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Introduction

The development of new technologies, new trends in economics of technology, mathematical and computer process modeling have been a legitimate reason to start the edition of a new international journal under the name ECONTECHMOD (INTERNATIONAL QUARTERLY JOURNAL ON ECONOMICS IN TECHNOLOGY AND MODELING PROCESSES). This is a quarterly published in English (Volume 1 and 2) and Russian (Volume 3 and 4), in a book and electronic form. This edition presents the first issue of the new journal. We hope that the problems raised in the works obtain the approval of readers and in the near future this quarterly magazine will be listed on the list of journals scoring by the Ministry of Science and Higher Education. The themes of the papers published in the journal ECONTECHMOD and its international character resulting from the participation of many prominent writers and recognized academics from Central and Eastern Europe will increase even more the status of cooperation among our countries, and in particular with Ukraine. It is worth emphasizing that the Program Council of the magazine consists of scientists of many countries in Europe, which ensures that the publications will be a perfect opportunity for a wide, multilateral exchange of scientific ideas and the lessons learned will be used to promote further international integration, regardless of geographic location. It should also be noted that the organization and publication of the magazine has been our great achievement on an international scale. As mentioned earlier, the involvement of numerous outstanding scientists from many countries in this project gives even more credibility to the fact that it will maintain a high scientific level of the published works.

Special congratulations are due to professor Eugeniusz Krasowski, who in spite of the accumulating difficulties with vigor improves and creates new forms of cooperation on the international arena.

With the above-mentioned facts in mind, professor Eugeniusz Krasowski, representing the Polish Academy of Sciences Branch in Lublin, as the Editor-in-Chief of TEKA and MOTROL, has invited the following major research centers to collaborate in the creation of the new international journal ECONTECHMOD: Rector of the Lviv Polytechnic National University prof. dr Yuriy Bobalo, Director of the Foundry Research Institute in Cracow prof. dr Jerzy Sobczak, Head of the Department of Technology Fundamentals prof. dr Andrzej Kusz and Professor of the Department of Management and International Entrepreneurs prof. dr Nestor Shpak.

Editors: Eugeniusz Krasowski
Yuriy Bobalo

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Nanostructure of the soluble sodium silicate in the aspect of basic mechanical characteristic of the moulding sands

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Abstract. The paper describes the consequential advantages of the use of inorganic binders, particularly soluble sodium silicate, in the aspect of the environmental protection. Nanostructure of the soluble sodium silicate as a silicate colloid is described. Research of the structure of the soluble sodium silicate is executed with the use of the *PCS* method (*Photon Correlation Spectroscopy*). Characteristic parameters of the nanostructure of the soluble sodium silicate and the method of the estimation of the quantitative structure of the colloid are introduced. It has been proved that the nanostructure of the soluble sodium silicate has an essential influence on its proprieties as binders of the moulding sands. Mechanical characteristic of the moulding sands executed with this binder are dependent on the kind of the nanostructural characteristic of the soluble sodium silicate.

Key words: nanostructure, colloid, soluble sodium silicate, moulding sand, casting, environmental protection.

INTRODUCTION

About 80% of all foundry moulds are made in Poland from standard sands with bentonite binder and coal dust, or with lustrous carbon carriers. The processing plants for sands of this type are equipped with wet or dry dust collecting systems. The sludge or dust formed during mould preparation is an unnecessary burden for the foundry. Besides, the condensates of compounds are generally considered as *HAPs* (*Hazardous Air Pollutions*), they contain silica, deactivated bentonite, active bentonite and thermally non-deactivated particles of organic binder-hardener systems (sulphonic acids, pyridine derivatives, esters, isocyanates, amines, copper salts, ammonium salts, hexamethylenetetramine). Numerous studies [12,16] have proved that coal dust, organic lustrous carbon carriers, cores with organic binders and protective coatings based on alcohol or water are the main sources of hazardous air pollutions (*HAPs*), emitted during the process of casting production in standard moulding sands. The pollutants emitted in the largest volumes include benzene, toluene, o-, m-, p-xylene, naphtalene, hexane, and their derivatives. When core sands with organic binders are used, others *HAPs* are formed, to mention only phenol and formaldehyde, both of which can occur in large amounts. Besides the above mentioned *HAPs*, the process of casting manufacture in standard moulding sands is the source of the emission of other compounds included in the group of *HAPs*, like acetaldehyde, acrolein, aniline, pyrokatechine, o-, m-, p-cresol, cumene, hexane, isophorone, methyl, indene, polyclic organic compounds, priopionaldehyde, styrene, triethylamine [11, 1, 3]. Other technologies of the casting production also generate injurious products of the thermal destruction [15, 19, 24]. It is the reason of great interest in inorganic binders, such as soluble sodium silicate. This is especially important in the case of producing casts from special alloys [20, 22].

The main advantage of soluble sodium silicate is low toxicity of this binder in all the processes of casting production - and thus - during the preparation of sands, pouring and knocking. The principal aim of these investigations is the limitation of quantity of soluble sodium silicate in moulding sands and cores, but at the same time the maintenance of their proper technological properties, especially the mechanical ones.

STRUCTURE OF THE SOLUBLE SODIUM SILICATE

A characteristic element of the structure of soluble sodium silicate is micella. The seed of this colloidal particle, possessing negative charge, is structural, individual – polijon $(Si_8O_{20})^{8-}$. Polijon enlarges as the result of condensing on his surface of ions of monomers and in final effect reaches the state of silicate poliparticle with the core in the form of molecular SiO_2 and with the

surface possessing negative charge due to groups OH^-. In certain circumstances, this kind of spherical particle has an ability of joining oneself to oneself (Si-O compounds). Adjoining molecules fix mutually one's own compound, due to which, in the final effect, they develop into porous, interlaced nets of fully extended chains. Thus, we can assume that the formation of structure in soluble sodium silicate is performed in three phases [4, 23]:

1. Mutual joining of monomers with rising spherical, colloid particles on warp of octamer ion.
2. Increase of spherical colloid particles.
3. Bonding of exchanged particles, at first in chains, and then in nets spreading in throughout the liquid medium and thickening it to the form of gel (naturally, this phase is reached in the situation of disturbing the state of equilibrium in a glass of water).

Molecules SiO_2 create the core of micel adsorbing ions $[SiO_3]^{2-}$ and in this way micels starts possessing negative charge. It absorbs the ions of opposite charge $[H^+]$, creating micels. Ions $[H]^+$, in absorption layer, create electric double layer. Adsorbing ions $[H]^+$, stepping out in further distances from core, they create dyfusion layer of micel. During the movement of micel in solution, part of adsorbing ions $[H]^+$ stays in solution, and a difference of potentialsis created between the particle and the border free from its bounded ions. That is the so-called electrokinetic potential *Zeta* [5, 6, 14, 17, 18]. Potential *Zeta* usually qualifies the stability of the colloid arrangement [14, 17]. So, we can ascertain, that the surface of particle occurring in soluble sodium silicate possesses negative charge and becomes surrounded with ions of opposite charge, strongly bounded with it. The layer of liquid surrounding the particle consists of two parts:

1. Parts determining internal area ("*Stern layer*"), in which ions are strongly bounded with particle.
2. Parts determining external area (difusion layer), in which ions are considerably more weakly bounded with particle.

Inside difusion layer extends the agreed border of area, of which antiions and colloidal particle of soluble sodium silicate create a stable part. When a movement of the particle occurs (e.g. under an influence of Brownian motions or gravitation), ions present in this area shift together from it. Ions staying outside the area do not perform movements together with the particle. Summing up – soluble sodium silicate - practical in foundring, is an electrolyte, and its ions are also present in hydration layer.

Characteristic build of colloid, which is soluble sodium silicate - will imply the use of *Photon Correlation Spectroscopy* (*PCS*), to qualifications of size and decay of size elements of the structure of these binders [7, 10, 13].

The analysis of *PCS* determines a considerable progress in the area of measuring methods for determination of particle sizes. It makes it possible to investigate a sample in the natural state, does not cause its destructions or structural changes. In this kind of method, the measurement of stochastics Brownian motions takes place and on this basis the size of particles is analyzed.

