of Belarus. As for Ukraine, there was about one million of trips of foreign carriers (export, import, transit).

Despite the fact that enterprises and organizations of the railway, running through the Lugansk region, are not involved in organization of cargo-and-passenger flows directly, following the direction of Europe – Asia – Europe, their role in the near future can increase substantially because of the appearance of new, more optimal routes branching ITC and the necessity to increase the occupancy and the intensity of transit traffic.

For this purpose is initiated: the reconstruction of rail transport nodal point that includes the stations "Dolzhanskaya", "Chervona Mogila; the changing of the international railway crossing point status "Lantratovka" and renaming it from the "passenger" into the "cargo-and-passenger"; the creation of the warehouse complex, including the functions of intermodal freight terminals in the direction of Debaltsevo – Lugansk – Kondrashevskaya. The State Administration of the Lugansk region before the Government of Ukraine has been initiating the rail communication on the route Lugansk – Millerovo and the construction of a new branch railway in the direction of Svatovo – Starobelsk – Melovoe – Chertkovo. The implementation of only these measures will increase the speed characteristics of railway stations, extend the volume of transit traffic, that will certainly have positive impact on economic and other indicators. Material and technical basis, personnel potential of Donetsk railway enterprises and organizations located within the Lugansk region, confirm the reality of the plans and the availability of technological projects aimed at better use of reserves to increase cargo-and-passenger flows.

It is admitted that the Lugansk region – is the transit gate of Eastern Ukraine and Lugansk, as a regional center and the city, located less than 45 km from the Russian Federation border, almost at the crossroads of the main railway and highways, in fact is the key, the use of which has been providing a positive trade balance volume between the neighboring regions. For example, in the first quarter of 2010 foreign trade turnover of the Rostov region with Ukraine had increased by 55% and had reached almost $ 400 million. Due to close interaction of border areas, the share of Ukraine in foreign trade turnover of the Southern Federal District of Russia has been growing steadily and now comprises almost 30% [Nechaev 2003, Nechaev 2008, Nechaev 2010, Slobodyanyuk 2009].

The fact that the Lugansk region takes one of the first places in Ukraine in its transit potential, defines the special importance of its territory and the necessity of implementing this active transport policy here.

Foreign economic operations with goods the region performed with partners from 108 countries.

The largest volume of exports were done into the Russian Federation – 63,6%.

The integration of communication continues to develop increasingly, the arrangements of business partnership in the territories of Russian-Ukrainian border work positive as follows:

- The Public corporation "Luganskteplovoz" increases the activity of direct contacts with the Novocherkassk Electric Locomotive Plant "NEVZ" on the main-line locomotive 2EL5.
- The Ukrainian Mashine Building Holding Ltd Company has acquired additional 50% of shares in Kamensk Engineering Plant, which produces material mining equipment.
- The “NORD Group” Company in the city Matveev Kurgan of Rostov’s region started the production and the maintenance of refrigeration equipment, transport air conditioners.
- The Ukrainian company "Shahtostroymontazh" Co Ltd has acquired the processing plant "Sholohovskaya", which did not work with the Public corporation "Zaporizhstal" jointly.

By the year 2020, the growth of intra-regional cargo turnover will be increased by more than 100%. After EU enlargement, more than half of existing European transport corridors became the part of the network TEN-T. At present appeared the necessity to restate the existing network of international transport corridors (ITC) again and to define the priority projects for the coordination and concentration of the EU financial resources, as well as the development of a new transport strategy for the enlarged European Union. An important reason for this is the increasing number of problem areas with insufficient capacity, poor quality of transport and logistics infrastructure, weak interaction of different modes of transport and EU enlargement including eastern states.

Investments of 600 billion euros are needed to complete and upgrade the European networks in the enlarged EU.

Relying on the conceptual positions above, can be distinguished the most relevant activities for each administrative-territorial formation of the Lugansk region to develop cross-border partnership, including:

- simplification of procedures relating to State border crossing by citizens of neighboring states;
- giving the legal position of law to authorities of cross-border cooperation, established by local governments, that provides the formation of governments' budget, the adoption of funds from public and private sources, performing other functions according to the law;

- harmonization of national legislation, for the purpose of establishing joint productions on the territories of several states, providing the joint flow of goods and simplifying the tax treatment;
- equalization of transport costs connected with insufficient development of transport and logistics infrastructure, undeveloped border checkpoints, overpriced fares for interstate and transit traffic;
- approximation of laws in customs, tax, insurance, civil, immigration and other fields.

The specificity of the Lugansk region is that it is closely connected with the Donetsk and Kharkiv regions, and, as a part of Ukraine, it is situated between the economic space of EU on the one hand, and on the other – its transport communications around the perimeter of the eastern border are available, close to markets in Russia and Asia. The neighborhood with the developed and fast-developing countries gives the region huge benefits and creates many problems at the same time, associated with the competitiveness of the local cross-border production, cross-border migration, prevention of smuggling, protection of natural resources and environmental protection. The Lugansk region can and should play an important role in the interaction of Western Europe, Ukraine and Russia in entering the Central Asian space, in the direction of China, Kazakhstan, India, and function as a transit economic bridge and as an active participant of economic integration.

Thus, sustainable development of the transport system and the transport complex of the region and its "linkage" with the system of international transport corridors, passing through the territory of Ukraine, is becoming one of the main challenges in the development of the region and East of Ukraine as a whole.

The ITC Europe-Asia is the key, unalternative international transport corridor, which decides security issues and economic development of the Lugansk region. In its framework the parts of Crete corridors № 5, 3 are used and further from Fastov by the railway route ITC № 8. The given route using the roads in Ukraine has a system of road transit traffic (to Volgograd, Makat, Chardzhou) in the directions: Krakovets – Lvov – Rovne – Zhytomyr – Kiev – Poltava – Kharkov – Debaltsevo – Lugansk – Izvarino, with turn-off to Donetsk and Lugansk. For border industrial and agricultural areas of the region is important that the trunk ITC could be used by maximum for development of their own territories, so that the export of transit services, ie the national product of Ukraine, would be the most profitable for the regional community, through the development of various transport and other related services.

For the analysis and implementation of all the works relating to cross-border activities, accounting, construction and reconstruction of road and transport facilities, their more efficient operation and safety, it is necessary to create the national-wide structure – the Agency "Ukrgranitsa" with relevant offices in each region taking into account the example of other countries.

CONCLUSIONS

The implementation of the tasks above in the sphere of cross-border activities will allow the transport and logistics infrastructure of the Lugansk region to accept and handle the total transit cargo following from Europe to Ukraine and further to the East, which according to optimistic forecasts, will amount 1 trillion UAH by 2015. This implementation will provide jobs for thousands of citizens and increase income in the budgets of different levels by 30-35%.

REFERENCES

1. Grigoriy Nechaev, Sergey Izotov, Igor Kaver 2010.: Transit potential of Ukraine. Post-crisis strategy // Teka Kom. Mot. i Energ. Roln. – OL PAN, 10D, p. 207-213.
2. Burkinsky B., Kotlubai A. 2009.: Ukraine in the WTO: the problems and development prospects of national shipping. Kiev: ‘Transport’, ‘Shipping’, ‘Ports of Ukraine’.
3. Slobodyanyuk M., Nechaev G. 2010.: The evaluation technique of logistics’ system cargo transportation efficiency development // Teka Kom. Mot. i Energ. Roln. – OL PAN, 10B, p. 162-170.
4. Nechaev G., Luchko M. 2010.: The position of diagnostics and motor-service in transport-logistic system of the Ukraine // Teka Kom. Mot. i Energ. Roln. – OL PAN, 10B, p. 65-71.
5. Rabotnev V. 2010.: Interview with Deputy Minister of Transport and Communications, [electr. res]. – http://tbu.com.ua.
6. Izotov S. 2010.: Tasks of macroeconomic logistics in the subsystem ‘ocean fishery – transport – wholesale trade’ // Visnik of the East-Ukrainian national university. – № 4 (146) part 1. – P. 109-115.
7. Kaver I., Verkhodanov V., Izotov S. 2008.: Creative imperative of fisheries sector. Monograph. – Sevastopol: Ukrainian Maritime Institute. – 200 p.
8. Primatchev N., Primatchev A. 2006.: Principles of Integration in trade shipping. – Odessa: «Fenix», Moskow: «TransLit». – 359 p.
9. Nechaev G., Korop G., Slobodyanyuk M. 2009.: Automation of classification work planning at rail mod / G. Nechaev, G. Korop, M. Slobodyanyuk // International Scientific Journal “Problemy transportu” Gliwice. – P. 85-89.
10. Nechaev G., Smirniy M., Nikishkin Yu., Gucalo B., Savel’eva M., Kislicin A. 2010.: Regional’naya logistika: metodologicheskie osnovi formirovaniya evroregiona: Monografiya. – Lugansk: East-Ukrainian national university. – 200 p.
11. Nechaev G. 2008.: Tendencies, prospects and problems of transport-logistical processes dataware automation at Ukraine enterprises / G. Nechaev, M. Slobodyanyuk // International Scientific Journal “Problemy transportu” tom 3. zeszyt 4. Gliwice. – P. 27-32.
12. Slobodyanyuk M. 2009.: Model of transportational system for freight insurance automation based on digital signature / M. Slobodyanyuk // International Scientific Journal “Problemy transportu” tom 2. zeszyt 4. Gliwice. – P. 85-91.
13. Nechaev G., Slobodyanyuk M. 2005.: Strategicheskoe upravlenie vzaimootnosheniyami kompaniy s klientami v transportnih logisticeskich sistemah // Visnik of the East-Ukrainian national university. – № 2 (84) part 1. – P. 150-154.
14. Nechaev G., Slobodyanyuk M. 2006.: Konceptual’na model informaciynoji sistemi organizaciji vantazhoperevezeh’ aukcionnim sposobom u torgovih, transportnih informaciynih sistemah, birzhah vantazhiv // Visnik of the DIAT № 2-3. – P. 37.
15. Nechaev G. 2007.: The informational system model of Ukrainian national transport workflow improvement based on electronic signature introduction / G. Nechaev, M. Slobodyanyuk // International Scientific Journal “Problemy transportu” tom 2. Gliwice. – p. 11-14.
16. Nechaev G., Omel’chenko O., Subotin R., Slobodyanyuk M. 2005.: Struktura ta principi formuvannya logistichnih transportnih system mikro- i makrorivniv pri vzaemodiyi z

ruhomim skladom // Visnik of the East-Ukrainian national university. – № 8 (90) part 2. – P. 258-263.
17. Nechaev G., Slobodyanyuk M. 2003.: Effektivnost' transportnoy logistiki // Zbirnik dopovidey mizhnarodnoyi naukovoyi praktichnoyi konferenciyi «Rinok poslug kompleksnih transportnih system ta prikladni problemi logistiki». – Kiyiv. – 270 p.
18. Slobodyanyuk M. 2009.: Research of freight insurance automation // Visnik of the East-Ukrainian national university. – № 4 (134) part 2. – 169 p.
19. Nechaev G. 2010.: Razvitie prigranichnogo sotrudnichestva Ukraini. Gl. Logistika: «Problemi i resheniya» // International scientific magazine № 3. – Kiev. – P. 74-77.
20. Nechaev G., Tararichkin I, Slobodyanyuk M. 2010.: Kachestvo i konkurentosposobnost' transportnich uslug pri gruzovih perevozkah // Visnik of the East-Ukrainian national university. – № 3 (145). – P. 252-262.
21. Nechaev G., Slobodyanyuk M. 2008.: Ways enhancement of information logistic freight flow organization systems // Dokladi ot Sedmata: mezhdunarodna konferenciya «Logistikata v promenyashiyase svyat». – Sofiya. – IBIS. – P. 318.

СОСТОЯНИЕ И ПЕРСПЕКТИВЫ РАЗВИТИЯ ИНФРАСТРУКТУРЫ МЕЖДУНАРОДНЫХ ТРАНСПОРТНЫХ КОРИДОРОВ ВОСТОКА УКРАИНЫ

Григорий Нечаев, Максим Слободянюк

Аннотация. В статье рассматривается состояние и перспективы развития инфраструктуры международных транспортных коридоров Востока Украины.

Ключевые слова: транспортные коридоры, логистика, транспортные технологии, транспорт, Луганская область.

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ANALYSIS OF DESIGN AND CALCULATION OF PARAMETERS OF NON-CONTACT DRIVE SINGLE-SUPPORT SYSTEM

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Summary: The design variants of rotary motion non-contact drive single-support system are analyzed. A design model and determination of bearing capacity, inflexibility and air consumption of single-support system with aerostatic conical angular contact bearing are suggested. Calculation of parameters and comparative analysis of single-support system aerostatic bearing in traditional design is being done and also with up-to-date ring shape cage and labyrinth packing in outcome gas lubricant.

Key words: non-contact bearing, single-support system, backpressure, bearing capacity, inflexibility.

INTRODUCTION

We understand non-contact drive single-support system of rotation moment as self-sufficient, in terms of stability, system with an aerostatic angular contact bearing. The purpose of contact is to put the drive into the rotational movement of working bodies, such as a diamond cutter or pumps impellers, compressors, etc., which are held supporting by bearing systems [1].Non-contact rotation is made by dividing movable and fixed parts of a drive with gas-lubricated gap, and electromagnetic forces transfer rotating moment to the moving part (rotor).Aerostatic suspension single-support system has minimal friction losses and other advantages, but sufficient bearing capacity and stiffness level at low cost air consumption and the lowest feed pressure should be reached.

Single-support system that is being considered has several features taking it research and calculation beyond existing techniques because of short bearing length ratio, bearing face incline relative to the rotation axis. The article objective is to engineer design model and design procedure of single-support system to provide rational choice of geometric parameters and to improve structure of aerostatic suspension drive for maximal inflexibility and bearing capacity.

CALCULATION OF KEY PARAMETERS OF SINGLE-SUPPORT SYSTEM

The typical example of single-support system is spindle assembly of mono-crystal automatic plating machine – "Almaz-150 ASA" [2]. It's 3D model spindle assembly with inward cutting detachable circle (IBDC) **6** and mono crystal **7** fixed on holder **8** [3] are shown on fig.1. Single-support system consists of aerostatic (gas-static) angular contact bearing, strainer **3**, direct drive magnetic system **4** for rotation moment non-contact drive due to interaction with stator **5**. Aerostatic bearing has movable support **1** and stable support **2**. Their conical bearing have contact angle α relative to the axis that determines relation between radial and axial loads of gas lubricate. Contact angle has to be minimum permissible for the systems with dominant radial load at the same time secure with axial stability of single-support system.

The system under consideration is a single-support system. The movable support **1** is one piece part of wide ring shape having two conical bearing faces and non drainage gas lubricant between them. It is divided in two equal parts that have contact angle α relative to the axis reacting axis loads.

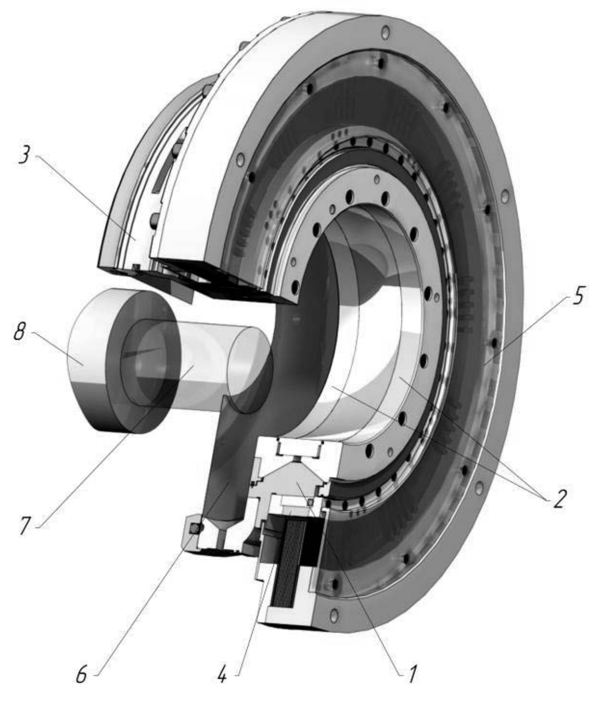

Fig.1 Spindle assembly 3D model

The air is supplied via inlet to the annular space under pressure (0,4 – 0,63) MPa, from annular space through feed-hole gets to the air gap, separating movable support **1** from stable support **2**. Pressure distribution in air gap is a function of constructive parameters, inlet and outlet gas pressure and place of movable support to stable one, which is determined by eccentricity. It occurs at load and leads to pressure difference in air gap producing elevating power. If there is no mechanical contact, single-support bearing is functional [4 – 7].

The so called rotor "levitation" of single-support system is provided with continuous air input. Therefore permanence of its attitude position can be viewed as stability of rotor motion in "rotor-bearing" dynamic system [8 – 16]. Bearing capacity in radial and axial directions is determined by the system of interacted parameters such as contact angle of reference plane α, its radius, feed pressure, diameter and a quantity of feed-holes etc. Air pressure is distributed axial-symmetric in any ring cross-section and its resultant equals zero in central (symmetrical) position of movable support. If movable support floats to the bearing on eccentricity e under external load W_e, ring cross-section of a gap gets variable changing pressure in the gap. The pressure is maximal in minimal gap pressure area and vice versa is minimal in maximal gap pressure area [17 – 19].

Engineering process requirements determine running speed. For instance, it is 1000 – 1500 rpm for mono-crystal automatic plating machine, 20000…200000 rpm for grinding pneumatic spindle [6]. Rotation frequency of given single-support system can be changed from 0 rpm (when bearing runs as aerostatic suspension) to limit rotation frequency, where gas lubricant flow gets turbulent (6500 to 70000 rpm).

Determining following parameters such as limit rotation frequency, natural and cutoff frequency, required power and loss power, starting and stopping time, coefficient of mechanical efficiency, axial and radial limit load, inflexibility and air consumption give single-support system design. The gas-static bearing of single-support system is specified by the last three parameters.

The existing methods of gas bearings calculation [6, 7, 17, 20 – 22] don't work for aerostatic bearing that have bearing length ratio to the diameter less than 0.5 (λ parameter) and conical bearing face with more than 20^0 angle α.

The most appropriate method in this case for single-support system design from the mentioned above is the one suggested in [17]. Non conical gas-static bearings are described there, however, we assume that all the parameters of angular contact bearing correlate with parameters of radial one in the design model of single support system (fig.2).

Given design model on fig.2 includes following changes:

- bearing faces with α contact angle relative to the axis turned horizontal ($\alpha = 0$) in point of mean radius $\boldsymbol{R} = (R_{\min} - R_{\max})/2$;
- total length of aerostatic bearing L consists of two lengths conical parts and a gap between those that is a space under pressure joining as a single bearing face;
- labyrinth packing rings are removed to fit the design method [17] most (see fig.2 a).

According to design model the radius of the bearing is R = 175 mm, the length is L = 97 mm and the mean gap is C = 10…30 micrometer. Two lines of feed-holes with diameter D_d = 0.5 mm, quantity N = 22 in one pressure boost line and the distance between lines l^* = 40 mm help the air to get in the gap. Getting through each feed-hole the air throttles twice in machining gap and feed-hole.

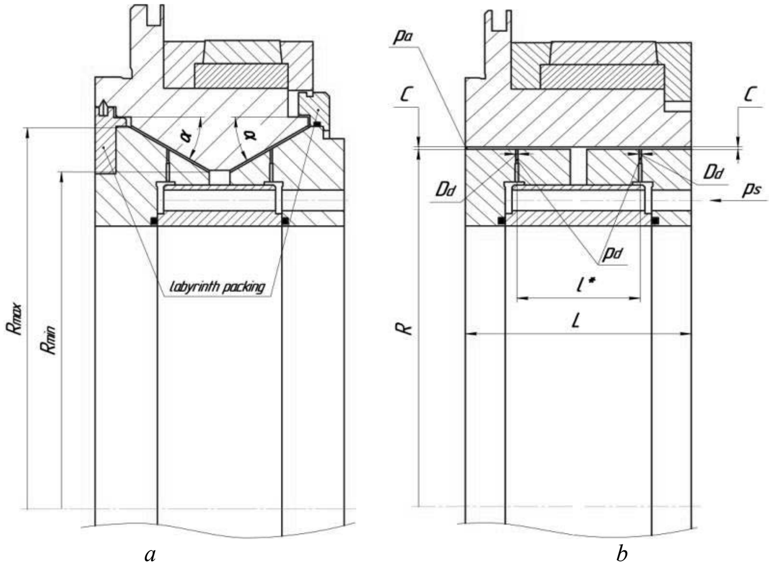

Fig.2 Construction (a) and design model (b) of single-support system

Dislocation of movable support leads to air dynamic forces calculation that is determined by confluent inflexibility matrix. If there is no rotation, there are only two elements $\overline{K}_r^{\varepsilon}$ and $\overline{K}\gamma$ – coefficients of radial and angular inflexibility. Last two characterize bearing capacity and radial suspender inflexibility. We are to determine dimensionless parameter $\overline{m}$, machine pressure difference along air lubricated layer (p_d - p_a) and in feed-hole (p_s - p_d). It depends on bearing design trait and gas feed property [17, 18]:

$$\overline{m} = \frac{12\mu a_1 \left(\frac{2}{k+1}\right)^{\frac{k+1}{2(k-1)}} N\, n_d\, D_d}{C^2 p_s}, \tag{1}$$

where: C – is a mean gap at zero eccentricity;

k –adiabatic index for two-atom gas and air is equal 1.4.

Counterpressure $\overline{p}_d$ is a relation of feed-hole output pressure (p_d) to feed pressure (p_s); $\overline{p}_d$ is determined through outflow function:

$$\overline{p}_d = \sqrt{\frac{\left(\overline{p}_a\right)^2 + \overline{m}\,\zeta}{1+\overline{m}\,\zeta}}, \tag{2}$$

where: ζ – is a function that depends on bearing geometrical parameters (λ – comparative boost lines separation – $b = l^*/L$):

$$\zeta = \frac{\lambda(1-b)}{2}. \tag{3}$$

Air outflow speed via feed-holes is specified by pressure difference:

$$\bar{p}_d = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}. \tag{4}$$

When the counterpressure gets higher air outflow speed becomes critical – sonic speed. If $\bar{p}_d \le 0.528$, flow speed surmounts sonic speed with possible shock-wave absorbing energy and dropping area pressure. Gas flow conditions via feed-holes are to be undercritical to secure stable bearing run. Usually $0.528 < \bar{p}_d < 0.9$ [6] is in aerostatic bearings. If p_a = 1atm, the counterpressure calculation on formula (2) demands boost pressure to get lower.

To calculate inflexibility index we use unified formulas:

$$\bar{K}_r^{\varepsilon} = \frac{C}{4\lambda R^2 p_s} K_r^{\varepsilon} = \frac{2}{3} \cdot \frac{0.75\pi\nu}{ch\lambda + 0.5\bar{m}U_r \cdot chb\lambda \cdot sh(1-b)\lambda} \times \left(\frac{shb\lambda \cdot sh(1-b)\lambda}{\lambda \bar{p}_d} + I_0 \frac{chb\lambda}{\sqrt{\nu\lambda}} \right), \tag{5}$$

$$\bar{K}^{\gamma} = \frac{C}{4\lambda^2 R^4 p_s} K^{\gamma} = \frac{0.75\pi}{\lambda} \times$$

$$\times \left(\frac{2}{3}\left[(2+b)\bar{p}_d - 3\bar{p}_a + \frac{2(1-b)p_a^2}{\bar{p}_d + \bar{p}_a} \right] + \frac{\left(\bar{p}_d - \bar{p}_a\right)\eta}{\lambda^2(1-b)} \cdot \left(b \cdot chb\lambda - \frac{shb\lambda}{\lambda} \right) - \sqrt{\frac{\bar{p}_d - \bar{p}_a}{1-b}} \cdot \left[I_1 - \left(th\frac{(1-b)\lambda}{2} + \eta \frac{shb\lambda}{sh(1-b)\lambda} \right) \cdot I_2 \right] \right), \tag{6}$$

where: U_r – approximated outflow function with Prandtl formula: $U_r = 0.5\bar{p}_d$;

$$\eta = \frac{ib\lambda \; sh\bar{b}\lambda + ch\bar{b}\lambda - 1}{sh\lambda + 0.5\bar{m}U_r \; shb\lambda \; sh\bar{b}\lambda};$$

I_0, I_1, I_2 – stereotyped integrals line: $I_0 = \int_b^1 \frac{sh\lambda(1-x)}{\sqrt{\beta - x}}\,dx$, $\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \int_b^1 \frac{x}{\sqrt{\beta - x}} \begin{bmatrix} ch\lambda\ (1-x) \\ sh\lambda\ (1-x) \end{bmatrix} dx$.

To calculate single-support system bearing capacity for linear problem we use:

$$W_e = \lambda A_{\Sigma} \cdot p_s \cdot \bar{W}_e = \lambda A_{\Sigma} p_s \bar{K}_r^{\varepsilon} \varepsilon_r, \tag{7}$$

where: $A_{\Sigma} = 4R^2$ is global area scale;

$\varepsilon_r = \frac{l}{N}$ is relative eccentricity where its maximal value equals peak bearing capacity and can reach maximal value 0.8.

Angular contact bearing with conical bearing faces under angle α to rotation axis is used in single-support system, thus gas lubricant resultant action has the same angle.

Then angular contact bearing capacity Wеку is determined by radial component (along axis 0У):

$$W_{ek\acute{o}} = W_e \cdot \cos\alpha \,. \tag{8}$$

Peak (maximal calculation at $\overline{p}_a \to 0$) volume gas consumption Q via bearing at normal terms:

$$Q = \frac{\pi \acute{N}^3 p_s^2}{12\mu\, p_a} \cdot \overline{m} \cdot 3600. \tag{9}$$

Single-support system main parameters calculation results at gap variation and undercritical mode of gas flow are given in table 1.

Table 1. **Single support main parameters at mean gap modification**

Air lubricated mean gap ***C***, m	Feed pressure $\boldsymbol{p_s}$, MPa	Single-support system bearing capacity		Angular limit load $\boldsymbol{M_\gamma}$, N·m	Air consumption $\boldsymbol{Q}$, m³/h
		Radial direction $\boldsymbol{W_{eky}}$, Н	Axial direction $\boldsymbol{W_{ekz}}$, Н		
10×10^{-6}	0.69	8192	2364	26716	2.4
15×10^{-6}	0.38	2524	728	6470	2.0
20×10^{-6}	0.29	1131	327	2468	2.1
25×10^{-6}	0.25	600	173	1177	2.2
30×10^{-6}	0.22	335	97	611	2.3

As $\overline{p}_d = \text{f}\left(\overline{p}_a{}^2\right)$, reducing feed pressure p_s (see table 1) and also increasing gap outlet pressure p_a we can obtain the counterpressure interval and avoid critical gas flow through feed-holes. Increasing gap outlet pressure will rise boost pressure and considerably increase bearing capacity or to reduce air consumption at invariant bearing capacity. Hereby, we can improve single-support system features with λ<0.5. Technically it is realized by air flows from the gap not into the atmosphere but in the annular space where the pressure gets normal in all circle and it won't get lower than the atmosphere pressure level due to labyrinth packing (see fig. 2 a). Fig. 3 shows counterpressure $\overline{p}_d$ and gap outcome pressure p_a relation.

$$\overline{p}_d = \sqrt{\frac{\left(\overline{p}_a\right)^2 + \overline{m}\zeta}{1+\overline{m}\zeta}} = \sqrt{\frac{\left(\frac{p_a}{p_s}\right)^2 + \overline{m}\cdot\frac{\lambda(1-b)}{2}}{1+\overline{m}\cdot\frac{\lambda(1-b)}{2}}}\,.$$

The calculation was done for three bearings with different elongation $\lambda = L/D$ ($\lambda = 0.15, 0.25, 0.5$).

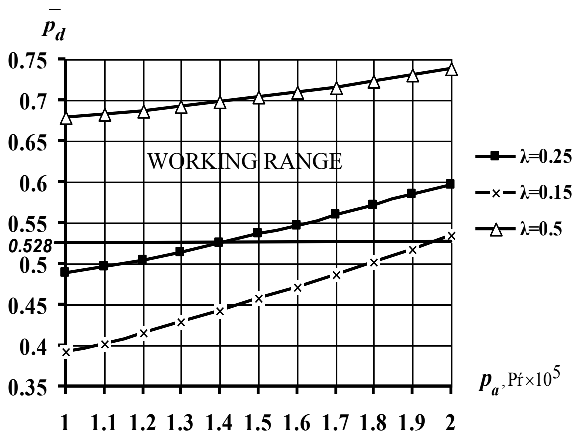

Fig. 3 Counter pressure relation to p_a for different length bearings

Thereby due to labyrinth packing we get gap outlet pressure increase that helps to avoid undercritical bearing behavior with bearing length reduce. According to mentioned above we are going to calculate single-support system pressure outlet variation.

Single-support system pressure outlet and mean gap variation calculation results are given in table 2.

Table 2 **Single-support system main parameters**

Air lubricated mean gap C, m	Pressure inlet and outlet quotient p_a/p_s, MPa	Single-support system bearing capacity		Angular limit load M_γ, N·m	Air consumption Q, m^3/h p_a, Pſ×10^5
		Radial direction W_{eky}, N	Axial direction W_{ekz}, N		
10×10^{-6}	0.1/0.45	5524	1595	17616	1.6
	0.1/0.55	6694	1932	21422	1.9
	0.1/0.63	7568	2185	24236	2.2
15×10^{-6}	0.143/0.45	2599	750	6007	1.7
	0.2/0.55	2681	774	5672	1.5
	0.24/0.63	2768	800	5613	1.4
20×10^{-6}	0.19/0.45	1180	340	2225	1.7
	0.245/0.55	1196	345	2158	1.6
	0.28/0.63	1248	360	2111	1.6
25×10^{-6}	0.21/0.45	621	179	1075	1.9
	0.262/0.55	634	183	1069	1.9
	0.304/0.63	640	185	1064	1.8
30×10^{-6}	0.22/0.45	365	105	605	2.2
	0.271/0.55	373	108	608	2.1
	0.313/0.63	376	109	606	2.1

Analyzing table 2 data, we can see that applying labyrinth packing gap outlet secures undercritical bearing behavior and improves technical characteristics. For example, if there is no outlet pressure regulation, single-support system bearing capacity obtains 2524 N with mean gap C = 15 μm and air consumption 2 m^3/h (see table 1), but with outlet pressure regulation bearing capacity can obtain 2724 N with air consumption 1.3 m^3/h.

CONCLUSIONS

Non-contact drive single-support mechanical system that is based on aerostatic angular contact bearing with conical bearing faces is able to secure sufficient bearing capacity, inflexibility and speed range condition for effective application on cutting machine tool, pumps and compressors. It is characterized by minimal friction loss, high vibration resistance and considerable speed range, it has regulating inflexibility. The suggested here design procedure is based on design model conversion and allows to research bearing systems parameters with diverse bearing faces contact angle. Single-support system retrofit consists of placing labyrinth packings allowing to 10% raise bearing capacity and 30% reduce process gas.

REFERENCES

1. Breshev V. E., 2010.: Developments in technology of non-contact drives and changing to resource-saving technology of non-contact drive / V.E. Breshev, A.V. Breshev // The production of resource-saving technology and materials processing under pressure in mechanical engineering: scientific study collection – Luhansk: Publ. Volodymyr Dahl East-Ukrainian National University. – 153–159. (in Russian).
2. PA “Donets”, 1996.: Catalogue of output goods. – Lugansk: AT “CoDr”,. – 16. (in Russian)
3. Bochkin O.I., 1983.: Semiconducting materials mechanical treatment / Bochkin O.I., Bruk V.A., Nikiforova-Denisova S.N.– Moscow, High School. – 112. (in Russian).
4. Grehessem N.S., 1963.: Gas lubricated bearings / edited by. N.S. Grehessem, G. U. Paujella; transl. from eng. P.P. Mostovenko and others. – Moscow: Mir. – 423. (in Russian)
5. Peshti Yu.V., 1993.: Gas lubrication / Yu.V. Peshti. – Moscow: ed. by MIPT. – 381(in Russian).
6. Sheynberg S.A., 1969.: Support of sliding with gas lubrication / Sheynberh S.A., Zhed V.P., Shysheev M.D. – Moscow: Machine building. – 336. (in Russian).
7. Konstantinescu V.I., 1968.: Gas Lubrication / V.I. Constantinescu; translated from Romanian, ed. M.V. Korovchinskogo. – Moscow: Machine building. – 709. (in Russian).
8. Lyapunov A.M., 1950.: The general problem of the stability of motion / Lyapunov A.M. – M.–L.: State Publishing House of technical and theoretical literature. – 472. (in Russian).
9. Alphutov N.A., 2003.: Stability of motion and equilibrium: [higher educational establishments students’ textbook]. / Alphutov N.A., K. S. Kolesnikov; ed. by K. S. Kolesnikov. – [second edition] – M.: MSTU, – (Set of "Mechanics at the technical university" 8 volume). Vol. 3. – 256. (in Russian).
10. Merkin D.R., 2003.: Introduction into the theory of stability of motion / Merkin D.R. – [4th edition]. – StP.: Lahn. – 304. (in Russian).

11. Butenin N.V., 2002.: The course of classical mechanics: [higher educational establishments students' textbook]: in 2 volumes / Butenin N.V., Lunts Ya. L., Merkin D.R. – [2d edition] – SP.: Lahn. – 736. (in Russian).
12. Malkin I.G.,1966.: The theory of stability of motion / Malkin I.G. – [2d edition]. – M.: Science. – 530. (in Russian).
13. Nikiforov A.N., 2010.: Problems of oscillation and dynamic stability of rotors [Electronic source]: National production team / Nikiforov A.N. // Technological planning bulletin – №3(31). – Mode of access to the Journal: http://www.vntr.ru. (in Russian).
14. Kehlzon A.S., 1982.: Dynamics of rotor in resilient support / Kehlzon A.S., Cimanskii Yu.P., Yakovlev V.I. – Moscow: Science. – 280. (in Russian).
15. Kehlzon A.S., 1977.: Calculation and design of rotor machines / Kehlzon A.S., Yu.N. Zhuravlev, N.V. Yanvarev; edited by A.S. Kehlzon. – L.: Machine science. – 288. (in Russian).
16. Demidovich B.P, 2008.: Lectures on mathematical stability theory: manual / Demidovich B.P. – [3d edition] – StP.: Lahn. – 480. (in Russian).
17. Pinegin S.V., 1982.: Static and dynamic features of gas static bearings / Pinegin S.V., Tabachnikov Yu.B., Sipenkov I.E. – M.: Science. – 265. (in Russian).
18. Pinegin S.V., 1984.: Precision of rolling contact bearings and gas lubricated gas bearings: Reference book / Pinegin S.V., Orlov A.V., Tabachnikov Yu.B. – M.: Machine science. – 216. (in Russian).
19. Zablodsky N.D., Sipenkov I.E., Philippov A.Yu., 2004.: Dedicated to the 50s anniversary of Loinyansky L.G. gas lubricant school [Electronic resourse]: Turbulence issues and computational fluid dynamics (to 70 anniversary of «Aero hydrodynamics» department) / Zablodsky N.D., Sipenkov I.E., Philippov A. Yu. // Engineering register, – №2. – 159–176. – Mode of access to the journal is: http://aero.spbstu.ru/science/public/dept70.html. (in Russian).
20. Fedotov V.O., 2010.: Spindle units of gas lubricated: monograph / Fedotov V.O., Fedotova I.V. – Vinnytsya: VESU. – 244. (in Russian).
21. Drozdovich V.N., 1963.: Gas dynamic bearings / Drozdovich V. N. – L.: Machine science, 1976. – 208 p.
22. Chernavsky S.A. Journal bearing / .Chernavsky S.A.– M.: MASHGIZ. –244. (in Russian).

АНАЛИЗ КОНСТРУКЦИЙ И РАСЧЕТ ПАРАМЕТРОВ ОДНООПОРНОЙ СИСТЕМЫ БЕСКОНТАКТНОГО ПРИВОДА

Павел Носко, Алексей Брешев, Павел Филь, Владимир Брешев

Аннотация. Проанализированы варианты конструкции одноопорной системы бесконтактного привода вращательного движения. Предложена расчетная схема и методика определения несущей способности, жесткости и расхода воздуха одноопорной системы с конусным радиально-упорным аэростатическим подшипником. Выполнен расчёт параметров и сравнительный анализ одноопорной системы с аэростатическим подшипником традиционной конструкции, а также с модернизированной – с кольцевой камерой и лабиринтным уплотнением на выходе газовой смазки.

Ключевые слова: бесконтактная опора, одноопорная система, противодавление, несущая способность, жесткость.

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MATHEMATICAL MODELLING OF THE UNSTATIONARY FRICTION INTERACTION OF THE WORKING ELEMENTS OF THE LOCOMOTIVE DISK BRAKE

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Summary. The article considers the mathematical model which gives the possibility to predict the work of the frictional elements of the locomotive disk brake the functioning base of which is ensured by joint use of both materials which are situated independently on the brake pad and it exerts an integral influence on the friction characteristics. A developed mathematical model permits to predict the work of the above frictional unit due to the friction coefficient criteria.

Key words: friction coefficient, temperature, locomotive disk brake.

INTRODUCTION

Speed growth on the railway requires new demands to the frictional disk brake connected with improvement of its technical and economical indexes concerning stability of brake characteristics, reliability and value decrease. In the nearest future a disk brake is to ensure high operational qualities under the conditions when its power capacity attains 100 MJ (at present 40 MJ), working temperature – 1000^0 C (at present 600^0 C).

The solution of this task is realized due to complex approach, main components of which are the improvement of the disk brake, development of effective algorithms of its work, development of the working materials with high working qualities and creation of favourable conditions for full realization of their frictional possibilities in the regime of braking. In this case the last two tends are considered of some priority and great attention is paid to them [1, 2].