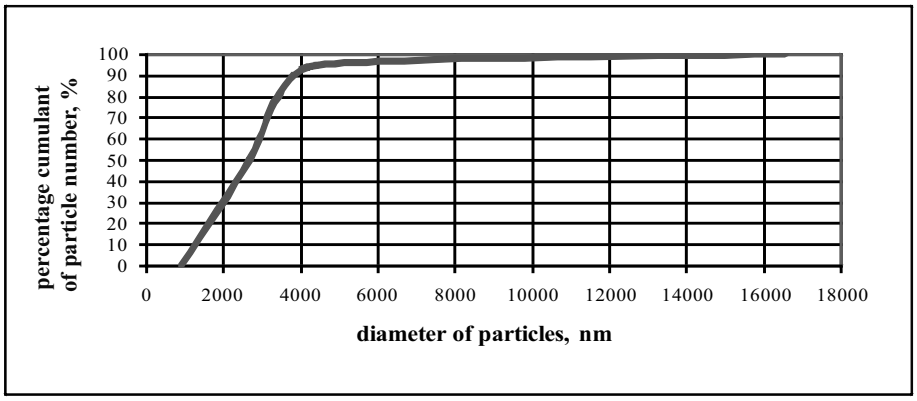

Fig. 1. Percentage cumulant of the number of particles in soluble sodium silicate *m_2,1_1,45* after filtration by filter *C*

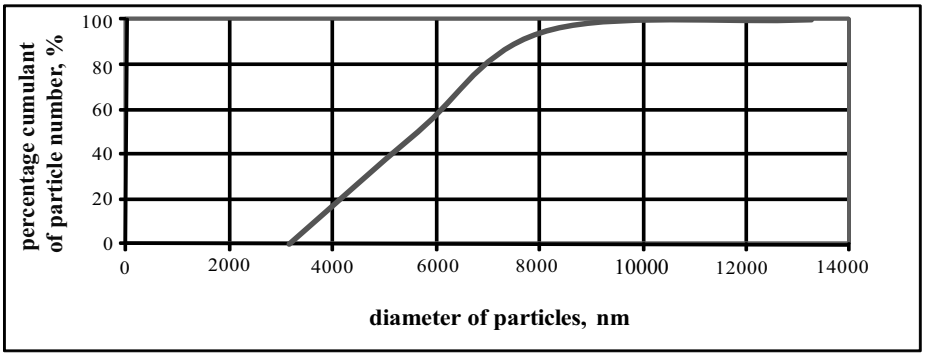

Fig. 2. Percentage cumulant of the number of particles in soluble sodium silicate *m_2,3_1,40* after filtration by filter *C*

As an example, it is possible to present the results of investigations of soluble sodium silicate with modulus M = 1,95; 2,1 and 2,3 - obtained from sodium-silicate glasses melted with the above values of modules. Every kind of soluble sodium silicate had the density 1,40; 1,45 and 1,50 g · cm^{-3}.

The second kind of soluble sodium silicate possesses analogous values of module and density, but is obtained from sodium-silicate glasses with modulus 3,3 by the method of modification of chemical composition (using NaOH).

Considering the fact, that the investigated solutions were in the state of polidyspersity and high polidyspersity, it was necessary to use their filtration in order to ascertain the presence of elements of structure, which in basic solutions (not filtered) can be dominated by elements of large sizes [4].

An easier and more exact interpretation of the investigations results is possible by calculation and constructing the percentage cumulant of numbers of particles in dependences of sizes of their diameters. Figure 1 and 2 illustrate cumulants for samples *m_2,3_1,40* (soluble sodium silicate obtained with the method of modification of chemical composition, with modulus 2,3 and density 1,40 g · cm^{-3}) and *m_2,1_1,45* (soluble sodium silicate obtained with the method of modification of chemical composition, with modulus 2,1 and density 1,45g · cm^{-3}) after filtration by filter *C* [4].

Qualification of characteristic parameters of the structure for the soluble sodium silicate is possible - values of average diameter of particles of the main fraction *dG*, halfwide *dsG* and range of particles of diffuse fraction *dsR*. (Fig. 3).

Description of characteristic parameters of structure, makes the so-called "partial indicator of structure WB_i" possible, calculated for solutions not filtered (*nf*) and for solutions obtained after filtration (*fA*; *fB*; *fC*). Diameters of pores of the used filters are: *A>B>C*:

$$\mathrm{WB_i} = \frac{\mathrm{dG_i}}{\mathrm{dsG_i} + \mathrm{dsR_i}}. \tag{1}$$

Indicator *WB*, determining sum of indicators WB_i, became accepted as indicator of nothomogeneity of soluble sodium silicate:

$$\mathrm{WB} = \sum_{\mathrm{i=nf}}^{\mathrm{i=fC}} \mathrm{WB_i}. \tag{2}$$

The second indicator of structure of the investigated samples of soluble sodium silcate - *DWB*, expresses the maximum difference of value of partial indicators WB_i. This indicator is characterized by a lack of homogeneities in arrangement, pointed out by indicator *WB*:

$$\mathrm{DWB} = \mathrm{WB_i\ max} - \mathrm{WB_i\ min}. \tag{3}$$

Values of indicators WB for different kinds of water glass are presented in Figure 4.

Investigations of the hydrations enables the qualification of dependence among the form of water (free water and bounded water), the quantity of this kind of water in a glass and the kind of its structure (Fig. 5). These investigations were performed by deriwatograph method. In the temperature from about 20^{0}C to about 70^{0}C and