At present, the development of new frictional materials does not bring some positive results in a unique manner and they (the materials) require a sharp cost increase of production. Such a position proved to be correct only with respect to the brake disk, the working period of which is to be equal to the working period of the wheel set.

In this connection the perspective tend of the research is the ensurance of stable braking characteristics of the railway rolling stock by means of creation of new integral frictional properties of the disk brake due to simultaneous use of both frictional materials which produce some integral influence on the friction characteristics.

CALCULATION MODEL

The solution of the given task is attained by the solution of the heat problem concerning frictional brake of the rolling stock taking into account the temperature influence as a dominating factor which determines the friction unit behaviour on the physical and mechanical properties of the materials which are applied in the calculations.

The differential equality of heat conductivity (Fourier - Kirchhoff) in the cylindrical system of coordinates without internal heat sources (calculated diagram is given in the fig. 1) serves as the model basis of heat interaction of the working elements of the frictional brake.

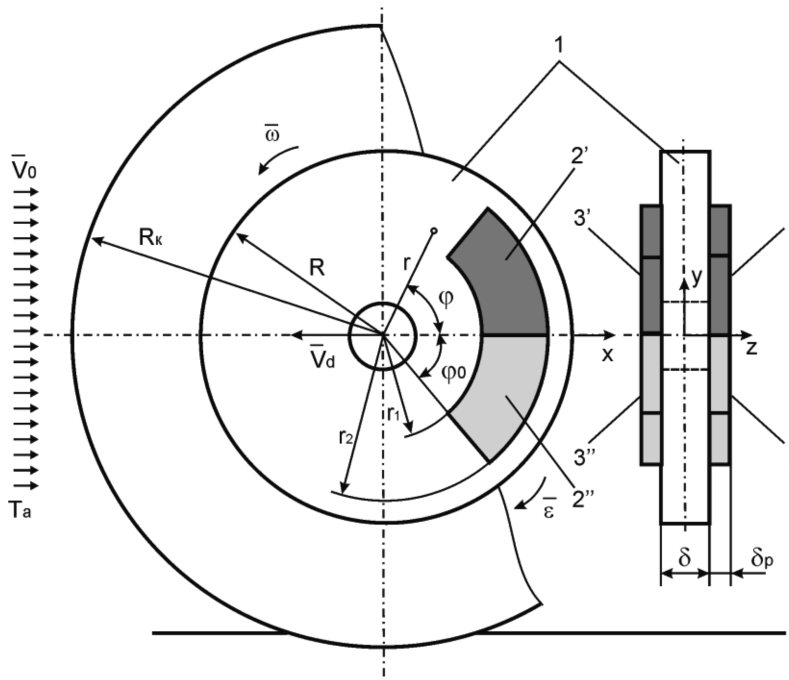

Fig. 1. Design model of the disk brake of rolling stock:
1 - brake disk 2, 3 - brake pads, which contain two frictional material with of the different properties (marked ” ’ ” and “ ’’ ” respectively)

This is achieved by the solution of the heat problem concerning the frictional brake of the rolling stock taking into account the temperature influence as a dominating factor which determines the friction unit behaviour on the physical and mechanical properties of the materials applied in the calculations.

The model gives the possibility to determine the temperature pattern of the frictional and interacting brake surfaces (both local and mean integral) and also heat flows which pass through marked surfaces in the process of braking. There considered the case of application of the friction brake property – a disk brake the pad of which hold two frictional materials with different properties, each of which is loaded independently from each other. However the given model can be also used for a block brake [3 – 5]:

$$\frac{\partial T}{\partial \tau} = \vartheta\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2}\frac{\partial^2 T}{\partial \varphi^2} + \frac{\partial^2 T}{\partial z^2}\right), \tag{1}$$

where: $\vartheta = \lambda / (c_p \cdot \rho)$ – coefficient of thermal diffusivity material, here λ – heat conduction coefficient, c_p – isobar specific heat, ρ – density; τ – current value of the time when braking; T – absolute temperature ($T = f(r,\varphi,z,\tau)$, де φ – angle between the radius vector r and axis x).

The diagram (Fig. 1.) adopted the following labels: R, R_k – radius of the brake disc and wheel locomotive respectively; δ, δ_p – thickness of brake pad and disc respectively; V_0 – the speed of oncoming air flow; T_a – the average temperature on the distance from brake disc; V_d – current engine speed; ω – angular velocity of brake disc; ε – angular acceleration (deceleration) brake disc during braking.

Point of origin located at the geometric center of the brake disk.

Equation (1) supplemented by the following boundary conditions. For the side and end surfaces of brake disc (excluding areas of its frictional contact with braking plates) used the boundary conditions of 3rd sort (without internal heat sources):

$$\pm\lambda\left(\frac{\partial T}{\partial z}\right) = \alpha_z (T - T_a),\ z = \pm\delta/2, \tag{2}$$

where: α_z – coefficient of heat transfer between the end surfaces of the brake disk and the ambient air;

On the side (cylindrical) surface of the brake disk:

$$\lambda\left(\frac{\partial T}{\partial r}\right) = \alpha_r (T - T_a),\ r = R, \tag{3}$$

where: α_r – coefficient of heat transfer between the lateral surface of the brake disk and the ambient air;

For the surface area of sliding contact with the disc brake pads are used boundary conditions of the 4th sort of surface heat source (for the case of non-ideal thermal contact). This is because in the set the next time the basic principles that are based on the research area of thermal tribocontact, the source of heat is considered the finest continuous surface layers directly adjacent to the actual platform contact each of the friction-interacting bodies and reproduce like a single system [6 - 8].

$$\left.\begin{aligned} -\lambda_1\left(\frac{\partial T_1}{\partial z}\right) &= \alpha_{ет}\,q - \frac{1}{R_c}(T_1 - T_2), \\ \lambda_2\left(\frac{\partial T_2}{\partial z}\right) &= (1-\alpha_{ет})\,q + \frac{1}{R_c}(T_1 - T_2), \end{aligned}\right\},\ z = \pm\delta/2, \tag{4}$$

where: q – specific heat flow generated during sliding contact with the brake disk plate;
R_c – thermal resistance contact. During thermal contact resistance is understood value: $R_c = \Delta T / q$, where ΔT – average temperatures drop contacting surfaces;
$\alpha_{ет}$ – energy distribution coefficient of friction ($0 < \alpha_{ет} < 1$) shows how much heat energy is formed on the surface friction of the first body as a result of destruction of the adhesive bonds in the actual contact area and deformation microirregularities roughness of the interacting surfaces. On the surface of the second body is formed another portion of heat energy equal to $(1 - \alpha_{ет})$ [9, 10]:

$$\alpha_{ет} = \frac{\sqrt{\lambda_1 \cdot c_{p1} \cdot \rho_1}}{\sqrt{\lambda_2 \cdot c_{p2} \cdot \rho_2} + \sqrt{\lambda_1 \cdot c_{p1} \cdot \rho_1}}.$$

Here and below the index "1" refers to the corresponding value of brake disk, the index "2" - to the brake linings. Moreover, for each of the friction materials that are in interaction with the brake disk must use the corresponding system of equations (4).

Other (not marked in Figure 1.) Surfaces are insulated.

Specific heat flow generated during braking one type of friction material [4, 11]:

$$q(\varphi, r, \tau) = \frac{1}{n_k \iint\limits_S r(\varphi)ds} \frac{m R_к^2 \cdot \varepsilon}{n_n} r(\varphi)(\omega^* - \varepsilon \cdot \tau),$$

where: m – mass brakes;
n_k – number of types of friction material used in pads;
n_n – number of brake pads with a material that is involved in braking (at the design scheme (Fig. 1). using two types of friction material);
r – radius vector describing the contact area of the disk pad S;
ω^* – angular velocity of the disc that precedes braking ($\varepsilon > 0$);
$\tau \in [0; \tau_к]$, $\tau_к = (V^* - V_к)/a^*$, – braking time (time interval from the start of braking to achieve the ultimate engine speed).
Where $V_к$ – the final speed of the locomotive, a^* – linear deceleration when braking ($a^* > 0$), V^* – speed of the locomotive that precedes braking.

To determine the heat transfer coefficients, which are included in expressions (2) and (3) are used, respectively, the following criterial equation [6, 12]:

$$\left.\begin{aligned} Nu_z &= 0{,}135 \cdot [(0{,}5 \cdot Re_\omega^2 + Re_a^2 + Gr) \cdot Pr]^{0{,}33}, \\ Nu_r &= 0{,}037 \cdot (Re_a^{0{,}8} + Re_\omega^{0{,}4}) \cdot Pr^{0{,}33}, \end{aligned}\right\} \tag{5}$$

where: Re_ω, Re_a – Reynolds number, which are caused by rotation of the brake disk and the blowing wind blowing, respectively:

$$\left.\begin{aligned} Re_\omega &= \frac{4\cdot\omega\cdot R^2}{\nu} = 4\cdot\left(\frac{V_d}{R_к}\right)\cdot\frac{R^2}{\nu}, \\ Re_a &= \frac{2\cdot V\cdot R}{\nu}, \end{aligned}\right\}$$

where: ν – kinematic viscosity of air;
$V = V_d + V_0 = (V^* - a^* \cdot t) + V_0$, – current speed of the airflow, which run on a disc brake ($a^* > 0$).

Hrashof, Prandtl and Nusselt numbers for air:

$$Gr = 8\cdot\beta\cdot g\cdot R^3\cdot(T - T_a)/\nu^2;$$

$$Pr = c_a\cdot\mu/\lambda;\ Nu = 2\cdot\alpha\cdot R/\lambda,$$

where β – coefficient of volumetric expansion of air;
λ – thermal conductivity of air;
c_a – specific isobar heat capacity of air;
μ – viscosity of air;
α – heat transfer coefficient of the surface of the brake disk, which is determined by the system (5).

Value of thermal resistance contact, which is part of the system (4) serves for finding the ratio of heat flow transmitted by contact with heat transfer surfaces interacting combination of brake disk - overlay. Since it is the contact thermal resistance caused by imperfect mechanical connection friction surfaces significantly affect the relationship between transferred through a heat flow and temperature difference of the interacting surfaces.

Its definition is as follows [8, 13]:

$$\frac{1}{R_c} = 1{,}15\cdot10^{-4}\,\frac{\sigma_1+\sigma_2}{\sigma_1/\lambda_1+\sigma_2/\lambda_2}\left(\frac{P_n^2}{\Omega}\cdot\frac{E_1+E_2}{2\cdot E_1\cdot E_2}\cdot\frac{T_c}{T_m}\cdot K^2\right)^{0{,}302},$$

$$\left.\begin{aligned} &K = 1 \text{ при } (\sigma_1+\sigma_2) > 3\cdot10^{-5}, \\ &K^2 = \left(\frac{30\cdot10^{-6}}{\sigma_1+\sigma_2}\right)^{2/3} \text{ при } 1\cdot10^{-5} < (\sigma_1+\sigma_2) \le 3\cdot10^{-5}, \\ &K = \frac{15\cdot10^{-6}}{\sigma_1+\sigma_2} \text{ при } (\sigma_1+\sigma_2) \le 1\cdot10^{-5}, \end{aligned}\right\}$$

where: $\sigma_{1,2}$ – average height microirregularities performances in the area of contact mating surfaces;
$\lambda_{1,2}$ – thermal conductivity of materials interacting surfaces;
P_n – nominal contact pressure;
Ω – tensile strength of more pliable material;
$E_{1,2}$ – modulus of elasticity of contacting materials;;
T_c – average contact temperature;
T_m – melting point of a fusible material;

K – factor that determines the change of geometrical characteristics of contacting surfaces.

Using the equation given above, the obtained mathematical model of temperature field of brake disc surfaces:

$$T^*(r^*,z^*,\Theta) = q\cdot\sqrt{\frac{\delta}{2R}}\cdot\frac{\sqrt{A}+B}{\pi\sqrt{A}+B\cdot(\pi-2\varphi_0)}\cdot\left[\frac{2\varphi_0}{\sqrt{A}+B}\cdot\exp\left(-\sqrt{\frac{2A\cdot R}{\delta}}\times\right.\right.$$
$$\left.\times(1-r^*)\right)+\frac{1}{P}\cdot\sqrt{\frac{\delta}{R\cdot r^*}}\cdot\sum_{K=-\infty}^{\infty}\frac{\sin(2\alpha_{e\text{т}}\cdot\varphi_0)}{\alpha_{e\text{т}}}\cdot\exp\left(2P\cdot R\frac{\sqrt{\alpha_{e\text{т}}}}{\delta}\cdot(r^*-1)\right)\times \quad (6)$$
$$\left.\times\cos\left(2\alpha_{e\text{т}}\cdot\Theta+\frac{\pi}{4}-P\cdot\frac{2R\cdot\sqrt{\alpha_{e\text{т}}}}{\delta}\cdot(r^*-1)\right)\right],$$

where: $T^* = (T - T_a) / T_a$, – dimensionless temperature;
$r^* = r / R$, $z^* = 2z / \delta$, – dimensionless coordinates;
$\tau^* = \omega\cdot\tau$, – dimensionless time; $\Theta = \varphi - \tau^*$;
$P = \omega\cdot c_p\cdot\rho\cdot\delta^2 / (4\lambda)$, where c_p i ρ – isobar specific heat and density of materials of brake disk; $A = \alpha_z\cdot\delta / (2\lambda)$; $B = \alpha_r\cdot R / \lambda$;

To calculate the friction coefficient in case of simultaneous use of two different friction materials (according to that shown in Figure 1.) Considering temperature field work surfaces interacting elements of disk brakes, received the following dependence [14 - 18]:

$$f = \frac{1}{3N\cdot R_m}(\varphi_2^2-\varphi_1^2)\left[(r_2^3-r_1^3)\left(f_m\cdot P_n+\frac{0{,}84\nu\cdot(\nu-1)\cdot h^{0,5}\cdot k\cdot N^{\frac{2\cdot\nu+1}{2\cdot\nu}}\cdot 2^{\frac{2\cdot\nu+1}{2\cdot\nu}}}{\pi\cdot R_h^{0,5}\cdot HB^{0,5/\nu}\cdot b^{0,5/\nu}}\right)\right], \quad (7)$$

where: f_m – molecular component of friction coefficient, which depends on the tangential stresses at the interface of interacting surfaces of the brake disk pad;
N – normal strain clamping pads to brake disk;
HB – the smallest of the two values of hardness of the material of the contacting surfaces;
R_h – radius of curvature microirregularities a solid surface (average);
R_m – average radius of the friction brake pad;
k – coefficient that depends on the geometrical and mechanical properties of surfaces that are in friction interaction;
h – convergence of the contacting surfaces of the brake disc and pads;
b, ν – parameters of the curve bearing surface;

To obtain total coefficient of friction disc brakes should be determined by the formula (7) the coefficients for each material separately, and summarize the values obtained. Physical and mechanical properties of materials that come in the above equation is considered as a function of temperature.

INPUT DATA AND RESULTS OF CALCULATION

Sample calculation depends disc brake friction coefficient on the relative velocity of sliding friction of its elements, filled with using the above mathematical models, shown in fig. 2.

Considered by frictional contact of metal surfaces in the following combinations: steel brake disc - steel pad, steel brake disk - cast iron pad, steel brake disk - a metal and cast iron pads.

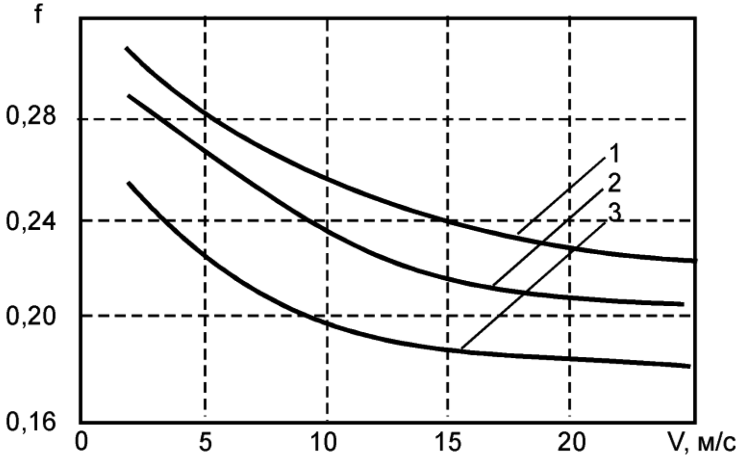

Fig. 2. Dependence of coefficient of friction disc brakes on the relative velocity of sliding friction of its elements obtained for these combinations of contacting materials:
1 - steel brake disk - cast iron pad;
2 - steel brake disk - a metal and cast iron pad;
3 - steel brake disc - steel pad

Calculations are based typical performance curve of the core surface (take from the literature) as well as physical, mechanical and thermal properties of materials considered in the functional dependence on temperature [19, 20]. Thus the average values: $\nu = 2$, $b = 4$, $h = 12{,}5$ μm (maximum value), $k = 0{,}8$. Geometric dimensions of brake linings and disc match these used traction rolling stock of railways. Maximum value $N = 15$ kN. The molecular component of friction coefficient was considered constant.

Fig. 3 shows the results of the calculation of the integral value of the coefficient of friction disc brakes depending on surface temperature in the contact zone for combinations of "iron-steel," "carbon-steel" and "iron and carbon-steel."

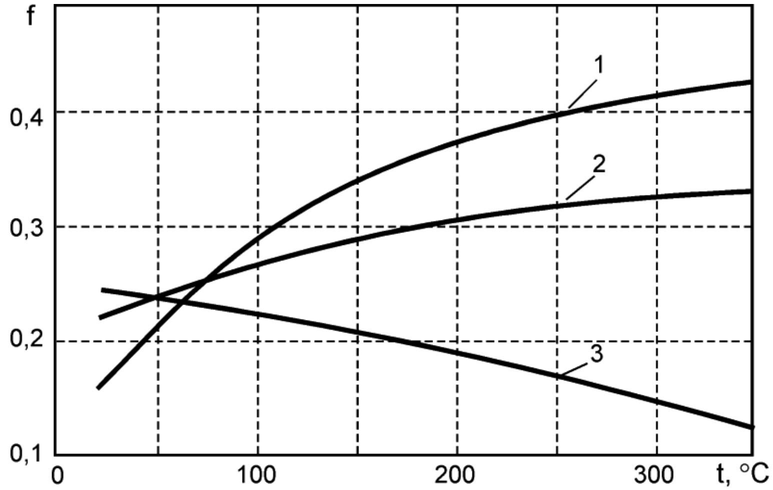

Fig. 3. Estimated value of coefficient of friction disc brake as a function surface temperature of the contact elements of his work, obtained by using the mathematical model for the following combinations of friction: 1 - steel disc and pads of carbon; 2 - steel disc and pad with two working materials: iron and carbon; 3 - steel disc and block with cast iron

CONCLUSIONS

Mathematical models, considered above, give the possibility to determine the friction coefficient value of the frictional brake (especially a disk brake) of the rolling stock which was attained as an integral value from the joint action of several frictional materials with different properties and loading conditions which are placed simultaneously on the disk brake pad (the given models differ from the existing ones in this aspect). This is carried out due to the temperature influence, which is generated while braking, on the major physical and mechanical properties of the materials which are in the position of the frictional interaction. In this case the temperature value of the brake system elements, motion speed of the locomotive and contrary air flow at the moment before braking are used.

There obtained mathematical models which account all the main design (R, δ, r_1, r_2, φ_0), technological (ν, b, k, R_h, $\sigma_{1,2}$), material (HB, $E_{1,2}$, Ω, T_m) and operational (f_m, h, P_n) parameters of the rolling stock frictional brakes (especially disk brakes).

The analysis of the obtained results allow to make the following conclusion: the application of simultaneous combination of two (as minimum) frictional materials having different frictional properties, in the brake pad design gives the possibility to obtain new integral properties of the disk brake as a whole. The combination of the materials cast iron – coal has higher frictional properties than in the case of two pads of cast-iron. This combination of the materials ensures higher friction coefficient values in the beginning of the braking moment in the difference from the friction couple coal –

coal (though further the given combination of the materials attains higher friction coefficient values).

As a result it is possible to state, that the way of effectiveness increase of the frictional brakes (especially disk brakes) by means of application of the materials which are in operation becomes possible due to new integral characteristics which are stipulated by their joint simultaneous application in the given brake pads.

REFERENCES

1. Ehlers H.-R. et. al. Potential and limits of opportunities of the block brake // Glasers Annalen. 2002. - №6/7 - P. 290-300.
2. Modern brake systems [electronic resource] / Shlosser V., Aurikh S. // World railways, 2003, №4. – access regime: http://www.css-rzd.ru/zdm/04-2003/02224-1.htm.
3. F.E. Nedopekin. Heatmasstransfer. – Donetsk: DonNU, 2007. – 174 p.
4. Biloborodova I.M., Sosnov I.I. Heat exchange modelling of the locomotive disk brake with environment // Collection of reports of the East-Ukrainian National University named after V. Dal. – 2009. – №7 - P.1. – P. 13-20.
5. Industrial heat power engineering and heat engineering. Reference book / Editors V.A.Grigorieva, V.M.Zorina, – 2-nd edition, changed. – M.: Energoatomizdat, 1991.
6. Biloborodova I., Sosnov I., Sergienko O. On contact thermal resistance in the system of active effective cooling of the locomotive disk brake // TEKA Commission of Motorization and Agriculture. – Lublin, Polska Akademia nauk Oddzial w Lubline, 2010 – Vol.XB. – p.362-370.
7. M. Bahrami, J.R. Culham, M.M. Yovanovich. Thermal Contact Resistance of Nonconforming Rough Surfaces // Journal of Thermophysics and Heat Transfer, 2004, vol.18, part 2, p. 218-227.
8. S.Yu. Mesnyankin, A.G. Vikulov, D.G. Vikulov. Up-to-date outlook upon the problems of heat contact of the solids // Success of physics, 2009, V. 179, №9. - P. 943-970.
9. Kolesnikov V.I. Heat and physical processes in metalpolymer tribosystems / V.I. Kolesnikov; - M.; Science. 2003. – 279 p.
10. Belyakov N.S., Nosko A.P. Unideal heat contact of the bodies while friction. M.: Publishing house «Librokom», 2010. – 104 p.
11. Popov V.M. Heat exchange in the zone of contact of detachable and permanent joints. M.: Energy, 1971. - 216 p.
12. Uong Ch. Main formula and data in heat exchange for engineers: Trans. from English. / Reference book. – M.: Atomizdat, 1979. – 212 p.
13. Ginzburg A.G. Coefficients of heat flows distribution while braking // Calculation and testing of frictional pairs. – M.: Machine-building, 1974. – № 4. – P. 37-41.
14. Mikhin N.M. External friction of solids. – M.: Science, 1977. – 211 p.
15. Reference book on tribotechnology / Editors M. Khebda, A.V. Chichinadze. - V. 1. Theoretical foundations. – M.: Machine-building, 1989 . – 400 p.
16. Kragelsky I.V., Vinogradov I.E. Friction coefficients. – M.: Mashgiz, 1962. – 220 p.
17. Sergienko O.V., Osenin Yu.Yu. Effectiveness increase of the frictional brake // Collection of reports of the East-Ukrainian National University named after V. Dal. – 2008. – №10. - P.2. – P. 315 – 317.
18. Kragelsky I.V., Mikhin N.M. Friction units of the machines: Reference book. - M.: Machine-building, 1984. – 280 p.
19. Petrov S.Yu. Properties of the materials of the tribosystem block-wheel-rail. – M: MIIT, 2000. – 210 p.

20. V.S. Chirkin. Heat and physical properties of the materials. M.: State publishing house of physical and mathematical literature, 1979. – 356 p.

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ НЕСТАЦИОНАРНОГО ФРИКЦИОННОГО ВЗАИМОДЕЙСТВИЯ РАБОЧИХ ЭЛЕМЕНТОВ ДИСКОВОГО ТОРМОЗА ЛОКОМОТИВА

Юрий Ю. Осенин, Игорь И. Соснов

Аннотация. В статье рассмотрена математическая модель, которая позволяет прогнозировать работу фрикционных элементов дискового тормоза локомотива, основу функционирования которого обеспечивает совместное использование двух материалов, независимо расположенных на тормозной накладке, которые оказывают интегральное влияние на характеристики трения. Разработанная математическая модель позволяет прогнозировать работу указанного выше фрикционного узла по критерию коэффициента трения.

Ключевые слова: коэффициент трения, температура, дисковый тормоз локомотива.

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INFLUENCE OF WATER SATURATION OF CONCRETE OF PIPES ON THEIR RESISTIBILITY

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Summary. The results of research of influence of unequal water saturation on performance characteristics of modified concrete of special purpose are introduced in this article. There were defined the dependences of concrete resistibility on the degree of saturation of liquids of different polarity, including water. It is shown that one of the directions of achievement of project performance characteristics of concrete can be an active physical chemical influence on the process of structure forming of cementing matrix of concrete and the development of the ways of increase of homogeneity spreading of internal voltage in it.

Key words: modified concrete, water saturation, resistibility, coefficient of softening.

ACTUALITY OF RESEARCHES AND PROBLEM DEFINITION

Resistibility of concretes, including any other stone materials, is coming down at water saturation. This happens in consequence of the fact that micro crack formation is reduced at adsorption by hard body of polar liquid [Gagarin 1999]. The degree of reduction of material's resistibility depends on its physical mechanical properties and is characterised by the coefficient of softening.

The important role play the other phenomena and factors in concretes besides adsorption effect, complicating dependence of concrete resistibility on its degree of water saturation [Alexeev, Ivanov, Modry, Shysl 1990, Komokhov, Latypov, Vaganov, Latypova 1999]. In this connection the resistibility of water saturated concrete proves to be even higher than the resistibility of dry concrete of the same composition under certain conditions. That fact that it was not taken into consideration the whole possible complex of conditions during the research of the resistibility of water saturated concrete led to contradicting results. Thus, for instance, it was observed in experiments [Polak 1986] the increase of resistibility of concrete with the increase of its humidity, and in experiments [Kladko 1983] – the decrease.

PURPOSE AND OBJECT OF INVESTIGATION

The purpose of this work is in the investigation of the influence of irregular water saturation on service characteristics of modified concrete of special purpose.

MATERIALS AND RESULTS OF INVESTIGATION

Having investigated the dependence of the resistibility of the samples of cement sandish matrix drilled out of the concrete on the degree of its saturation by the liquids of different polarity including the water, there were established the possible reasons of getting contradicting results by carried experiments. The degree of saturation has been varied from the zero to the maximal pore filling with the liquid (fig. 1).

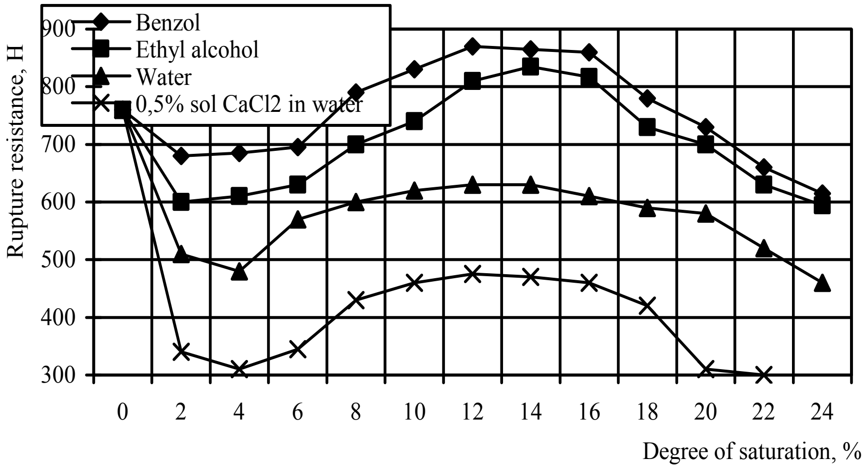

Fig. 1. Dependence of rupture resistance of cement sandish matrix of concrete on degree of saturation by different liquids

As it can be seen on fig.1, all the curve lines have two extremum: minimum at the humidity of the solution 2...4 % and maximum at the humidity of the solution 12...14 %. For the concretes under research the investigating relations are qualitatively analogic. The analysis of the results of the experiments has shown that in first case the humidity of the samples has been changing within the limits of ascending part of the curve from minimum to maximum (see fig. 1), and in the second case it was on descending part of the curve, after the maximum.

The presence of the extremum on the curve lines can be explained by the different force of capillary squeeze of the sample. Thus, at the law saturation (within the limits 0...3 %) the capillary squeeze of the samples is not considerable, the resistibility is lowed because of manifestation of adsorption effect. At the increase of the degree of saturation of the concrete is enlarged the quantity of the pores taking part in the capillary squeeze. The reinforcing effect of capillary forces compensates the adsorption effect of the decrease of resistibility, and, in some cases, leads to the elevation of load-carrying ability of the sample, exceeding it. With the further increase of the degree of saturation, the large pores are filled with the liquid, and the capillary squeeze is decreased (descending part of curve lines). At full saturation of the samples and their research in the state when they are in the liquid, the capillary forces are equal to zero. The decrease of resistibility of concrete in this case corresponds to the full adsorption effect of resistibility decrease [Shchukina 1988, Vagner 1980]. It is important to note that its index is growing only on the first part of the curved line that is at the increase of saturation from the zero to some not large value which, apparently, is corresponding to maximal hygroscopic moisture capacity or to the volume of micro pores. Filling by the liquid of larger pores does not increase the achieved effect of adsorption decrease of resistibility because it is enough water filling in micro pores for its full manifestation.

In carried out experiments it was revealed the influence of polarity of liquids. The resistibility of the samples at its saturation by nonpolar benzol decreased on 10 %, at saturation by water – on 40 %, and at saturation by more polar 0,5 % water solution of $CaC\ell_2$ – on 50 %. Analogic results are obtained at the impregnation of cementing matrix of concrete (Table 1).

Table 1. **Bending resistance R_{bend} and coefficients of softening C_{soft} of cementing matrix of concrete in different media**

Media	**R_{bend}, MPa**	**C_{soft}**
Air	18,2	1,00
Toluene	17,6	0,97
Water	14,2	0,78
0,5 % water solution $CaC\ell_2$	12,6	0,69

The dependence of the coefficient of softening C_{soft} on the polarity of the liquid proves that one of the main reasons of the decrease of concrete resistance at water saturation is the adsorption effect of relief of micro crack formation.

The results of investigation introduced in [(Akhverdov 1981] showed that at full water saturation the resistibility of concrete is coming down on 20...60 % in dependence on its pore volume. A great meaning has the character of structure of the concrete at this. With the decrease of the grain of large pores the value C_{size} is increased. For the samples moulded under the pressure 40 and 200 MPa, C_{size} was equal accordingly 0,60 and 0,91. The author [Akhverdov 1981] recommends to restrict W/C in thin-walled reinforced-concrete constructions working in the conditions of water saturation. In particular, the value W/C in flow pipes should be so at which the pore volume of cementing stone does not exceed 11%. The formation of fine-pored structure of the concrete is provided by its hardening in humid medium and more over is better in water. It was established by the experiments that the grain of macro pores with the rad more than 1 mcm in cementing matrix of concrete hardening in the air was about 40%, and while hardening in the water it was only 10%.

The favourable conditions of structure formation of concrete of pipes in humid medium provide more intensive growth of its resistibility than in the air. As the result, the resistibility of the concrete after its long-term operation in water-cut conditions despite adsorption effect can turn to be higher than during the operation in air dry conditions [Kaprielov, Batrakov, Sheinfeld 1999, Batrakov 1998].

It is necessary to mark that both in non-ramming and in water-pressure constructions not the whole volume of the concrete is saturated with water. Its humidity varies in wide limits [Dvorkin, Solomatov, Vyrovoi, Chudnovsky 1999, Kaprielov, Sheinfeld, Silina 2000].

There is not enough data of investigation of the influence of humidity of concrete on its resistibility directly in construction for the establishment of process regularities. The obtained characteristic curves prove the decrease of concrete resistibility nearly 2 times with the increase of its humidity from 2 to 12%. In this case one of the respective reasons of the decrease of resistibility should be the increased pore volume of concrete in more water saturated samples. Because the density of the concrete in water-cut constructions is ranged in rather wide limits, and it can be observed the direct correlation relationship between water saturation and its pore volume, so the dependence of resistibility of concrete on its humidity reflects also the influence of pore volume on its resistibility in latent form. The dependence of resistibility of concretes on its pore volume is enough vivid in general. As it is marked in the work [Alekseev, Ivanov, Modry, Shysl 1990], nearly all famous formulas of resistibility of concrete reflect in different way this dependence.

Thus, it should be taken into consideration that true dependence of resistibility of concrete on its humidity can be obtained only on laboratory samples.

On the ground of the summary of the results of investigation is proposed the linear dependence of resistibility of concrete under the compression and stretch from the humidity:

$$R_W = R_{W_0}\left(1 - \frac{W - W_0}{a}\right), \quad (1)$$

where: R_W и R_{W_0} – the resistibility of concrete at humidity according to the weight equal to W и W_o accordingly;

a – empirical coefficient depending on the composition of concrete and its structural characteristics.

The dependence (1) is true for the samples of concrete hardening in constant humid conditions during of which the humidity W_0 had been established in the concrete. It is supposed that in distinction from it the humidity W henceforth is established in concrete for the relatively short term directly before the research of the samples so the change of humidity practically does not manage to influence the kinetics of natural strength generation of concrete.

Irregular distribution of humidity on the section of concrete element influences its resistibility. [Sheinich, Popruga 2007, Troshchenko 2005]. The concrete removed from the water during the first time has large additional internal stress caused, on one side, by capillary squeeze of internal zone of section by external layer which gets additional intensity of tension, on the other side, while drying-out of gel constituent, fixed distribution of internal stress in crystal aggregation is disturbed. In such transitional humid regime the resistibility of concrete is usually coming down because of the deformation of the character of the work of different elements of the section.

While stabilizing humid state of the concrete, the irregularity of stress in it is flatten. In the work [Gusev 1989] are given the values of the duration of air keeping of the samples of the concrete of different sizes removed from the water, after which «internal stresses disappear». In reality the internal stresses in cementing matrix of the concrete are always present, but the irregularity of their distribution is coming down [Rudenko 2010, Punagin 2010, Pilipenko 2010].

In fulfilled experiments the relaxation of shrink stress is fixed with the help of magneto-elastic stress gauges. The gauges have been put inside of the samples of fine-aggregate concrete with the size $10 \times 10 \times 40$ cm at concrete pairing. In the samples of modified concrete the gauges did not register considerable changes of stress. While hardening the samples of usual concrete the gauges registered shrink deformations and stresses (fig. 2). During the first 2...3 days when it was observed maximal intensity of shrink deformations, the shrink stresses in internal zone of the samples were not considerable because of the plasticity of the concrete. Further on the stresses have grown violently and at the same time the deformations damped. On the 12^{th}...16^{th} day the growth of stresses stopped and then started their slow reduction. At practically stabilised deformation the shrink stresses have reduced on 30^{th} …40^{th} day to 30…40% of achieved maximal values having left the trace in the structure of the concrete in the way of ruptures of the most strained connections in crystal aggregation.

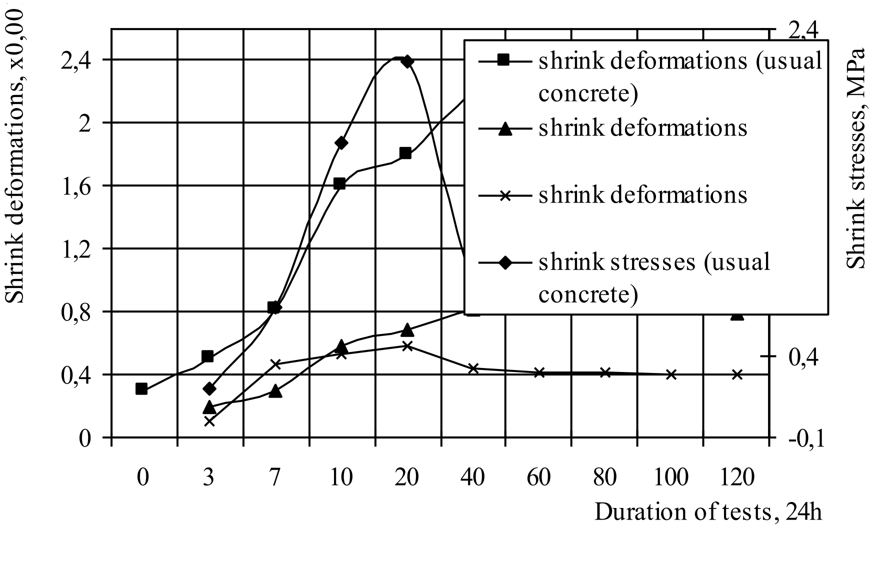

Fig. 2. Change of shrink deformations and stresses in concrete hardening in the air

There did not appear any additional internal stresses in the samples of modified concrete. After removal the samples from the water the indicator of the device immediately started to move showing the growing compressive stress in internal zone of the concrete. This stress, without any doubt, has capillary nature: being immersed in water it disappeared and the indicator came back to zero.

In the experiments the samples made of fine-aggregate concrete have been kept within several months in the air and then they have been tested for the bend after different terms of keeping the samples under water pressure (from 1 to 67 days).

If to ignore the acceleration of the growth of resistibility of the samples during their water saturation, then analysing the results of the tests, it can be done the conclusion of the tendency of modified concrete to restore temporary decreased resistibility in the process of a long-term water saturation.

The degree of decrease of resistibility of the concrete during the first 24 hours of its water saturation depends on the per cent of its loss of humidity during the preceding period of hardening in the air. Under the action of shrink stresses developing during the expulsion of bound water out of the concrete, the definite quantity of internal connections is torn, and it is more, the higher shrink stresses are. [Shchukina 1988, Kruglitskiy 1988].

There are two mutually contrary processes during the water saturation of the concrete: the decrease of resistibility because of adsorption effect and increase of resistibility thanks the decrease of irregularity of distribution of internal stresses caused by shrinkage properties. Besides this, at a long-term water saturation are intensified the processes of the growth of new-growths, partially compensating the relief of cementing matrix. [Pilipenko 2011]. As the result is the achievement of resetting of resistibility of water saturated concrete at a definite complex of conditions of the experiment.

At a periodic humification-torrefaction the resistibility of the concrete is gradually coming down because of repetitive changes in distribution of internal stresses, when each time is accompanied by the destruction of a definite number of connections.

There have been carried out the experiments of the influence of the change of the media on the resistibility of concrete of pipes at the axial tension. The samples-cylinders with the diameter 100 mm and the length 760 mm have been kept in the water during 3 months from the first day of production till the moment of the trial. The part of the samples removed from the water from the testing machine and tore in the air within 30 minutes. The other part of twins-samples has been tested in rubber boots filled with water. The results of the tests are introduced in table 2.

Table 2. **Resistibility of concrete of water storage at strain**

Quantity of cement, kg / m^3	**Resistibility of concrete, MPa, during test at strain**		**Change of resistibility of concrete, tested in the air, %**
	in water	**in the air**	
250	2,13	1,44	– 32,39
300	2,25	2,06	– 8,44
350	2,57	2,90	+ 12,84

The obtained results cannot be explained without taking into consideration the influence of irregularity of distribution of internal stresses in the section of the sample. The decrease of rupture stress at removing the samples out of the water into the air cannot be on the account of the capillary squeeze of the sample in radial directions.

Though the force from the squeeze multiplied by the coefficient of transformation is composed with external force of tension, but more capillary force presses the sample with end bays. The action of all-round capillary squeeze manifested in this case only in the enlargement of irregularity of distribution of stresses in section of the sample. Whereas the concrete of all the samples was fully saturated with water, the adsorption decrease of its resistibility was equal. Breaking of the fixed distribution of internal stresses because of the appearance of capillary forces at the removal of the concrete out of the water led to the decrease of rupture stress.

The samples of cementing stone of water storage sustained in the air different time. The maximal decrease of resistibility was observed after 24 hours of predrying. During further keeping in the air the resistibility of the samples had been gradually restored. The decrease of resistibility is explained by the appearance of shrink stresses, and restoration – by their disappearance. Such explanation is only partially near to reality and it demands the correction taking into account the influence of irregularity of distribution of internal stresses in section of the sample.

With the aim to investigate the influence of humid regime on concrete have been carried out the experiments on bars with the size $2\times3\times25$ cm of modified cementing sandish solution. The small thickness of the samples besides large filler had been chosen with the purpose of achievement of quick distribution of humidity in section and its stabilization. The experiments showed that both at drying water saturated samples and and water saturation of dried samples i.e. during the first hours of change of humid regime takes place the decrease of resistibility of usual cementing sandish solution. Further storage in the same media (in first case is drying, in the second one is water saturation) leads to the restoration of resistibility. During the test of the samples out of modified cementing sandish solution was no considerable decrease of resistibility at the change of humid regime.

With the enlargement of the thickness of the samples the time of stabilization of their humidity is considerably coming down and at generally accepted sizes of section of samples lasts many months. It is possible that according to this reason, as the result of short investigations was marked only the decrease of resistibility at water saturation of dried samples. On the other side, in experiments with modified concrete was not observed adsorption effect of decrease of resistibility.

In fulfilled experiments had been manifested one of many sides of complex aggregate of phenomena taking place in concrete at change of its humidity – the increase of the coefficient of softening in the process of long water saturation and stabilization of humidity in its section which, possibly, is real. Obviously the increase of the coefficient of softening at long water saturation of modified concrete should be taken into consideration in calculations, and in this connection the stock of reliability will be increased somehow.

The results of investigations of dependence of resistibility of water saturated modified concrete at squeeze on the speed of its load showed that at relatively low speed of load the resistibility of water saturated samples is lower the speed of dried samples as in the definite measure is manifested the effect of adsorption decrease of resistibility. After exceeding some critical speed of load, the humidity does not manage to penetrate into micro crack formation and adsorption effect disappears. At the same time with the increase of speed an important meaning in water saturated concrete has the effect of dynamic acceptation of load of gel constituent. Thanks to this effect is increased the limit of resistibility of concrete by the way that at the speed of load which is more critical the resistibility of water saturated concrete turns to be higher than the resistibility of dried concrete. The average speed of load in critical point is equal to 207 MP a / c, and the average speed of deformation 0,01 m / (m·c).

There have been carried the investigations of the influence of water saturation of concrete on its resistibility at dynamic loads. There have been tested on squeeze the prisms with the size $10 \times 10 \times 30$ cm out of the concrete of the class B 40 at σ_{max} = 14 MPa. The cubes with the size $10 \times 10 \times 10$ cm out of the concrete of the same composition have been tested for the static load. After a long storage of the samples in the air, there was established the humidity 2,3 %. The separated groups of the samples were then saturated with water up to higher values of humidity and were isolated by PVC film. The results are introduced in table 3.

Table 3. **Resistibility and hardness of concrete of different humidity**

Humidity of concrete, %	**Static tests of blocks**		**Dynamic tests of wedges – the quantity of cycles up to destruction, mio.**
	R_{sq}, MPa	**C_{size}**	
2,3	57,2	1,00	More 6
3,3	52,7	0,91	3,72
4,3	50,0	0,86	2,09
5,8	40,6	0,70	0,80

Thus it was defined with the help of experiments that for the operation conditions, the humidity of concrete should not exceed 4%, taking into consideration the conditions of work for its endurance (2 mio of cycles of load).

In many experiments according to the definition of resistibility of concrete the large-scale effect manifests vividly that in some cases cannot be discovered at all. The nature of this effect is not finally clear. At present the most accepted is the static theory of large-scale effect which essence is in increase of probability of transfer dangerous defects of structure of material in section of the sample with the increase of its sizes. The analysis of wide experimental material shows that besides of probable factor of large-scale effect act simultaneously the others. They are sometimes determinant.

It was established by carried investigations of manifestation of large-scale effect in concretes that the last one is caused not by the sizes of the sample but their function – the degree of non-uniformity of the structure of concrete.

On the ground of mathematic processing of results of specially planned of experiments was obtained empiric formula of large-scale coefficient for the samples of modified concrete:

$$К_{м} = \frac{1}{5C_{\upsilon}^{2}\left(\frac{1}{М} - 1{,}67\right) + 1}, \qquad (2)$$

where: C_υ – coefficient of variation of resistibility of concrete;

$M = S / V$ – module of surface – dependence of surface of the sample to its volume.

Developing this thought, it can be done the conclusion that the large-scale effect is the consequence of non-uniformity of distribution of stresses in section. With increase of non-uniformity, the resistibility of the material is coming down not depending on the sizes of the sample. The sizes make indirect influence: with the increase of the sizes of the sample in many cases the non-uniformity of stresses in section increases, and the decrease of resistibility of concrete takes place, but it is not always. Thus, for example, as the result of carried experiments it was established that the resistibility of modified concrete at axial squeeze and strain does not depend on the sizes of cross section of the sample on condition that in all samples the humidity is equal and is regularly distributed in section. From this point of view the analysis of foreign literature is very interesting [Smadi, Mohammad, Slate, Floyd 1989, Neely, Billy, Saucier, Kenneth 1990]. From the published materials follows that the resistibility of the concrete drilled out of solid monolith does not depend on the diameter of the kern. It can be explained only by equal law of distribution of internal stresses in kerns of al sizes as it is predetermined by equal conditions of structure formation and humidity distribution in all the volume of internal zone of concrete monolith.

Thus, the results of carried out experiments allow to define the ways of decrease of irregularity of distribution of internal stresses in cementing matrix of modified concrete. The main way of decrease of irregularity of distribution of internal stresses is likely to be the destruction of the most stressful connections at the early stages of concrete hardening in order that instead of them there have been formed new connections of the same material with initial stress coming close to average value for the whole crystal aggregation. The destructions of the most stressful connections to some degree is achieved at vibro impactive poly-roll of concrete mixture.

The increase of the resistibility of concrete in the result of physical modification of concrete mixture should be partially referred for the removal of aggregations of sediment water under the grains of huge filler. The increase of resistibility of concrete as the result of vibro activation is explained by the increase of structural uniformity by destruction of primary weak aggregations and on their place formation of fine-pored structure of cementing matrix with regular distribution of internal stresses.

CONCLUSIONS

1. It was established that early loading of modified concrete leads to the increase of its resistibility on 30 %. It is evidently also connected with the destruction of overstrained connections and new connections formation with a low internal stress.

2. One of the directions of the achievement of project operating abilities of concrete can be active physical chemical influence on the process of structure formation of cementing matrix of concrete and the development of ways of the increase of uniformity of distribution of internal stresses in it.

REFERENCES

1. Gagarin V.G., 1999.: Theory of humidity movement in material at capillary adsorption of water // Longevity and defence of constructions from corrosion. // M.: Materials of international conference., P. 166-176.
2. Alexeev S.N., Ivanov F.M., Modry S., Shysl P., 1990.: Longevity of reinforced concrete in aggressive media. // M.: Stroyizdat., 316 p.
3. Komokhov P.G., Latypov V.M., Vaganov R.F., Latypova T.V., 1999.: Estimation of aggressiveness of sulphate media to concrete and reinforced concrete // Longevity and defence of constructions from corrosion. // M.: Materials of international conference., P. 294-301.
4. Polak A.F., 1986.: Modelling of corrosion of reinforced concrete and forecast of its longevity // Results of science and technics. Corrosion and defence from the corrosion. // M.: Higher school., V. 12., P. 278-297.
5. Kladko S.N., 1983.: Increase of longevity of river concrete hydro technical aggregations. // M.: Transport., 207 p.
6. Shchukina E.D., 1988.: Surface films of water in dispersive structures. // M.: Izdatelstvo MSU., 279 p.
7. Vagner G.R., 1980.: Physics-chemistry of the processes of activation of cementing despersions. // K.: Naukova Dumka., 200 p.
8. Akhverdov I.N., 1981.: The foundations of physics of concrete. // M.: Stroyizdat., 464 p.
9. Kaprielov S.S., Batrakov V.G., Sheinfeld A.V. 1999.: Modified concretes of a new generation: reality and perspectives // M.: Concrete and reinforced concrete., № 6., P. 6-10.
10. Batrakov V.G., 1998.: Modified concretes. Theory and practice. // M.: Technoproject., 768 p.
11. Dvorkin L.I., Solomatov V.I., Vyrovoi V.N., Chudnovsky V.S., 1999.: Cementing concretes with mineral fillers. // K.: Budivelnyk., 137 p.
12. kaprielov S.S., Sheinfeld A.V., Silina E.S., 2000.: High strength concretes of increased frost-resistance with organic mineral modificator // M.: Transport construction., № 11., P. 4-27.
13. Alexeev S.N., Ivanov F.M., Modry S., Shysl P., 1990.: Longevity of reinforced concrete in aggressive media. // M.: Stroyizdat., 313 p.
14. Sheynich L.A., Popruga P.V., 2007.: High strength concretes for monolith house building // Collection of scientific works. Building constructions. // K.: Higher school., P. 311-314.
15. Troshchenko V.T., 2005.: Strength of materials and constructions. // K.: Akademperidioka., 1088 p.
16. Gusev A.S., 1989.: Resistance to fatigue and stability of constructions at casual loadings. // M.: Machine building., 248 p.
17. Rudenko N., 2010.: The development of conception of new generation concretes. TEKA Commission of Motorization and Power Industry in Agriculture. V. XB, P. 128-133.
18. Punagin V., 2010.: Properties and technology of beton for high altitude monolithic construction. TEKA Commission of Motorization and Power Industry in Agriculture. V. XB, P. 114-119.
19. Pilipenko V., 2010.: Principles of structure formation of modified matrixof corrosion resistant concrete. TEKA Commission of Motorization and Power Industry in Agriculture. V. XB, P. 100-104.
20. Kruglitsky N., 1988.: Essays in physical chemical mechanics. // K.: Naukova dumka., 224 p.
21. Pilipenko V., 2011.: Technological peculiarities of forming of axisymmetric unreinforced concrete pipes. TEKA Commission of Motorization and Power Industry in Agriculture. V. XL, P. 198-206.

22. Smadi, Mohammad M., Slate, Floyd., 1989.: Microcracking of High and Normal Strength Concretes under Short – and Long-Term Loading // ACI Materials Journal., V. 86., № 2., P. 117-127.
23. Neely, Billy D., Saucier, Kenneth L., 1990.: Laboratory Evolution of Concrete and Techniques for Underwater Repair // Technical Report REMR-CS-34 // Vicksburg.: US Army Engineer Waterway Experiment Station., 15 p.

ВЛИЯНИЕ ВОДОНАСЫЩЕНИЯ БЕТОНА ТРУБ НА ИХ ПРОЧНОСТЬ

Владимир Пилипенко

Аннотация. В статье представлены результаты исследований влияния неравномерного водонасыщения на эксплуатационные характеристики модифицированного бетона специального назначения. Установлены зависимости прочности бетона от степени насыщения жидкостями различной полярности, в том числе водой. Показано, что одним из направлений достижения проектных эксплуатационных свойств бетона может быть активное физико-химическое воздействие на процесс структурообразования цементной матрицы бетона и разработка способов повышения однородности распределения внутренних напряжений в нём.

Ключевые слова: модифицированный бетон, водонасыщение, прочность, коэффициент размягчения.

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STATIC CHARACTERISTICS OF VALVE – AMPLIFIERS FOR PNEUMATIC DRIVES OF MECHANICAL SYSTEMS

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Summary. The static characteristics of pneumatic valves - amplifiers of drives of mechanical systems with the improved response curves are reviewed. The relations discharge coefficients μ_1 and μ_2, rigidity of seals and membranes $c_{км}$, $c_{кс}$, $c_к$, and hydrodynamic force **Pr** are by practical consideration are retrieved. The approximating model for determination of discharge coefficients μ is obtained and its adequacy also is determined.

Key words: valve-amplifiers, pneumatic drive, discharge coefficients.

INTRODUCTION

One way of the solution of increase of technical and economic efficiency of mechanical systems is the development and research of new effective devices of monitoring pneumatic drives, that can ensure essential positive effect.

The pneumatic drives with valves - amplifiers with different control and different negative feedbacks find wide use in the mechanical systems as control elements from the small moved masses and practically absence of friction forces, that provides high dynamic properties [1].

Valve-amplifier with pneumatic control and pressure and position negative feedback is the base element [2]. For providing high dynamic qualities it is necessary to choose correctly the geometrical sizes of elements, define influence of energy parameters on its work. From this point of view it would be useful to analyze the valve-amplifier work on the basis of its mathematical model [3].). However, with determination of some values, which are included in the system of equation certain difficulties appeared, related to impossibility of analytical way determination of calculation values. The discharge coefficients μ_1 and μ_2, rigidity of seals and membranes $c_{км}$, $c_{кс}$, $c_к$, and hydrodynamic force $F_{гд}=G_2v$ cover to them. Therefore, in this work the decision about e coefficients determination experimentally is accepted, receipting their approximation dependence on the process parameters and using them in mathematical model.

The valve-amplifier with pressure negative feedback (fig.1) is considered in this paper

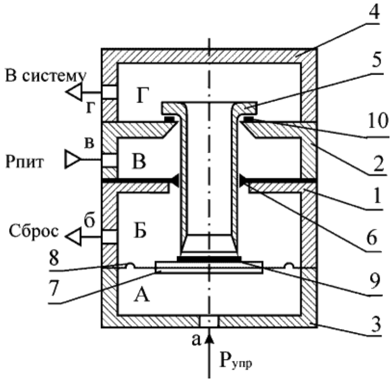


Fig.1 Valve - amplifier

This valve - amplifier is represented by the analogue pneumatic amplifier, in which one

$$p_{вих} = k\, p_{вх},$$

where: $p_{вых}$- upstream pressure (chamber Г),

$p_{вх}$ - pressure of control (chamber A),

к - gain dependent on a ratio of the effective areas of a diaphragm 6, diaphragm 8 with rigid center 7, diameter of the valve.

For maintenance of high dynamic qualities it is necessary correctly to select the geometrical sizes of its elements, to determine influencing on its activity of energy parameters. With this purpose the operational analysis of the valve - amplifier is conducted on the basis of its mathematical model. [3]. However, with determination of some values logging in equations there were definite difficulties, bound with impossibility of determination by an analytical way of their design values. The flow coefficients $\boldsymbol{\mu_1}$ and $\boldsymbol{\mu_2}$, rigidity of seals and diaphragms $\mathbf{c_{км}}$, $\mathbf{c_{кс}}$, $\mathbf{c_{к}}$, $\mathbf{c_{м}}$ and value of a hydrodynamic force **Fгд = G2v** concern to them. The basic purpose of experimental researches of pneumatic valves - amplifiers for mechanical systems of control fnd regulation was:

- Determination of factors of a mathematical model, which one can not be determined analytically or on the basis of a reference data.
- Determination of a degree of adequacy to a mathematical model to experimental data.

RESEARCH OBJECT

For research of static characteristics of the valve – amplifier, determination of flow coefficients $\boldsymbol{\mu}$, viscous friction $\boldsymbol{\alpha}$ and hydrodynamic force $\boldsymbol{\psi}$ the special experimental installation was designed.

The outcomes of static tests are shown on fig. 2 -12.

The relation of output pressure $\mathbf{p_{вых}}$ and flow $\mathbf{Q_{вых}}$ from pressure of control $\mathbf{p_{упр}}$ at different pressure of a feed $p_{пит}$ and different diameters of conditional passage $\mathbf{d_y}$ is adduced on fig.2 and fig.3.

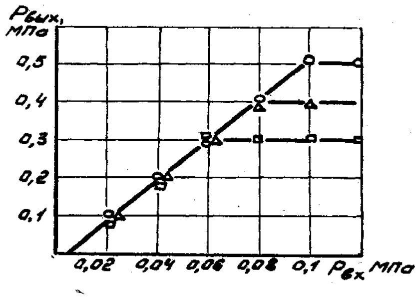


Fig. 2. Relation of delivery pressure from pressure of control
at different pressure of a feed

Experiments show (fig.2), the output pressure $\mathbf{p_{вых}}$ linearly depends on pressure of control $\mathbf{p_{упр}}$ and practically does not depend on the geometrical sizes of valves - amplifiers (diameter of conditional passage), i.e:

$$p_{вых} = k_p\, p_{упр},$$

where: k_p- a pressure gain, in this case $k_p = 5$.

Dead zone Δ in all measurement range and for all diameters of conditional passes during tests did not exceed 0,01 МПа, which is quite acceptableas the minimum value of an analog signal of pressure is peer 0,02 МПа.

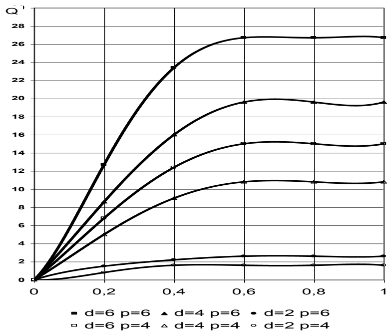


Fig. 3. Relation of the output flow **Q** (л/с) from pressure of control $\mathbf{p_{упр}}$ (ат)
at different pressure of a feed $\mathbf{p_{пит}}$ and diameters of conditional passage **dy**

As seen from fig.3, at some pressure of control ($\mathbf{p_{упр}}$ = 0,04 … 0,05 Мпа) the output flow is not augmented, and remains by a constant at a further pressure buildup of control. Up to this value relation of the output flow from pressure of control has linear nature, i.e.

$$\mathbf{Q_{вых} = Kq\, p_{упр}},$$

In a fig. 4 the relations of the output flow $\mathbf{Q_{вых}}$ (l/c) from a height of valve lift $\mathbf{h_к}$ (mm) are shown at different diameters of conditional passage $\mathbf{d_y}$ and parameters of a gas stream $\boldsymbol{\beta}$.

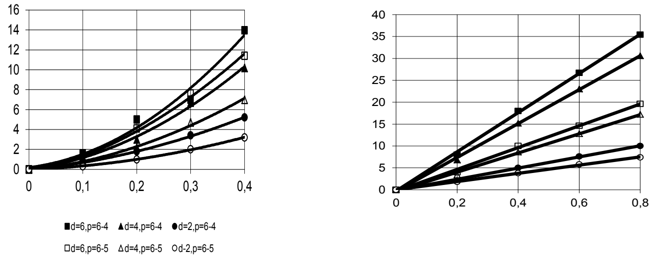


Fig. 4. Relation $\mathbf{Q_{вых}} = f(\mathbf{h_к})$ at $\boldsymbol{\beta} < \boldsymbol{\beta_{kp}}$. and $\boldsymbol{\beta} > \boldsymbol{\beta_{kp}}$

Φs seen from the graphs fig.4 in a case β <βkp the relation of the output flow to a height of valve lift at miscellaneous dy has practically linear nature in an effective range of heights of valve lift, i.e. hк > 0,1мм.

Flow coefficient μ is a composite function dependent as on geometry of the valve - amplifier, and from flow parameters of gas. Generally flow coefficient does not depend from value of a valving slot type gasdynamical of process (supercritical and subcritical flow), difference of pressure, flow regime etc. More often flow coefficient μ is on t published in [4-6],] or on computational relations [7, 8], obtained by results of researches. However, these relations are applicable only to particular pneumatic instrumentation, or for calculation of a flow coefficient μ It is necessary to know other hydraulic parameters (for example factors of local resistances ξ), which one are in turn determined also by experimental way.

For experimental determination of a flow coefficient μ the technique was selected, that the volume flow is determined by experimental way, and the flow coefficient **μ** was calculated by a relation of the experimental flow to idealized, computed on the formula of the Saint-Venant, i.e.:

$$\mu = \frac{Q_{ýêñ}}{Q_{ô}} = \frac{m_{ýêñ}}{m_{ô}} .$$

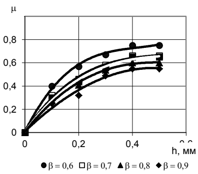
It is possible to approximate and to use experimental values of the flow depending on a difference of pressure, altitude of a slot and diameter of conditional passage then in a mathematical model [3]. Such way of determination of a flow coefficient is known and enough is simple, for its determination the presence of pressure gauges, flowmeters and precise meter of a height of valve lift is necessary only. The solution in the given activity about determination of flow coefficients **μ**, viscous friction α and hydrodynamic force ψ by practical consideration therefore was accepted, and then obtaining of approximating relation.

The method and procedure of the experiments were as follows :

The range of paramttres:

1. Diameters of conditional passages - **dy** = 2, 4, 6 mms.
2. Pressure of a feed (exuberant) - $p_{пит}$ = 0.2, 0.3, 0.4, 0.5 МПа.
3. Back pressure (exuberant) - $\mathbf{p_{пр}}$ = 0.1, 0.2, 0.3, 0.4 МПа.
4. Height of valve lift -**hк** = 0.1 … 1.0 mms.
5. Pressure ratio -**β** = 0.1 … 0.9.

Relations of a discharge coefficient **μ** = f (**h**$_к$) at different parameters of a gas stream (**β**$_{Кр}$) are shown in a fig. 5-6 and fig..7-8.



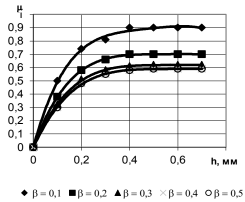
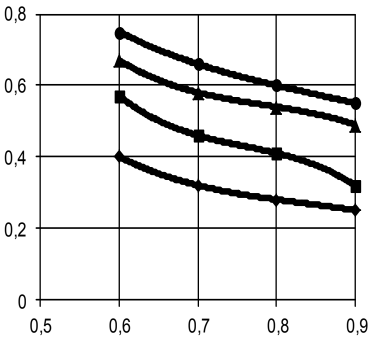


Fig.. 5. **μ=f (h$_к$)** at **β<β$_{кр}$** Fig. 6. **μ=f (h$_к$)** at **β>βкр**



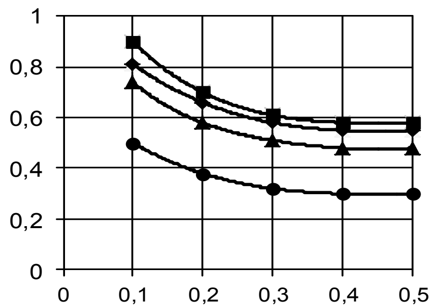


Fig. 7. **μ=f (β)** для **β>β$_{кр}$** Fig. 8 **μ=f (β)** при **β< β$_{кр}$**

Relations of a discharge coefficient **μ** of flapper – nozzle from parameters of a flow **β**$_{Кр}$ and the altitudes of a slot **hк** are shown on fig. 9,10,11,12.

As seem from the fig. 5 -12 the discharge coefficient **μ** does not depend on diameter of conditional passage of valves - amplifiers, and depends on pressure of a feed, and this relation has linear nature.

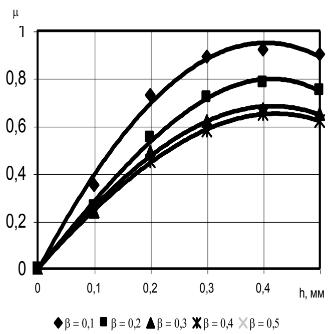


Fig. 9. **μ=f (hш)**

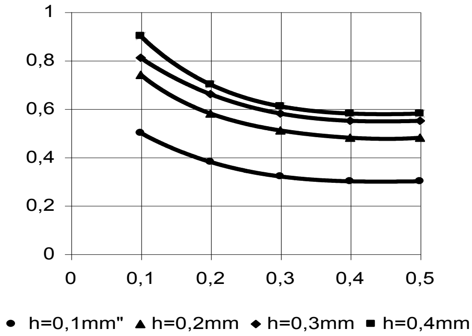


Fig. 10**. μ=f (β**

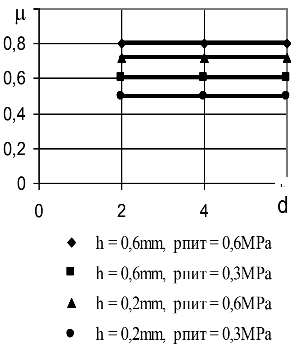


Fig 11. **μ = f (d)**

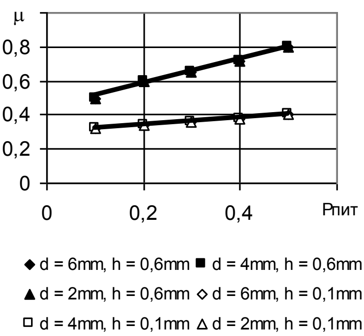


Fig.12. **μ = f ($p_{пит}$)**

In equations of motion includes values rigidity of diaphragms - $\mathbf{c_к}$ and $\mathbf{c_м}$ both seals of the valve and saddle - $\mathbf{c_{кс}}$ both valve and diaphragm - $\mathbf{c_{км}}$. These values in the present activity were determined by an experimental way on known techniques of determination of rigidity of any springs, loading their known efforts and determining in the same time of thickness of seals and course of diaphragms. The experience were conducted some times at load and unloading. The obtained experimental data allow to consider(count) the law of change of rigidity linear (in the given range of variation of parameters), and values **c** - as constants.

Rigidity of seals $\mathbf{c_{кс}}$ и $\mathbf{c_{км}}$ at load and unloading oscillated in limits:

$\mathbf{c_{кс}}$ = 9 … 11 н/mm and $\mathbf{c_{км}}$ = 3 … 5 н/mm.

For calculation were selected the average value of these parameters:

$\mathbf{c_{кс}}$ = 10 н/mm and $\mathbf{c_{км}}$ = 4 н/mm.

To rigidity of equivalent springs $\mathbf{c_к}$ and $\mathbf{c_м}$, , cloning elastic properties of diaphragms made from the same material, were peer each other and their average value

$\mathbf{c_к}$ = $\mathbf{c_м}$ = 4 н/mm.

Equilibrium equation of the valve 5 (fig. 1.) has a kind:

$$p_{\text{ïèò}} \cdot F_{\text{â}} + M_{kg} + c_k y + M_{mg} + P_{\text{ã}} + c_m x + p_{\text{àòì}} (F_A - F_{\tilde{A}})$$
$$= p_A \cdot F_A + P_{kc} + P_{km},$$

where: $P_{\text{êñ}} = \tilde{n}_{\text{êñ}} \cdot z_{\text{êñ}}$ i $P_{\text{êì}} = \tilde{n}_{\text{êì}} \cdot z_{\text{êì}}$.

From this equation, knowing values of weights of the valve and diaphragm Mк and Mm, effective areas F_A, F_B and $F_Г$, force $P_{кс}$ and $P_{км}$ for definite value of valve lift and diaphragm is possible to determine force Pг, which one is peer:

$$P_{\text{ã}} = p \cdot F_{\text{ã}} + G_2 \cdot v .$$

To determine value of hydrodynamic component force Pг it is possible by different ways. For example, knowing value of the flow of drop G_2, temperature T, pressure p and the area $F_г$ is possible to determine flow rate of air in the valve 5 **v** and to count up the hydrodynamic component $P_{гд} = G_2$ v.

However, the same value can be determined on [9] Till these techniques:

$$P_{\text{ãä}} = \psi \cdot p \cdot F_{\text{ã}} ,$$

where: **ψ** - coefficient of a hydrodynamic force.

Coefficient **ψ** generally is not a constant and depends on a mode and flow pattern of a liquid, coefficient of local resistances **ξ** geometrical parameters. So for example, in [8] the formula for determination of a coefficient **ψ** is adduced:

$$\psi = 1 + (1 - \xi) \cdot 16 \cdot \mu_{\tilde{n}}^2 \cdot h^2 / d_c^2$$

But under this formula for calculation of a coefficient of a hydrodynamic force it is necessary to determine by an experimental way a coefficient of local resistance **ξ**. Therefore was selected a path of determination of a coefficient of a hydrodynamic force **μ** by a substitution in an equation experimental values of pressure, effective areas and weights at different pressure of a feed.

The experiments have shown, what a coefficient of a hydrodynamic force **ψ** depends on pressure of a feed and its mean values are peer:

For pressure of a feed $\mathbf{p_{пит}}$ = 0,3 Мпа **-** **ψ** = 1,4,

$p_{пит}$ = 0,6 Мпа **-** **ψ=** 1,56.

In calculations the values for the valve in a closed position were adopted **ψ** = 1 (valve in a closed position) and **ψ** = 1,48 (the valve in a open position).

Coefficients of viscous friction **α** to were determined experimentally on [10]

Equation of motion of the valve and diaphragm [3] is possible to present as:

$$\frac{dv_{\text{ê}}}{dt} = \frac{1}{M_k}\left[P_{kc} + P_{km} - M_k g - c_k y + P_m F_{\text{Â}} - pF_k\right] - \frac{\alpha_k v_k}{M_k} .$$

$$\frac{dv_m}{dt} = \frac{1}{M_m}\left[p_a F_{\text{À}} - p_{\text{àòì}} (F_{\text{À}} - F_{\tilde{A}}) - P_{\tilde{A}} - P_{\text{êñ}} - P_{\text{êì}} - \tilde{n}_{\text{ì}}\, x - M_{\text{ì}}\, g\right] - \frac{\alpha_{\text{ì}}\, v_{\text{ì}}}{\text{Ì}_{\text{ì}}} ,$$

(for constant speed $\mathbf{v_к}$ and $\mathbf{v_м}$ and coefficient of a hydrodynamic force **ψ** = 1 (the valve is gone together with a diaphragm), knowing earlier definite values of rigidity of diaphragms and seals, and also it's effective areas, is possible to determine coefficient of viscous friction $\alpha_г$ and $\boldsymbol{\alpha_м}$.

The experiments have shown, that in the given pressure range at constant rigidites of seals and diaphragms, for the data of geometrical parameters it is possible to consider coefficients of viscous friction as constants and:

$\alpha_г$ = 20Нс/м and $\boldsymbol{\alpha_м}$ = 10Нс/м.

All experimental values will be used in a non-linear mathematical model as design values.

RESEARCHE RESULTS

With the purpose of reduction of number of experiments at preservation of veracity of the obtained data the method of orthogonal planning [11] was applied. Generally it is possible to dedicate following representative problems of planning of experiment:

Determination of an extremum of a function in the field of its research.

Selection of eligible model for the description of object or determination of parameters of a known functional connection.

Determination of adequacy to a mathematical model of composite process, at which one realization of physical experiments is connected to definite handicappings.

At usage of a method of Box - Wilson [12,13] approximating functions are represented as a power series and more often will use a polynomial of the second order:

$$F = C(1)\cdot x^2 + C(2)\cdot x + C(3)\cdot x\cdot y + C(4)\cdot y + C(5)\cdot y^2 + C(6)\ ,$$

where: W (1), W (2), W (3), W (4), W (5), W (6) - coefficients of an interpolation polynomial;
x, y - varied factors.

The verifying calculations have shown necessity of usage of a matrix of planning of the second order. The factors are a height of valve lift both nozzles $\mathbf{h}_k$ and pressure ratio on input and output $\boldsymbol{\beta}$.

The designed valves - amplifiers have following ranges of change of parameters subcritical - $\boldsymbol{\beta}$ = 0.1-0.5, **h** = 0.1-0.7мм, supercritical mode $\boldsymbol{\beta}$ = 0.6-0.9, **h** = 0.1-0.5мм. Therefore for $\boldsymbol{\beta} \leq \boldsymbol{\beta}_{кр}$ the index plane was selected -**h** = 0.4мм, $\boldsymbol{\beta}$ = 0.3, step of variation on each parameter $\boldsymbol{\Delta\ \beta}$ = 0.2 and $\boldsymbol{\Delta h}$ = 0.3мм. For $\boldsymbol{\beta} \geq \boldsymbol{\beta}_{кр}$ an index plane h = 0.3мм and $\boldsymbol{\beta}$ = 0.75 with a step $\boldsymbol{\Delta\ \beta}$ = 0.15 and $\boldsymbol{\Delta h}$ = 0.2мм and for a flapper – nozzle **h** = 0.3,
$\boldsymbol{\beta}$ = 0.3 and $\boldsymbol{\Delta\ \beta}$ = 0.2, $\boldsymbol{\Delta h}$ = 0.2мм.

After processing the experimental data obtained by the response function equation in the form of second-degree polynomial has the form:

$$\boldsymbol{\mu} = A + B\mathbf{h} + 3\ \boldsymbol{\beta} + D\mathbf{h}^2 + E\ \boldsymbol{\beta}^2 + F\ \boldsymbol{\beta}\ \mathbf{h}.$$

1. Subcritical mode:

A = 0,56256, B = 3,5915, C = -1,1919, D = -3,1679, F = -1,0257

2. Supercritical mode:

A = 0,33117, B = 2,897, C = -1,8009, D = -2,6393, F = -1,0257

3. Flapper – nozzle:

A = 0,17648, B = 3,9293, C = -1,3826, D = -4,1215, F = -1,3826.

To test the adequacy of the approximation obtained dependences of the coefficients are assessing the significance of the regression equations. Let's consider, that the coefficient is significant, if its absolute value is more than admissible error. Such check of a significance of coefficients of an equation of a response function has not allowed it to simplify. For check of adequacy of the obtained approximating relations the criterion of the Fisher is used. The dissipation of experimental points concerning an equation of a response function is characterized by a residual dispersion or dispersion of adequacy:

$$S^2{}_{\grave{a}\ddot{a}} = \frac{\sum_{1}^{n} \delta_{\ddot{e}}}{f},$$

where: f - a difference between number of experience and number of factors of model, which one are computed by results of these experience:

$$f = K - (n + 1),$$

where: (n + 1) - number of factors of model.

At determination of adequacy to approximating model f = 5.

The dispersion of reproducibility $S^2_{\div}$ is determined by a measuring error (systematic and random errors). Estimated value of Fisher's exact test:

$$F_{\eth} = \frac{S^2_{\grave{a}\ddot{a}}}{S^2_{\div}},$$

compared with the table (at a given confidence level and the relevant degrees of freedom) is exceeded the table value of the adequacy of the hypothesis is rejected. In our case, the approximation model Fp = 1.8, and valued F_T = 2.1, which indicates the adequacy of the equation obtained the response function.

On the fig. 13-15 the comparative relations of a discharge coefficient **μ** are shown from value of valve lift and backlash a flapper - nozzle for different parameters of gasdynamic process **β**.

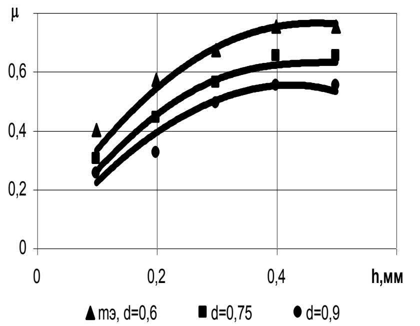


Fig. 13. μ= f(h) при β>$\beta_{кр.}$

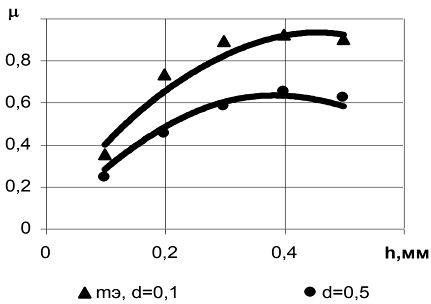


Fig. 14. μ=f (h) при β ≤ $\beta_{кр.}$

As can be seen from the graphs, the approximation depending accurately describe the processes taking place and these equations can be used in a mathematical model of the pneumatic positioner mechanical systems for the calculation of static and dynamic characteristics and of the numerical experiment.