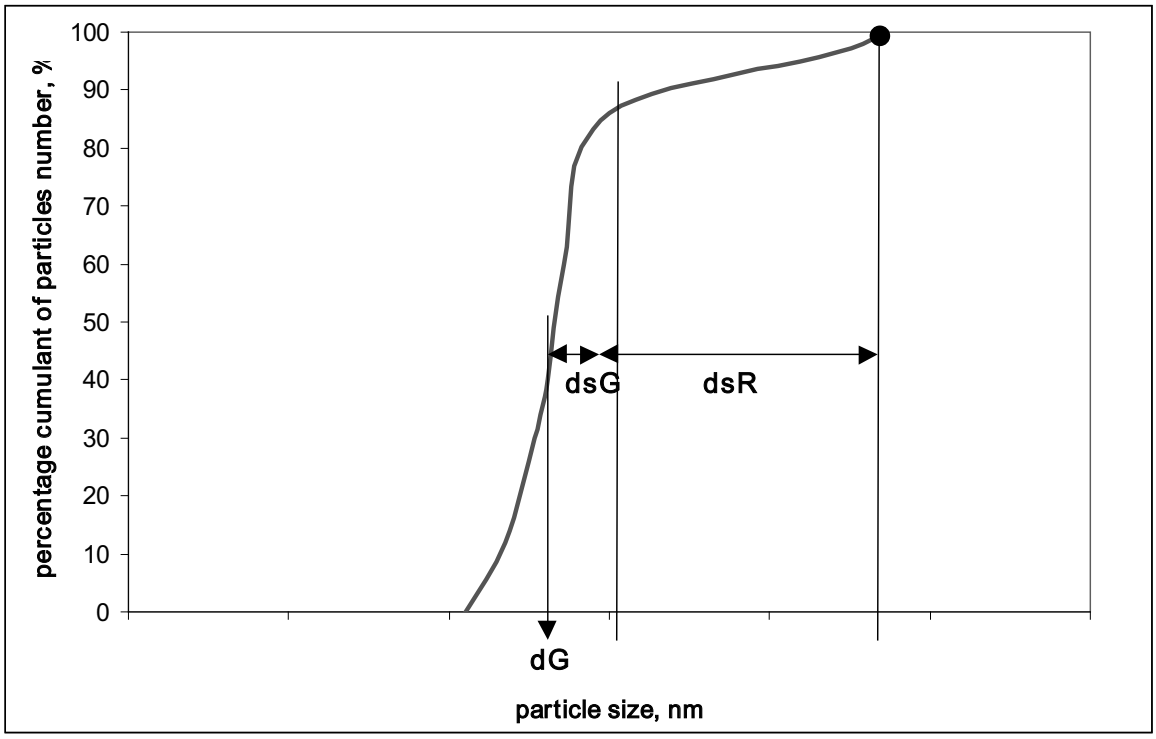

Fig. 3. Percentage cumulant of the number of particles

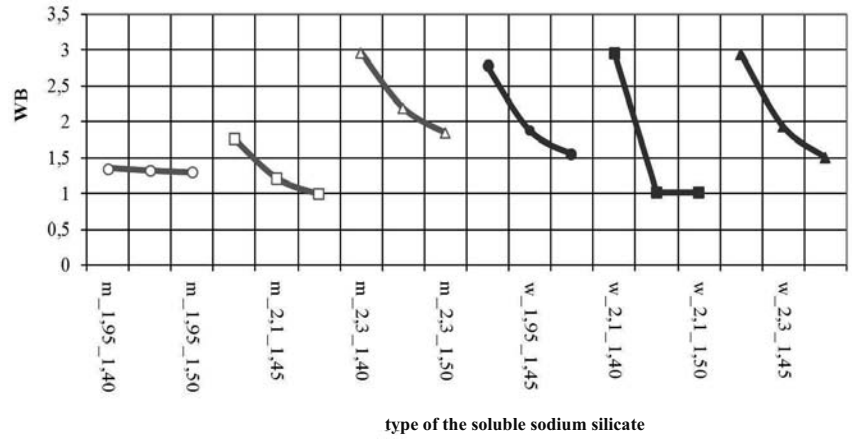

Fig. 4. Coefficient of structure *WB* for the soluble sodium silicates with different values of modulus and density, produced by different methods

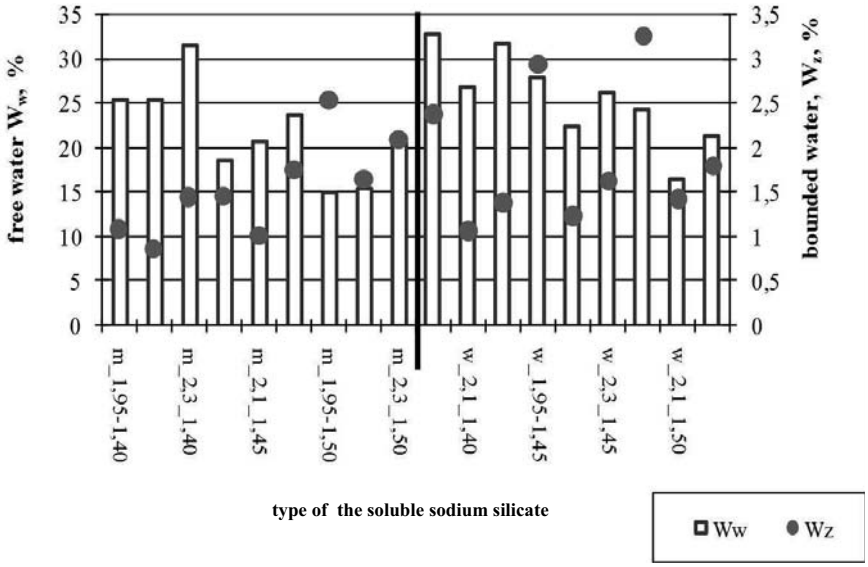

Fig. 5. Coefficient of structure *WB* for the soluble sodium silicates with different values of modulus and density, produced by different methods

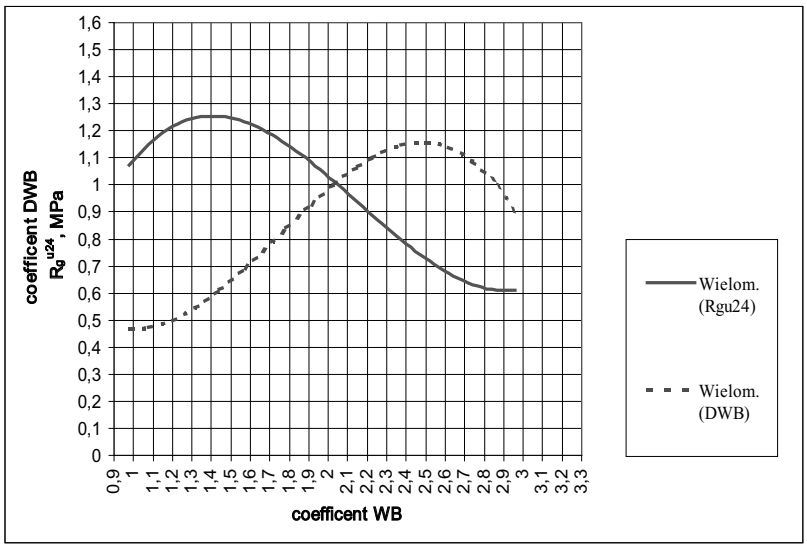

Fig. 6. Bending strength Rg^{u24} of moulding sand with soluble sodium silicate and ester, (after 24 hours of curing) and corresponding to them values of coefficent *DWB*, in dependence from values of coefficent of structure *WB* for different types of the soluble sodium silicate

from about 115^{0}C to about 140^{0}C, on *DTG* appears piques testifying about dehydration of soluble sodium silicate, related to a little endothermic effect on *DTA* [4].

Technological verification of investigations was performed. The moulding sands containing soluble sodium silicate with identical quantity sum of the oxides (SiO_2 + Na_2O), were cured with diacetate eyhylene glicol. Moulding sands were made, cured and investigated in identical conditions of environment (20^{0}C and 60% r. h.) in the climatical chamber. Figure 6 presents the dependency of strength properties of the moulding sands *vs* structure indicator *WB*.

CONCLUSIONS

1. We can accept, that in the range of the temperature from about 20^{0}C to about 70^{0}C, first the dehydration of soluble sodium silicate appears (loss of the free water W_w). In the range of the temperature from about 115^{0}C to about 140^{0}C, bounded water W_z is removed from the soluble sodium silicate.

2. It is very probable, that the content of the free water W_w has a great influence on the size of nanoelements in the soluble sodium silicate.

3. Two value of indicators *WB* and *DWB* can be defined as follows:

$$\mathrm{WB} \in (3,0;1,8) \text{ and } \mathrm{WB} \in [1,8;1,0),$$

$$\mathrm{DWB} \in (1,44;0,8) \text{ and } \mathrm{DWB} \in [0,8;0,13).$$

The most profitable strength properties of the moulding sands were obtained for the structures of the soluble sodium silicate with the values of indicators *WB* in the range up to 1,8 and *DWB* in the range below 0,8.

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The problem of highly effective cleaning of air from dust

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A b s t r a c t. The article deals with the problem of providing high performance apparatuses for cleaning air from dust in various branches of industry in order to reduce hazardous emissions to the level conforming to sanitary-hygienic norms. The article describes new trends in the development of dust catching apparatuses based on the use of centrifugal-inertial forces, permitting to significantly improve the effectiveness of dust catching.

K e y w o r d s: dust. catching, air cleaning, pollution, centrifugal, cyclone.

INTRODUCTION

Along with various natural phenomena (volcanic eruptions, forest fires, soil weathering and erosion, etc.) the human activities causing pollution of the atmosphere, connected with the use of natural resources and the development of industry, agriculture, construction and transport, play an ever growing role in the appearance of the problem and its solution. Due to the insufficient level of knowledge, inadequate technology or absence of comprehensive prognostic analysis these activities are accompanied by unwanted processes – emission into the atmosphere of the whole range of harmful by-products. Polluting the atmosphere, these by-products cause tremendous, often unjustified harm not only to the environment, but to humans as well.

The problem of prevention of atmosphere contamination has long ago crossed the borders of separate nations and even entire continents, and has acquired the status of the international problem and become common for practically all countries of the world. This has been determined by a number of reasons: solidarity of interests in the development of measures and means aiming at the reduction of levels or complete elimination of emissions of hazardous admixtures into the atmosphere, by the importance of collaboration and exchange of information on the development of methods and means of prevention of harmful consequences of atmosphere contamination and losses they create and, finally, by the fact, that the hazardous materials are carried over great distances regardless of the state borders.

Once it becomes evident, that the improvement of technological processes, establishment of sanitary-hygienic zones, increased height of smokestacks and other measures cannot reduce the level of pollution of atmospheric air to the maximum permissible concentration level, emissions must be purified to such a level, that in the end they do not exceed the norm of maximum permissible concentration.

The analysis of latest research works: at present the cleaning of contaminated air and gases is the main method of protection of air basin from pollution, applied in all cases when the use of active cleaning methods is still impossible or economically unfeasible. The task of industrial gas cleaning is the neutralization of the air basin from organized gas emissions and stationary pollution sources.

The cleaning of emissions is simplified considerably if emitted gases, for example stack gases, move along the gas ducts. In many cases, however, for example in operating mills, pickling installations, electroplating tanks, in dressing and cleaning castings, in plastic, glass-reinforced plastic, fabric-based laminate materials processing, etc. it is necessary to use special measures to avoid a direct emission of these materials into the atmosphere. In other cases, the admixtures not only become dangerous for the operators and adverse for the product quality, but become hard to catch.

For this reason, catching hazardous materials directly from the source of emission is the guarantee of not only improved hygienic conditions of labor at work places, but of high effectiveness of dust catching installations, which, as a rule, consist of the following elements:

– collecting device, which may consist of one or several dust collectors,
– grid of pipe-lines,
– fan, drawing off dust-laden or gas-contaminated air via pipe-lines to the dust-cleaning installation.

The systems of cleaning and decontamination of gas emissions can be conventionally divided into 2 large groups:
– group I – installations for cleaning from toxic gas admixtures (chemical cleaning),
– group II - installations for cleaning gas emissions from sprays (dust, smoke, droplets or fog).

MATERIALS AND METHODS

The greatest achievements in centrifugal catching of solid particles from a gas flow have been noted in the field of hardware design (engineering) and not in the field of scientific projects, which is explained on the one hand by the accumulation of long experience of operation of industrial installations and, on the other hand, by exceptional complexity of description of separate phenomena and characteristics of heterogeneous systems: rigid body – gas in centrifugal force field. For this reason, the theory of cyclone operation is still underdeveloped and does not provide an opportunity to calculate cyclones of various designs. For example, the problem of the most suitable shape of a cyclone till now is resolved only empirically or experimentally.

Different requirements are presented as to the level of final dust content in gas flows depending on physico-chemical properties of dust, technological parameters of dust-gas flows, especially with respect to fine toxic dust. For this reason, it is possible to find a range of decisions when solving the problem of design of centrifugal force apparatuses for separation of solid particles from gas flows. The analysis we have carried out showed a great number of various designs of centrifugal force apparatuses, whose design most often has not been supported by theoretical and experimental investigations of the structure of the formed flows and the process of separation of their particles.

We shall note, that the main effect on the efficiency of separation of solid dust particles in centrifugal force apparatuses is produced by improvements made on the apparatus body, whose purpose is, predominantly, to increase the centrifugal factor of separation or reduce the harmful effect of increased centrifugal factor of separation, or reduce the harmful effect of radial removal of dust.

A large number of various constructions of dust catchers for the same purpose, which do not have any clear specifications, stand in the way of selecting an appropriate system of cleaning in the process of design of dust catching devices, and absence of standardized dust cleaning equipment is an obstacle on the way to resolve the problem of organization of manufacture of such equipment.

To simplify the process of choosing the type of dust catchers for each specific case an attempt has been made to standardize, arrange in an order all known constructions of dust catchers, placing them by way of comparative testing in a small specific order by their efficiency, hydrodynamic resistance and specific quantity of metal per structure with equal power, air consumption in order to specify design of the apparatus with the best operating characteristics, which may become a prototype for the design of a new type of apparatus.

RESULTS AND DISCUSSION

For this purpose we have used the “Uniform techniques of comparative testing of dust catchers”, which include the item of preparation of experimental dust, determination of its parameters, means of contamination with dust of the air supplied to the dust catcher,

Table 1. Indices of dry dust catchers

Cyclone type	Degree of dust removal, %	Diameter, mm	Height, mm	Specific quantity of metal per structure, m^2	Surface area, m^2
LIOP	1.23	1.17	0.8	2.07	1.05
SIOP СІОП	1.05	1.62	0.7	1.82	0.92
VNDIOP	1.05	1.25	0.91	2.22	1.05
T-4/630	0.96	1.14	1.57	3.64	1.85
STN-11	1.00	1.00	1.00	1.96	1.00
STN -15	1.05	0.90	0.93	1.67	0.85
STN -15У	1.26	0.92	0.70	1.29	0.66
STN -24	1.35	0.75	0.72	1.09	0.55
Matroshka	1.62	1.43	0.92	3.67	1.86
UST -38	0.78	1.60	1.25	3.86	1.73
4B STSH	0.82	1.10	0.53	2.47	1.26

degree of diagglomeration of dust in case of artificial contamination of the air with dust, established as mandatory for conducting of bench tests of various types of dust catchers: air filters, dry-type cyclones, wet-type dust catchers, fabric filters, individual duct catching apparatuses.

Principal parameters dry-type dust catchers with similar power and air consumption, efficiency and pressure 1•103 Pa are shown in Table 1.

Efficiency is shown in the form of relation of dust removal from the given cyclone to dust removal from cyclone CN-11 (standard). Specific quantity of metal per structure is the value of the cyclone surface per 1000 m3/hr of the cleaned air.

To determine the place of domestic dust catchers we have provided specifications of the best foreign apparatuses in Table 2.

Modern gas-cleaning units for cleaning exhaust industrial gases to the degree, which meets the requirements of sanitary-hygienic norms, and installations, intended for cleaning of technological process, as a rule, cannot operate with high efficiency, because most of gas-cleaning units are rather complicated installations, consisting of a number of gas-cleaning apparatuses of various types, installed in several stages.

Table 2. Specifications of foreign apparatuses

Type of dust catcher	Productivity, m^3	Hydrodynamic resistance, Pa	Efficiency, %
D1-DIV Poland	800-100000	1350	92.2
TGL Germany	800-5760	1200	90
SGA Czechia	800-100000	1650	90.8
SHA England	800-100000	1730	91.2
TOSHIBA Japan	800-100000	850	94.1

Using our theory of the process of separation of heterogeneous systems by way of destruction of turbulent vortexes in dust catchers we can determine the minimal size of the particle moving under the influence of centrifugal force to the body wall upon its separation from the vortex and the maximal size of the vortex itself, thus determining dimensions of the apparatus, specifically the distance from the external to the internal wall of the body. Fine dust particles are under the influence of turbulent efficiency, which does not permit them to separate from the flow and they continue to move with the flow to the internal wall. The main task at this stage is freeing the particle from the influence of vortex, which is possible only in case of destruction of the latter. This can be achieved provided, that the internal wall of the apparatus is made in the form of shutter-type separator instead of one-piece wall.

Taking into consideration the mathematical model of the process of separation in centrifugal-inertial force dust catchers we have proposed a new group of apparatuses, whose operating principle is based on the combination of centrifugal, inertial forces and weight. The know-how of all groups is the presence in the apparatus body of the second cleaning stage – shutter-type separator, in which dust-and-gas flow is subjected to additional cleaning passing through the shutters.

The cleaning of air from dust in the apparatuses we have designed takes place as follows: dust-laden air comes in tangentially, predominantly to the upper part of the apparatus, where at first under the influence of centrifugal forces the flow is separated layer by layer: larger (by size and weight) particles of spray are deflected to the internal wall of the apparatus body and continue their circular motion along the wall, while fine particles move in circles along the internal single-piece outlet pipe for cleaned air. One half of revolution is sufficient for this process, which has been proved experimentally. At section 1 of the apparatus, the cleaning of the air from dust occurs in the way similar to cyclone operation. At section 2 of the apparatus, additionally to this process the secondary cleaning of the air from dust begins along the shutter separator placed coaxially to the apparatus body. Gas flow flows past the separator shutters and turns at the angle over 900 but less than 1800 and goes out to clean air outlet pipe through the openings between them. Fine dust particles which have not been separated from the flow by centrifugal forces also approach the separator, but owing to their inertia they lag behind gas and hit the separator shutters and, depending on their location on the shutters they are either repelled to the wall of the body and caught up by the dust flow moving there, or dragged again by gas going to the separator for additional cleaning, hit the shutters again and so on, till they finally get into dust flow moving along the walls of the apparatus body, which will transport them to dust outlet pipe. The number of collisions depends on the parameters of dust (dispersion composition, physico-chemical and morphometric indices), gas flow (velocities: when entering the apparatus, of movement in the apparatus body, of passage through the shutter separator) and design features of the shutters, determining the angle of attack (angle between the direction of movement of gas flow and area of each shutter) and clear opening area.