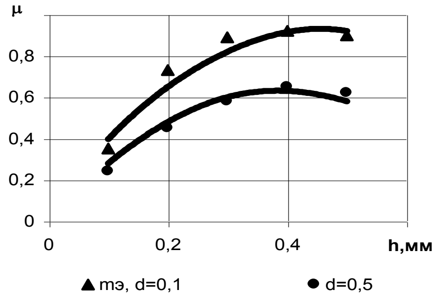


Fig. 15. **μ= f (h)** for flopper – nozzle at **$\beta \leq \beta_{кр}$.$d_у$**=2мм

CONCLUSIONS

To determine the coefficients in the system of equations of the experimentally determined static characteristics of the positioner. Empirically found dependence of discharge coefficients μ of construction-setting parameters positioners and gasdynamic regimes. Are retrieved of rigidity of diaphragms - $c_к$ i $c_м$, seals of the valve and saddle $c_{кс}$, valve and diaphragms - $c_{км}$., value hydrodynamic component of forces **Рг** and coefficients of viscous friction $\alpha_г$ and $\alpha_м$.

Obtained an approximation model to determine the discharge coefficient and μ is defined by its adequacy.

REFERENCES

1. Morgan Jones,2004.: Duilding Valve Amplifiers//Ntwnes.-363 p.
2. Osenin Y.. Remen V., 2010: Accuracy increase of positioning of pneumatic drives for mechanical systems. TEKA Commission of Motorization and Power Industry in Agriculture, V XB, p. 95-99.
3. Osenin Y.. Remen V., Epifanova O., 2010.: Mathematical model of valve - amplifiers for pneumatic drives of mechanical systems. TEKA Commission of Motorization and Power Industry in Agriculture, V XC, p. 255-260.
4. Andruxin N.N., Polin L.P., 1971.: To a problem of experimental determination of a discharge coefficient in the distribution device pneumatic drive.- Pneumatic drives and control systems. M.: p.236-239.
5. Govorkov V.C., Chalatov E.M., 1971.: A way of determination of a discharge coefficient.- Pneumatic drives and control systems. M.: p.233-236.
6. Esin V.I., Nugnov V.I., 1971.: Determination of a drag and discharge coefficient in composite pneumatic systems.- Pneumatic drives and control systems. M,: p.230-232.
7. Dmitriev V.N., Gradecky V.G., 1973.: A fundamentals of a pneumoautomatics. M.: Mashinostroenie, - p.360.
8. Bogacheva A.V., 1966.:. Pneumatic devices of automatic control systems. M.: Mashinostroenie.- P.240.

9. Adler Y.P., Markova E.V., Granovsky Y.V., 1971.: Planningof experiment by looking up of optimal conditions. - M.: Nauka. - p. 286.
10. New ideas in planningof experiment 1969.: / Under red. V.V. Nalimov. - M.: Nauka. - p.334.
11. B Bundy. Methods of optimization. 1988.:- M.: Radio i sviaz. - p.128..
12. Zalmanzon. L.A. Running elements of pneumatic devices of control and management. It is M.:?? SSSR.1961.-p.247.
13. Zaporozhets V.P. 1976.:Research of expense descriptions of membrane strengtheners for stream sequencing control system.- Stream technique. Theses of lectures VI Mezhdunarod. Conf. Yblonna. M.. P.91-95.
14. Popov D.N. 1977.: Dynamics and adjusting of hydraulic and pneumatic systems: Uchebnik dlya mashinostr. VUZoz.-M.: Mashinostroenie, 1977. -p.424.
15. Suliga S.V. 1982.:Research of transients in membrane pneumatic amplifier by computer.- Iz.vuzov. Mashinostroenie,, № 6, p.53-58.
16. Popov D.N., Suliga S.V. 1982.: Bases of calculation and choice of optimum diameters of twocascade membrane pneumatic amplifiers.- Vestnik mashinostr., № 4, p.7-15.

СТАТИЧЕСКИЕ ХАРАКТЕРИСТИКИ КЛАПАНОВ - УСИЛИТЕЛЕЙ ПНЕВМАТИЧЕСКИХ ПРИВОДОВ МЕХАНИЧЕСКИХ СИСТЕМ

Ванетин Ремень, Александр Вялых, Михаил Лордкипанидзе

Аннотация. Рассмотрены статические характеристики пневматических клапанов-усилителей приводов механических систем с улучшенными динамическими характеристиками. Опытным путем найдены зависимости коэффициентов расхода $\mathbf{\mu}$ от конструктивных параметров позиционеров и газодинамических режимов, твердости мембран - $\mathbf{c_к}$ і $\mathbf{c_м}$, уплотнений клапана и седла- $\mathbf{c_{кс}}$, клапана и мембрані - $\mathbf{c_{км}}$., величину гидродинамической составляющей силі $\mathbf{P_г}$ и коєффициенты вязкого трения $\boldsymbol{\alpha_к}$ і $\boldsymbol{\alpha_м}$. Получена аппроксимационная модель для определения коэффициента расхода μ и определена ее адекватность.

Ключевые слова: клапан-усилитель, пневматический привод, коэффициенты расхода.

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THE RESEARCH AREA IN TERMS OF POLY SUSTAINABILITY

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Summary. The region is considered as a complex system that consists of three interrelated components: economic, social and environmental

Key words: Region, a system , a model, territorial integration, effective governance, economic, social and environmental components, infrastructure.

INTRODUCTION

"Region" is the key concept of the regional economy and thus a fairly meaningful. In economic terms the allocation of structural units "region" is considered from the standpoint of the territorial division of labor. Integrative capabilities allow the region to consider it as an economic region, the subject of federation or other political subdivision within the country, as any territorial integration, including international (transnational region).

PROBLEM DEFINITION

Awareness of the systemic nature of the category of "area" now can be considered common. Methods of finding an effective management system, how it is itself the result of management in a large extent determined by what is the model of controlled system, the extent to which this model corresponds to the real system.[5] Contemporary stage of development of the international community, along with globalization is the active Going regionalization: some moving the center of decision-making at regional and local level, the growing role of regions and their cooperation in economic, social and cultural development.[3] It is significant regional experience in Belgium, Germany, Great Britain, Austria and Spain.[8,7] Since the process of regionalization region acts as a universal category, it seems, will have practical significance of the regional modeling system without determining its particular species.

In research there are different models of regional systems that will definitely have something in common with each other, but at the same time isolated in a regional system of different components [11].

There are several reasons, and not the last will be the fact that building a content model of a creative process, and, therefore, suggests that diversity results. In terms of system analysis the region is a complex dynamic poorly structured system. For a deeper understanding of the relationships of structural elements (components), and management processes that occur in the administrative and territorial units, will present the region as a field component model.

SOLUTION

The main characteristics of the regional system are ecological, social and economic components that can objectively be considered subsystems of the first level of "region" (their constituents, according subsystems levels further in the hierarchy). Subordination of subsystems is organized according to their targeted "contribution" in the ecological and socio-economic situation of the region. [1,4,13]

The bases of the model are environmental and social components that make up the resource potential of the region. Parts of the environmental components do not require additional comments. [2,6]Say only that subcomponent "environmental conditions" has dual subordination, not only because it is part of the environmental components, but also is due to the impact on the environment of economic entities of the region.

Poly sustainability model of the region represented by figure 1.The basis of social components of the region is the population; its different characteristics comprise two components of a lower level – the "demographic" and "human resources". [10]Component "labor" reflecting popular participation in the economic subsystem, also has dual subordination: acting as a resource for industrial components, it is changing under its influence.[12] Characteristic for the region a special community of people from certain ethnic composition, traditions and way of life is come by producing one more component – "socio-cultural environment". Since the quality of life of the region has been defined by the social infrastructure (it is housing stock, objects of social sphere, trade, utilities, transport), it is also highlighted by component next level[15]

Central to the model region gains the economic component that is the foundation of life in the region. It contains two large blocks: production and finance. The production component is considered as a set of business entities of various industries in the region and economic ties between them, here is the production of real income of the region (GNP, GDP, national income, GRP).[14]

Of course, finance permeates the entire structure of the regional system, but following the principle of decomposition, the financial unit is included in the economic components. It was made by the formal basis – finance objective is an economic category, as an expression of areas of distribution relationships. Since the region has been seen as yet universal category to pinpoint the financial component of the region is difficult, in each case there will have its own set of elements. [9]

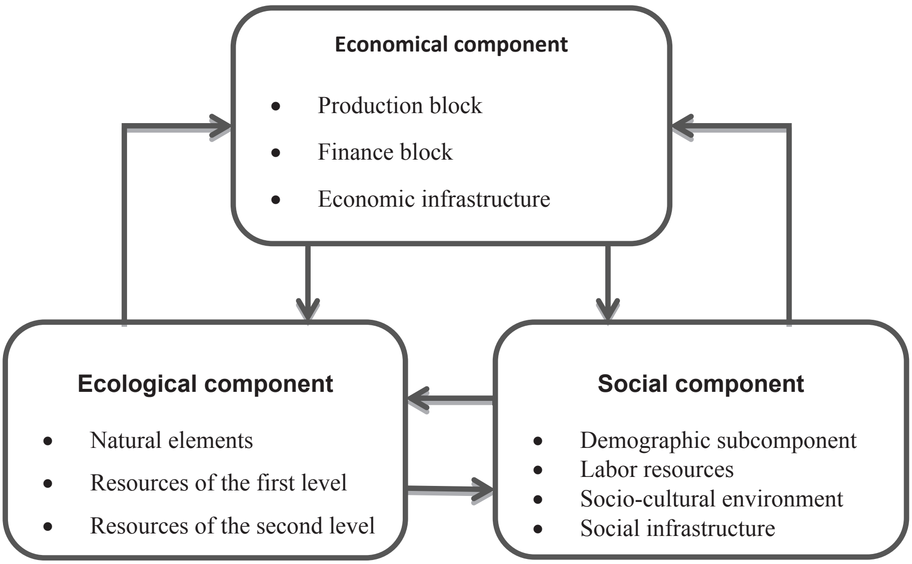

Fig. 1. Poly component model region

CONCLUSIONS

Submitted field component model of the region reflects the same true level of abstraction as the object of its research and modeling, and reaffirms the relationship between elements of the system. By elemental analysis of the regional system shows that each of these components is only conditionally can be separated from one another. It explains as even by the simple and multifunctional "primary" elements that are depending on the objectives of the research to various components and as interconnectedness of components that interact with each other form a quality regional socio-economic (territorial social) system.

REFERENCES

1. Gladkyi Y. N. 2000.: Region Study: textbook / Y. N. Gladkyi, A. I. Chistobaev. – M.: Gardariki,.
2. Gudz P. V.2001.: Economic problems of the resort and recreational areas: a monograph. P. V. Gudz: SAS of Ukraine. Economic and Law Studies Institute. – Donetsk: «South – East, LTD.».
3. Pisarenko S. M.2004.: Socio-territorial system in the theoretical concepts of regionalism / S. M. Pisarenko / / Socio-economic research in the transition period. Regional societies: Scientific Papers; Editorial Board and Executive M. I. Dolishnyi. – ADD. 3. – Lviv: Publishing of the Institute of Regional Studies of SAS of Ukraine.

4. Tretyak V. V.2005.: Development of Regional Foreign Economic Relations: Theory and Practice: Monograph / V. V. Tretyak: SAS of Ukraine. Economic and Law Studies Institute. – Donetsk: «South – East, LTD.».
5. Ymanets T. V.2007.: Regional Economic Development of Ukraine: the theoretical foundations of management, integrated assessment, diagnosis: Monograph / T. V. Ymanets. – Donetsk: VIK.
6. Silina S.2004.: The marketing management concept of regional development / S. Silina // Marketing.
7. Mirzodaeva T. V.2004.: Patterns of spatial development of regional socio-economic systems / T. M. Mirzodaeva // Productive forces and the regional economy: Scientific Papers: in the part 2: DPF of Ukraine SAS of Ukraine. – Part 2. – К.: Publishing DPF of Ukraine SAS of Ukraine.
8. Vasilenko V. N.2009.: Diagnosis of regional development: the structure, limits, methods: monograph / V. N. Vasilenko: Donetsk: «South – East, LTD.».
9. E. A. Lasychev.2008.: The regional system as object and subject of management of regional development: the article / Lasychev E. A. – The State Board of Tomsk Region.
10. V. K. Bugaev.2008.: System properties in the region as the object of control: Article / Bugaev V. K. – Journal "Regions` Studies" №2.
11. T. O. Stetsenko.2002.: Analysis of the regional economy: Textbook — K.: КNEU.
12. V. V. Maksimov.2002.: The economic potential of the region (analysis, evaluation and use): Monograph. – Luhansk: The Publisher of Volodymyr Dahl East – Ukrainian National University.
13. Z. S. Varnalii.2005.: Regions of Ukraine: problems and priorities of socio-economic development: Monograph / Edited by Z. S. Varnalii. – К.: Znannia of Ukraine.
14. V. B. Daskovskyi, I. A. Teberdieva.2000.: On the alignment of social and economic development: article / / Food Industry №3.
15. D. E. Beliakov. 2003.:The development of socio-economic potential of regions in a market economy: monograph / / Russian Academy of Sciences Development and Trade of the Russian Federation. SOPS. – Moscow.

ИССЛЕДОВАНИЕ РЕГИОНА С ТОЧКИ ЗРЕНИЯ ПОЛИКОМПОНЕНТНОСТИ.

Наталья Рязанцева

Аннотация. Рассматривается регион как сложная система, состоящая из трех взаимосвязанных компонент: экономической, социальной и экологической.

Ключевые слова: Регион, система, модель, территориальная интеграция, эффективное управление, экономическая, социальная и экологическая компоненты, инфраструктура.

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INFLUENCE OF HAULING FORCE ON FIRMNESS OF PLURAL STATIONARY MOTIONS OF PASSENGER CAR MODEL

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Summary. The question of influence of hauling force which operates on front axle of passenger car is considered in the article, on the plural of stationary motions of passenger car. It is set that the presence of hauling force changes the diagram of firmness substantially (bifurcation plural).

Key words: car, course firmness of motion, bifurcation plural, trajectory phase, trajectory of motion.

INTRODUCTION

Character of dependence of lateral force as influences the function of slip corner the most substantial rank on descriptions of course firmness of car [Volkov V.P., Kravchenko A.P., 2009, Podrigaylo M.A., Volkov V.P., Boboshko A.A. and others, 2008, Podrigaylo M.A., Volkov V.P., Stepanov V.Y. and others, 2006]. In-process by descriptions course firmness the areas of firmness of plural of steady-states are understood inplane the guided parameters. For the simplest bicycle model in the case of droningly growing dependence of force of the lateral taking any changes of firmness of steady-states, at the change of two guided parameters there are the systems, related to appearance (disappearance) of pair of the special points. In the cases of general, answers these points or branching of fold is the double special point, or branching of collection is the triple special point [Arnold V.I., 1990]. Therefore interest presents determination of areas inplane two guided parameters with the different amount of the stationary modes – limit between them is a critical value (a bifurcation plural has the name) [Arnold V.I., 1990, Poston T., Stewart I., 1980].

The geometrical method of finding of the stationary modes [Pevsner J.M., 1947, Pacejka. H.B., 1978, Verbitskii V.G., Lobas L.G., 1981], complemented the algorithm of construction of bifurcation plural [Verbitskii V.G., 1995, Verbitskii V., Danilenko E., Nowak A., Sitarz M., 2007], is known, enables to conduct the previous analysis of amount of the stationary modes and define limit of firmness inplane the guided parameters: longitudinal rate of movement, corner of turn of the guided module [Verbitskii V., Danilenko E., Nowak A., Sitarz M., 2007, Lobas L.G.; Verbitskii V.G., Boruk I.G., 2000]. From the review of that hauling forces which operate in the contact of wheels with a road [Gillespie Thomas D., 1992, Kosenko A.V., 2010] were not taken into account in these works, but realization of the simplified geometrical method of construction of bifurcation plural at presence of longitudinal force on front wasp is done impossible, the construction of bifurcation plural is in-process conducted on the basis of numeral realization of analytical and geometrical method of lengthening after two parameters [Shinohara Y., 1972, Troger H., Zeman K., 1984, Holodniok M., Klic A., Kubicek M., Marek M., 1991] both at the account of longitudinal force and at its absence (the plane of the guided parameters is broken up on an area with the different amount of the stationary modes; there is a change of firmness of stationary motions on limit of areas). To the points of sharpening (cusps) of critical plural answers branching of collection, and to the regular points is branching of fold [Arnold V.I., 1990, Poston T., Stewart I., 1980, Bruce J., Giblin P., 1988]. The sizes of areas, where proof steady-states will be realized, give a quantitative estimation influence of hauling force on descriptions of course firmness.

A purpose of the article is research of influence of hauling force which operates on front wasp, on firmness of plural of stationary motions of passenger car.

RESULT OF RESEARCHES

For research the «bicycle» model of car is utillized with the fastened steering management, equalizations of motion of which look like:

$$\begin{cases} m(\dot{v} + uw) = X_1\cos(\theta) - Y_1\sin(\theta) - X_{fr}; \\ m(\dot{u} + vw) = X_1\sin(\theta) + Y_1\cos(\theta) + Y_2; \\ J\dot{w} = a(Y_1\cos(\theta) + X_1\sin(\theta)) - bY_2, \end{cases} \tag{1}$$

where: m – mass of car;

Y_1, Y_2 – lateral forces which arise up between a wheel and road;

X_{fr} – force of resistance of car motion;

X_1 – hauling force.

Forces of the lateral taking Y_i, that included in the system of equalizations (1), determined empiric (functions are from the corner of taking δ_i), presented as droningly growing dependence:

$$Y_i = \frac{k_i\delta_i}{\sqrt{1 - \left(\frac{k_i\delta_i}{N_i\varphi_i}\right)^2}}, \tag{2}$$

where: k_i – coefficient of resistance to the lateral taking;

N_i – vertical loading;

φ –coefficient of rolling friction with a road.

Monotonous approximation of forces of taking is not of principle limitation for the select in-process numeral method of construction of identical curves and біфуркаційних plurals, and enables easily to define influence of longitudinal force (the case of monotonous approximation in default of longitudinal force is well investigational [Verbitskii V.G., 1995, Verbitskii V., Danilenko E., Nowak A., Sitarz M., 2007, Lobas L.G.; Verbitskii V.G., Boruk I.G., 2000]).

Force of resistance of motion X_{op} consists of force of resistance rolling and forces of resistance of air environment [Tarasik V.P., 2006]:

$$X_{fr} = mgf + k_w F v^2, \tag{3}$$

where: $f = f_0(1+(0,0216v)^2)$ - coefficient of resistance to rolling [19];

k_w – coefficient of windage;

F – frontal area of car.

At calculations which will be executed below, the next values of parameters are accepted: $\varphi = 0,8$; m = 1325 kg; coefficients of resistance of taking: $k_1 = 50$ кN/rad, $k_2 = 40$ кN / rad; $f_0 = 0,015$; $k_w = 0,3$ Ns^2/m^4; F = 1,8 m^2; base l = 2,42 m; distance is from front a landmark to the barycenter a = 1,2 m; distance is from back a landmark to the barycenter b.

The analysis of equalizations which determine the plural of steady-states specifies on possibility of direct decision of this system in relation to forces of taking, that allows substantially to simplify procedure of construction of bifurcation plural.

Two last equalizations of the system (4) determine the plural of steady-states:

$$X_1 = \frac{\left[b\left(vwmtg(\theta) - uwm + X_{fr}\right) - a\left(uwm - X_{fr}\right)\right]\cos(\theta)}{b+a};$$

$$Y_1 = -\frac{\left[-vwmctg(\theta) - b\left(uwm - X_{fr}\right) - a\left(uwm - X_{fr}\right)\right]\sin(\theta)}{b+a}; \tag{4}$$

$$Y_2 = \frac{m\omega va}{b+a}.$$

Utillizing the method of continuation after two parameters [Verbitskii V., Danilenko E., Nowak A., Sitarz M., 2007, Holodniok M., Klic A., Kubicek M., Marek M., 1991], will define the critical values of the guided parameters, that will build a bifurcation plural (graph, which represents parameters which a divergence loss of firmness of steady-states is at). On fig. 1 the got bifurcation plural which specifies on the high-quality changes of bifurcation plural during realization of tractive force on front wasp is resulted: area of the guided parameters θ and v distributed on an area with the different amount (presented numbers in circles) of the stationary modes of motion. In areas with two stationary modes one mode will be proof, and second unsteady. Accordingly in areas with four stationary modes – two proof and two unsteady.

Most dangerous from the point of view course firmness are areas where the stationary modes of motion absent, or there is one unsteady mode.

For the subsequent analysis of firmness of the stationary modes the method of continuation is utillized after one parameter [Shinohara Y., 1972, Lobas L.G., Verbitskii V.G., 1990].

As example an area is considered with four stationary modes of motion (see rice. 1) in the case when longitudinal constituent of speed C.M. car v = 23 m/s.

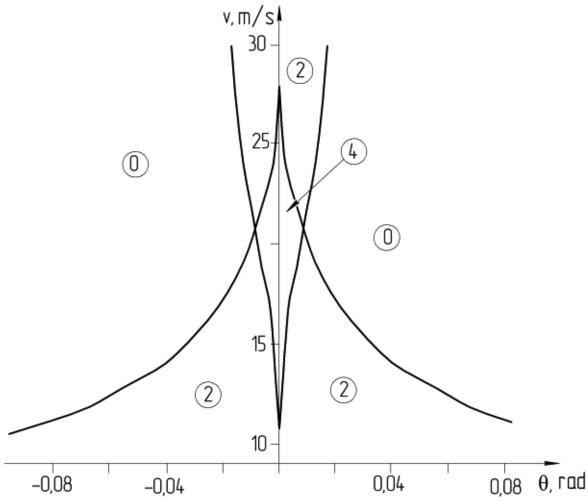

Fig. 1. Bifurcation plural

On fig. 2 dependence of angulator round vertical the landmark of car body ω from the corner of turn of the guided wheels θ is resulted. The points of turn on the graph (1 – 4 on of fig. 2) answer the double stationary modes [Lobas L.G., Verbitskii V.G., 1990, Holodniok M., Klic A., Kubicek M., Marek M., 1991] (divergence loss of firmness) – bifurcation plurals which outline an area with four stationary modes at speed coincide with interfaces 23 m/s (continuous line answers the graph to the proof modes of motion, stroke – unsteady).

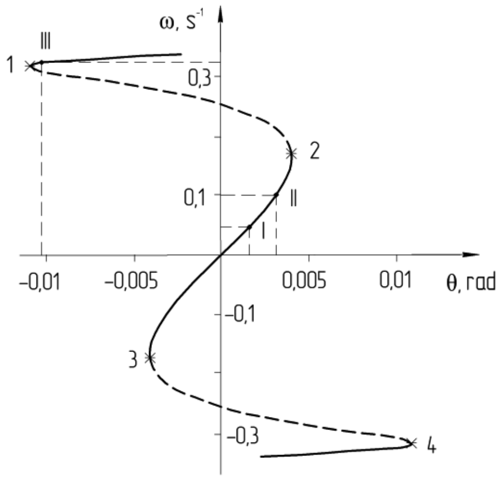

Fig. 2. Dependence $\omega = f(\theta)$

For clarification of parameters of the got stationary modes will consider three from them, that to in obedience to fig. 2 is proof. The modes have the followings parameters:

$$u_I = -0{,}496 \text{ m/s}; \quad \omega_I = 0{,}065 \text{ s}^{-1}; \quad \theta_I = 0{,}0021 \text{ rad};$$
$$u_{II} = -1{,}092 \text{ m/s}; \quad \omega_{II} = 0{,}133 \text{ s}^{-1}; \quad \theta_{II} = 0{,}0037 \text{ rad};$$
$$u_{III} = -7{,}387 \text{ m/s}; \quad \omega_{III} = 0{,}319 \text{ s}^{-1}; \quad \theta_{III} = -0{,}0108 \text{ rad}.$$

For each of these modes will define the corners of taking of front and back axes [Pevsner J.M., 1947]of, which can serve as the certain criterion of practical realization of the proper withstand motions:

$$\delta_1 = \theta - \frac{u + a\omega}{v}; \qquad \delta_2 = \frac{-u + b\omega}{v}.$$

The next values of corners of taking are got:

Mode I – $\delta_1 = 1{,}16^\circ$; $\delta_2 = 1{,}43^\circ$.

Mode II – $\delta_1 = 2{,}54^\circ$; $\delta_2 = 3{,}12^\circ$.

Mode III – $\delta_1 = 16{,}83^\circ$; $\delta_2 = 19{,}37^\circ$.

Obviously, that realization of the third mode needs certain experimental confirmations, that it is related to the large enough values of corners of taking. It should be noted that in opposition to the cases turn of car to the right, for a case III, needs turn of steering wheel. For the first two modes the trajectories of motion of centre-of-mass car are numeral built (fig. 3).

Thus radiuses of trajectories of C.M. it is possible approximately to define after a formula $R = v/\omega$: for the mode I – R_I = 354 m; for the mode II – R_{II} = 173 m, III – R_{III} = 72 m (radius of trajectory of point D of longitudinal ax which has a rate of longitudinal movement v = 23m/s). Distance of this point is from C.M. determined correlation $L = u/\omega$: I – L_I = -7,6 m, II – L_{II} = - 8,2 m, III – L_{III} = - 23,2 m, that explains the numeral coinciding of radiuses of C.M. and points of D, or their divergence, and the radius of CM is determined by $R_C = \sqrt{R^2 + L^2}$: R_{CI} = 353,9 m; R_{CII} = 173,1 m; R_{CIII} = 75,7 m.

The values of radiuses are resulted higher coincide with those which are got on the basis of numeral integration. For finding out of influence of longitudinal force of X1 on fig. 3 the fragments of basic branches of bifurcation plurals are resulted for two cases: hauling force of $X_1 = 0$; hauling force of $X_1 = 0$. Will notice that the second and third equalizations of the system (1) were utilized in last case only, in what $X_1 = 0$.

Fig. 3 illustrates differences between the bifurcation plurals of frontpulling and rearpulling cars. But it follows to notice that in this case influence of hauling force is not taken into account on the size of coefficients of resistance of taking, that is why have «unchanging» critical speed of rectilineal motion $v_{cr}^2 = k_1 * k_2 * l * g/(k_1 - k_2)$; ($v_{cr}$ = 28,1 m/s).

For additional research of bifurcation plurals and their verification it is necessary to choose control parameters θ and v, values of which are in near of border of bifurcation plurals.

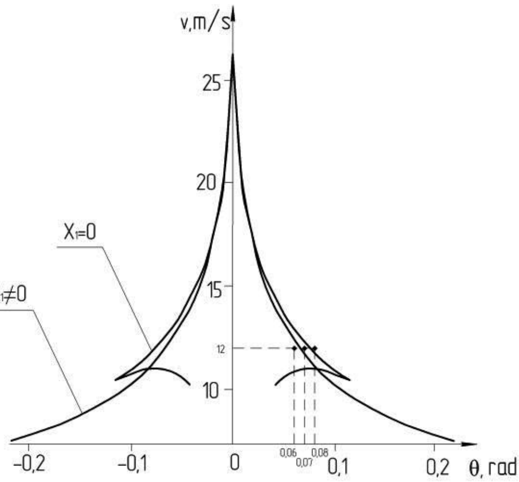

Fig. 3. Comparison of bifurcation plurals

Will consider the graph $X_1 \neq 0$ (look on fig. 3), in quality an example elect speed of car v = 12 m/s but value of corner of turn of the guided wheels θ = 0,06 rad (it is under a curve) and θ = 0,07 rad (it is outside the graph which is examined).

For the select guided parameters numeral integration is build phase trajectories narrow-mindedness of which specifies on realization of proof stationary motions; the proof stationary modes are answered by the circular trajectories of centre-of-mass car inplane road (fig. 4).

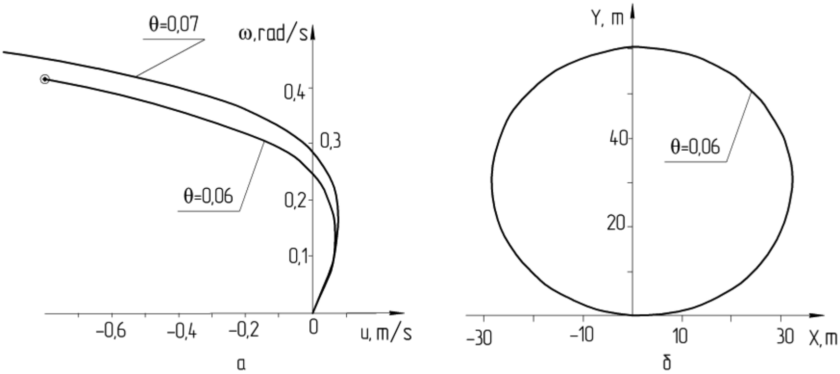

Fig. 4. Phase trajectories (a) and trajectories of motion of centre-of-mass (b) at v = 12 m /s and $X_1 \neq 0$

From fig. 4, *a* evidently, that at θ = 0,06 advices have the proof mode of motion with parameters (u = - 0,699; ù = 0,397), this mode is answered by the circular trajectory of C.M., which is resulted on rice. 4; at the value of θ = 0,07 advices a phase trajectory is unlimited, it specifies or on absence of the proof modes, or on that beginning of co-ordinates does not belong to the area of attracting of the proof mode (from lines. 1 swims out in actual fact, that for the proper guided parameters steady-states absent in general).

In case $X_1 = 0$ elect the guided parameters: v = 12 m/s, θ = 0,07 рад (it is under the basic branch of bifurcation of curve); v = 12 m/s, θ = 0,08 rad (it is outside of bifurcation plural).

On fig. 5 a phase trajectory (a) and trajectory of centre-of-mass (a), which are built for the case of v = 12 m/s, θ = 0,07 rad.

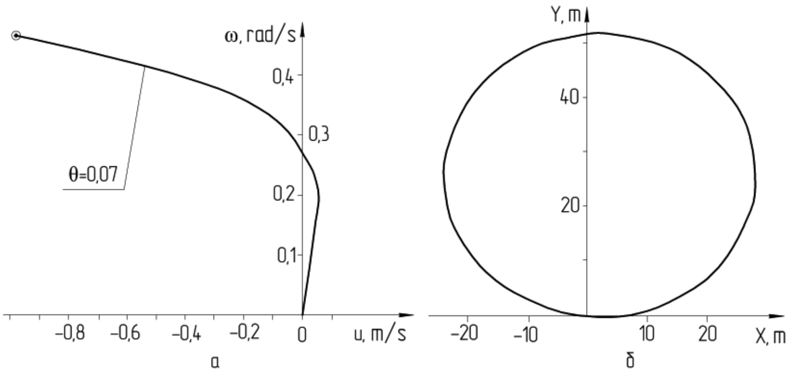

Fig. 5. Phase trajectory (a) and trajectory of motion of centre-of-mass (b) at v = 12 m/s, θ = 0,07 rad ($X_1 = 0$)

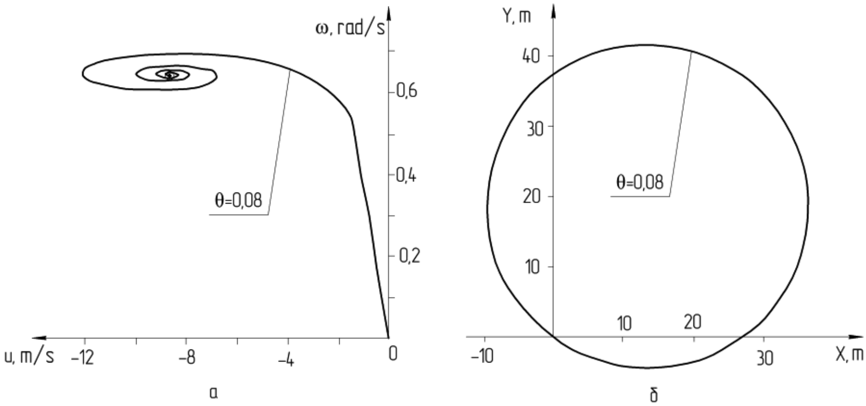

Fig. 6. Phase trajectory (a) and trajectory of motion of centre-of-mass (b) at v = 12 m/s, θ = 0,08 rad ($X_1 = 0$)

From fig. 5, a evidently, that at the fixed guided parameters v = 12 m/s, θ = 0,07 rad a car goes out on the proof circular mode (u = - 0,998 m/s; ω = 0,465 rad/s), inplane road he is answered by the circular trajectory of CM (resulted on fig. 5, б).

On fig. 6 a phase trajectory and trajectory of centre-of-mass, which are built for a case is resulted v = 12 m/s, θ = 0,08 rad.

Fig. 6 specifies on realization of the proof mode (u = - 8,6800 m/s; ω = 0,6454 rad/s), although coming from bifurcation plurals (fig. 3), it would follow to expect the unsteady mode. A similar situation can testify to the presence of additional (or additional) branches of bifurcation plurals and in case X1 = 0.

These additional stationary modes do not have a practical value, because the corners of taking on axes exceed 40 degrees ($\delta_1 = 0{,}7388,\quad \delta_2 = 0{,}7889$).

CONCLUSIONS

Hauling force influences on descriptions of course firmness of passenger car – changes the type of bifurcation plural (integral description of firmness of all to pluralness of the stationary modes of motion). For the analysis of influence of hauling force on descriptions of firmness additional research of phase portraits (task of estimation of areas of attracting of the proof stationary modes) which would answer the areas of plane of the guided parameters with the different amount of the stationary modes is needed in large.

REFERENCES

1. Volkov V.P., Kravchenko A.P., 2009.: Bases of theory of operating properties of car: study aid / – Lugansk: Publ. SNU n.a. V. Dalya. – 248 p.
2. Podrigaylo M.A., Volkov V.P., Boboshko A.A. and others, 2008.: Dynamics of car. – Kharkov: Publ. KhNADU. – 424 p.
3. Podrigaylo M.A., Volkov V.P., Stepanov V.Y. and others, 2006.: Stability of the wheeled machines at skidding and methods of its increase / Under red. M.A. Podrigaylo. - Kharkov: Publ. KhNADU. – 335 p.
4. Arnold V.I., 1990.: Catastrophe Theory. - Moscow: Nauka. – 128 p.
5. Poston T., Stewart I., 1980.: Catastrophe Teory And Its Applications. - Moscow: Mir. – 607 p.
6. Pevsner J.M., 1947.: Theory of stability of automobile. – Moscow: Mashisdat. – 156 p.
7. Pacejka. H.B., 1978.: Tyre factors and vehicle handling // Delf Univ. Technol. – №108. - 31 p.
8. Verbitskii V.G., Lobas L.G., 1981.: Method of determination of the special points and their character // Applied mathematics and mechanics. – №45(5). – P. 944 – 948.
9. Verbitskii V.G., 1995.: Bifurcation sets and catastrophes in manifold of the steady states of pneumowheel vehicles // Pricl. Mech. Vol. 31, ¹3, Kiev, P. 89 - 95.
10. Verbitskii V., Danilenko E., Nowak A., Sitarz M., 2007.: Introduction in the Stability Theory of the Wheel Vehicles and Railway. – Donetsk department: «Veber». – 255 p.
11. Lobas L.G.; Verbitskii V.G., Boruk I.G., 2000.: Bifurcations and catastrophes in dynamical systems with central symmetry (Russian) // Rigid body mechanics. - № 30. - P. 151 - 157.

12. Gillespie Thomas D., 1992.: Fundamentals of Vehicle Dynamics / Thomas D. Gillespie. – Society of Automotive Engineers, Inc. – 470 p.
13. Kosenko A.V., 2010.: Influence of longitudinal force which arises up in the spot of contact of wheel with a road, on course firmness of motion of passenger car / A.V. Kosenko, V.V. Kondratev, A.N. Efimenko // Announcer of the Zhitomir State Technological University. – Zhitomir: GhDTU. - №2 (53). – P. 74 – 78.
14. Shinohara Y., 1972.: A geometric method for the numerical solution of non-linear equations and its application to non-linear oscillations. Publ. Res. Inst. Math. Sci., Kyoto Univ. 8, 1. - P. 13 - 42.
15. Troger H., Zeman K., 1984.: A nonlinear analysis of the generic types of loss of stability of the steady state motion of the tractor –semitrailer // Vehicle System Dynamics. V. 13. -№ 4. - P. 161-172.
16. Lobas L.G., Verbitskii V.G., 1990.: Qualitative and Analytical Methods in the Dynamics of Wheel Machines. – Kiev: Naukova Dumka. – 232 p.
17. Holodniok M., Klic A., Kubicek M., Marek M., 1991.: Methods of Analysing Non-linear Dynamic Systems. - Moscow: Mir. – 368 p.
18. Bruce J., Giblin P., 1988.: Curves and Singularities. – Moscow: Mir. – 262 p.
19. Tarasik V.P., 2006.: Theory of car motion: textbook for the institutes of higher / V.P. Tarasik – SPb. : BKhV – Petersburg. – 478 p.

ВЛИЯНИЕ ТЯГОВОЙ СИЛЫ НА УСТОЙЧИВОСТЬ МНОЖЕСТВА СТАЦИОНАРНЫХ ДВИЖЕНИЙ МОДЕЛИ ЛЕГКОВОГО АВТОМОБИЛЯ

Владимир Сахно, Александр Кравченко,
Андрей Костенко, Владимир Вербицкий

Аннотация. В статье рассмотрен вопрос влияния тяговой силы, которая действует на передней оси легкового автомобиля, на множество стационарных движений легкового автомобиля. Установлено, что наличие тяговой силы существенно изменяет диаграмму устойчивости (бифуркационное множество).

Ключевые слова: автомобиль, курсовая устойчивость движения, множество бифуркационное, траектория фазовая, траектория движения.

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CONTACT AREA INCREASE OF THE WORKING ELEMENTS OF THE BLOCK BRAKE BY MEANS OF DESIGN METHODS

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Summary. There offered the design of the block brake which is characterized by sectionalization of the working material that ensures the increase of the heat removal total area and the level decrease of mechanical and thermal deformations. The consequence of it is the temperature decrease of the contact area of the block and rail and coefficient increase of block brake elements.

Key words: rolling stock, block brake, contact area.

INTRODUCTION

Nowadays the mechanical brake systems are widely used in the rolling stock and are the irreplaceable means of the rolling stock braking [2, 14].