During many years we have been improving the design of these groups of apparatuses, upgrading their efficiency and structural elements in principle. We have most dramatically and effectively have improved the construction of the separator's shutters. Construction features of dust catchers and their elements are protected by the author's certificates and patents.

All experimental investigations were carried out using the standard experimental stand of the State University «Lviv Polytechnic» in accordance with the «Uniform manual» for comparative specifications of dust catchers using standard quartz dust with clearly specified median diameter.

As the result of experiments the following has been determined:

1) The effectiveness of dust catching increases with the increase of: total consumption of the air in the stand; median diameter of dust particles entering the dust catcher; hydrodynamic resistance.

2) The fraction effectiveness of dust catchers increases with the increase of median diameter of dust particles.

3) The hydrodynamic resistance of the dust catcher increases with the increase of consumption of the air in the stand.

Summing up the above, it is possible to claim that the effectiveness of dust catching will be increasing with:

– higher velocity of the dust particle before the separator,
– greater weight of the dust particle,
– greater density of the dust particle,
– smaller angle between the direction of movement of the flow and area of the shutter,
– lower velocity of the movement of cleaned air flow to the separator opening,
– greater clear opening area of the shutter separator,
– greater flexibility of dust particle,
– greater stability of the velocity of dust-air mixture along the separator, ensuring constant velocity of air passage through the separator.

CONCLUSIONS

Comparative investigations have proved, that the effectiveness of operation of the proposed dust catcher surpasses the effectiveness of operation of cyclone CN-11 (standard) by 15-17%, hydrodynamic resistance is reduced by 150-250 Pa, and dimensions by 1.5 times, which permits to make a statement of considerable reduction of power and metal consumption.

Further works in this field should be conducted towards an improvement of the design of shutter separator as the second stage of cleaning, towards optimization of the dimensions of dust catcher body and improvement of the processes of separation for further increase of effectiveness of dust catching, development of new energy saving technologies and protection of the environment.

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Mathematic model of the process of dust catching in an apparatus with a movable separator

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Abstract. The article considers the mathematical model of the process of cleaning of dust-laden stream in centrifugal - inertia vehicles and the obtained designs are confirmed by conducting complex processes of dust colection in radioelectronics.The article describes new trends in the development of dust catching apparatuses based on the use of centrifugal-inertial forces, permitting to significantly improve the effectiveness of dust catching

Key words: dust catchers,centrifugal - inertia vehicles, mathematical model.

MATERIAL AND METHOS

Radio engineering industry brings in considerable cost in contamination of atmosphere. Concentration of dust in the air, thrown out to the by atmosphere radio engineerings enterprises, in obedience to operating normative documents, cannot exceed 60…120 mg/m^3, which imposes additional requirements to the dust-catching equipment.

The problem of creation of new highly-efficient vehicles is determined by the complexity of the separation process. A lot of factors make the process of cleaning difficult. Therefore, at present there is no perfect scientific basis which would be based on the combination of practical and theoretical researches, that in a complete measure would describe the afore-mentioned processes. One of the aims of the present task is the creation of dust collection options of new type, the action of which is based on the principle of combination of different methods of cleaning.

ANALYSIS OF THE LATEST RESEARCH

The presently existing vehicles for the cleaning of air from dust are not able to catch its fine fraction with sufficient efficiency and simultaneously provide low power indexes, due to the imperfection of their construction and complication of the separating processes. Therefore, the necessity has appeared of the creation of vehicles which would be able to effectively catch the hazardous emissions of dust and also ones with reduced power and metal construction elements.

The realization of an engineering construction of a vehicle which would answer these requirements on the basis of theoretical grounds and research of the processes of dust collection in the conditions of radio engineering production determines the validity of the presented work.

It is possible to solve the set problem only through the process of mathematical design subject to the conditions of the process of motion of particles of dust in dust catchers.

STATEMENT OF TASK

Movement of air flow in the cyclone will be considered on the basis of viscous liquid equations that look as follows:

$$div\ v = 0,$$

$$\frac{dv}{dt} = -\frac{1}{p} grad p + v\Delta.$$

We assume that the flow is one-dimensional, if speeds are parallel to some direction in space, while at the plane points that are perpendicular to this direction, hydrodynamic variable can take different values. Choose the direction of motion as the direction of axis x. Then:

$$v_y = v_z = 0. \quad (1)$$

We will calculate the system of equations of viscous fluid, taking into account (1):

$$\frac{dv_x}{d_x} = 0, \tag{2}$$

$$\frac{dv_x}{d_t} + \upsilon_x \frac{dv_x}{d_x} = -\frac{1}{p}\frac{d_p}{d_x} + \upsilon\left(\frac{d^2v_x}{dx^2} + \frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dz^2}\right). \tag{3}$$

$$\frac{dp}{dy} = 0, \qquad \frac{dp}{dz} = 0. \tag{4}$$

From (2) it follows that υ_x is independent on x, and from (4) -p that p is independent on y and z, ie:

$$v_u = v_x(y,z,t), \tag{5}$$

$$p = p(x,t). \tag{6}$$

Given (5), rewrite equation (3) as follows:

$$\frac{dv_x}{d_t} - \upsilon\left(\frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dz^2}\right) = -\frac{1}{p}\frac{d_p}{d_x}. \tag{7}$$

The left side of (7) does not depend on x, therefore, $\frac{dp}{dx}$ can depend only on time:

$$\frac{dp}{dx} = f(t), \quad p = f(t)x + f_1(t). \tag{8}$$

Thus, in one-dimensional movement pressure is the linear function of x. Functions $f(t)$ and $f_1(t)$ can be found if in the two chopping and the pressure p is set, rather

$$p(x_1,t) = f_1(t), \quad p(x_2,t) = f_2(t).$$

Then

$$\frac{dp}{dx} = \frac{f_2(t) - f_1(t)}{x_2 - x_1} = \frac{\Delta p}{\Delta x}. \tag{9}$$

For a given pressure differential, the speed is found from equation (7):

$$p\frac{dv_x}{dt} = \mu\left(\frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dy^2}\right) - \frac{\Delta p}{\Delta x}. \tag{10}$$

Equation (10) in its form coincides with the heat equation. Non-homogeneous equation (10) can be reduced to a uniform one by the replacement:

$$v_x = v_x - \frac{1}{p}\int_0^t f(t)dt.$$

To find solutions for equation (10) initial and boundary conditions should be given. One-dimensional movements can be carried out at liquid flow in cylindrical tubes (or beyond). Therefore boundary conditions are written on the contours l_k that we obtain by chopping cylinder with area x = const:

$$v_x\Big|_{l_k} = u_k(t). \tag{11}$$

Hence - speed contour points. Initial conditions have the form

$$v_x\Big|_{l_{t=t_0}} = F(y,z). \tag{12}$$

The task is simplified if the flow is constant. In this case, the final pressure is constant, and equation (10) is reduced to the Poisson equation:

$$\mu\left(\frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dy^2}\right) = \frac{\Delta p}{\Delta x}. \tag{13}$$

The initial conditions disappear, and the boundary conditions are independent on time:

$$v_x\Big|_{l_k} = u_k. \tag{14}$$

In the most general case, the speed $v_x\Big|_{l_k}$ may vary depending on the contour points $v_x\Big|_{l_k} = v_x(t,M)$.

A special case of the flow is represented by a free-flow movement of fluid, when $\frac{dp}{dx} = 0$, p=const. Thus, instead of (10) we get the equation:

$$\frac{dv_x}{dt} - v\left(\frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dz^2}\right).$$

If the motion is set, the speed is detected by solving the Laplace equation:

$$\frac{d^2v_x}{dy^2} + \frac{d^2v_x}{dz^2} = 0. \tag{15}$$

which satisfies boundary conditions (14).