However, the use experience of frictional brake systems showed their imperfection from the point of view of heat capacity [1, 6, 13] and it creates definite problems in the result of overheating of the friction elements and it brings to the decrease of the friction coefficient and the increase of the wear intensity. Thus, the heat removal improvement and the temperature decrease of the block brake friction zone is an actual technological problem.

OBJECTS AND PROBLEMS

According to molecular and mechanical ideas of friction of the solids [4, 5, 12] external friction forces are determined as the sum of resistances relatively to the displacement of the solids stipulated by atom-molecular interaction and deformation of the surface layers by inculcation microunevennesses. Hence, the simple way of the friction force rise of the elements is the contact area increase of the interacting elements [8].

The increase of the contact area of the block and a wheel of the rolling stock allows to obtain additional advantages which are understandable from the point of view of logic. It means the prolongation of service life of cast-iron blocks.

Practically, the increase of the contact area of a block and a wheel due to the size increase of the block is problematic because the blocks are heated and deformed while braking. As a result, the shape and a block outline are distorted and it is unevenly snug against the wheel. Besides, while increasing the block length, the block rigidity is decreased stipulated by the size "*d*" and it also has an influence on the homogeneity of the block pressing to the wheel. As a result, the effect from the increase of the contact area (the length of the block) does not bring the expectable result (fig. 1).

It is experimentally ascertained that the size of the blocks, particularly their length (the width of the block is determined by the thickness of the tyre), where thermal deformations are not told, is not to exceed 230 - 330 mm [11].

Fig. 1 offers the illustration of a new design of the brake block which gives the possibility to increase the summable area of all the blocks. A main idea of the offered principle consists in the sectionalization of the block working surface that has an influence on the level decrease and nature of thermal and mechanical deformations and it ensures both the contact area increase and it is snug against the wheel in comparison with the prototype. In this case the bearing density of the block to the wheel is determined only by the rigidity of the block arm stipulated by the size "d" which can be raised by design methods.

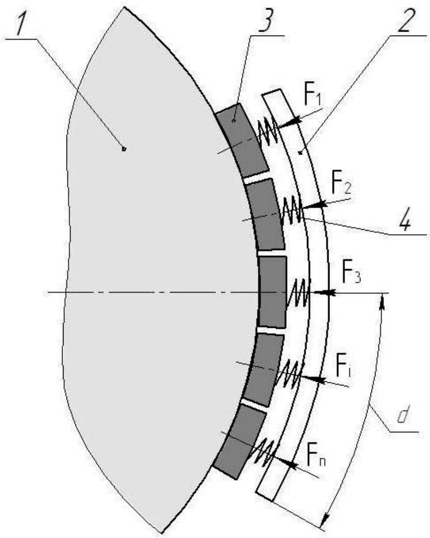

Fig. 1. A new principle of the brake block design which ensures the increase of the contact area with a wheel
1 – a rolling stock wheel; 2 – shoe; 3 – brake block; 4 – elastic elements

Ordinary calculations show that under the conditions of conservation of the rigidity level and absence of mechanical and thermal deformations it is possible to increase summary length of the brake blocks up to 550 mm (in comparison with 380 mm of the series block).

Such a length increase of the brake blocks promotes to the increase of the total contact area by 40 %. In this case the friction force is increased and wear intensity is decreased.

This is confirmed by the calculations of the friction force and wear intensity which are made on the basis of the friction theory formula [3, 5, 10, 12]. The calculations are made for rigid non-saturated contact of a wheel and a block [8]:

$$F = \frac{A_c b\nu(\nu-1)\varepsilon^{\nu}}{2\pi R R_{\max}}\left[\frac{\pi R R_{\max}\tau_0}{\nu(\nu-1)} + \frac{0{,}4\pi\beta k_1 R^{1/2} E\varepsilon^{1/2} R_{\max}^{3/2}}{1-\mu^2} + \frac{0{,}5\alpha_{эф} E\varepsilon R_{\max}^2}{\nu(\nu^2-1)(1-\mu^2)}\right]; \quad (1)$$

$$f = \frac{2{,}4\tau_0\left(1-\mu^2\right)^{4/5}}{p_c^{1/5}\Delta^{2/5}E^{4/5}} + \beta + 0{,}24\alpha_{эф} p_c^{1/5}\Delta^{2/5}\left(\frac{1-\mu^2}{E}\right)^{1/5}. \quad (2)$$

Formulas (1) and (2) set the interconnection between the friction force F, friction coefficient f and parameters which characterize the properties and conditions of the brake block and wheel of the block brake.

Correspondingly, the wear intensity of the block was calculated in accordance with the formula:

$$I_h = \frac{0{,}34(k')^t\left(1-\mu^2\right)p_c}{\sigma_B^t E}\cdot\left[\tau_0 + 0{,}5\beta\frac{p_c^{1/5}E^{4/5}\Delta^{2/5}}{\left(1-\mu^2\right)^{4/5}}\right]^t. \quad (3)$$

The formula includes:

p_a – nominal pressure;

τ_0 – molecular shear strength;

$R_{\max}$ – maximum height of microroughness;

R – curve radius of microroughness peak;

ν, b – parameters of degree approximation of initial part of support curve;

k_1 – integration constant depending on ν;

A_c – contact contour area;

β – piezocoefficient of molecular bond;

p_c – contour pressure;

μ – Puasson coefficient;

E – modulus of elasticity;

Δ – complex criteria of roughness;

α_{eff} – the coefficient of hysteresis losses.

ε - relative rapprochement of contacting surfaces;

σ_B - stretching tension, resulting in destruction at single influence;

$t = 3 \div 14$ - index of the crooked fatigue;

$k^{/}$ - coefficient $k' = 5$ - for fragile materials.

Relative rapprochement ε of surfaces is determined as absolute rapprochement of surfaces h in the ratio of the maximal height of microrougness:

$$\varepsilon = \frac{h}{R_{\max}} . \tag{4}$$

The calculations show that the friction force under the conditions of sectionalization of the working surface of the friction block is increased by 2,2% while simultaneous decrease of wear intensity by 3,7%.

The brake block design (fig. 2) was developed on the basis of the offered principle and it is defended by the patent of Ukraine [9].

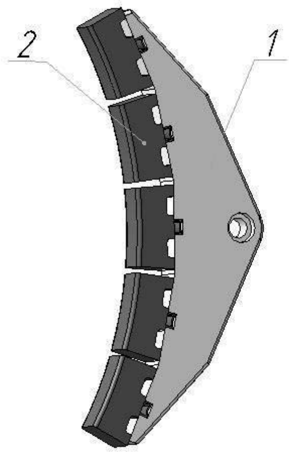

Fig. 2 A new brake block design
1 – shoe; 2 – brake block

The characteristic feature of a new brake block consists in sectionalization of its working surface. Working sections 2 are installed on the shoe 1. A new brake block is interchangeable with a serial sample.

The application of several sections of brake elements on one shoe allows to obtain one more operation advantage. It is connected with the increase of total external area of brake elements and it gives the possibility to improve heat removal from the body of the brake block into environment.

CONCLUSIONS

1. One of the ways of improvement of the block brake characteristics is the increase of the contact area of the block and the wheel and it is problematic because of the blocks irregularity of heating and deformation while braking. As a result of it, the shape and outline of the block are distorted and it has an influence on the contact area of the block and rail.

2. Sectionalization of the working surface of the brake block allows to increase its contact area with a rail. In this case it is possible to increase friction force by 2,2% while simultaneous decreasing wear intensity by 3,7%. Critical value has not been obtained when thermal deformations begin to be told.

3. There offered a new design of the brake block of the block brake of the railway vehicle which is characterized by sectionalization of the working surface. The design of the brake block is defended by the patent of Ukraine as a helpful model.

REFERENCE

1. Asadchenko V.R., 2006.: Automatic brakes of the rolling stock: Training appliances for the students of the transport educational institutions. – M.; Route, 392 p.
2. Ehlers H.-R. et al., 2002.: Potential and limits of opportunities of the block brake. Glasers Annalen, № 6/7, P. 290-300.
3. Kombalov V.S., 1983.: Evaluation of tribotechnological properties of the contacting surfaces. – M.: Science, 136 p.
4. Kragelsky I.V., Dobichin M.N., Kombalov V.S., 1977.: Principles of the calculations friction and wear. – M.: Machine-building, 526 h.
5. Kragelsky I.V., Mikhin N.M., 1984.: Machine friction units. – M.: Machine-building, 280 p.
6. Modern Railways, 2002, № 641, p. 54, 56.
7. Osenin Yu.I., Marchenko D.N., Shvedchikova I.A., 1997.: Frictional interaction of the wheel and rail. – Lugansk: VUGU Publishing, 226 p.
8. Osenin Y., Sergienko O., 2009.: An ifluence of geometrical characteristics of frictional elements on the effectiveness of disk brake. // TEKA Commission of Motorization and Agriculture. – Liblin, Polska Akademia nauk Oddzial w Lubline, Vol. IX., P. 285 – 289.
9. Patent on a helpful model № 44270 «Block brake» (recorded in the State Register of patents in Ukraine of helpful models 28.10.09).
10. Reference book on tribotechnology / Edition: M Khebda, A.V. Chichinadze. V.1. Theoretical principles. – M.: Machine-building, 1989. – 400 p.
11. Reference book: Brake equipment of the rolling stock / V.I. Krylov, V.V.Krylov, V.N.Efremov, P.T. Demushkin. - M.: Transport, 1989. - 487 p.
12. Reference book: Friction, Wear and Lubrication / Editors: I.V. Kragelsky, V.V. Alisin. – M.: Machine-building, 1978. – B. 1. 1978. - 400 p.
13. Raison J., 1998. Revue Gйnйrale des Chemins de Fer, № 3, p. 9 - 15.
14. W. Schlosser, S. Aurich., 2001. :Modern brake systems // Glasers Annalen, № 8, P. 273 – 277.

ПОВЫШЕНИЕ ПЛОЩАДИ КОНТАКТА РАБОЧИХ ЭЛЕМЕНТОВ КОЛОДОЧНОГО ТОРМОЗА КОНСТРУКУКТОРСКИМИ МЕТОДАМИ

Оксана Сергиенко

Аннотация. Предложена новая конструкция тормозной колодки, которая характеризуется секционированием рабочего материала, что обеспечивает увеличение общей площади теплоотвода и снижение уровня механических и термических деформаций. Следствием этого является снижение температуры области контакта колодки с рельсом и повышение коэффициента трения элементов колодочного тормоза.

Ключевые слова: подвижной состав, колодочный тормоз, площадь контакта.

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THE DISPERSIVE FIELD OF THE MARK, WHICH APPLIED U-SHAPED RECORDING HEAD

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Summary. The methodology of determining the optimal location of fluxgate sensors for reading the information on the magnetic carrier, record to which is carried out U-shaped recording head is offered.

Key words: wagon weights, fluxgate sensors, external magnetic field, magnetic mark, U-shaped recording head.

INTRODUCTION

The railway transport of Ukraine is important to the livelihoods of the economy, consisting of the provision of timely and high-quality passenger and cargo transportation. Recently, there has been as increase of volumes of transportations, and the growth of deficiency of a rolling stock, first of all freight carriage [Belov V., 2003]. For sustainable operation of the industry at the expense of improvement of quality indicators of work of railway transport, the increase of traffic speed, use of reserves acceleration of the turnover of railcars, minimization of unproductive idle runs railcars and locomotives should create the required reserve weight measuring points [Kurlaev A., 2003]. Such a possibility exists, taking into account the increased availability of railway-owned highways means of information-measuring engineering [den Buurman G., 2005].

Amenities such weight measuring points anchor wagon weights does not in all cases justified economically because of the high cost of weights and high labor-intensiveness of their installation[Sergeev A., 2000]. To solve this problem it is suggested magnet metric weighing system railcars [Bikhdricker A., 2010], intended for weighing of railcars in motion in the train with documentary registration of the weight of each railcar. It can be easily installed on the routes of the railway stations and access roads of open pits, mines, ports, and other industrial enterprises.

RESEARCH OBJECT

For weighing it is proposed to use the method of magnetic recording on the railroad track. It is known, that the intensity of the external magnetic field of a marking depends on the impact of dynamic loads [Bikhdricker A., 2001], and the degree of reduction of the strength of the magnetic field depends on the weight of the railcar. It is expedient to apply the magnetic marks on the neck of the rail to determine the weight of railcars.

The purpose of the article is the analysis of the mathematical model of the dispersive field of the mark, which applied U-shaped recording head in the magnet carrier and determine the best location for fluxgate sensors on magnetic fingerprint.

RESULTS AND THEIR ANALYSIS

Residual magnetization mark creates, the configuration of which we find in the assumption that in this apply the same idealization, which were introduced in the analysis of fields of permanent magnets[Smirny M., 1982]. Model of magnetic carrier which has a thickness of ***2d*** is depicted in fig. 1, where indicated $y/d=\bar{y}$, $x/d=\bar{x}$.

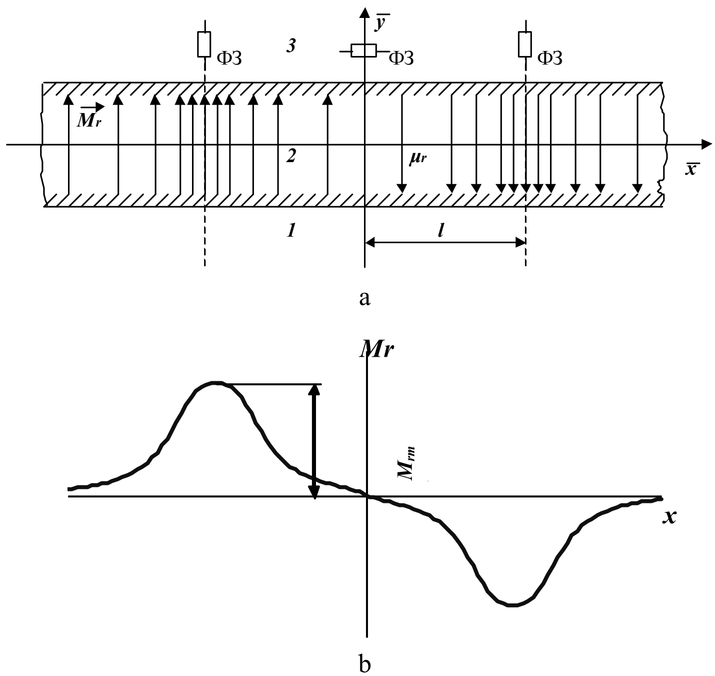


Fig. 1. The magnetic field of the marking: a – model of magnetic carrier; b – the distribution of residual magnetization

The nature of the field in a plane ferromagnetic body when recording a U-shaped head makes approximated the residual magnetization of the mark by using expressions [Smirny M., 2009, Pavlukov V., 1977, Polivanov K., 1975]:

$$\vec{M}_r^+(x) = \vec{j} M_{rm} \frac{\beta^2}{\beta^2 + (\bar{x} + l)^2}; \tag{1}$$

$$\vec{M}_r^-(x) = -\vec{j} M_{rm} \frac{\beta^2}{\beta^2 + (\bar{x} - l)^2}, \tag{2}$$

where: the $\boldsymbol{M_{rm}}$ is the amplitude of the residual magnetization;

$\boldsymbol{\beta>0}$ is the coefficient, depending on the length of the magnetic marking.

Decomposition (2) and (3) in the Fourier integral has the form:

$$\vec{M}_r^+(x) = \vec{j} M_{rm} \frac{2}{\pi} \int_0^\infty \frac{\pi}{2} \beta e^{-\beta\omega} \cos(\bar{x} + l)\omega d\omega; \tag{3}$$

$$\vec{M}_r^-(x) = -\vec{j} M_{rm} \frac{2}{\pi} \int_0^\infty \frac{\pi}{2} \beta e^{-\beta\omega} \cos(\bar{x} - l)\omega d\omega. \tag{4}$$

After the solution of the boundary value problem for one of the harmonics (3) and (4) which has a frequency $\omega = \Omega \neq 0$ $\vec{M}_{r\Omega} = \vec{j} M_{rm\Omega} \cos\Omega(x+3)$, where $M_{rm\Omega} = M_{rm}\beta e^{-\beta\Omega}$ is the amplitude of the magnetization [Bikhdricker A., 2007], the magnetic potential is determined in the area of 3, caused by all of the harmonic spectrum and then the components of the intensity of the external mark field are determined [Chatskis L., 1973, Loufer M., 1973]:

$$\begin{aligned}\varphi_3^+ = \beta \frac{M_{rm}}{\mu_r + 1} \Bigg[& \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}-1+4\alpha)\omega} \cos(\bar{x}+l) d\omega - \\ & - \frac{2\mu_r}{\mu_r+1} \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}+1+4\alpha)\omega} \cos(\bar{x}+l)\omega d\omega + \\ & + \frac{\mu_r - 1}{\mu_r + 1} \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}+3+4\alpha)\omega} \cos(\bar{x}+l)\omega d\omega \Bigg],\end{aligned} \tag{5}$$

where: $c = \left(\frac{\mu_r - 1}{\mu_r + 1}\right)^2$;

$$\begin{aligned}\varphi_3^- = \beta \frac{M_{rm}}{\mu_r + 1} \Bigg[& \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}-1+4\alpha)\omega} \cos(\bar{x}-l) d\omega - \\ & - \frac{2\mu_r}{\mu_r+1} \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}+1+4\alpha)\omega} \cos(\bar{x}-l)\omega d\omega + \\ & + \frac{\mu_r - 1}{\mu_r + 1} \int_0^\infty \frac{e^{-\beta\omega}}{\omega} \sum_{\alpha=0}^\infty c^\alpha e^{-(\bar{y}+3+4\alpha)\omega} \cos(\bar{x}-l)\omega d\omega \Bigg].\end{aligned} \tag{6}$$

Bringing the integrals into the forms which are tabulated and considering the relationship $\vec{H} = grad\varphi$ [Polivanov K., 1964], the expressions for horizontal and vertical components of the intensity of the field from the magnet pole are derived [Bikhdricker A., 2007]

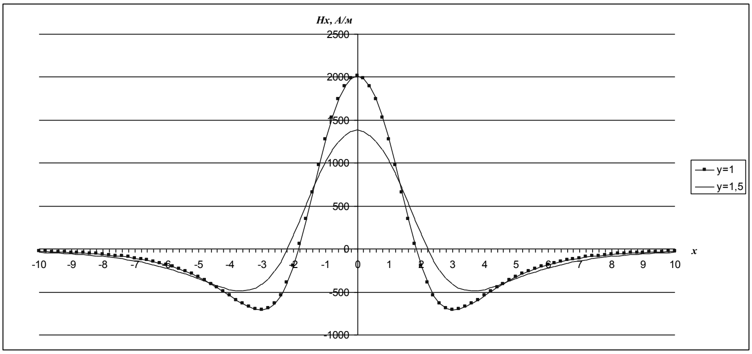
$$H_x^+ = \beta \frac{M_{rm}}{\mu_r + 1}\left[\sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}+l}{(\bar{y}+\beta-1+4\alpha)^2 + (\bar{x}+l)^2} - \right.$$
$$- \frac{2\mu_r}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}+l}{(\bar{y}+\beta+1+4\alpha)^2 + (\bar{x}+l)^2} + \tag{7}$$
$$\left. + \frac{\mu_r-1}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}+l}{(\bar{y}+\beta+3+4\alpha)^2 + (\bar{x}+l)} \right];$$

$$H_y^+ = \beta \frac{M_{rm}}{\mu_r + 1}\left[\sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta-1+4\alpha}{(\bar{y}+\beta-1+4\alpha)^2 + (\bar{x}+l)^2} - \right.$$
$$- \frac{2\mu_r}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta+1+4\alpha}{(\bar{y}+\beta+1+4\alpha)^2 + (\bar{x}+l)^2} + \tag{8}$$
$$\left. + \frac{\mu_r-1}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta+3+4\alpha}{(\bar{y}+\beta+3+4\alpha)^2 + (\bar{x}+l)} \right];$$

$$H_x^- = \beta \frac{M_{rm}}{\mu_r + 1}\left[\sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}-l}{(\bar{y}+\beta-1+4\alpha)^2 + (\bar{x}-l)^2} - \right.$$
$$- \frac{2\mu_r}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}-l}{(\bar{y}+\beta+1+4\alpha)^2 + (\bar{x}-l)^2} + \tag{9}$$
$$\left. + \frac{\mu_r-1}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{x}-l}{(\bar{y}+\beta+3+4\alpha)^2 + (\bar{x}-l)} \right];$$

$$H_y^- = \beta \frac{M_{rm}}{\mu_r + 1}\left[\sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta-1+4\alpha}{(\bar{y}+\beta-1+4\alpha)^2 + (\bar{x}-l)^2} - \right.$$
$$- \frac{2\mu_r}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta+1+4\alpha}{(\bar{y}+\beta+1+4\alpha)^2 + (\bar{x}-l)^2} + \tag{10}$$
$$\left. + \frac{\mu_r-1}{\mu_r+1} \sum_{\alpha=0}^{\infty} c^{\alpha} \frac{\bar{y}+\beta+3+4\alpha}{(\bar{y}+\beta+3+4\alpha)^2 + (\bar{x}-l)} \right].$$

For a marking, caused by U-shaped recording head with the most appropriate width of poles $2\Delta = 4{,}6\boldsymbol{d}$ [Smirny M., 1986], $\boldsymbol{\beta}$=2, The calculated curves $\boldsymbol{H_x}$ and $\boldsymbol{H_y}$ depending on $\bar{x}$ at various $\bar{y}$ presented in fig. 2. Parameter $\boldsymbol{l}$ is calculated as the optimal under fixed $\bar{y}$ and $\boldsymbol{H_x} \rightarrow$max [Smirny M., 2009].



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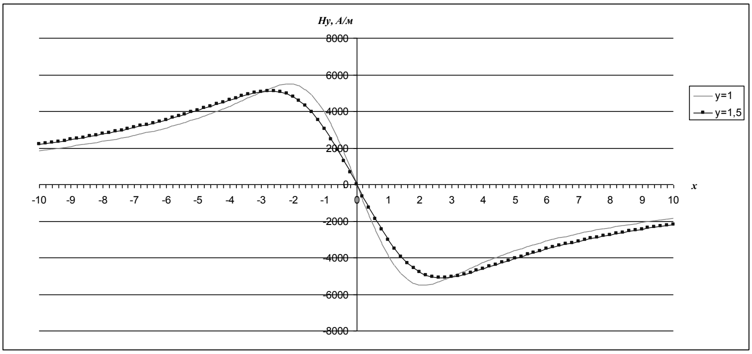

b

Fig. 2. The magnetic field of the mark: a – horizontal components of the field intensity $\boldsymbol{H_x}$ of the mark; b – vertical components of the field strength $\boldsymbol{H_y}$ of the mark

CONCLUSIONS

After the consideration of the curves we conclude that at $\bar{x}=0$ there is the maximum value of the horizontal component $\boldsymbol{H_x}$, and maximum values $\boldsymbol{H_y}$ are within the absolute values of the (2,2…2,6) $\bar{x}$, that is, at a distance from the center of the mark, approximately equal to the width $\boldsymbol{\Delta}$ of the recording head pole.

Received the maximum values can be used as informative parameters using the fluxgate sensors to control weight rail industrial vehicles.

REFERENCES

1. Belov V., Buyanov V., 2003.: The management of railway transport on the basis of automatic identification of rolling stock. Bulletin VSRIRT V. 1. p 25-36.

2. Bikhdricker A., 2010.: Magnet metric system of control of the weight of railroad cars. Lugansk : Knowledge. p. 306-308.
3. Bikhdricker A., Smirny M., 2001.: Device for weighing of railway vehicles. Bulletin SNU V. 5. p. 94-99.
4. Bikhdricker A., Smirny M., 2007.: Magnet-metric system of weighing of railway vehicles. Hoisting-and-transport technics. V. 3. p. 52–61.
5. Chatskis L., 1973.: Scientific research of static fields. Electricity. V. 2. p. 1059-1062.
6. den Buurman G., 2005: Measuring system Qui Vadis. European Railway Review, V 3, p. 80 – 86.
7. Kurlaev A., Sidorin Y, Ptentsov V., 2003.: Laser scales for weighing of railcars in motion. Bulletin VSRIRT V. 3.S. 35-43.
8. Loufer M., Chatskis L., 1973.: The analysis of the fields of magnetic heads. Electromechanics. V. 10, p. 1059 –1062.
9. Pavlukov V., Smirny M., Evtukhov V., 1977.: Programming rail vehicles with the help of magnetic recording. Odessa.
10. Polivanov K., 1964.: The distribution of magnetic flux in the rail when his magnetization of a plunging solenoid applied to the led system flaw detectors F.M. Karpova . Problems of ferromagnetism and magnetic dynamics. Moscow. AS USSR. p. 147-166.
11. Polivanov K., 1975.: Theoretical fundamentals of electrical engineering. V. III. Moscow.
12. Sergeev A., 2000.: Railway scales. Lawa 2000. Railways of the world. V. 2. p. 12.
13. Smirny M., 1982.: To the question of calculation of fields magnetizing device. Dep. UkrSRINGI. P 3534-D82.
14. Smirny M., 1986.: The calculation of the chain of magnetization in a transverse magnetic recording on the head of railway rail. Dep. UkrSRINGI, P 304-Uk86.
15. Smirny M., Bikhdricker A., 2009.: Definition of the optimum sizes of recording heads of device for weighing of railway vehicles Bulletin SNU. V. 12. p. 119–124.

ПОЛЕ РАССЕЯНИЯ МЕТКИ, НАНЕСЁННОЙ П-ОБРАЗНОЙ ГОЛОВКОЙ ЗАПИСИ

Михаил Смирный, Аркадий Бихдрикер

Аннотация. Предложена методика определения оптимального расположения феррозондовых датчиков для считывания информации с магнитного носителя, запись на который осуществляется П-образной головкой записи.

Ключевые слова: взвешивание вагонов, феррозондовый датчик, внешнее магнитное поле, магнитная метка, П-образная головка записи.

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LINEAR MODELLING OF THE ELECTROHYDRAULIC WATCHING DRIVE

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Summary. The linear mathematical model is presented and transfer functions of the electrohydraulic watching drive with throttle regulation are defined. The mathematical model is adapted on drives of the equipment for processing by the pressure, constructed on the basis of standard modules.

Key words: electrohydraulic watching drive, linear mathematical model, throttle regulation.

INTRODUCTION

The modern equipment for processing of materials by pressure demands much of characteristics of drives on accuracy of realization of the set laws of movement of a target link that is reached by use of epy electrohydraulic watching drive (EHWD) [1].

The important stage in EHWD designing is the estimation of stability, quality of regulation and correction of dynamic properties of a drive. Performance of the given stage is connected with working out of mathematical model of the non-stationary working processes proceeding in a drive. The mathematical models of dynamic processes presented in the literature [2, 3], cannot be generalized on all class considered EHWD. A number from them is focused on certain designs of devices of a drive, in particular electrohydraulic amplifier (EHA). In the majority of model definition of parameters which cannot be estimated from nameplate data of standard devices demand or are revealed at a stage of preliminary designing.

At small deviations of parameters of system from static values use of linear models for the mathematical description of non-stationary processes is admissible. It allows to receive the analytical decisions, giving the chance to find out and present prominent features of studied process for any combination of parameters of system. Besides, analytical decisions are "standards" for an estimation of accuracy of analytical decisions.

The work purpose is working out of linear mathematical model and definition of transfer functions of an electrohydraulic watching drive with the throttle regulation, adapted on drives of the equipment for processing by the pressure, constructed on the basis of standard modules, with use for an estimation of dynamic characteristics of nameplate data of devices of a drive.

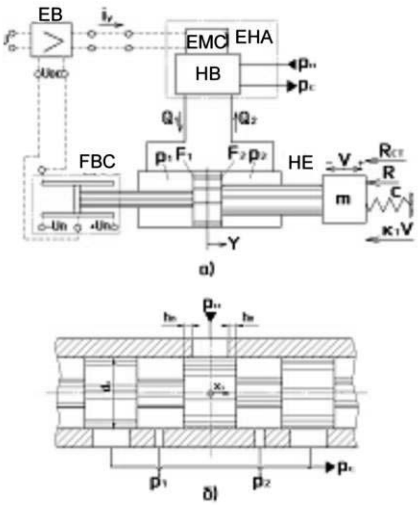

Fig. 1. Settlement scheme EHWD (a) and target cascade EHA (b)

OBJECTS AND PROBLEMS

Let's allocate basic elements of the EHWD: a hydraulic engine (HE), the electrohydraulic amplifier (EHA), the including electromechanical converter (EMC) and the hydraulic booster (HB), the feedback gauge (FBG), the electronic block (EB). Further it is considered the settlement scheme of a drive presented on fig. 1.

In works [4, 5] typical nonlinear mathematical model of the EHWD with throttle regulation which includes following equations and dependences is considered:

$$U_{OC}=k_{OC}Y;\ U_{YC}=k_{YC}(U-U_{OC});\ L_Y\frac{di_Y}{dt}+R_E i_Y=U_{YC};$$

$$T_{2y}{}^2\frac{d^2x_3}{dt^2}+T_{1y}\frac{dx_3}{dt}+x_3=k_{xi}i_y,$$

$$Q_1=\begin{cases}\mu_3\pi d_3k_n(x_3-h_n)\sqrt{\dfrac{2}{\rho}|p_н-p_1|}\,sign(p_н-p_1),x_3>h_n;\\ 0,|x_3|\le h_n;\\ \mu_3\pi d_3k_n(x_3+h_n)\sqrt{\dfrac{2}{\rho}|p_1-p_C|}\,sign(p_1-p_C),x_3<-h_n;\end{cases}$$

$$Q_2 = \begin{cases} \mu_3 \pi d_3 k_n (x_3 - h_n) \sqrt{\frac{2}{\rho} |p_2 - p_C|} sign(p_2 - p_C), x_3 > h_n; \\ 0, |x_3| \le h_n; \\ \mu_3 \pi d_3 k_n (x_3 + h_n) \sqrt{\frac{2}{\rho} |p_H - p_2|} sign(p_H - p_2), x_3 < -h_n; \end{cases}$$

$$m\frac{dV}{dt} = p_1 F_1 - p_2 F_2 - cY - k_T V - R_{CT} signV - R;$$

$$\frac{dY}{dt} = V, -H/2 \le Y \le H/2;$$

$$\frac{W_{HO} + F_1(H/2 + Y)}{E_{el}} \frac{dp_1}{dp_1} = Q_1 - F_1 V;$$

$$\frac{W_{HO} + F_2(H/2 - Y)}{E_{el}} \frac{dp_2}{dp_1} = -Q_2 + F_2 V,$$

here Y, V - moving and speed of the piston; p_1, p_2 - pressure in hydrocylinder cavities; m - the resulted weight of mobile parts; F_1, F_2 - the effective areas; c - rigidity of item loading; κ_T - factor of force of a viscous friction; R_{CT} - force of a dry friction; R - loading; H - a piston course; E_{el} - the module of elasticity of a working liquid; W_{HO}, W_{CO} - "dead" volumes of pressure head and drain highways; k_{OC} - factor of FBG transfer; k_{xi} - factor of EHA transfer; constants of time T_{2y}, T_{1Y} which are defined on shift frequencies ν_1, ν_2 on a phase on 45 and 90 hailstones:

$$T_{2y} = \frac{1}{2\pi\nu_2}; T_{1y} = \frac{1}{2\pi\nu_1} - \frac{2\pi\nu_1}{(2\pi\nu_2)^2},$$

where: p_H, p_C - pressure of pump station and on plum; h_n - size of positive overlapping; μ_3 - factor of the expense of a crack of a valve; d_3 - diameter of a valve; k_n - factor of completeness of use of perimeter of a valve; ρ - density of a working liquid; U - entrance (operating) pressure; U_{YC} - pressure on EB exit; k_{YC} - factor of EB strengthening; L_Y - inductance of a winding of management; R_E - active resistance of the electric chain.

Let's make the linearization of the received nonlinear mathematical model, preliminary having excluded as a first approximation force of a dry friction and item loading. Usually at drawing up of linear mathematical models of hydrodrives [6] the assumption of equality of "dead" volumes of pressure head and drain highways is accepted:

$$W_{но} = W_{co} = W_o \quad . \tag{1}$$

And the indissolubility equations register for average position of the piston, and also equality of the effective areas of the hydrocylinder:

$$F_1 = F_2 = F \quad (2)$$

Last assumption is the most essential, however allows to simplify considerably model for the account of following possibility to admit equality of expenses in EHA lines:

$$Q_1 = Q_2 = Q \quad (3)$$

With the account of the above-stated, the equation of movement and balance of expenses become

$$\frac{dy}{dt} = V; \quad (4)$$

$$\frac{Wo + F\,H/2}{E_{el}}\frac{dp_1}{dt} = Q - FV; \quad (5)$$

$$\frac{Wo + F\,H/2}{E_{el}}\frac{dp_2}{dt} = Q + FV\,. \quad (6)$$

By linear links are described FBG, EB and operating winding EHA:

$$U_{oc} = k_{oc}y \quad (7)$$

$$U_{yc} = k_{yc}(U - U_{oc}). \quad (8)$$

The linear accepts communication of displacement of HB valve with a current in a management winding:

$$T_{2y}^2\frac{d^2x_3}{dt2} + T_{1y}\frac{dx_3}{dt} + x_3 = k_{xi}i_y \quad (9)$$

We use the traditional approach [6,8] to linearization of the flow-transfer EHA characteristics:

$$Q = k_{Qx}x_3 - k_{Qp}(p_1 - p_2)\,, \quad (10)$$

where: factors of transfers k_{Qx}, k_{Qp} in a general view are defined on expressions:

$$k_{Q_x} = \frac{\partial Q}{\partial x}\bigg|_{\substack{x_3=x_{30}\\ p_1=p_{10}\\ p_2=p_{20}}} \; k_{Q_x} = \frac{\partial Q}{\partial x}\bigg|_{\substack{x_3=x_{30}\\ p_1=p_{10}\\ p_2=p_{20}}}\,, \quad (11)$$

$$k_{Q_x} = \frac{\partial Q}{\partial(p_1 - p_2)}\bigg|_{\substack{x_3=x_{30}\\ p_1=p_{10}\\ p_2=p_{20}}} \; k_{Q_p} = \frac{\partial Q}{\partial\left(p_1 - p_2\right)}\bigg|_{\substack{x_3=x_{30}\\ p_1=p_{10}\\ p_2=p_{20}}}\,, \quad (12)$$

x_{3o}, p_{10}, p_{20} - static values of variables.

As a first approximation in calculations it is possible to put values k_{Qx} and k_{Qp}, defined at $x_{зо} = 0, p_{10} = 0, p_{20} = 0$ for valve HB with zero overlapping [4]:

$$k_{Qx} = \mu_3 \pi d_з k_n \sqrt{\frac{p_n}{p}}; \tag{13}$$

$$k_{Qx} = 0; \tag{14}$$

where: $p_n = p_n - p_c$ - brought to EHA pressure.

For deviations of variables from static values it is had the following system of the linear equations:

$$\begin{cases} & (15) \\ \Delta U_{oc} = k_{oc} \Delta y; & (16) \\ \Delta U_{yc} = k_{yc} (\Delta U - \Delta U_{oc}); & \\ L_y \dfrac{d \Delta i_y}{dt} + R_E \Delta i_y = \Delta U_{yc}; & (17) \\ T_{2y}^2 \dfrac{d^2 (\Delta x_3)}{dt^2} + T_{1y} \dfrac{d(\Delta x_3)}{dt} + x_3 - k_{xi} \Delta i_y; & (18) \\ \Delta Q = k_{Qx} \Delta x_3 - k_{Qp} (\Delta p_1 - \Delta p_2); & (19) \\ \dfrac{W_0 + FH/2}{E_{el}} \dfrac{d(\Delta p_1)}{dt} = \Delta Q - F \Delta V; & (20) \\ \dfrac{W_0 + FH/2}{E_{el}} \dfrac{d(\Delta p_2)}{dt} = -\Delta Q + F \Delta V; & (21) \\ m \dfrac{d(\Delta V)}{dt} = (\Delta p_1 - \Delta p_2) F - k_T \Delta V - \Delta R; & (22) \\ \dfrac{d(\Delta y)}{dt} = \Delta V. & (23) \end{cases}$$

We subtract (23) of (22), we substitute result in (21) then system it is transformed on Laplas [7] and it is led to a kind:

$$\begin{cases} \Delta U_{oc}(s) = k_{oc}\Delta y(s); \\ \Delta U_{yc}(s) = k_{yc}(\Delta U(s) - \Delta U_{oc}(s)); \\ \Delta i_y(s) = L_y \dfrac{1/R_э}{T_{oy}s+1}\Delta U_{yc}(s); \\ \Delta x_3(s) = \dfrac{k_{xi}}{T_{2y}^2 s^2 + T_{1y}s + 1}\Delta i_y; \\ (\Delta p_1(s) - \Delta p_2(s)) = \dfrac{1}{\dfrac{FH}{4E_{eh}}s + k_{Qp}}\left[k_{Qx}\Delta x_3(s) - F\Delta V(s)\right]; \\ \Delta V(s) = \dfrac{1}{ms + k_T}\left[F(\Delta p_1(s) - \Delta p_2(s)) - \Delta R\right]; \\ \Delta y(s) = \dfrac{1}{s}\Delta V(s); \end{cases} \tag{24}$$

where: s – Laplas variable;

T_{oy} - a constant of time of a winding of management:

$$T_{oy} = L_y / R_э \,. \tag{25}$$

E_{eh} - the resulted module of elasticity of the hydrocylinder:

$$E_{eh} = \frac{E_{el}}{1 + \dfrac{2W_o}{FH}} \,. \tag{26}$$

To system (26) there corresponds the block diagramme presented on fig. 2.

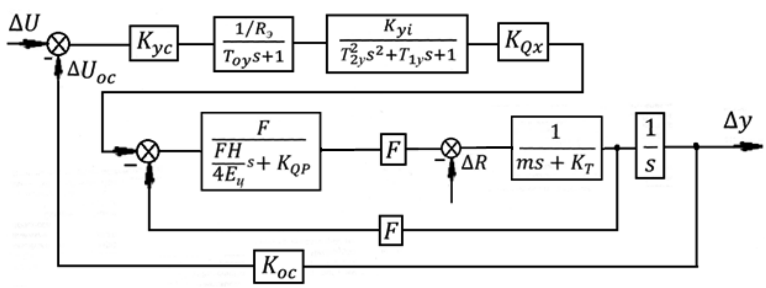

Fig. 2. The Block diagramme

Let's transform the block diagramme for what we will enter factor of transfer EB:

$$K_{eb} = K_{yc} / K_e \,. \tag{27}$$

And factor of strengthening EHA under the expense:

$$K_{Qi} = K_{xi} / K_{Qx} \,. \tag{28}$$

Value K_{Qi} it is possible to establish on nameplate data EHA [5]:

$$K_{Qi} = Q_n / i_n \,, \tag{29}$$

where: Q_n, i_n - the nominal expense and rated current management EHA.

The transformed block diagramme is shown on fig. 3.

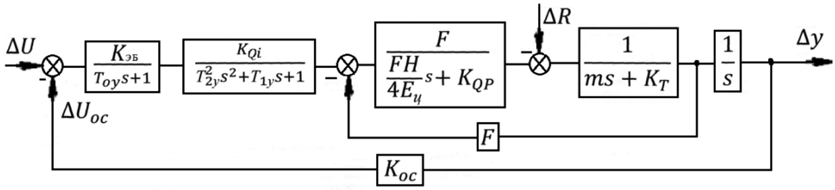

Fig. 3. The Block diagramme

Let's receive transfer function of a drive on an operating signal, for what we will transform the block diagramme (fig. 4) see, having excluded from consideration ΔR.

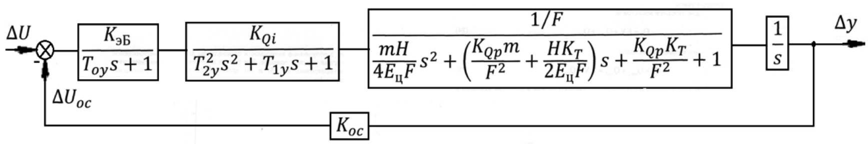

Fig. 4. To definition of transfer function EHWD on an operating signal

Let's define a hydromechanical constant of time of the hydrocylinder:

$$T_{eh} = \sqrt{\frac{mH}{4E_{eh}F}} \,. \tag{30}$$

And factor relative damping of the hydrocylinder:

$$\zeta_{eh} = \frac{1}{T_ц}\left[\frac{K_{Qp}m}{F^2} + \frac{HK_T}{2E_{eh}F}\right]. \tag{31}$$

In real drives [6]:

$$K_{Qp}\, K_T / F^2 \langle\langle 1 \,. \tag{32}$$

Therefore it is definitively possible to offer the block diagramme of transfer of the operating signal, resulted on fig. 5.

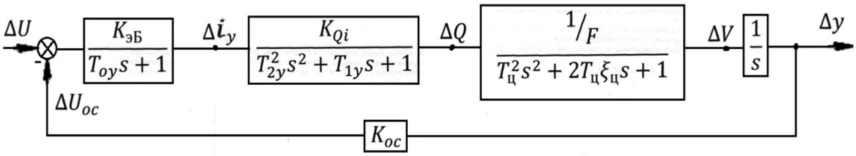

Fig. 5. The Block diagramme of transfer of an operating signal

According to the block diagramme it is established transfer function EHWD on an operating signal:

$$W_{yu}(s) = \frac{K_{yu}}{\frac{s}{D_{EHWD}}(T_{oy}s+1)(T_{2y}^2 s^2 + T_{1y}s+1)(T_ц^2 s^2 + 2T_{eh}\zeta_{eh}s+1)+1}, \quad (33)$$

Where: K_{yu} - factor of transfer EHWD on an operating signal:

$$K_{yu} = 1/K_{oc}; \quad (34)$$

D_{EHWD} - good quality EHWD (factor of strengthening of the opened system),

$$D_{EHWD} = K_{EB}K_{Qi}K_{oc}/F. \quad (35)$$

For reception of transfer function EHWD on loading we will exclude from the block diagramme presented on fig. 3, *ΔU* and we will transform the scheme, as is shown in fig. 6.

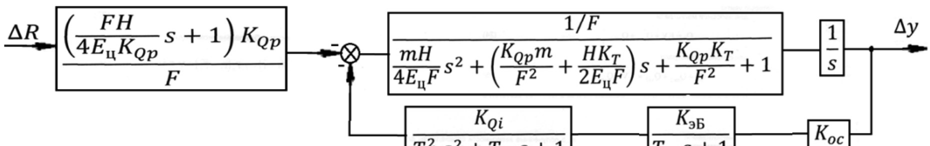

Fig. 6. To definition of transfer function EHWD on loading

Let's designate a constant of time of a link of forestalling:

$$T_R = \frac{FH}{4E_{eh}K_{Qp}}. \quad (36)$$

With the account (32-34) we transform the block diagramme to a kind it agree fig. 7.

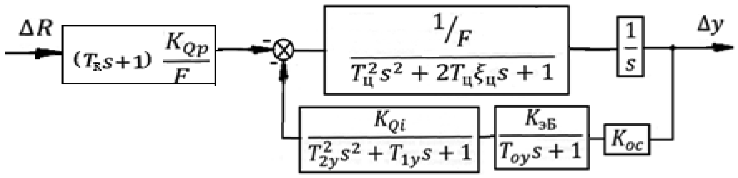

Fig. 7. The Block diagramme of transfer of loading influence

Under the block diagramme it is found transfer function EHWD on loading influence:

$$W_{yR}(s) = \frac{K_{yR}(T_{oR}s+1)(T_{2y}^2 s^2 + T_{1y}s+1)(T_{oy}s+1)}{\frac{s}{D_{EHWD}}(T_{oy}s+1)(T_{2y}^2 s^2 + T_{1y}s+1)(T_{eh}^2 s^2 + 2T_{eh}\zeta_{eh}s+1)+1}, \quad (37)$$

where: K_{yR} - factor of transfer EHWD on loading influence:

$$K_{yR} = \frac{K_{Qp}}{F^2 D_{EHWD}} \quad (38)$$

The target size is defined generally by result of operating and loading influence according to a superposition principle:

$$\Delta y(s) = W_{yu}(s)\Delta U(s) - W_{yR}(s)\Delta R(s). \quad (39)$$

CONCLUSIONS

Thus, the linear mathematical model is offered and transfer functions of the electrohydraulic watching drive with throttle regulation are defined. The mathematical model is adapted on drives of the equipment for processing by the pressure, constructed on the basis of standard modules, and allows to make an estimation of stability, quality of regulation and correction of dynamic properties of a drive with use of nameplate data for drive devices.

REFERENCES

1. Leshchenko V.A.: Hydraulic servo system and drive machines with computer control. – M.: Engineering, 1975. – 672 p.
2. Popov D.N.: Dynamics and regulation hydro-and pneumatic systems / D.N. Popov. - M: Mechanical engineering, 1987. - 464 p.
3. Terskyh V.Z.: Comparative analysis of dynamic properties of throttle hydrodrives// Publishing house of high schools. Mechanical engineering, 1976. №7. - 59-62 P.

4. Abramov E.I., Kolesnichenko K.A., Maslov V. T.: Hydrodrive elements: the Directory. - К: "Technics", 1977. - 320 p.
5. Chuprakov JU.I.: Electrohydraulic amplifiers. - M: MADI, 1975. - 124 p.
6. Sveshnikov V.K, Usov A.A.: Moustaches hydrodrives: the Directory. - 2 publ. - M: Mechanical engineering, 1988. – 512 p.
7. Dorf R. Modern systems of management / Dorf R., Bishop R. – M.: Laboratory of Base Knowledge, 2002. – 831 p.
8. Sokolova Ya.V. Nonlinear mathematical model of the electrohydraulic watching drive with throttle regulation / Sokolova Ya.V., Tavanuk T.Ya., Sokolov V.I. // Messenger of the East-Ukrainian National University named by V. Dal. – 2010. - № 10 (152). – P. 168-175.
9. Popov D.N.: Non-stationary's hydromechanical processes / D.N. Popov. - M: Mechanical engineering, 1982. - 240 p.
10. Aerohydrodynamics: textbook for universities / M.D. Andrijchuk [etc.]. - Lugansk: Publishing house of Volodymyr Dal East-Ukrainian National University, 2009. - 516 p.
11. Hohlov V.A.: Electrohydraulic watching drive. - M: the Science, 1964.
12. Chuprakov JU.I.: Electrohydraulic watching drives. - M: MADI, 1977. – 88 p.
13. Navrotsky K.L.: Theory and designing hydro-and pneumodrives. - M: Mechanical engineering, 1991. - 384 p.
14. Yakovlev V.B.: Adaptive Cruise Control: A Textbook. - L.: Len University, 1984. – 428 p.
15. Alexeev A.A.: Control theory / A.A. Alekseev, D.H. Imayev, N.V. Kuzmin, V.B. Yakovlev. - St. Petersburg.: ETU "LETI", 1999. – 526 p.
16. Gamynin N.S.: Hydraulic drive control systems. - Moscow: Mashinostroenie, 1972. – 756 p.
17. Leshchenko V.A.: Hydraulic servo drives. - Moscow: Mashinostroenie, 1968. – 822 p.
18. Goodwin G.K.: Design of Control Systems / G.K. Goodwin., F. Grefe, M.E. Salgado. – M.: Knowledge Lab, 2004. – 218 p.

ЛИНЕЙНОЕ МОДЕЛИРОВАНИЕ ЭЛЕКТРОГИДРАВЛИЧЕСКОГО СЛЕДЯЩЕГО ПРИВОДА

Яна Соколова, Татьяна Таванюк, Дмитрий Грешной, Владимир Соколов

Аннотация. Представлена линейная математическая модель и определены передаточные функции электрогидравлического следящего привода с дроссельным регулированием. Математическая модель адаптирована на приводы оборудования для обработки давлением, построенные на основе стандартных модулей.

Ключевые слова: электрогидравлический следящий привод, линейная математическая модель, дроссельное регулирование.

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MATHEMATICAL MODEL TO MINIMIZE OPERATING COSTS FOR INTERCITY PASSENGER TRAFFIC

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Summary. The given paper presents an elaborated mathematical model of making optimal scheduling of passenger transport in long-distance communication. The model is based on the analysis of the distribution laws of demand, taking into account the possible presence of heterogeneous passenger flows.

Keywords: passenger transport, passenger flow, the distribution law, forecasting, schedules.

INTRODUCTION

Current systems of traffic management are not optimal, rolling stock is used with low efficiency. The reasons are the lack of validity of the routing and timetables, lack of or inadequate traffic control operations, the discrepancy of passenger fleet to the passenger flows etc. As a consequence a low level of passenger service remains.

In this paper we consider the task of organizing and planning for long-distance passenger transportation - and the use of rational combination of possible resources to meet the maximum transport work for better public services.

For any production of services the loss of two types may be possible:

- of unmet demand, in this case there is shortfall in profits;
- the excess of supply over demand, in this case there are losses from the production of services not found in demand.

The presence of excess vehicles is not profitable, because it leads to "empty carriage," and lack of vehicles also leads to losses due to shortfalls in revenue and the rise of competitors in the market of services.

Governance is associated with adjusting the distribution of departure for the distribution of transport demand. In this paper we study primarily the distribution of demand and data processing is aimed at finding and forecasting parameters of the distribution law according to which an optimal schedule of traffic is sought.

MATHEMATICAL MODEL OF THE PROCESS

We introduce the following notations:

- let it be on the route, which is denoted by W, buses go forward with X^{st} in X^{fn}, and in the opposite direction from X^{fn} to X^{st};
- t_{st}^{fwd} (t_{st}^{rev}) – start time of buses on the route маршруте W in the forward (backward) direction;
- t_{fn}^{fwd} (t_{fn}^{rev}) – end time of buses on the route of W in the forward (backward) direction. Where ($t_{fn}^{fwd} - t_{st}^{fwd}$), ($t_{fn}^{rev} - t_{st}^{rev}$) $\in N$;
- $T^{fwd} = \left([t_{st}^{fwd}, t_{st}^{fwd}+1], [t_{st}^{fwd}+1, t_{st}^{fwd}+2], \ldots, [t_{st}^{fwd}+n_{fwd}-1, t_{fn}^{fwd}]\right)$ - an ordered sequence of time intervals per 1 hour, where $n_{fwd} = t_{fn}^{fwd} - t_{st}^{fwd}$;
- $T^{rev} = \left([t_{st}^{rev}, t_{st}^{rev}+1], [t_{st}^{rev}+1, t_{st}^{rev}+2], \ldots, [t_{st}^{rev}+n_{rev}-1, t_{fn}^{rev}]\right)$ - an ordered sequence of time intervals per 1 hour, where $n_{rev} = t_{fn}^{rev} - t_{st}^{rev}$;
- $m_{t_i^{fwd}}^{fwd}$ ($t_i^{fwd} \in T^{fwd}$, where i - the serial number corresponding to t in T^{fwd}) – number of passengers who have tickets to each of the periods of time in the forward direction;
- $m_{t_i^{rev}}^{rev}$ ($t_i^{rev} \in T^{rev}$, where i - the serial number corresponding to t in T^{rev}) – number of passengers who have tickets to each of the periods of time in the opposite direction.

Statistical data to be processed - data on the sale of tickets for several years on the route W. Data on the ticket was originally processed for each day separately, and the algorithm processing is identical, so further in paragraphs 1-7, the algorithm is regarded as an example of day.

1. Initial data processing

At the initial processing of data for each t_i^{fwd} (t_i^{rev}) is found $m_{t_i^{fwd}}^{fwd}$ ($m_{t_i^{rev}}^{rev}$). Data processing algorithm in the forward and backward directions is similar, so the algorithm of paragraphs 2-7 as an example of direct destinations. For simplicity, it is written:

- instead T^{fwd} - T;
- instead of $m_{t_i^{fwd}}^{fwd}$ - m_i (where i – the serial number corresponding to t in T);
- instead of t_i^{fwd} - t_i (where i – the serial number corresponding to t in T)

2. Reflection of the real length of time on the interval [0, 1] as a necessary condition for the beta distribution

In the future, to obtain the theoretical distribution function of the data a beta distribution will be used, for this it will need to use an ordered sequence of time intervals T, turned into a:

- x - an ordered sequence of number of segments belonging to the interval [0,1];

- $\bar{x}$ - an ordered sequence of numbers belonging to the interval [0, 1]

An ordered sequence of numerical segments x belonging to the interval [0, 1], is computed as follows. Every $t_i \in T$ – the length of time, that is $t_i = [t_1^i, t_2^i]$, is transformed into a sequence of x according to the formulas:

$$x_1^i = \frac{t_1^i - t_{st}^{fwd}}{t_{fn}^{fwd} - t_{st}^{fwd}} \text{ и } x_2^i = \frac{t_2^i - t_{st}^{fwd}}{t_{fn}^{fwd} - t_{st}^{fwd}}, \tag{1}$$

and $x_i = [x_1^i, x_2^i]$ that is computed $t_i \in T$, while any $x_i \in [0,1]$.

An ordered sequence of numbers $\bar{x}$, which belongs to the interval [0,1] is computed as follows. From an ordered sequence of segments x an ordered sequence of numbers is received $\bar{x}$, where $\bar{x}$ is the middle of the segment x_i:

$$\bar{x}_i = \frac{x_1^i + x_2^i}{2}. \tag{2}$$

3. Partitioning data on flows

When a general law of distribution is not unimodal, which means that it is heterogeneous, the data are broken down into multiple threads, each of which is unimodal.

Due to the fact that in most cases within days there are two maxima - so-called clock "peak" - morning and evening, we consider the distribution of transport demand during the day as a bimodal distribution law. In all other cases, the data must be split in a similar way. Due to the fact that in most cases within days there are two maxima - so-called clock "peak" - morning and evening, we consider the distribution of transport demand during the day as a bimodal distribution law. In all other cases, the data must be split in a similar way. All the calculations in the future will be for the two streams of the distribution law. The result of decomposition is presented in table 1.

Table 1. **Result of splitting into two streams of data**

THE FIRST STREAM			
t	$t_1 = [t_{st}^{fwd}, t_{st}^{fwd} + 1]$	…	$t_l = [t_{st}^{fwd} + l - 1, t_{st}^{fwd} + l]$
x	$x_1 = [x_1^1, x_2^1]$	…	$x_l = [x_1^l, x_2^l]$
$\bar{x}$	$\bar{x}_1 = \frac{x_1^1 + x_2^1}{2}$	…	$\bar{x}_l = \frac{x_1^l + x_2^l}{2}$
m	m_1	…	m_l
THE SECOND STREAM			
t	$t_l = [t_{st}^{fwd} + l - 1, t_{st}^{fwd} + l]$	…	$t_{n_{fwd}} = [t_{st}^{fwd} + n_{fwd} - 1, t_{fn}^{fwd}]$
x	$x_l = [x_1^l, x_2^l]$	…	$x_{n_{fwd}} = [x_1^{n_{fwd}}, x_2^{n_{fwd}}]$
$\bar{x}$	$\bar{x}_l = \frac{x_1^l + x_2^l}{2}$	…	$\bar{x}_{n_{fwd}} = \frac{x_1^{n_{fwd}} + x_2^{n_{fwd}}}{2}$
m	m_l	…	$m_{n_{fwd}}$

Each thread represents a unimodal distribution and data processing algorithm is similar in different threads, so in paragraphs 4-7, an algorithm for data flow on the example of the first stream is given.

4. Obtaining the empirical distribution function flow

To obtain the empirical distribution function we will use the data obtained after the initial processing of statistical data. The algorithm to obtain the empirical distribution function $\widetilde{F}$:

4.1 You must obtain the empirical distribution of the flow that is to calculate for each $t_i \in T$ the probability $\widetilde{p}_i$:

$$\widetilde{p}_i = \frac{m_i}{\sum_i m_i} . \tag{3}$$

4.2 Empirical function flow distribution $\widetilde{F}$ is as follows:

$$\widetilde{F}_1 = \widetilde{p}_1, \widetilde{F}_2 = \widetilde{F}_1 + \widetilde{p}_2, \ldots, \widetilde{F}_l = \widetilde{F}_{l-1} + \widetilde{p}_l \tag{4}$$

5. The primary estimation of the parameters of beta distribution

The primary parameters of the beta distribution are calculated by the method of moments:

$$\alpha_0 = \frac{MX^2(1-MX)}{DX} - MX \quad \text{and} \quad \beta_0 = \alpha_0\left(\frac{1}{MX} - 1\right) . \tag{5}$$

To calculate α_0 and β_0 to find mathematical mean Mx and variance Dx :

$$Mx = \sum_i \overline{x}_i p_i \text{ and } Dx = \sum_i (\overline{x}_i)^2 p_i - (Mx)^2 . \tag{6}$$

Once Mx and Dx would be found, α_0 and β_0 computed.

6. The theoretical distribution function of the flow

Algorithm to obtain the theoretical distribution function:

6.1 You must obtain the theoretical flow distribution that is to count theoretical probability ($\hat{p}_i$) for each $t_i \in T$:

$$\begin{aligned} &\hat{p}_1 = \hat{p}_{t_1} = \hat{p}_{x_1} \\ &\hat{p}_2 = \hat{p}_{t_2} = \hat{p}_{x_2} \\ &\ldots\ldots\ldots\ldots\ldots \\ &\hat{p}_{l-1} = \hat{p}_{t_{l-1}} = \hat{p}_{x_{l-1}} \\ &\hat{p}_l = \hat{p}_{t_l} = \hat{p}_{x_l} \end{aligned} \tag{7}$$

The theoretical probability calculated by the formula:

$$\hat{p}_{a;b}(\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \int_a^b x^{\alpha-1}(1-x)^{\beta-1} dx , \text{ where } [a,b] \in [0,1] \tag{8}$$

$$\hat{p}_1 + \hat{p}_2 + \ldots + \hat{p}_{l-1} + \hat{p}_l = 1 . \tag{9}$$

6.2 The theoretical distribution function is calculated as follows:

$$\hat{F}_1 = \hat{p}_1, \hat{F}_2 = \hat{F}_1 + \hat{p}_2, \ldots, \hat{F}_l = \hat{F}_{l-1} + \hat{p}_l . \tag{10}$$

7. The optimization of parameters and_ of theoretical distribution function of the flow.

To optimize the parameters α and β the theoretical distribution function the method of global search is applied. For this we introduce a new feature:

$$d(\alpha,\beta) = ||\hat{F} - \tilde{F}|| = \sqrt{\sum_i (\hat{F}_i - \tilde{F}_i)^2} \, . \quad (11)$$

Such α and β must be found for a function $d(\alpha,\beta)$ to be minimal, that is to rate the difference between the theoretical distribution function $\hat{F}$ of the flux and flow empiric distribution function $\tilde{F}$ to be the lowest.

The function $d(\alpha,\beta)$ is optimized by using the combined global search for the conservation of information.

Prediction of beta distribution parameters

Using the algorithm described above in paragraphs 1-7, the parameters α and β are calculated for all days (for which we have data on the ticket) for all flows in the forward and reverse direction. After that you can predict the parameters of beta distribution for the next period of time.

To align our series we apply a polynomial of the third degree [Kolyakina A., Pozhidaev V. 2009]:

$$\hat{y} = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \, . \quad (12)$$

The parameter estimates will be obtained using the method of least squares. As a result, for each day of the next year we will get the theoretical values α and β for all flows in the forward and reverse direction. Using these α and β, for each day separately constructed the demand curve for passenger car traffic is constructed and the timetable is made up.

The construction of passenger demand curve

In the forward and backward the way to build passenger demand curves is the same, so we will consider a method for constructing the curve in the forward direction.

According to the formula of density β - distribution:

$$f(x) = \frac{1}{\mathrm{B}(\alpha,\beta)} x^{\alpha-1}(1-x)^{\beta-1} = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}, \quad (13)$$

where: $0 \le x \le 1$, $\alpha > 0$, $\beta > 0$,

using the parameters obtained after the prediction of beta distribution for each flow - α_i, β_i (i – number of flow) the demand curve is constructed. An example of the demand curve is shown in Figure 1.

Upon receipt of the demand curves (the distribution parameters of each stream), passenger traffic in the forward and reverse directions, the timetable of passenger vehicles is made up.

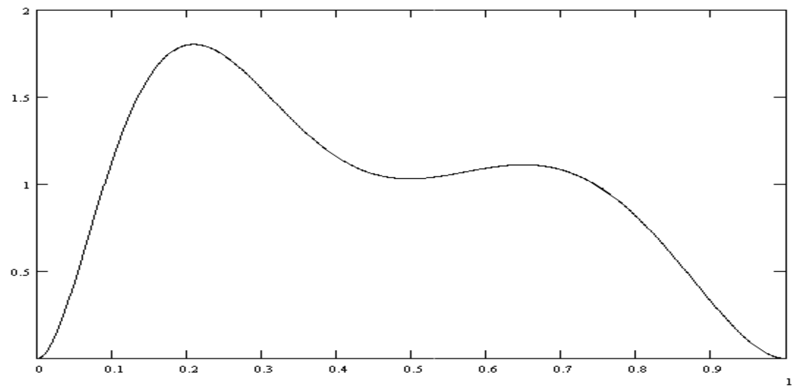

Fig. 1. The demand curve of passenger traffic on the route "Lugansk - Sverdlovsk" forward

Scheduling of traffic

The algorithm to schedule the motion is identical for all days, so further d an algorithm to schedule the movement of vehicles for one day is described. This algorithm is implemented by the programmed way.

The passenger demand curve in the forward direction and OX the axis form a figure, let's note it as F. The passenger demand curve in the opposite direction and the axis OX form a figure, let's note it as F'.

The algorithm to schedule the motion:

1. In the forward direction:
   - the first bus always leaves at $x_1 = 0$, the bus number will be av_1, the bus, which travels to x_1, is chosen randomly from those buses that can travel at this time from X^{st};
   - in order to determine the departure time of the next bus - x_2, you need to find a value of x_2' that area of the figure F, bounded by straight lines $x = x_1$ and $x = x_2'$, multiplied by the number of passengers in the stream, in which received figure is equal to the capacity of the bus av_1. The following cases are possible:
     - if the area of the figure F, bounded by straight lines $x = x_1$ and $x = x_2^{n_{fwd}}$, multiplied by the corresponding number of passengers is less than or equal to the capacity of the bus av_1, it means that the search for the schedule in the forward direction is over, and the difference between the capacity av_1 and the area – these are the losses of underutilization of the bus;

- if you find the desired value x_2', but there is no bus that can travel at this time, we are looking for $x_2'' > x_2'$, such that for any $x \in [x_2', x_2'')$ there is no bus, and to have at least one bus that would go. Then $x_2 = x_2''$ and av_2 is randomly selected of those buses that can go to x_2;
- the area of the figure F, bounded by straight lines $x = x_2'$ and $x = x_2''$, multiplied by the appropriate number of passengers –these are the losses (the number of people who at that time were not provided with the transportation services);
- if you find the desired value of x_2' and there are buses that can travel at this time, then $x_2 = x_2'$ and av_2 is chosen randomly.

- the search of the subsequent departure time of buses and determination of their numbers is similar to the previous search - x_d, av_d, is calculated using x_{d-1}, av_{d-1}.

2. In the opposite direction: the search for timetables of buses in the opposite direction is similar to scheduling in the forward direction in the opposite direction up the schedule using the figure F'.
3. Once time and number of the bus in either direction are found, one should randomly determine to continue the search schedule in a given direction, or go to the search schedule in the other direction (this is necessary for the rotation search).

When scheduling the random selection is used, therefore, when you use an algorithm with the same demand curves different schedules are obtained. After selecting the optimal schedule, the time of departure of transport is back transferred from $x \in [0,1]$ into real time.

CONCLUSIONS

The application of this mathematical model allows minimizing costs in the organization of passenger traffic. With the accumulation of statistical information, the predicted passenger demand curves can be changed that allows to take trends in demand for road transport into account , when scheduling the movement of vehicles.

REFERENCES

1. Aleksakhin S., 2001.: "Applied Statistical Analysis. "Prior". Moscow.
2. Afanasyev V., Yuzbashev M. , 2001: Time Series Analysis and Forecasting. Moscow, Finances and Statistics, 228 pages.
3. Blatnov M., 1981.: Passenger transport by road: A Textbook for motor colleges. 3rd ed. Rev.and add. Moscow: Transport, 222 pages.
4. Brillinger D., 1980.: Time series. Processing of data and theory. Springer-Verlag, 536 pages.
5. Bronstein I., Semendyaev K., 1986.: Handbook of mathematics for engineers and students of technical colleges, 13th ed., Revised, M.: Science, 544 pages.
6. Gluschenko V. Forecasting, 1999.: 2nd ed., Rev. and add. SPb: SPGUVK, 245 pages.

7. Gmurman V., 1972.: Probability theory and mathematical statistics. Ed.Fourth, Textbook annual for schools, 368 pages.
8. Karlin S., 1971.: Fundamentals of the theory of ans. from English. Springer-Verlag, 256 pages.
9. Kasatkin F., Konovalov S., 2004.: Organization of transport services and traffic safety potsessa. Textbook allowance. Moscow: Academic Project, 352 pages.
10. Kurganov V., 2003.: Logistic transport streams. Training and practical guide. Moscow: Publishing and Trading Corporation "Dashkov K0", 252 pages.
11. Lukashin Y., 1979.: Adaptive short-term forecasting. Moscow: Statistics, 254 pages.
12. Golovanenko S., Kramarenko I., Perfiliev F., Soslovsky V., 1981.: Organization of transport of passengers by road. K.: Tehnika,.167 pages.
13. Pozhidaev V., 1998.: Applied problems of mathematical statistics. Lugansk Univ of East State University, 156 pages.
14. Pravdin N., Negrei V., 1980.: Forecasting of passenger traffic.
15. Ryabushkin B., 1987.: Application of statistical methods in economic analysis and forecasting. Finance and Statistics, 75 pages.
16. Smirnov N., 1970.: Probability theory and mathematical statistics., 288 pages.
17. Kolyakina A., Pozhidaev V. 2009.: Statistical analysis of passenger traffic. The bulletin of Eastern-Ukrainian University. Lugansk. №9 (132). p. 180-185.
18. Spirin I., 2003.: Organization and management of passenger road transport: A Textbook for stud. institutions, – 400 pages.
19. Pozhidaev V, Kolyakina A., Ishchenko N. 2008.: Statistical analysis of passenger traffic. The bulletin of Eastern-Ukrainian University. Lugansk. №6 (127). p.160-164.
20. Chetyrkin E., 1977.: Statistical methods for forecasting. "Statistics", p. 17-22.

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ МИНИМИЗАЦИИ ПРОИЗВОДСТВЕННЫХ ЗАТРАТ ДЛЯ МЕЖДУГОРОДНИХ ПАССАЖИРСКИХ ПЕРЕВОЗОК

Валерий Старченко, Виталий Пожидаев,
Анастасия Колякина, Наталья Ищенко

Аннотация. Приведена математическая модель составления оптимальных графиков движения пассажирского автотранспорта в междугороднем сообщении. Модель построена на анализе законов распределения спроса, с учетом возможности наличия неоднородных пассажиропотоков.

Ключевые слова: пассажирские перевозки, пассажиропотоки, закон распределения, прогнозирование, расписание движения.

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MONITORING OF THE TECHNICAL STATE OF THE RAILWAY TRAIN WITH THE PURPOSE OF PASSENGERS' SAFETY IMPROVEMENT UNDER THE CONDITIONS OF TERRORIST ACTIONS

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Summary. There is grounded possibility of automatic management of the train in condition of actuating of explosive or using of gas in passenger electrical train in the article. Block schematic diagram and principle of function of device is developed. List of necessary functions are defined. Recommendations on arrangement in the train suitable sensors are given. Algorithm and program of computer realization of devise operating is proposed.

Key words: railway transport, passengers' safety, safety sensors.

INTRODUCTION

It is well known, that terrorism takes one of the basic places among the problems facing the humanity nowadays [4, 5, 10, 13, 14]. Terrorism penetrates into all the spheres of human activity [8, 15, 16] including railway transport. It is proved by numerous examples of terrorist actions on the railway (Moscow metro in 2010; railway station in Spain in 2007; the section Moscow – St. Petersburg in 2008, etc.)

Monitoring of the train state is an actual problem because it creates the conditions for prevention the act of terrorism or, as minimum, decreases negative consequences.

The actuality of monitoring consists in the ability to disclose dangerous technological situations not connected with terrorism such as running the wheels off the rails, fire or non-adequate behaviour of the engine-driver because of physical or psychological problems.

OBJECTS AND PROBLEMS

Terrorism on railway can be shown in the following types: ill-intentioned creation of the conditions for running the wheels off the rails; use of poisonous substances; fire; explosion; harm to the engine-driver.

Monitoring is a systematic collection of information and its processing, which can be used for improvement of making decisions, for informing the people or as a means of retroactive connection with the purpose of the project realization, program evaluation or politics making.

The train can conditionally be divided into such components: a running part, saloon of carriages, platform of a railway carriage, engine-driver's cabin [2]. Each of these components is equipped by a sensor (detector). The monitoring sensor of the running the wheels off the rails is mounted on the wheels (fig. 1)

In the carriage and platform there carried out the explosion check, presence of toxic agents, fire and smoke check. For monitoring in the saloon-carriage and platform there installed a sensor for recording fire, a sensor for recording explosion (fig. 2).

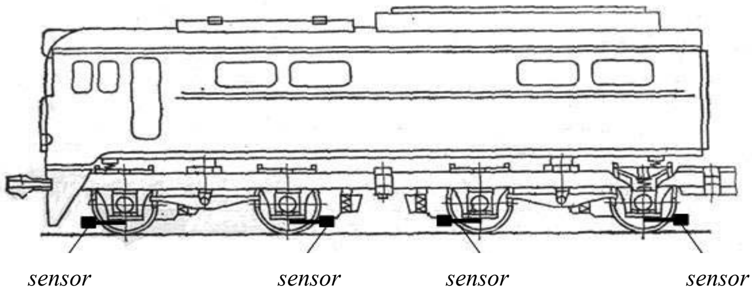

Fig. 1. Arrangement of the sensors that record the running the wheels off the rails

Additional monitoring of adequate behaviour of the driver is carried out in the engine-driver's cabin. It is executed with the help of comparison of current actions of the driver with the standard that is kept in a special data bank.

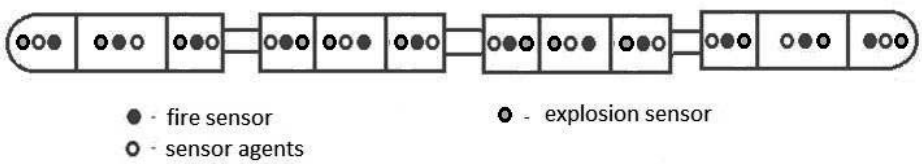

Fig. 2. The placement diagram of the sensors in the train

The sensors and the systems of the rolling stock are functionally connected and compose a device with the help of which it is possible to carry out monitoring the train as a whole and to execute necessary actions. In this case the following problems are being solved: recording explosion in the saloon-carriage, recording the presence of toxic agents, recording fire in the saloon-carriage, recording the running a wheel-set off the rails, recording non-adequate behaviour of the engine-driver, automatic train control according to special algorithm in dependence on the situation.

The device holds five groups of the sensors (fig. 3):

- sensors recording explosion 4;
- sensors recording the presence of toxic agents 3;
- sensors recording the running a wheel-set off the rails 10;
- sensors checking adequacy of the engine-driver's actions 12;
- sensors recording fire 13.

The sensors 3, 4, 10, 12 and 13 are functionally connected with microprocessor control block 5. The control block 5 is designed for information processing that comes from the sensors and signal formation needed for automatic train control.

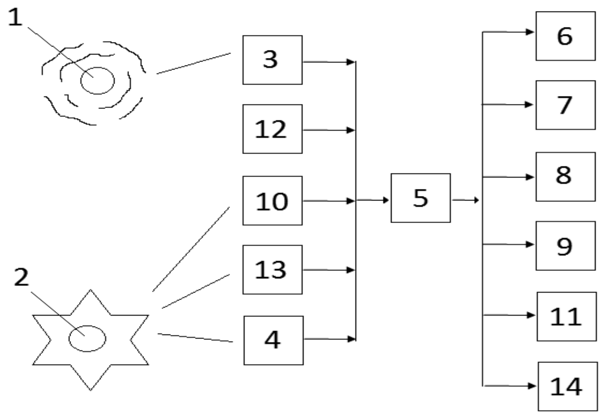

Fig. 3. Block-diagram of the device

In its turn a microprocessor control block 5 has connection with the following technical train systems: brake system 6, the system of door opening 7, emergency signals 8, ventilation system 11, radio-station 9, fire-prevention system 14.

The actions of the monitoring depend on the results of the sensor indexes and are determined on the basis of corresponding rules which are the base of the algorithm of the device functioning. For the development of the program component of the monitoring system the language of logic program Prolog [1, 6, 9, 11, 12] was chosen, namely, SWI-Prolog [17].

A main cause for it is that basic functionality of Prolog program consists in declarative component [1, 7, 11, 12], and programming consists in the formulation of facts and rules which determine the desirable relations between inlet and outlet values of the data.

Several combined formalisms [3] were analyzed with the purpose of getting some knowledge of the problem. In the result a productive model was chosen which is suitable for formulation and gives the possibility to organize easy checking for non-contradictoriness and completeness.

The diagram of the variants of the application was made in the beginning of development (fig. 4).

The developed system is the program prototype for automatic train control under the condition of the act of terrorism. This program has no graph interface and it has a cantilever view because the given program is a prototype and requires further development for its application in real conditions.

In dependence on the sensor indexes the program characterizes the situation by means of one of the two regimes: extraordinary and emergency.

Extraordinary regime comes when there was running the wheel off the rails and it requires urgent train stop. Emergent regime comes while recording toxic agents in the saloon-carriage, fire or explosion, non-adequate behaviour of the engine-driver but the running the wheel off the rail is not recorded. The actions in emergency regime foresee the analysis of the surroundings for determination the favourable stop place.

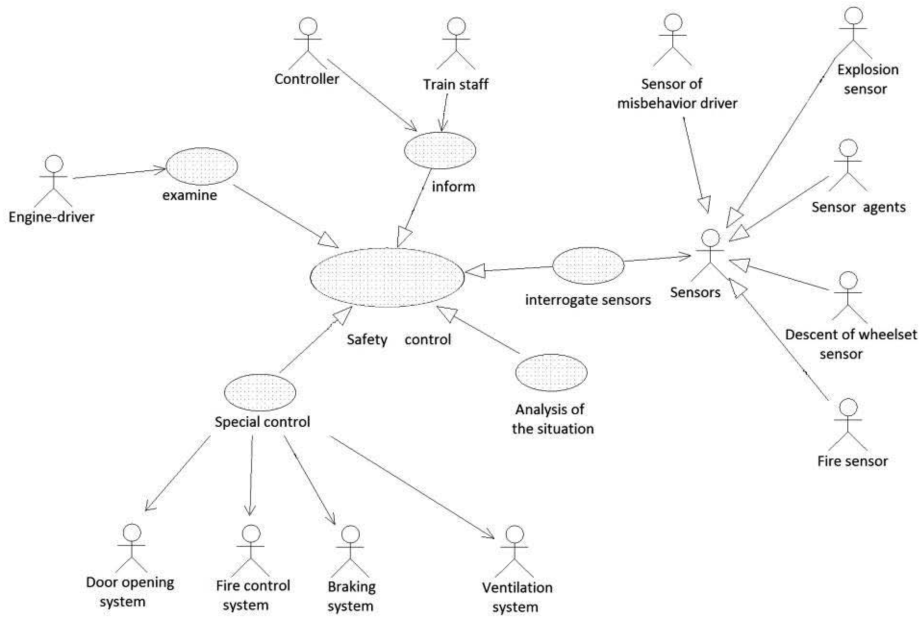

Fig. 4. Diagram of the variants of the application

In order to make any decisions the system determines the regime of the situation. It decides to stop the train immediately or to find a favourable place for it. The next step of the program is determination of further actions in dependence on the specific combination of the sensor indexes.