Problem (15), (14) (u_k constant on the contours l_k) is equivalent to the problem of finding the flow function φ in plane flows of an ideal incompressible fluid:

$$\frac{d^2\varphi}{dy^2} + \frac{d^2\varphi}{dz^2} = 0, \qquad \varphi\Big|_{l_k} = u_k.$$

Hence, in particular, in order to solve the problem (15) (14) it is possible to use the method of conformal mappings. It is easy to show that the force f_k, acting on the contour in a viscous fluid, is expressed in terms of G circulation of the ideal fluid flow:

$$f_k = \oint_{l_k} \tau_{nx} dS = \mu \oint_{l_r} \frac{dv_x}{dn} ds = \mu \oint \frac{d\phi}{dn} dS = \mu G.$$

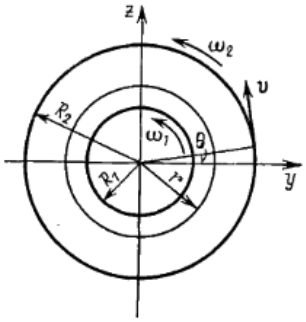

Fig. 1. Movement scheme

Movement of air flow in the cyclone can be represented as a flow movement between two infinitely long circular cylinders with a common axis with the radius R_1 and R_2 during the absence of mass forces (Fig. 1.). Let us transfer axis x along the axis of the cylinders. Suppose that the inner cylinder rotates with angular velocity ω_1, and external - with ω_2. To solve the problem it is convenient to introduce cylindrical coordinates r, θ, x and write in these coordinates the system of equations of viscous fluid. You need to find expression $div\, v, \frac{dv}{dt}$, $grad\ p$, Δv in this system of coordinates. Naturally, assuming that the velocity is directed tangent to the circle $r = const$ and depends, as well as pressure, from r only, then $v_x = v_r = 0$, $v_0 = v(r)$, $p = p(r)$. The obtained system of equations can be applied to this problem and when the movement is set, takes a simple form and allows you to immediately get the solution of the problem as:

$$v_0 = C_1 r + \frac{C_2}{r},\ p = p_1 + \int_{R_1}^{r} \frac{v^2(r)}{r} dr.$$

Constants C_1 and C_2 are determined from the boundary conditions. But to solve this problem we use a different path.

To find the dependence $v = v(r)$, we write the law of angular momentum conservation in the layer $R_1^2 \leq\sim y^2 + z^2 \leq r^2$, $r < R_2$ (Fig.). Let M be - the moment of forces acting on this layer. Since the flow is on a plane, the vector M is directed along the axis x. Since the traffic is stationary, we have the equation $M = 0$. It is obvious that $M = M_1 + M_r$, where M_1 – the moment of forces acting on the inner cylinder, M_r – the moment of viscous friction forces, which are attached to the cylinder radius r. The magnitude of this vector:

$$M_r = \int_0^{2\pi} r(\tau_{r\theta} r d\theta) = r^2 \int_0^{2\pi} \tau_{r\theta} d\theta. \qquad (16)$$

Here: $\tau_{r\theta}$ - the pressure projection on axis θ (i.e. direction v) acting on the part with the normal r. In our assumptions it depends only on r, so:

$$M_r = \tau_{r\theta} 2\pi r^2.$$

Thus, the moment conservation law gives the equation:

$$\tau_{r\theta} 2\pi r^2 + M_1 = 0.$$

Let angle θ be formatted from axis y. Obviously:

$$\tau_{r\theta}\big|_{\theta=0} = \tau_{yz}\big|_{z=0}.$$

Since $\tau_{r\theta}$ does not depend on θ, the last ratio is fair at all θ. Thus:

$$\tau_{r\theta} = \tau_{yz}|_{z=0} = \mu \left(\frac{\partial v_y}{\partial z} + \frac{\partial v_z}{\partial y} \right)\Bigg|_{z=0}. \qquad (17)$$

Hence we have:

$$v_y = -v \sin\theta = -v\frac{z}{r}, \quad v_z = v\cos\theta = v\frac{y}{r}$$

and

$$\frac{\partial v_y}{\partial z}\bigg|_{z=0} = \frac{\partial}{\partial z}\left(-v\frac{z}{r}\right)\bigg|_{z=0} = -\frac{v}{r},$$

$$\frac{\partial v_z}{\partial y}\bigg|_{z=0} = \frac{v}{r} + \left(\frac{d}{dr}\frac{v}{r}\right)\frac{y^2}{r}\bigg|_{z=0} = \frac{v}{r} + r\left(\frac{d}{dr}\frac{v}{r}\right). \qquad (18)$$

Using this equation, based on (18) we get:

$$\tau_{r\theta} = \mu r \frac{d}{dr}\left(\frac{v}{r}\right). \qquad (19)$$

Substituting (19) for (16) we obtain the equation for finding v:

$$M_1 + 2\pi r^3 \mu \frac{d}{dr}\left(\frac{v}{r}\right) = 0. \qquad (20)$$

The general solution of this equation is expressed by the formula:

$$v = C_1 r + \frac{C_2}{r}. \qquad (21)$$

Where: $C_2 = \frac{M_1}{4\pi\mu}$. Constants C_1 та C_2 are determined from the boundary conditions:

$$v\big|_{r=R_1} = \omega_1 R_1, \qquad v\big|_{r=R_2} = \omega_2 R_2, \qquad (22)$$

or more precisely,

$$C_1 R_1 + \frac{C_2}{R_1} = \omega_1 R_1, \qquad C_1 R_2 + \frac{C_2}{R_2} = \omega_2 R_2. \qquad (23)$$

Solving the system (8), we obtain:

$$C_1 = \frac{\omega_1 R_1^2 - \omega_2 R_2^2}{R_1^2 - R_2^2}, \quad C_2 = \frac{R_1^2 R_2^2 (\omega_2 - \omega_1)}{R_1^2 - R_2^2}. \qquad (24)$$

Thus, the velocity distribution between cylinders with a common axis is given by the formula:

$$v = \frac{\omega_1 R_1^2 - \omega_2 R_2^2}{R_1^2 - R_2^2} r + \frac{R_1^2 R_2^2 (\omega_2 - \omega_1)}{R_1^2 - R_2^2} \frac{1}{r}. \qquad (25)$$

With formula (25), it can easily be calculated that: $\tau_{r\theta}$ and M_r:

$$\tau_{r\theta} = \mu r \frac{d}{dr}\left(\frac{v}{r}\right) = -2\mu\frac{C_2}{r^2}, \quad M_r = \tau_{r\theta} 2\pi r^2 = -4\pi\mu C_2, \qquad (26)$$

where: C_2 has the form (1.24).

Note also that by taking measurements during the experiment M_r, we can determine the viscosity. Partial cases of flow:

a) two cylinders rotating with equal angular velocity: $\omega_1 = \omega_2 = \omega$. For this case from (26) we get: $v = \omega r$.

b) The liquid fills the infinite space outside the cylinder.

$R_1 : R_1 = R, \omega_1 = \omega, R_2 = \infty, \omega_2 = 0$. In this case $v = R_1^2 \frac{\omega}{r}$.

c) One of the cylinders is stationary $\omega_1 = 0$, $\omega_2 = \omega$:

Then $v = \frac{R_2^2}{R_2^2 - R_1^2}\omega r - \frac{R_1^2 R_2^2}{R_2^2 - R_1^2}\frac{\omega}{r}$.

Next we verify the movement of air flow in the moving coordinate system that rotates around the axis of the cyclone with an angular velocity equal to the speed of the flow around a vertical axis. Then we will deal with the case when the outer wall rotation speed will be equal to ω_z, and internal (inertial separator) - ω_s.

CONCLUSIONS

Conclusions and perspectives of further scientific studies: comparative investigations have proved that the effectiveness of operation of the proposed dust catcher surpasses the effectiveness of operation of cyclone CN-11 (standard) by (15-17)%, hydrodynamic resistance is reduced by (150-250) Pa, and dimensions by 1.5 times, which permits to make a statement of considerable reduction of power and metal consumption.

Further works in this field should be conducted towards the improvement of the design of shutter separator as the second stage of cleaning, towards optimization of the dimensions of dust catcher body and improvement of the processes of separation for further increase of effectiveness of dust catching, development of new energy saving technologies and protection of the environment..