Its grounding is conducted after the decision has been taken. It is necessary in order to rise some trust to the system decisions and to give the possibility to disclose the defect of the “meditation” system.

Later on the given prototype can be applied for the program development taking into account the factors that influence on the passengers’ safety of the railway trains.

CONCLUSIONS

In this paper there offered one of the possible problem solutions connected with the passengers’ safety of the railway transport under the conditions of the act of terrorism. It consists in monitoring the state of basic systems of the rolling stock responsible for the passengers’ safety and taking decisions on its base in the automatic regime.

For monitoring a special device is developed which records the running the wheel off the rails, toxic agents, fire, explosion and non-adequate behaviour of the engine-driver. The device ensures taking necessary actions according to the algorithm which depends on the sensor information.

There developed an expert system using agents-sensors – the program prototype for automatic train control. According to these requirements the given system gives the substantiation to each decision in order to rise trust to the system decisions and to check the search process with the purpose of disclosing possible defects of “meditation” on the stage of the system adjust.

REFERENCES

1. Bratko I., 1990.: Prolog programming for artificial intelligence. – M.: World, 560 p.
2. Golubenko A., Osenin Yu., 2010.: Minimization of terrorist action consequences in the trains of railway transport // TEKA Commission of Motorization and power industry in Agriculture. – Lyblin: Polska Akademia nauk Oddzial w Lubline, Vol. XD, P. 129 – 135.
3. Jekson P., 2001.: Introduction into expert systems. – M.: Publishing house “Williams”, 624 p.
4. Emelyanov V., 1999.: Object of terrorism: its signs. – K.: Law of Ukraine, № 11.
5. Ivchenko V.I., 2000.: Terrorism. – K.: Politics and time, №№ 1, 2.
6. Kloksin Y., Melish K., 1987.: Prolog Language Programmingю – M.: World, 336 p.
7. Kovalsky R., 1979.: Logics for problem solution. – M.: Science, 280 p.
8. Krasnov A., 2000.: “Bloodless wars” – reality and myth // Foreign military revision, №1, P. 3-6, – access regime: http://ww-4.narod.ru/warfare/page0008.htm.
9. Malpas I., 1990.: Prolog relation language and its application. Trans. from English / Editor V.N.Sobolev. – M.: Science, 464 p.
10. Morosov Y. I., 1997.: International terrorism //USA, economics, ideology, № 11, 12 p.
11. Sterling Z., Shapiro E., `1990.: Art of Programming in Prolog language. – M.: World,
12. Stobo I., 1993.: Prolog language of programming. – M.: Science, 366 p.
13. Yatsko A., 1998.: Ontology of violence: terror and terrorism as the elements of political struggle // Ukrainian problems, № 9, P. 1070 – 1079.
14. Zamkovoy V., Ilchikov M., 1996.: Terrorism – global problem of present - M.: World, 43 p.
15. Electronic source: http://scbist.com/uchebnye-materialy-zheleznodorozhnoi-tematiki/6456-organ-zac-ya-tehnolog-avar-ino-v-dnovlyuvalnih-rob-t-na-zal-znicyah.html.

16. Electronic source: http://zakon.nau.ua/doc/?uid=1078.8366.0.
17. Electronic source: www.swi-prolog.org.

МОНИТОРИНГ ТЕХНИЧЕСКОГО СОСТОЯНИЯ ПОЕЗДА ЖЕЛЕЗНЫХ ДОРОГ С ЦЕЛЬЮ ПОВЫШЕНИЯ БЕЗОПАСНОСТИ ПАССАЖИРОВ В УСЛОВИЯХ СОВЕРШЕНИЯ ТЕРРОРИСТИЧЕСКОГО АКТА

Юрий Статывка, Галина Осенина, Владимир Орлов

Аннотация. В статье обосновывается возможность автоматизированного управления поездом в условиях срабатывания взрывного устройства или применения отравляющих веществ в пассажирском электропоезде. Разработана блок-схема и принцип действия устройства. Определен перечень необходимых функций. Даны рекомендации по размещению в поезде соответствующих датчиков. Предложен алгоритм и программа компьютерной реализации функционирования устройства.

Ключевые слова: железнодорожный транспорт, безопасность пассажиров, датчики безопасности.

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COSTS SHARING ON CONTROL STATE OF PIPELINE TRANSPORT SYSTEMS

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Summary. The principle of the selective approach to a task of distribution expenses on realization of the control a technical condition linear elements pipeline transport systems is formulated. The level of expenses on performance control operations should be connected to a role of separate elements system in transport process.

Key words: system, pipeline, transport, control, expense.

INTRODUCTION

Pipeline transportation systems are intended for delivering liquid or gaseous products to customers in various sectors of economical activity [5,8,10-13,16]. As the damage or destruction of such objects can be related to environmental pollution and cause an extensive material damage, so the control of their reliability and the technical state is an actual problem [2-4,9,14,15].

ANALYSIS OF LAST RESEARCHING AND PUBLICATIONS

There are different approaches to the problem of costs sharing on controlling the technical state of linear elements of transport systems. Thus the most effective is the scheme under which the costs on the element state control are proportional to the extent of risk related to its operation [1,6,7,18-21].

It means that the most important pipelines of the system should be controlled more often than the pipelines, the role of which in the process of the system functioning is insignificant .

In accordance with provisions of work [17], a measure of risk is a dimensionless quantity, which is determined as:

$$\sqrt{R} = \sqrt{(1-p)\cdot\Phi}\ .$$

It depends on the reliability of the pipeline p and the transit coefficient Φ, which represents a share of the product generated by the source and passing through the pipeline in unit time.

GOAL OF RESEARCHING

The purpose of the present job is the formulation principles of the selective approach to a task distribution expenses on realization control of a technical condition linear elements pipeline transport systems.

MATERIALS AND RESULRS OF RESEARCHING

If a part of the pipeline system consists of *n* line elements, in accordance with the proposed approach the total unit costs on control of its state are determined as follows:

$$\Theta_{\sum} = z_0 \sum_{i=1}^{n} l_i \cdot D_i \cdot \sqrt{R_i} \cdot$$

where: z_0 - the average costs on the state control of the pipe surface area in unit time;

l_i and D_i - the length and diameter of the i - pipeline system.

The share of unit costs for the i - element:

$$\vartheta_i = \frac{l_i \cdot D_i \cdot \sqrt{R_i}}{\sum_{i=1}^{n} l_i \cdot D_i \cdot \sqrt{R_i}} . \qquad (1)$$

The value ϑ_i characterizes the share of costs on the state control of the i - element in the scale of the whole transport system. This scheme of costs should be regarded as rational, if the share of costs on the state control of linear elements of the transport system is distributed according to the dependence (1).

Different level of costs on the technical state control of pipelines system also includes different volumes of control operations. In this case, the recommended level of control depends on the value and determined in accordance with the data in the table. 1.

In general case the usage of four levels is provided. The consecutive transition from the baseline level to the peak one should be accompanied by the control extension over the volume, frequency, increasing reliability, etc.

Table 1. **The recommended levels of technical state control of transport systems pipelines**

Level of technical state control	Baseline	Advanced	Strengthened	Peak
Share of costs per unit ϑ_i	less 0,125	0,125... 0,25	0,25... 0,5	0,5... 1,0

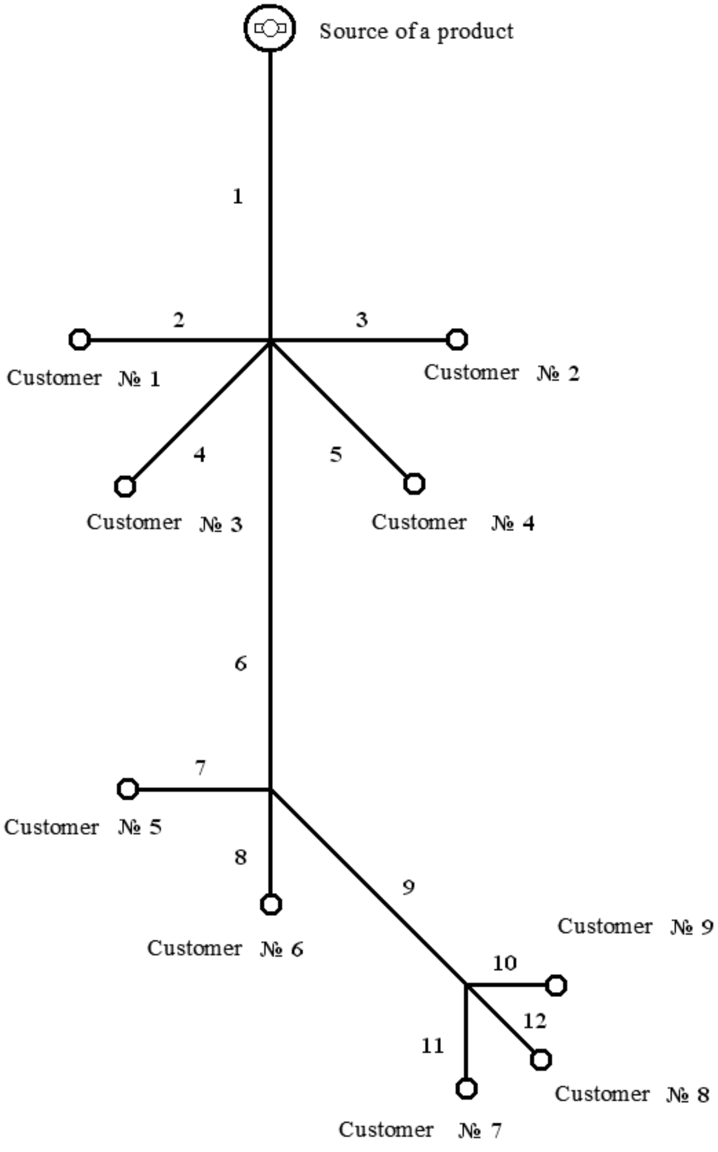

Fig. 1. Calculation scheme of pipeline transport system

Determination of the recommended control level for all the pipelines of the system can be performed having the information about their reliability, diameter, length and values of transit coefficients.

The initial data for calculation of such a system are given in the table 2. Here are given the values ϑ_i set by relation (1). The results of the calculations can be represented in graphical form, by placing all the elements in order of decreasing values.

Table 2. **Calculated characteristics of the pipeline system**

Number of element i	Length of pipeline l_i, m	Diameter of pipeline D_i, m	Reliability of pipeline p_i	Transit coefficient Φ_i	The share of unit costs ϑ_i
1	70	0,325	0,992	1,0	0,364
2	25	0,159	0,980	0,08	0,028
3	25	0,159	0,980	0,08	0,028
4	40	0,159	0,985	0,08	0,039
5	60	0,273	0,990	0,68	0,242
6	40	0,159	0,985	0,08	0,039
7	25	0,168	0,991	0,08	0,020
8	20	0,168	0,991	0,1	0,018
9	40	0,219	0,984	0,5	0,140
10	20	0,159	0,989	0,2	0,027
11	20	0,159	0,989	0,2	0,027
12	25	0,159	0,986	0,1	0,027

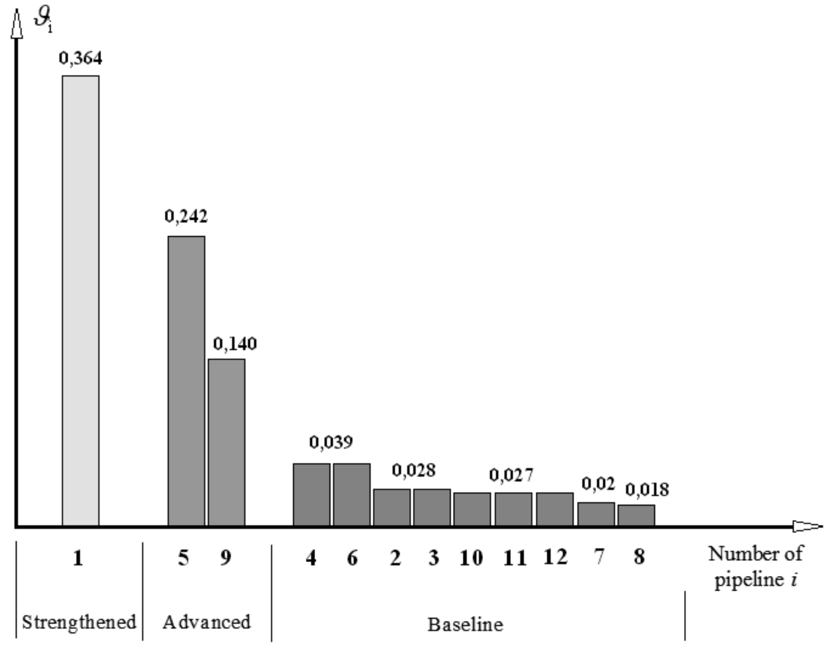

Fig. 2. Diagram of the costs sharing and recommended levels of state control of pipelines transport system

This kind of rank diagram is shown in pic. 2 and gives opportunity to estimate the recommended ratio of costs on control of the technical state of various pipelines of the system.

In accordance with the received data the group of pipelines with the strengthened level of control includes one element (pipeline № 1), with the expanded level includes two elements (pipelines № 5 and № 9). All other pipelines belong to the group with the baseline control.

Thus, distribution of resources in accordance with the presented column diagram allows to create a rational scheme of costs on the technical state control of the elements of the analyzed transport system.

CONCLUSIONS

The rational scheme of costs sharing on the technical state control of the transport system can be provided if the costs sharing on the state control of individual pipelines is approximately proportional to their diameter, length and extent of risk which is related to their functioning.

REFERENCES

1. Akimov V.A., Lapin V.L., Popov V.M., Puchkov V.A., Tomakov V.I., Fateev M.I. 2002.: Reliability of technical systems and technological risk. - Moscow: ZAO FID "Business Express" – 368P.
2. Akimov V.A., Radaev N.N. 2001.: Methodological apparatus for studying natural and technological risks / Health and Safety. - № 2. - p. 34-38.
3. Chernikin V.A., Sultanov L.M. 2009.: Integrated quality control system of pipes and pipelines of main reliability / Pipelines: Theory and Practice. - № 1 (13). – p.37 - 41.
4. Dubov A.A., G GGnushev M.A., Veliyulin N.I. 2005.: Assessment of residual life of gas - oil based on modern methods of technical diagnostics / Gas Industry. - № 2. p.76-78.
5. Foliyants A.E., Martynov N.V., Serebryanyi V.B. 1988.: Maintenance and repair of process piping under pressure to 10 MPa (100 kgf/sm2). - Moscow: Khimiya, – 288P.
6. Grazhdankin A.I., Belov P.G. 2000.: Expert system for man-caused risk of dangerous industrial objects / Safety in industry. - № 11. – p. 6-10.
7. Hanley E., Kumamoto H. 1984.: Reliability of engineering systems and risk assessment / Translated from Eng. By Syromyatnikova V.S., Danilin G.S. M MMoscow: Mashinostroenie. -528P.
8. Ivakin A.V. 2007.: Providing of pipeline transportation safety and security / Pipelines: Theory and Practice. - № 2 (8). - p. 106 - 111.
9. Khromchenko F.A. 2007.: Technical diagnostics of welded joints of pipelines / Mechanical Engineering Technology. - № 5. p.66 - 70.
10. Krasnikov A.F., Kuzmin S.V. 2005.: The calculation of pipeline efficiency after the implementation of various strategies for selective repair / Universities, oil and gas. - Tyumen: TyumGNGU. - p. 55-60.
11. Lebedev A.S., Milko - Butovskiy G.A., Aladinsky V.V. 2006.: Evaluation of reliability of linear sections of trunk pipelines / Pipelines: Theory and Practice. №3 (5). - p. 66 - 70.

12. Makarov G.I. 2007.: Mathematical foundations of the stress and strain state monitoring o oof the pipe wall in main pipeline / Pipeline transportation: theory and practice. - № 1 (7). - p. 92 - 95.
13. Masaylo M.N., Aladinskiy V.V., Filonenko I.A. 2007.: Defining of pipeline defects parameters according to the magnetic in-line inspection / Pipeline transportation: theory and practice. - № 2 (8). – p. 96 - 101.
14. Samoilenko N.I. Gavrilenko I.A. Functional Safety of Pipeline Transport Systems / Ed. Samoilenko N.I. - Kharkov: HNAGH, 2008. - 180 p..
15. Seleznev V.E., Aleshin V.V., Pryalov S.N., 2009.: Mathematical modeling of trunk pipeline systems: additional chapters / Seleznev V.E. - M. MAKS Press, – 36 P.
16. Sultanov M.H., Chernikin V.A., Bikbulatov A.R. 2009.: The methodological basis of optimization studies of technological pipelines pumping stations MNPP / Pipelines: Theory and Practice. - № 2 (14). - p.20 - 22.
17. Tararychkin I.A., Slobodyanyuk M.E. The Structural Analysis of Pipeline Transportation Systems / / Pipelines: Theory and Practice. - 2011 .- № 1 (23). - p. 32 - 34.
18. Terekhov L.T. 2006. The main approaches to the process of pipelines maintenance and repair / Pipelines: Theory and Practice. - № 1 (3). - p. 105 - 108.
19. Vasin E.S., Sachkov A.B., Martynov V.O. 2007.: Informational analytical system for monitoring of t ttrunk pipeline technical condition / / Pipeline transportation: theory and practice. - № 3 (9). - p. 96-102.
20. Vetoshkin A.G. 2003.: Reliability of technical systems and technological risk. - Penza: Izd PGUAiS, -155P.
21. Vladov Y.R. 2005.: Automated identification of pipeline systems state in engineering / Study allowance. Orenburg: SEI OSU.- 101P.

РАСПРЕДЕЛЕНИЕ ЗАТРАТ НА КОНТРОЛЬ СОСТОЯНИЯ ТРУБОПРОВОДОВ ТРАНСПОРТНЫХ СИСТЕМ

Игорь Тарарычкин, Грегорий Нечаев, Максим Слободянюк

Аннотация. Сформулирован принцип избирательного подхода к распределению затрат на контроль технического состояния линейных элементов трубопроводных транспортных систем. Уровень затрат на выполнение контрольных операций должен быть пропорционален той роли, которую играют отдельные элементы системы в транспортном процессе.

Ключевые слова: системы, трубопровод, транспорт, контроль, затраты.

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DIAGNOSTICS OF THE STATE OF BEARINGS KNOTS A NONCOLLAPSIBLE METHOD

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Summary. This paper presents problems of the diagnostics of bearings a noncollapsible method.

Key words. Diagnostic, bearing knot, noncollapsible method, technical state, vibroacoustic, friction.

INTRODUCTION

Frictionless bearing sinews the revolved parts of mechanisms and machines. He has the limited term of service, that, in same queue, influences on a capacity and longevity of mechanism. Breakage of frictionless bearing entails the abrupt ends of equipment, failures in work, high cost of repair.

The decision of problem of diagnostics of the state of bearings a noncollapsible method will help to decide the task of prognostication of death of bearing knot and timely conducting of repair.

It is presently suggested to examine all of period of service of bearings as five stages [1] (fig. 1). We consider that on the first stage, general technical state of the new bearing – «ideal».

On the first stage the set bearing works without the display of some defects. There is earning extra the money of bearing on the second stage. On the third stage appears and begins to develop some defect, there are shock vibroimpulses, growings on a size. On the fourth stage shock impulses in bearing arrive at on the energy practically a maximal value. On the fifth stage the area of development of defect is so great, that bearing begins to "lose" the basic setting - to provide the rotation of billows with a minimum friction, stage of expectation of failure [1, 5, 6, 7, 9].

The analysis of vibroacoustic of information allows operatively to find out a developing disrepair, estimate the degree of its meaningfulness and undertake measures to prevention of unplanned stop of production process. Practically all of the known vibroacoustic methods of control are based on the analysis of either signal or his frequency descriptions. In most cases the vibration of bearing is registered a vibration sensor, set on the corps of bearing which besides additionally collects signals from other mechanical sources of vibration. During work of bearing in composition a mechanism there is a signal with the large level of noise, therefore his sound description is distributed in in relation to to the wide bar of frequencies, which noise and low-frequency effects is laid on on.

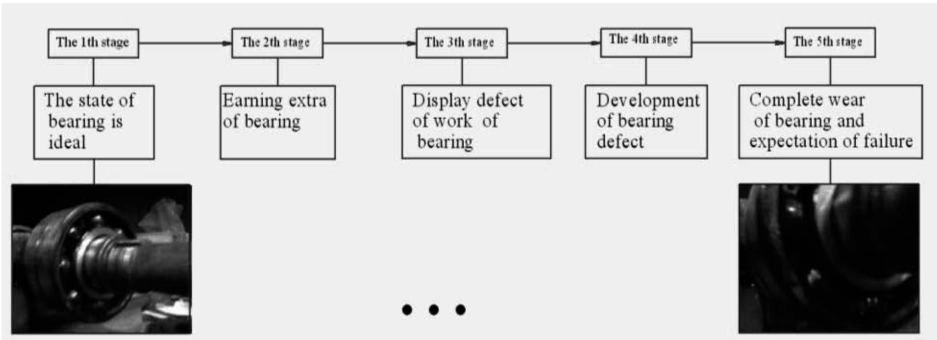

Fig. 1. Flow-chart of the stages of work of bearing

Lately actively the methods of control of bearings develop rolling, based on an analysis and comparison of narrow-band making spectrums. At the same time in works of Yavlenskogo k.N., Yavlenskogo a.K. [3, 9, 10] is shown possibility of application of continuous veivlet transformation for the analysis of vibration signals of frictionless bearing.

The analysis of literary data [2, 3, 11, 12] showed that vibrodiagnosticians expected most authenticity and most effect from introduction of diagnostics of frictionless bearing on the spectrums of vibroacoustic signals. A spectrum is distributing of power of initial temporal signal in a frequency area. It was before considered that appearance of the obviously expressed narrow peaks on a spectrum in the area of characteristic frequencies of one or another element of frictionless bearing, having not only large amplitude but also substantial power, it is necessary to expect only in that case, when a defect will develop to such degree, that his power will be commensurability with power of the expressly diagnosed peaks on a spectrum. In other words, a defect will be visible on a spectrum only then, when he will be developed enough [1].

DESCRIPTION OF EXPERIMENT

Authors are conduct experimental research of work of frictionless bearing №310 (basic parameters of bearing GOST 8338-75 resulted in a table. 1).

For the record of sound of work interesting us workings elements the microphone of the directed action (for basis of which the microphone of Philips SBC MD110 was taken), which passed him on the personal computer, was used. Then findings were processed through the program MATLAB and appendix of "Spectrogram" written for it, which allow to make the spectral analysis of record of sound of work of knot.

Table 1. **Basic parameters of bearing № 310**

Denotation of bearing	d	D	B	r	Marbles		Mass, kg	C, H	C0, H	N
					Dw	z				
310	50	110	27	3,0	19,05	8	1,08	61800	36000	6,3

The new bearings, being in the ideal state were set in the probed knot. During all of term of work of this bearing knot the record of his work and treatment of results was systematic made.

The results of treatment of signals on the different stages of work of bearing are shown out as the graphs (fig. 2-9). On an ax X time of record is represented, on an ax Y frequency, and a color is show force of sound in certain moment of time on certain frequency.

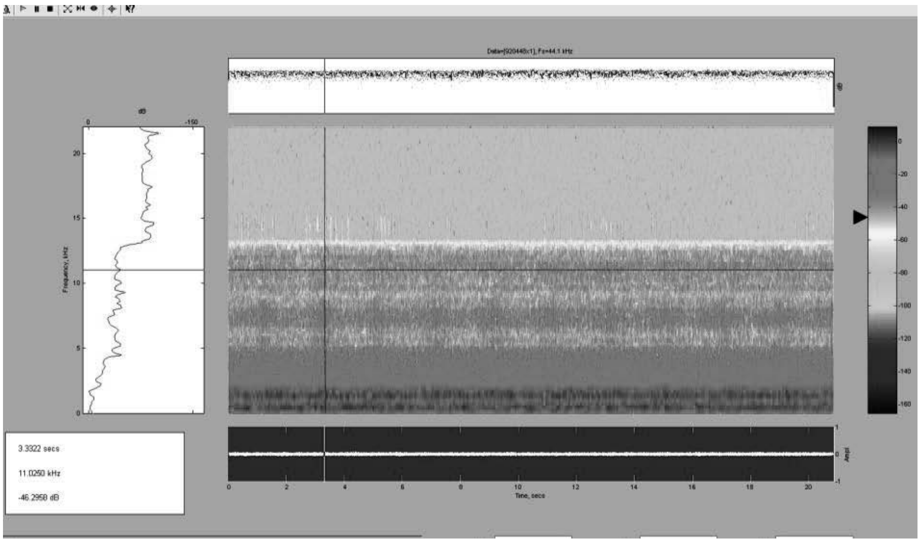

Fig. 2. The 1th stage. Spectral analysis of sound of work of bearing

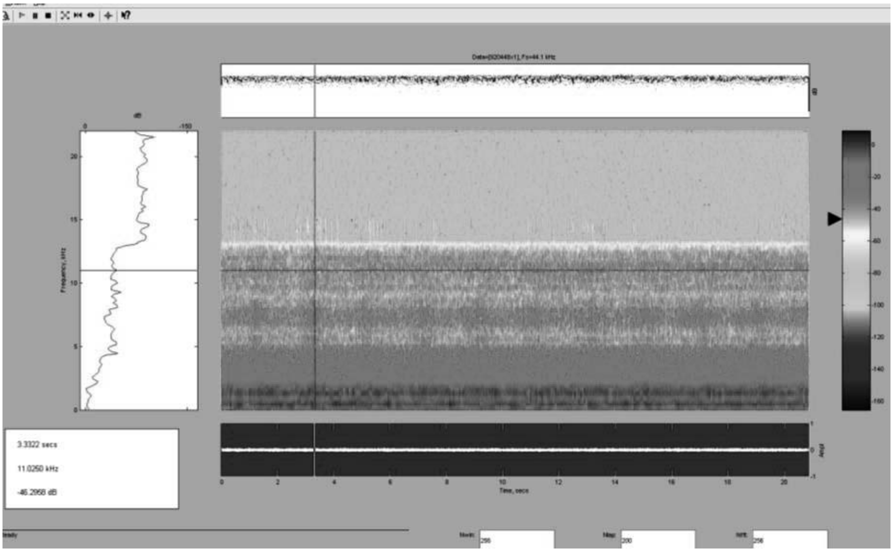

Fig. 3. The 1th stage. Spectral analysis of sound of work of billow

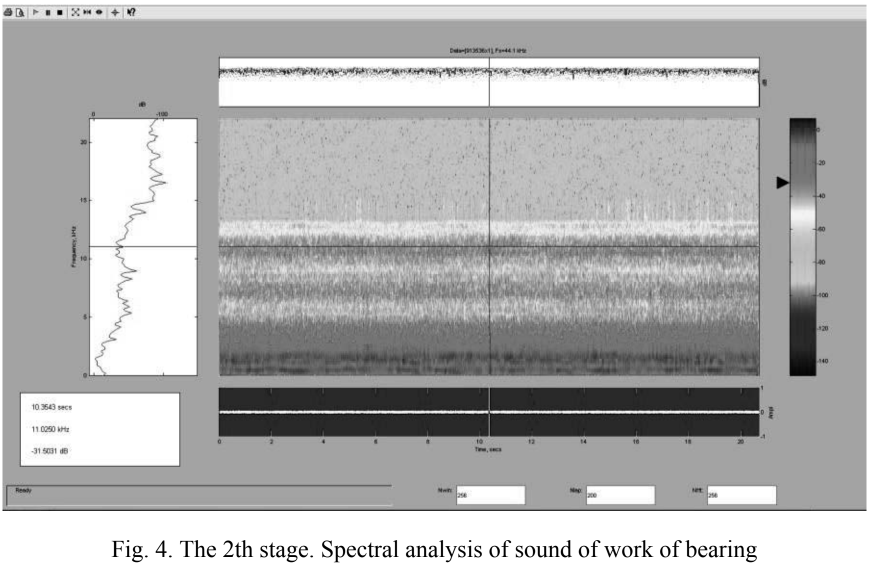

Fig. 4. The 2th stage. Spectral analysis of sound of work of bearing

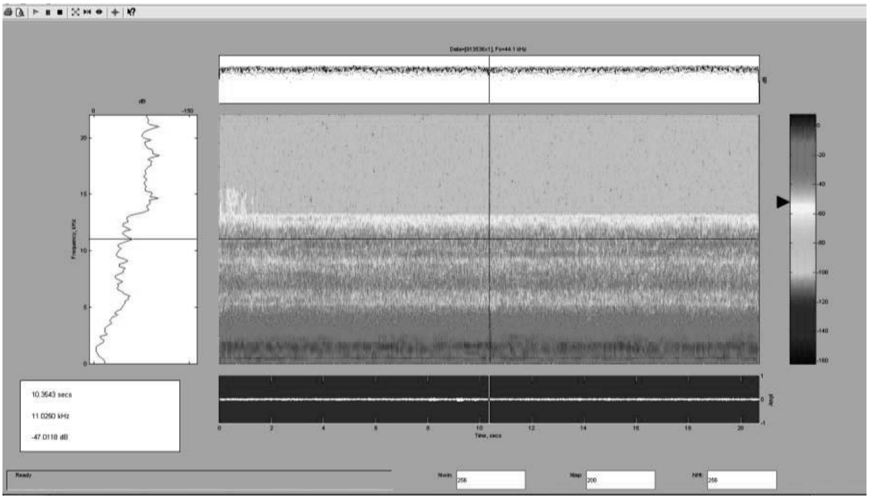

Fig. 5. The 2th stage. Spectral analysis of sound of work of billow

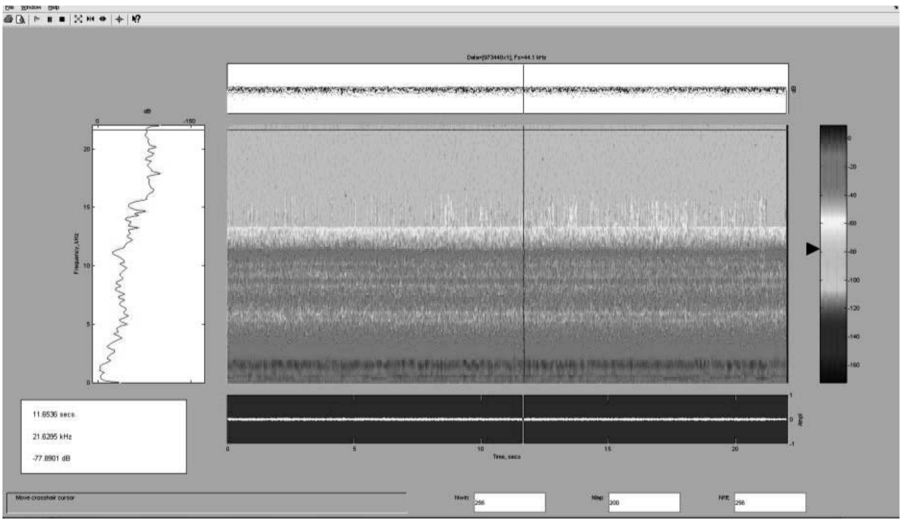

Fig. 6. The 3th stage. Spectral analysis of sound of work of bearing

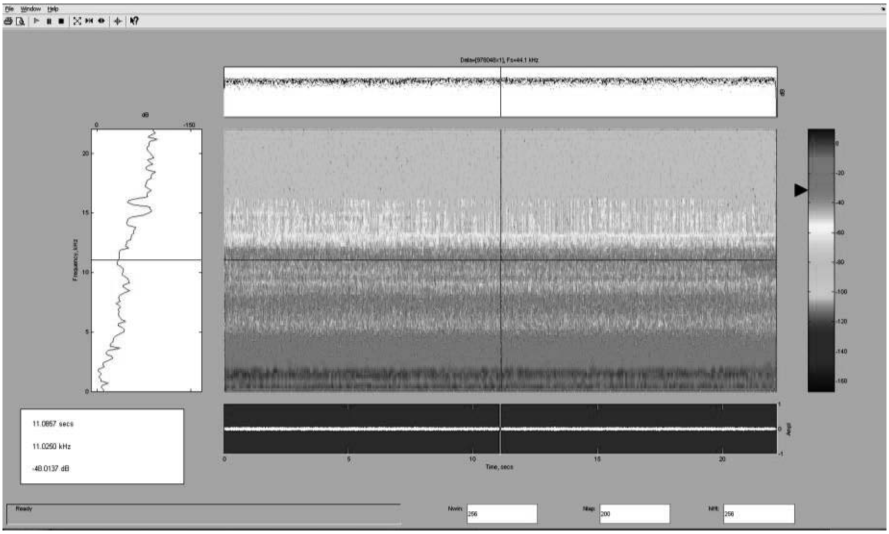

Fig. 7. The 3th stage. Spectral analysis of sound of work of billow

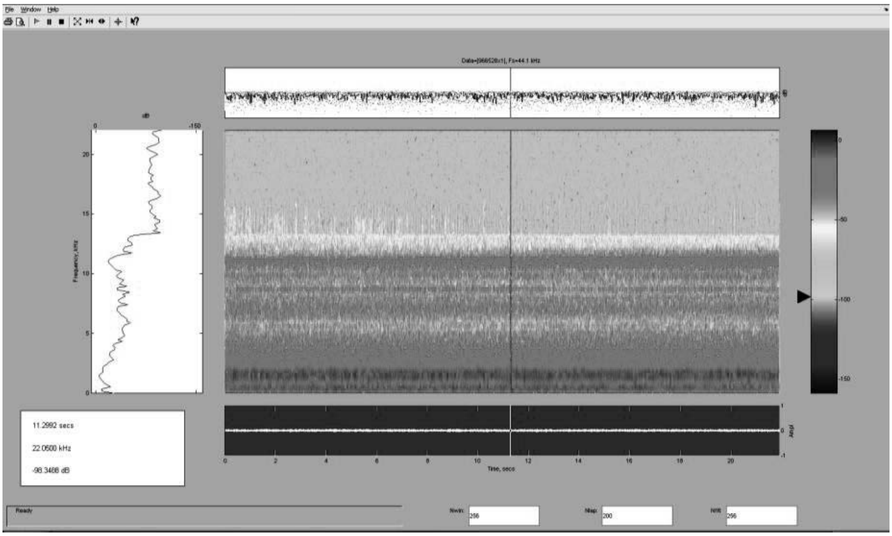

Fig. 8. The 4th stage. Spectral analysis of sound of work of bearing

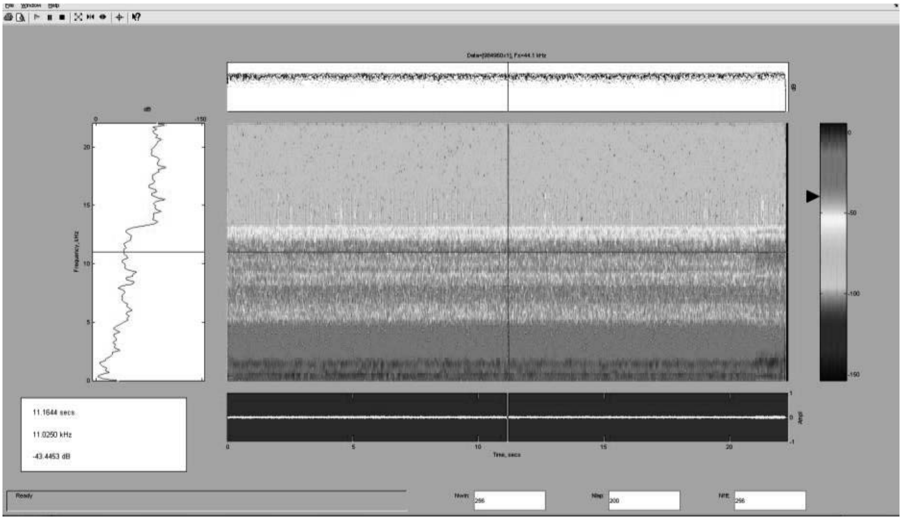

Fig. 9. The 4th stage. Spectral analysis of sound of work of billow

1th stage – a difference between the spectral analysis of sound of work of billow and bearing is not observed.

2th stage – a difference between the spectral analysis of sound of work of bearing and billow shows up as a spectrum of yellow.

3th stage – a difference between the spectral analysis of sound of work of bearing and billow shows up as a spectrum of yellow-red color.

4th stage – a difference between the spectral analysis of sound of work of bearing and billow shows up as a spectrum of red color.

CONCLUSIONS

It was set as a result of analysis of the got data, that spectrum, responsible for the state of bearing № 310, is in a frequency range from 10 to 11,5 kGc. Comparing the results of signals it is possible to assert on the different stages of work of bearing, that with worsening of the state of bearing (development of wear processes, defects) force of sound is increased in the indicated spectrum.

For the probed bearing № 310 under reaching force of sound of 120 dB in a frequency range from 10 to 11,5 kGc it is necessary to make his replacement.

Thus, the use of microphone of the directed action and considered method of the signal processing is given by possibility to conduct monitoring of bearings knots a noncollapsible method. The same chart of monitoring can allow to control any other knots of different machines and mechanisms.