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Ionization processes in grain weight under strong electric field

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Abstract. The results of studies depending on the relative intensity characteristics of ionization processes in grain weight of the electric field of high intensity, humidity and established empirically analytical dependence.

Key words: strong electric field, ionization processes, ozone, grain weight, environmentally friendly processing of grain.

INTRODUCTION

Grain sector of Ukraine is a strategic sector of the economy of the state, which determines the volume of supply and cost of main food for the population, including food grain processing and animal products, forms a significant proportion of agricultural incomes, determines the status and trends in rural areas, creates a state for foreign exchange earnings by exports. Grain industry is the basis and source of sustainable development of most sectors of agriculture and the basis for agricultural exports.

Increase of production and improvement of the quality of crop production is possible by reducing crop losses from plant pathogenic microorganisms and utilization of the potential of biological features of seed.

The microflora of grain mass consists almost entirely of anaerobic microorganisms. Mushrooms represented about 85% of pathogens causing the most dangerous diseases of cereals and toxic agents - 80%. Especially rapid was the contamination of grain cereals by the fungi that form the toxins: Fusarium, Alternaria, Repisilium, Mucor, Cladosporium and others. Fighting these fungi can classify the grain commodity to the particular food category, and the presence of toxins formed by these fungi in greater amount than 5 mg per 1 kg makes it unfit even for feeding purposes.

These pathogens alter the biochemical composition of grain and contaminate it with mycotoxins. This creates a serious problem for the food industry. The situation is complicated by the fact that to date there are no biologically acceptable and cost-effective ways to detoxify the grain. During storage (3 to 6 months) in adverse conditions, the surface contamination of grain with fungi can grow by 35 ... 40 times, internal – by 3 ... 4 times. This dramatically increases infestation complex Fusarium, Alternaria, Penicillium. This is an annual loss of 3.2 million tons of grain and a significant reduction in biological value of further millions of tons.

Ozonization is one of the most promising technologies designed to combat the influence of chemical and microbiological nature in agriculture, medicine, ecology and public utilities. Ozonization as a method of disinfection was thoroughly studied with hygiene items and received approval of sanitary and medical facilities of all advanced countries (USA, Germany, Japan, France, etc.) [1]. Significant reduction of cost of production of ozone in relation to other chemicals appropriate for this application, in recent years has also contributed to increasing interest in its wider use in agriculture. Due to the urgent problem, there has been rapid development of such systems.

But modern electroozonators used in agriculture have not found wide use because of their low efficiency. Low productivity has mainly been due to the fact that large losses of ozone occur in the supply network from ozone generators to the product processing units.

MATERIALS AND METHODS

The Department "Electrified Technologies in Agriculture" at the National University of Life and Environmental Sciences of Ukraine has developed a method and device for treatment of seed crops with ozone in an electric field of high voltage direct current. Apparatus

Fig. 1. Apparatus settings for the treatment of seed crops in a strong electric field

settings for curing grain with high voltage electric field are shown in Fig. 1.

When processing the seed crops in high voltage electric fields, when the material is located directly between the plate electrodes, one of the important factors is the mode of processing, electrical discharges, accompanied by ionization processes that occur in air inclusions mixture. The intensity of the ionization process at atmospheric pressure will be determined mainly by voltage applied to electrodes, grain moisture and geometrical form of seeds. At present these electrical processes in the grain mass, under the influence of electric fields of high voltage, were not considered in the scientific work of researchers, so to ensure effective treatment regimes, there is need to explore and establish patterns of change in the intensity discharge processes. For this purpose it was designed in research laboratory settings (Fig. 2).

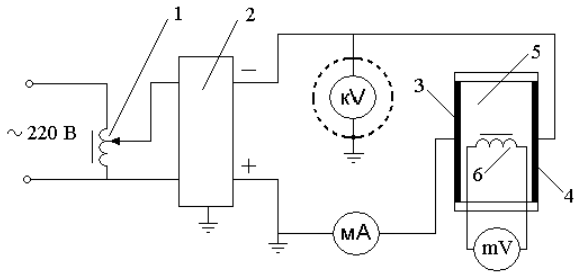

Fig. 2. Circuit diagram for the study of the intensity of ionization processes in vertically arranged electrodes: 1 – autotransformer; 2 - high voltage transformer with a rectifier; 3, 4 - plane-parallel plate electrodes; 5 - chamber for placing seeds; 6 - inductive sensor

There are different methods of registration ionization characteristics in insulating materials [2, 3, 4, 5, 6, 7]. One of the methods used is the method of tangent of dielectric loss angle. This method is based on the principle that with increasing voltage due to the increased intensity of discharge, tg δ is increased. So the point of inflection depending on tgδ (U) is considered at the beginning of discharges, and it is stressed that the initial voltage is responsible for partial discharges.

But these methods have several disadvantages, the main of which is a great sensitivity to external interference and difficulty settings. To investigate the relative characteristics of the ionization processes, the experience withdrawal was used of oscillograms intermittent phenomena in the corona discharge, which was engaged in the research of Loeb School. Researchers at the oscillograph removed currents in voltage at the ends of the resistance, and induced the impulses, Yaki at the "antenna" [8].

RESULTS AND DISCUSSION

Prior to research, grain mixture was filled into the chamber. It was located between two plate electrodes. When the voltage is fed to the plate electrodes, the voltage of primary ionization in the chamber with the grain mixture starts bit processes. As a result, inductance coil 6 having high fluctuations that accompany ionization. As an instrument registering a stable voltage (steady) ionization U_{cm} a switch gear can for example be used. In our case, the voltmeter was used of universal type B7-26. Further, we denote its measurement as U_i. The magnitude of the voltage on the voltmeter connected to the inductor, we will call the relative intensity of characteristic ionization processes, and to characterize the formation of ozone in the mass of seeds under high voltage electric field, the notion was used of the specific characteristics of the intensity of ionization processes $U_{i\,num}$ accommodation experts (мВ·м). $U_{i\,num}$ accommodation experts were determined by the formula:

$$U_{inum} = \frac{U_i \cdot S}{h}, \qquad (1)$$

where: S - area of the electrode is covered with seed mass, m^2. h - distance between the electrodes, m.

As a result of the work the dependence was determined by analytical U_{inum} of the electric field of high voltage and the initial intensity of ionization processes. When considering the ionization processes in the future we will assume their start when *Ui = 0.1* mB·m. In the above mathematical expression, the calculation of $U_{i\,num}$ accommodation experts begins with the electric field intensity level of initial ionization processes because at lower electric field ionization processes can be neglected.

The resulting mathematical expression that is represented by formula (2) agrees well with the results of experimental studies:

$$U_{inum} = \frac{S}{h} \cdot \left(\exp\left(2,45 \cdot \frac{E - E_{poch}}{E_{poch}} \right) - 0,9 \right), \qquad (2)$$

where: E - electric field, кВ/см, E_{poch} - electric field of primary ionization кВ/cm;

$$E_{poch} = a - в \cdot W, \qquad (3)$$

where: W - moisture content of seeds,% a, $в$ - coefficients that are determined by type of crop (oats $a = 7,33$, $в = 0,423$, barley $a = 6,77$, $в = 0,356$; wheat $a = 9,04$, $в = 0,457$; rye $a = 9,15$, $в = 0,425$).

Experimental studies were performed on barley variety "Scarlet." The research results are cpresented in Tables 1-2 and Fig. 3.