REFERENCES

1. Acutin M.V. 2009.: Metod controlya sostoyaniya podshipnikov kacheniya na osnove sravneniyz veyvlet sceylogram: avtjref. Dis… kand. Teh. nauk:05.11.13. / M.V. Acutin – Kazan – 16 c.
2. Genkin M.D. 1987.:Vibroakusticheskaya diagnostika mashin I mehanizmov / M.D. Genkin, A.G. Sokolova. – M. Mashinostroyeniye – 288 c.
3. Yavlenskiy K.N. 1983.: Vibrodiagnostika I prognozirovaniye kachestva sistem / K.N. Yavlenskiy, A.K. Yavlenskiy. – L.: Mashinostroyeniye. Leningr. Otd-niye – 239 c.
4. Vibracionnaya diagnostika. Funkciya express diagnostiki sostoyaniya podshipnikov kacheniya v portativnih priborah «DIAMEX 2000». № 5, 2007. Yezhekvartalniy nouchnotehnocheskiy zhurnal o vibrodiagnostike i balansirovke. OOO «DIAMEX 2000», Moskva.
5. Diagnostika nepoladok podshipnikov. http://offerpro.com.ua/bearings-diagnostics/vse-stranicy.
6. Mitchel John S. "An Introduction to Machinary Analisis and Monitoring." Tulsa: Penn Well Books, 1993.
7. Barkov A.V., Barkova N.A., Mitchel J.S. "Condition Assessment and Life Prediction of Rolling Element Bearings, Sound amp Vibration." 1995, June pp.10-17, September, pp.27-31.
8. A.V. Barkov. 1996.: Optimization of Monitoring and Diagnostics Methods for the Rotating Machines by Vibration and Noise Measurements, Proceedings of the 4th International Congress on Sound and Vibration.." St. Petersburg, Russia, June 24-27, 1996, Volume 3, pp. 1573-1578.
9. A.V. Barkov, N.A. Barkova. 1996.: Diagnostics of Gearings and Geared Couplings Using Envelope Spectrum Methods,Proceedings of the 20th Annual Meeting of the Vibration Institute. Saint Louis, Missouri, USA, 1996, pp. 75-83.
10. Failed Bearings or Gears. http://www.vibratesoftware.com/html_help/html/Diagnosis/Reference/Failed_Bearings_and_Gears.htm.
11. Donald E. Bently. Fundamentals of Rotating Machinery Diagnostics. http://www.bpb-co.com/book/newpublication.php.
12. N. Sawalhi, R.B. Randall, Semi-Automated Bearing Diagnostics - Three Case Studies. http://www.spectraquest.com/tech/SEMI_AUTO_BEARING_DIAGNOSTICS.shtml.
13. Sovremennyemetodyisredstvavibroakusticheskogodiagnostirovaniyamashyn i konstrukciy // F.Ya. Balickiy, M.D. Genkin, M.A. Ivanova [i dr.]; podred. akad. K.V. Frolova.M., 1990. 252 c.
14. Barkov A.V. Optimization of Monitoring and Diagnostics Methods for the Rotating Machines by Vibration and Noise Measurements // Proc. of the 4th International Congress on Sound and Vibration. St. Petersburg, Russia, 1996, Vol. 3, pp. 1573–1578.
15. *ThomsonW.*T. Vibration theory and applications//London. 1971.
16. Airapetov E.L., SokolovaA. G., HomyakovE. I.Vibroakusticheskayadiagnostikavikrashivaniyaizaedaniyazubchatihkolesnaranneystadii // Tochnost i nadeznostmehanicheskihsistem. Stohasticheskayalokalizaciyavrozdennosti.Riga, 1983.
17. Vibroakusticheskayadiagnostikazarozdaushihsyadefektov /F. Ya. Balickiy, M. A. Ivanova, A. G. Sokolova, E. I. Homyakov.M., 1984.
18. BarshfordD.Metodydiagnostirovaniyamehanizmovvrasheniya. Tehnicheskayadiagnostika // IIIMegdunarodniysimpoziumIMEKO, 1983.

ДИАГНОСТИКА СОСТОЯНИЯ ПОДШИПНИКОВ НЕРАЗРУШАЮЩИМ МЕТОДОМ

Владимир Витренко, Ирина Кириченко, Михаил Кашура, Александр Кашура

Аннотация. В статье рассматриваются вопросы диагностирования состояния подшипников неразрушающим методом.

Ключевые слова: Диагностика, подшипник, неразрушающий метод, техническое состояние, виброакустика, трение.

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STUDIES OF WINPLC7 V4 PROGRAMMING ENVIRONMENT IN DEVELOPING ROBOTIC WORKCELL CONTROL SYSTEM

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Summary: The considered problem of using programmable logical controller VIPA series SYSTEM 100V in developing robotic workcell control system on base of the industrial robot MP-9S with pneumatic drive. Indication of number of cycles was displayed on text panel TD-03, setting up of which is performed by using TDWizard software. The presented fragment of robotic workcell control program is performed using LADDER language in WinPLC7 V4.42 programming environment.

Key words: logical controller, industrial robot, pneumatic drive, software, program, language.

INTRODUCTION

Due to the rapid development of microprocessor technology the programmable controllers are used widely in various systems to regulate and control technological processes. Using relatively cheap, reliable, compact microprocessing means, designed for industrial environments significantly simplify the design process of control systems, facilitate their maintenance, and improve efficiency of used automated equipment [5].

VIPA controllers have proved their work in many various industrial branches in different countries. One of their main fields of applications is automotive industry, control of conveyors and automated warehouses as well as control of food and beverage production. There are several controller series manufactured by VIPA, which differ by their features and designed to solve various complexity tasks [17].

Compact design and good price/performance ratio makes controllers System 100V series as especially suited for applications with the great number of I/O points. However, compatibility with SIMATIC S7- 300 relative to set of instructions and advanced communication capabilities allow to use them for enough complex tasks, which require distributed control, including in combination with other VIPA controllers and third parties controllers. The product family includes several models of controllers with built-in I/O channels and with support of features in formation of interrupt signals, fast counters and pulse outputs. Quantity of I/O channels can be increased through expansion modules. This family includes modules distributed I/O for PROFIBUS and

CANOpen networks. Processor modules and expansion modules are mounted directly on 35 mm DIN-rail.

Series System 100V has modular design. This means that the user can select the combination of modules which the best suits to certain task and modify it flexibly in case of expanding or changing system requirements. All I/O modules and interface modules are versatile that is they can be used with any CPU of this series. In this case, it is possible to select the processor module with optimal performance for a particular purpose [12].

Therefore creation of control system of robotic workcell based on PLC VIPA SYSTEM 100V series is very urgent problem.

OBJECTS AND PROBLEMS

To investigate the possibilities of WinPLC7V4 software package during development of control system of robotic workcell based on PLC VIPA- 115 6BL02 a stand was designed, which simulates the operation of robotic workcell including the load device, industrial robot with a pneumatic actuator MP-9S and an output trough, figure 1.

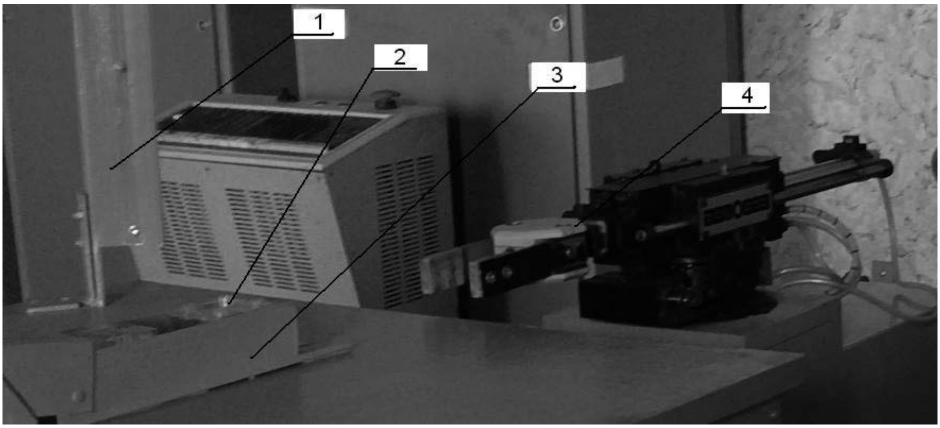

Fig.1. The layout of the robotic workcell based on industrial robot MP-9S:
1 – troughed loading mechanism, 2 - the subject of handling,
3 - outlet trough; 4 - industrial robot MP-9S

The robot MP-9S uses normally closed valve-type distributing devices with electric control. Every movement of executing unit of the robot the self-contained electric valve, type P-EPR3-112 UKhL4, Pnom = 1MPa, Du = 1.6 mm, U = 24V. As an executive drives the pneumatic cylinders are used with linear motion of double-acting piston. Gripper has single acting pneumatic drive. Signals of finishing of predefined movements come from the electromagnetic contacts (CEM). When designing control programs it was adopted both as an time-based principle of control for all segments of handling mechanism, the more so because it is cheaper and provides more reliable operation of given robotic workcell, and as path-based principle with using CEM signals.

Informal description of the operation algorithm of the robotic workcell involves following actions. Objects of handling come in oriented position by gravity along loading device to the gripping area of manipulator. Manipulator located in the lower position and turned to the gripping area must unclamp the gripper, move forward, clamp the object, turn the arm to initial position, turn to unload position, move upward, move the arm forward, move downward, unclamp the object of handling, turn the arm back, clamp the gripper, move the arm forward to transfer the object of handling in output trough, return the arm back and turn to the loading position. After that the cycle repeats.

To study the environment of WinPLC7 and opportunities of VIPA-115 16DI/16DO (CPU 115 6BL02) the activity diagram of movements of industrial robot MP-9S has been developed which is shown at figure 2.

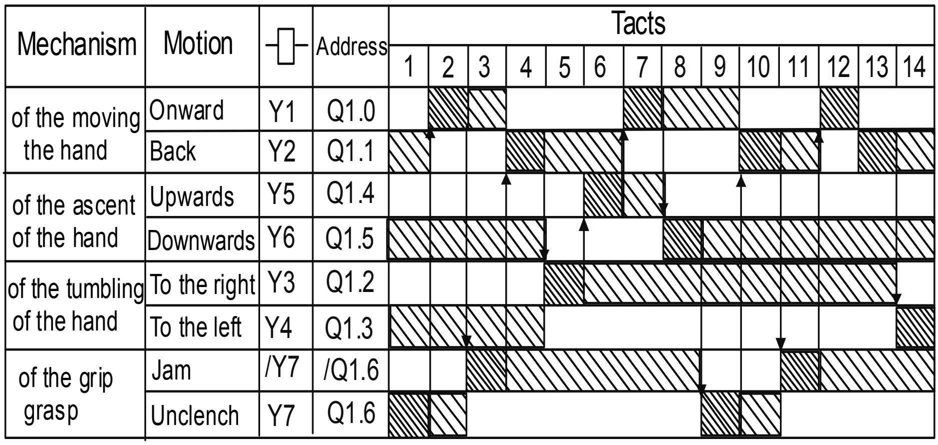

Fig.2. Activity diagram of robotic workcell operation

The control unit is shown in figure 3. The stand scheme includes buttons for selecting operation mode, for manual control, additional relay units of galvanic separation, performed on the interface relays RM84 with socket GZT80, equipped with LED signal module M61R and PLC VIPA-115 6BL02. The controller is powered from a standard power module VIPA 24VDC/2A (207-1BA00). The power supply for electromagnets of pneumatic valves (+,-) is carried out through a developed power unit.

Inputs and outputs of the system are signals (in brackets the notations are given used in synthesis), table 1.

In synthesis of control system it was used path- and time-based principle of control. All movements of the robot arm are controlled according to the path-based principle but gripper is controlled under time basis.

Fig.3. Robotic workcell control unit on the basis of VIPA-115 6BL02 controller

Table 1. **Input and output signals of control system**

Inputs (control buttons)	Inputs (buttons for mode selection)
SB0.0 (I0.0) – manipulator **“Forward”** (**“Manual”** mode)/ ***Cycle start*** (***“Automatic”*** *mode*)	SB8.0 (I2.0) – “Manual” mode
SB0.1 (I0.1) – manipulator **“To the right”** (**“Manula”** mode)/ ***Cycle stop*** (***“Automatic”*** *mode*)	SB8.1 (I2.1) – “Automatic” mode
SB0.2 (I0.2) – manipulator “Upward”	SB8.2 (I2.2) – “Cycle” mode
SB0.3 (I0.3) – manipulator “Clamp”	
SB0.4 (I0.4) – manipulator “Backward”	
SB0.5 (I0.5) – manipulator “To the left”	
SB0.6 (I0.6) – manipulator “Downward”	
SB0.7 (I0.7) – manipulator “Unclamp”	Outputs (electromagnets)
Inputs (sensors)	Y1 (Q1.0) – manipulator “Forward”
SQ1 (I1.0) – manipulator is in front pos.	Y2 (Q1.1) – manipulator “Backward”
SQ2 (I1.1) – manipulator is in rear pos.	Y3 (Q1.2) – manipulator “To the right”
SQ3 (I1.2) – manipulator is on the right	Y4 (Q1.3) – manipulator “To the left”
SQ4 (I1.3) – manipulator is on the left	Y5 (Q1.4) – manipulator “Upward”
SQ5 (I1.4) – manipulator is in upper pos.	Y6 (Q1.5) – manipulator “Downward”
SQ6 (I1.5) – manipulator is in lower pos.	Y6 (Q1.6) – manipulator “Unclamp”

In accordance with the cyclogram the program of robotic workcell has been designed using LADDER language, the fragment of which in programming environment WinPLC7 V4.42 (network 28... network 30) is shown in figure 4.

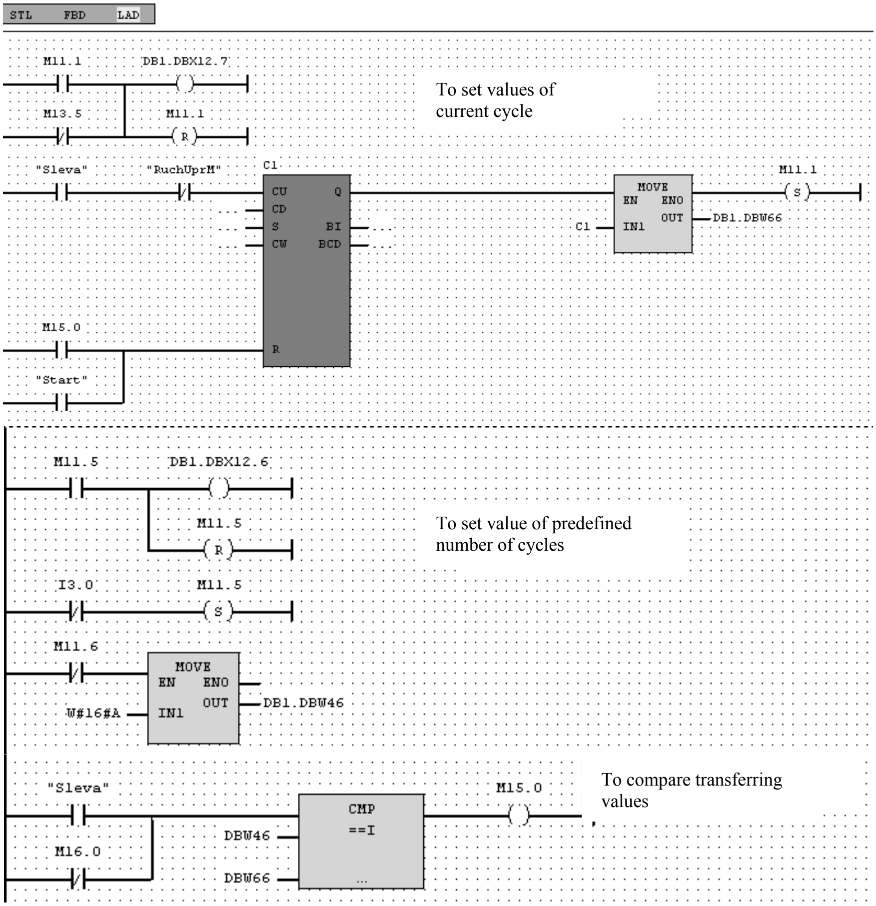

Fig. 4. Program fragment in LADDER language for functioning TD 03

Two input signals are used for program operation in order to switch control modes:

- input I2.0 – "Manual" mode: this mode involves 8 input signals more I0.0-I0.7 (for each movement);
- input I2.1 – "Automatic" mode: this mode involves 2 input signals more:

1. I0.0 – Start – when it is activated the cycle of MP-9S starts
2. I0.1 - Stop – when it is activated the cycle of MP-9S stops.

Programming environment WinPLC7 V4 includes operators MOVE, which allow to transfer numerical value (in hexadecimal format) to defined block and its memory area (e.g. record DB1.DBW46 indicates that the value will be transferred to block DB1 and will be assigned to the memory area DBW46), that is necessary for text display operation TD 03.

Indication of the number of cycles was performed on the text panel TD- 03 setup of which was made through TDWizard software. As a result of setting up the text panel displayed the message "Zad CIKLOV:" and the value of the block DB1 – DBW46. Record to this variable adjusted value of number of defined cycles was carried out by using "move" element. Continuous update of displayed data has been performed by activating the variable responsible for the pop-up message "TEKUSH CIKL:" - DB1-DBW66, figure 5.

Fig.5. Indication of robotic workcell operation on the text panel TD-03

Operator MOVE is used to transmit numerical values by DB1 block to text display TD 03. In block DB1, two messages were preprogrammed, with which appropriate value for memory area (DBW46 and DBW66) will be linked. One message having memory area DBW46, DBX12.6 at the start of the program shows the number of programmed cycles (input value in MOVE element in hexadecimal format *W#16#A*, i.e., 10). The second one (memory area DBW66, DBX12.7) displays the current cycle in triggering sensor I1.3 by using counter into MOVE element the counter value C1 is transmitted, which shows the change in number of cycles on the text display. Once the value of current and programmed value for specified number of cycles are coincide, the cycle MP- 9S stops (comparison of values provides an element WinPLC - comparator). By pressing Start button value the current cycle is reset to 0 and cycle counting begins again. In manual mode cycle counting is not performed.

When configuring PLC by enabling command "PLC Mask" a window with a virtual applied controller and extension units on the front panels is displayed, which reflects the presence of signals at respective inputs and outputs, similarly to operation of the real control system, which is very obvious and allows to quickly debug the control program.

CONCLUSIONS

Application of the software system Win PLC7 V4 allowed synthesizing the robotic workcell control system based on module Vipa-115 series CPU 115 6BL02, with testing programs in real time and allowed to use "TD03 Wizard" function for visual observation of the robotic workcell operation as displaying the current cycle.

The software allows easily adjusting execution time of a movement and provides synchronization of robotic workcell operation according to the limiting current conditions of transition.

Applying the operator "MOVE" in development of control systems allows quickly developing and debugging cyclic programs for real control systems.

REFERENCES

1. Verhovodov A.V. Using the programme package WinPLC V4 at development managerial system. Praci Lugansk Branch of IIA №2 (20) 2009. Part 2, p.10-13.
2. Verhovodov A.V. Study of the use pulsed sensor at development managerial system pipecarved tool. Praci Lugansk Branch of IIA №2 (22) 2010. p.18-22.
3. Verhovodov A.V., Oleinik R.G. Study of the using the block PI regulator of the programme package WinPLC at regulation temperature processes. Visnik SNU 2009 №3, p.32-35.
4. .Verhovodov A.V., Sereda A.A. Use the language and programming facilities SFC standard IEC 61131 at syntheses managerial system on base PLC Zelio Logic. Visnik SNU 2009 №3. p. 32-35.
5. Verhovodov A.V., Malahov O.V., Кalikhevich N.V. Syntheses managerial system horizontally-closed transport system with use the programming language FBD. System technologies. – № 2(31). – Dnepropetrovsk, 2007. p.104 -112.
6. Verhovodov A.V., Malahov O.V., Oleinik R.G. Studies of the possibility of the using PLC VIPA-100 for industrial robot governing MP-9. Praci Lugansk Branch of IIA 2008. №1. p.22-25.
7. Verhovodov A.V., Oleinik R.G. Study of the possibilities of the module of the analog entering-conclusion and text panel at regulation of the temperature. Praci Lugansk Branch of IIA 2008. №2. p.14-17.
8. Verhovodov A.V., Strelbytskyy A.A., Dyubakova V.M. Sintesing of control system of the packaging machine with use eventing operated logic. Visnik SNU 2010 №2 p.28-34.
9. AKM-Engineering production / www.akmeng.ru.
10. Catalogue of logic controllers Vipa/ http://umis-n.com.ua/vipa.
11. Components of industrial electricity saving and automation systems / http://svaltera.prom.ua.
12. Design of automatic process control system / http://energopolis.co.ua.
13. Industrial controllers / http://electroalyans.com.ua.
14. Manual WinPLC7 V4. / www.vipa.de.
15. Manual VIPA System 100V CPU-EM Order No.: VIPA HB100E_CPU-EM Rev. 06/14.
16. PLC Vipa / http://electromatica.ru.
17. Programmable logic controller Vipa / http://interexpo.com.ua.
18. VIPA art of automation/ www.vipa.de / www.speed7.com.

ИСЛЕДОВАНИЯ СРЕДЫ ПРОГРАММИРОВАНИЯ WINPLC7 V4 ПРИ РАЗРАБОТКЕ СИСТЕМ УПРАВЛЕНИЯ РТК

Александр Верховодов, Михаил Коваленко

Аннотация. Рассмотрена проблема использования программируемого логического контроллера серии VIPA SYSTEM 100V при разработке системы управления РТК на базе промышленного робота МП-9С с пневматическим приводом. Заданное количества циклов отображается на текстовой панели TD-03, настройка которой производится с помощью программного обеспечения TDWizard. Приведен фрагмент программы управления РТК выполненый на языке LADDER в среде программирования WinPLC7 V4.42.

Ключевые слова: логический контроллер, промышленный робот, пневматический привод, програмное обеспечение, програма, язык.

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IMPROVEMENT OF THE PREPARATION PROCESS OF MULTICOMPONENT FODDER FOR SMALL CATTLE

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Summary. Existing constructions of fodder chopper-mixers for small cattle are considered. Appropriateness of the design of a modular feed-preparing machine is proved.

Key words: Working body, module, technological effectiveness of the structure.

PROBLEM

At present, one can state with certainty that the basic direction of animal husbandry in Jordan is sheep breeding. Dynamics of sheep population is the evidence of this.

Table 1. **Dynamics of sheep population in Jordan according to the data of Food and Agriculture Organization of the United Nations (FAO)**

Year	1985	1990	1995	2000	2005	2010
Number of animals, head	582000	1121000	1556000	2181939	1833986	2331850

As it can be seen from the data of FAO as of 2010, 2331850 head of sheep were numbered in Jordan which on average made 0.4 sheep per one person. In addition, farmers of Jordan raise goats; in 2010 their total livestock population made 881970 head. Due to this reason fodder preparation for feeding is a very burning task which requires scientific researches.

Currently, fodder preparation process for feeding small cattle is not studied thoroughly. Absence of diversity of alternatives of fodder chopper-mixers adapted to a definite manufacturing environment indicates this. Therefore, it is necessary to work out a science-based theory of design of such machines.

Analysis of recent researches and published works. The basic results of theoretical and experimental researches of the efficiency of fodder chopper-mixers are given in the works of famous scientists: S.V. Melnikov, S.I. Nazarov, V.I. Perednya, L.P. Kartashov and others [1-4]. The works of these scientists are directed at the improvement of a working body which can chop several types of fodder and, at the same time, effectively mix ground components. However, in practice, chopping of concentrated fodder and roughage at the same time is not reasonable because fibrous materials of roughage decrease the impact force of nonground grains upon chopper's working surfaces.

The aim of the research is to determine the ways for improvement of a manufacturing process of fodder chopper-mixers for small cattle.

Results of the research. Effective sheep breeding is impossible without using multicomponent fodder (fodder mixtures) in ration.

Composition of loose fodder mixtures for small cattle is the following: 20 – 40% - straw, 12 - 26 – hay, 40 - 60 – silage, 7 - 17% – mixed fodder.

Composition of pelleted fodder mixtures for small cattle is the following: 35 - 50% – straw, 18 - 30 – grass meal, 20 - 40 – hay and grain fodder, 14 – 20% – mixed fodder.

Each component of a fodder mixture must correspond to definite zootechnical requirements which regulate: size of particles, number of admixtures, moisture and etc. In most cases, for manufacture of multicomponent fodder mixtures it is necessary to mix components which differ considerably by size features, see table 2.

Table 2. **Degree of grinding of fodder for small cattle**

Type of fodder	Size of particles, mm
Hay, straw	20-30
Silage, haylage	up to 50
Concentrated fodder	1-1.5
Tuberous roots	10-15

Taking into consideration the above-mentioned facts, we can say that increase of the efficiency of a mixing process of fodder for small cattle can be achieved using a mixing working body which can move effectively groups of particles of different size from one position into another. Moreover, an effective mixer must provide a continuous technological process with minimal energy and human resources expenses. It is also very important to take into account the fact that a fodder mixture of high quality can be obtained only from properly ground components.

The process of chopping and mixing of fodder mixture components for small cattle is effective only at a definite rotational frequency of a working body of a machine, see table 3.

Table 3. **Rotational frequency of a working body of a feed-preparing machine, turn/min**

Type of fodder	Chopper	Mixer
Hay, straw	650-800	18-250
Silage, haylage	700-1400	25-300
Concentrated fodder	980-1250	70-400
Tuberous roots	500-1000	275-350

As it can be seen from table 3 the rotational frequency of a working body is different for various fodder mixture components, though, despite such conditions, attempts are made to create fodder chopper-mixers which can provide rational modes of chopping and mixing during manufacture of multicomponent fodder mixtures.

It is necessary to make an analysis of the existing constructions of these machines in order to define the most rational construction of a fodder chopper- mixer for small cattle. The process of chopping and mixing is carried out simultaneously by a single working body of chopper-mixers. At present, the fodder chopper-mixer ISK-3 is very widespread (fig. 1).

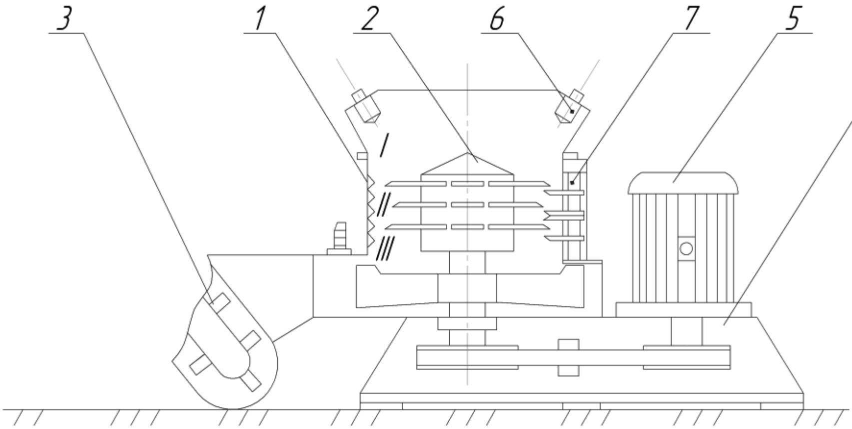

Fig. 1. Fodder chopper-mixer ISK-3:
1 – toothed deck; 2 – blade rotor; 3 – unloading conveyor; 4 – frame; 5 – power-driven station; 6 – nozzle; 7 – countercut; *I* – inlet chamber; *II* – chopping and mixing chamber; *III* – unloading chamber

The machine consists of a blade rotor 2; an inlet chamber *I,* a working chamber *II* and an unloading chamber *III* situated one above another; a bunker; an unloading conveyor 3; a set of countercuts 7; toothed decks 1; an electric motor and a V-belt drive equipped with a belt idler. Two nozzles 6 at an inlet and two of them at an unloading chamber are provided for the injection of liquid additives into the work bulk. The inlet and working chambers are connected by flip-up mounts. There are six openings in the walls of a working chamber where sets of blade-countercuts and toothed decks are installed.

Chopper’s blades, which are used as mixers, and hammers are situated on a working body-rotor. A two-blade spinner is situated in the lower part of the rotor situated in the unloading chamber.

A set of blade-countercuts is gathered at the shaft which is installed in a jointed position on the basis mounted to the body of the working chamber by bolts. In case if extraneous objects get into the chamber, a hinged spring mount of countercuts allow them to deflect without a breakdown and let solid objects in.

The productivity of the machine which works at mixing can reach 25 t/h, at mixing with partial regrinding – up to 5 t/h, at chopping, for example, of straw – up to 3-4 t/h at the cutting length of up to 30 mm and 4-8 t/h at the cutting length of 50 mm.

The chopper-mixer provides mixing of silage, straw, edible roots and mixed fodder with a degree of homogeneity – 80-90%; engine's installed capacity is 39.2 kW; rotor's rotational frequency – 17 c^{-1}; machine's dimensions –1600x1090x1150 mm; weight with an unloading conveyor – 2200 kg. The chopper-mixer is operated by one worker.

Advantages of ISK-3:

- continuity of the process;
- simplicity of the construction;
- chopping and mixing is carried out simultaneously;
- protection against consequences in case if extraneous objects get into the working zone;
- high homogeneity of mixture.

Disadvantages of ISK-3:

- high energy intensity of the process of fodder mixture preparation;
- pelleted fodder can't be added to a fodder mixture without being destructed;
- it doesn't mix fodder with grass meal;
- it doesn't chop concentrated fodder;
- the machine is stationary.

Fodder chopper-mixer-distributors are very widespread at present time. One of the disadvantages of ISK-3 has been removed; chopper-mixer-distributors are mobile machines. chopper-mixer-distributors are intended for preparation (loosening, partial chopping and mixing) and distribution (depending upon the used ration) of components (green bulk, silage, haylage, loose and pressed hay, liquid fodder additives) without a device for self-loading of components using an electronic system of weighting of fodder mixture components.

Working bodies of such machines are a twin-screw mixer with blades installed on its augers (fig.2).

The distinctive feature of these machines is a vertical or horizontal position of two augers of a higher pitch. It allows to obtain loose fodder mixture from several components. Availability of adjustable countercuts permits to change a degree of chopping of fodder mixture components. The productivity of such machines makes 12 t/h, bunker capacity – 12 m3, mixing time – 5-7 minutes; weight – up to 5300 kg; it is unitized with a 1.4-2 ton-force class tractor [5, 6].

Advantages of fodder chopper-mixer-distributors:

- high productivity;
- considerable body space;
- the machine is mobile;
- mixing time – 5-7 minutes;
- availability of an electronic system of weighting of fodder mixture components.

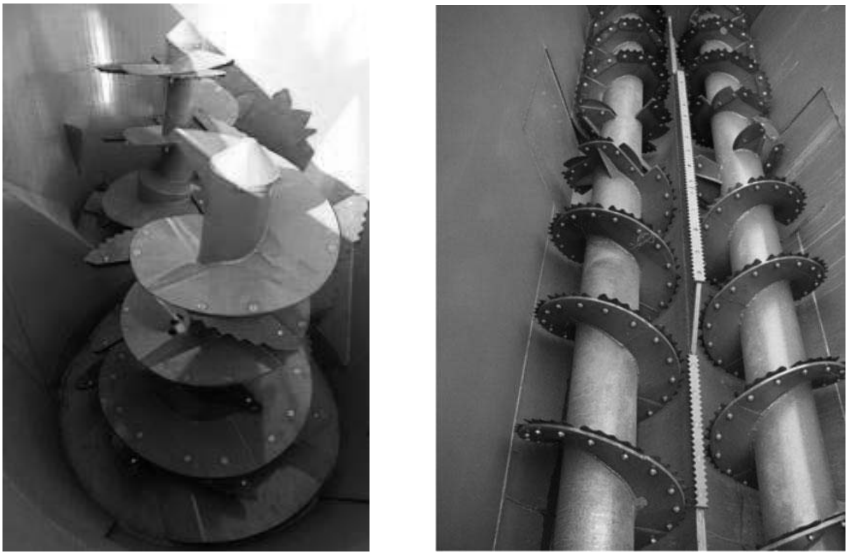

Fig. 2. Working bodies of fodder chopper-mixer-distributors:
a – a vertical twin-screw one (ISRV-12);
b – a horizontal twin-screw one (RSK-12)

Disadvantages of fodder chopper-mixer-distributors:

- the machine is of a sampling action;
- high energy intensity and materials consumption;
- low quality of chopping of roughage, stem and succulent fodder;
- chopping of concentrated fodder is impossible;
- low efficiency during mixing of concentrated fodder with roughage and succulent fodder.

It is possible to estimate technological effectiveness of the above-mentioned constructions of chopper-mixers with the help of a coefficient of block structure.

Block coefficient *Cb* increases technological effectiveness of the construction [1-4]:

$$Cb = \frac{\sum Caut}{\sum Ct},$$

where: $\sum Caut$ - number of the independent systems of the construction, table 4;
$\sum Ct$ - total number of systems of the construction (loading, chopping with mixing, unloading).

Table 4. **Calculation of block coefficient for analyzed machines**

Model of a machine	Total number of systems of the construction, pieces	Number of the independent systems of the construction, pieces	Block coefficient
ISK-3	3	1	0.33
ISRV-12	3	2	0.66
RSK-12	3	2	0.66

On the basis of Table 4 we can make a conclusion that an effective fodder chopper-mixer for small cattle must consist of several independent units (modules). It is evident that the number of independent modules must correspond to the quantity of the operations carried out by a chopper-mixer.

The analysis showed that equipping screw working bodies with blades doesn't provide the necessary degree of chopping of all the components of a fodder mixture for feeding small cattle so one can suppose that a mixing working body of a fodder chopper-mixer for small cattle and its chopping units must be an independent module.

CONCLUSIONS

1. Simultaneous chopping of concentrated fodder and roughage is not reasonable because fibrous materials of roughage decrease grain's impact force upon the working surface of a chopper; that is why equipping screw working bodies with blades doesn't provide the necessary degree of chopping of all the components of a fodder mixture for feeding small cattle.

2. An effective fodder chopper-mixer for small cattle must consist of several independent units (modules); the number of independent modules must correspond to the quantity of the operations carried out by a chopper- mixer.

REFERENCES

1. Melnikov S.V.: Mechanization and automatization of cattle farms / Melnikov S.V. – L.: Kolos, 1978.
2. Nazarov S.I., Bober O.A.: Improved fodder shredder -mixer / Nazarov S.I.., Bober O.A. Tractors and agricultural machines.- 1989.- № 5.- Pages. 39-40.
3.Perednya V.I.: Ground of vertical type fodder shredder-mixer characteristics. Interdepartmental subject collection.- Isssue 27 / Perednya V.I. CNIIMESH nonchernozem belt in USSR.- Mn.: Uradzhai, 1984.- Pages.20-24.
4. Kartashov L.P., Bashkov A.F., Manannikov P.P.: Improvement of a shredders' work process / Kartashov L.P., Bashkov A.F., Manannikov P.P. Farm mechanization and electrification.- 1987.- № 9.- Pages. 44-45.
5. A fodder shredder-mixer-dispenser ISRV-12. Bobruisk Agromash. Access mode http://www.agromash.by/catalog/foddermachine/isrv12/.
6. A fodder shredder-mixer-dispenser RSK-12. "BelMix" Access mode http://belrusagro.ru/kormorazdatchiki/razdatchik-smesitel-kormov-rsk-12-belmiks.html.

7. Aleshkin V.R.., Roshchin P.M.: Mechanization of cattle breeding / V.R. Aleshkin, P.M. Roshchin. - M.: Agropromszdat, 1985. – 336 pages.
8. Mzhelskii N.I., Smirnov A.I.: Information book in мechanization of cattle farms and complexes / N.I. Mzhelskii, A.I. Smirnov. - M.: – Kolos, 1984.
9. Belyanchikov N.N., Smirnov A.I.: Mechanization of cattle breeding / N.N. Belyanchikov, A.I. Smirnov. - M.: Agropromizdat, 1989.
10. Zavrazhnov A.I., Nikolaev D.I.: Mechanization of feed preparing and feed storage / A.I. Zavrazhnov, D.I. Nikolaev. - M.: Agropromizdat, 1990.
11. Mechanization and technology of manufacturing of cattle breeding / [Koba V.G., Braginets N.V., Murusidze D.N., Nekrashevich V.F. and others.]; under the editorship of Braginets N.V. - M.: Kolos, 1999.
12. Venediktov A. M.: Feeding of farm animals: information book.- publication 2 / venediktov A.M. – M.: Vishaya shkola, 1980. – 336 pages.
13. Braginets N.V., Palishkin D.A.: Course and diploma projecting in mechanization of cattle breeding / N.V. Braginets, D.A. Palishkin – M.: Agropromszdat, 1991.-191 pages.
14. Kulakovskiy I.V.: Machines and equipment for preparation of fodder / I.V. Kulakovskiy – M.: Rosselkhozdat, 1987.-226 pages.
15. Melnikov S.V.: Technological equipment of cattle farms and complexes: publication 2 / S.V. Melnikov – M.: Agropromszdat, 1985.-640 pages.
16. Ghalkin A.F.: Complex mechanization of production processes in cattle breeding / A.F. Ghalkin – M.: Kolos, 1986.
17. Justification of technological process and parameters of the working bodies of flexible universal compact feeds-preparing unit in the form grinding of coarsely feeds: dissertation of PhD: 05.20.01 / Volvak S.F. – Lugansk, 1998.- 178 pages.
18. Goryachkin V.P. Collection works: in 3 books. / V.P. Goryachkin. – M.: Kolos, 1968. – 484 pages.
19. Reznik N.E.: Theory of blade cutting and foundation of cutters counting / N.E. Reznik. – M.: Mashinostroenie, 1975. – 311 pages.

СОВЕРШЕНСТВОВАНИЕ ПРОЦЕССА ПРИГОТОВЛЕНИЯ МНОГОКОМПОНЕНТНЫХ КОРМОВ ДЛЯ МРС

Аль Атум Мохаммад

Аннотация. Изучены существующие конструкции измельчителей-смесителей кормов для мелкого рогатого скота. Доказана целесообразность разработки модульной кормоприготовительной машины.

Ключевые слова: Рабочий орган, модуль, технологичность конструкции.

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CONTENT