Table 1. Dependence of the specific intensity of ionization processes of barley from the electric field strength at 17,5% moisture barley

$E_{поч}$, кВ/cm	0,96	1.3	1,46	1,86	2,06	2,23
$U_{i\,num.}$, mB·m	0,006	0,099	0,185	0,621	1,075	1,674

Table 2. Dependence of the specific intensity of ionization processes of barley from the electric field strength at 14,9% moisture barley

$E_{поч}$, кВ/cm	1,62	1,83	2	2,46	2,86	3,16	3,3	3.6	3,8
$U_{i\,num.}$, mB·m	0,008	0,035	0,063	0,193	0,408	0,681	0,849	1,379	1,895

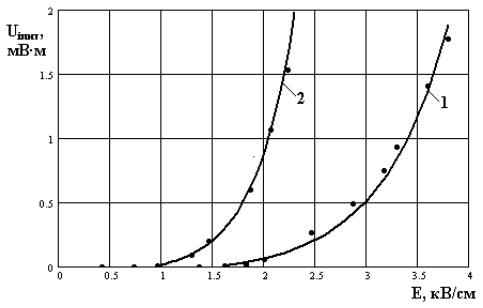

Fig. 3. Dependence of the specific intensity ionization processes in the mass of barley variety "Scarlet" on the electric field: 1 - moisture 14,8%; (2-17,5)% moisture content: - data obtained from materials research; — - graph of the function constructed by empirical formula

Substituting in the expression 2 values E_{poch} from the expression 3 we get:

$$U_{inum} = \frac{S}{h} \cdot \left(\exp\left(2,45 \cdot \frac{E - a + b \cdot W}{a - b \cdot W} \right) - 0,9 \right) \qquad (4)$$

The resulting empirical formula was evaluated for adequacy by the Fisher criterion. Estimated value of the criterion is Fisher's $\Phi = 1,88$, or less than the critical value at significance level 0.05 is $\Phi_{kp} = 2,01$.

The solution proposed by the Department of Electric and Electro Technology at the National University of Life and Environmental Sciences of Ukraine is a much more effective way in terms of uniformity of treatment and cost-effectiveness, because ozone is formed directly in the grain mass, which in this case plays the role of biological electrode system and an integral electrical complex.

Example results of sorghum seed variety Odessa 302 treatment and buckwheat seed variety Oranta seed treatment are shown in Fig. 4.

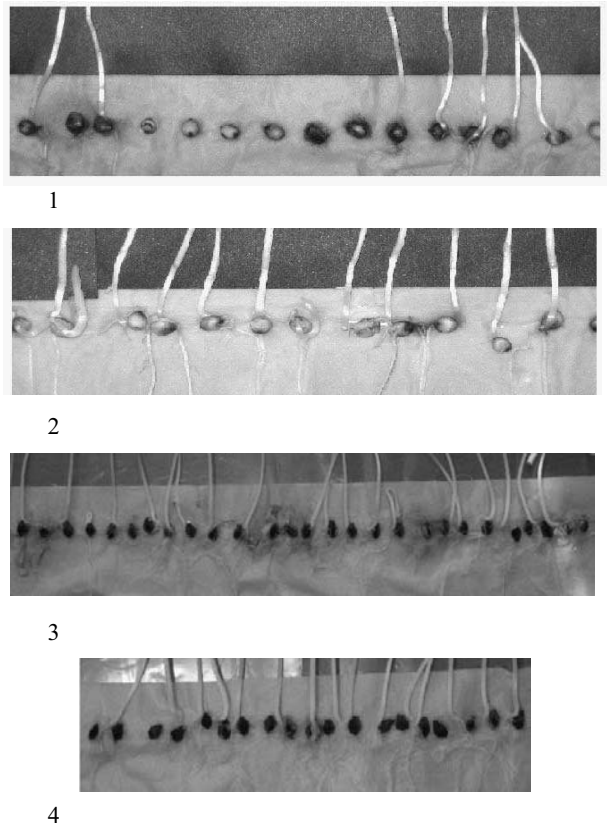

Fig. 4. Results of treatment of seedlings of sorghum seed variety Odessa 302 (biological method rolls) and buckwheat seed variety Oranta: 1 - control sorghum seeds; 2 - sorghum seeds treated in a strong electric field; 3 - control buckwheat seeds; 4 - buckwheat seeds processed in a strong electric field

Thus the proposed electrotechnic treatment is preffered to the existing ones. It is a low energy and environmentally safe process and allows for a better treatment of grain products.

CONCLUSIONS

1. Analytical dependence was established of the relative intensity of ionization processes characteristic of the electric field of high intensity, taking into account humidity seed mass. The obtained dependence is required for the processing regime.

2. Laboratory studies found out that the proposed method allows for the neutralization of about 90% of hard smut spores. It should be noted that the research was conducted on wheat with an artificial background. The concentration of spores of smut was about 500 units per sample of grain. In the natural background, this figure is considerably smaller (about 10).

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The use of labview environment for the building of the grain Dust control system in grain mill

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Abstract. The work environment in a grain mill is associated with the occurrence of many hazardous and troublesome factors at this work. However, the most important hazardous factor occurring in the work environment in grain mills is grain and flour dust. The aspiration and filtration systems applied in mills frequently do not provide proper protection for workers. The objective of the study was to present the assumptions of a complex system controlling the level of dustiness in a grain mill. LabView environment has been used for the building of such system. The acquisition of parameters was carried out basing upon the information and signals received from the sensors supporting the measuring cards. The actual as well as archived parameters occurring in individual rooms can be displayed on the computer screen via the built-in interface.

Key words: control and supervision systems, LabView environment, grain dust, grain-mill, Maximum Allowable Concentration (MAC),

INTRODUCTION

Work in grain mills is associated with the performance of activities at many sites of the work environment, where there occurs exposure to grain and flour dust. Frequently, mean weighted concentrations at workplaces exceed hygienic standards (MAC values). The work of the staff of a mill is most often connected with a frequent or continuous presence at the sites of the work environment, where high levels of dustiness occur. It is therefore necessary to provide safe dust conditions. This should be obtained by the reduction of dust emission or limiting the workers' access to the rooms where high dust concentrations occur, which may result in exceeding the MAC values at individual workplaces.

Long-term exposure to dust at workplaces in cereal processing may be the cause of morbidity due to dust-related diseases, such as: miller's lung, thresher's lung, asthma, bronchitis, grain fever, and may play an important role in the deterioration of the state of health of workers of grain processing plants [Buczaj A. 2008a, Dutkiewicz et al. 2000, Dutkiewicz 2009].

In order to provide safe working conditions in grain processing plants it is necessary to perform measurements of the hazardous factors occurring at workplaces. To-date, according to the legal requirements in effect concerning work safety and hygiene, measurements of two dust fractions are performed: total (inhaled) and respired (dust penetrating into the alveoli). The results of measurement are referred to the existing hygienic standards for dust of plant and animal origin according to the contents of free crystal silica [Official Journal 2002, No. 217, Clause 1833].

Grain and flour dust is produced both during the processing of grain (cleaning and milling), and while packaging of ready products. A significant risk for workers is also created by dust produced during transport, drying, and storage of grain. Grain dust contains bacteria, fungi, insects, sometimes pesticides residues, as well as dry parts of plants. In addition, grain dust contains free silica, which may create risk for health of the employees [Burdorf et al. 1994, Mołocznik 1981, Nieuwenhuijsen et al. 1994].

The computer system of controlling the level of dustiness by constant monitoring of the appliances connected with technological and extractor processes and by means of elements responsible for the measurement of the level of dustiness, described in the presented report, specifies conditions in which the MAC level is exceeded at a particular time and site of the work environment. In the case of exceeding the border levels, the role of the system consists in the start of the alarm mode. The procedure of the alarm mode consists in the switching on of the additional workplace aspiration systems, and an information signal after the MAC level is exceeded at a workplace and on the screen of computer controlling the operation of the system. In normal conditions information is only

provided concerning the current level of dustiness at all sites of the work environment in the grain mill.

DUSTY WORK ENVIRONMENT IN A GRAIN MILL

The studies of dustiness at workplaces in cereal processing plants conducted to-date at the Institute of Agricultural Medicine show a high level of the concentration of grain and flour dust [Buczaj A., 2008b]. The mean concentration of inhaled dust at a workplace of a head miller remained within the range from 1.28÷10.56 mg·m^{-3}, and for a packer – 4.06÷73.64 mg·m^{-3} (Table 1).

The concentrations of inhaled dust at individual measurement sites in the work environment were within the range 0.26÷81.55 mg·m^{-3} (Fig. 1). The highest mean concentration of inhaled dust was observed in the tunnels under the elevators – 68.32 mg·m^{-3} (57.37÷81.55), while dumping grain into the grain hopper– admission of grain - 20.16 mg·m^{-3} (11.20÷37.5), manual cleaning of flour dust - 17.19 mg·m^{-3} (7.12÷28.60) and dumping of grain from the elevator's chamber to the mill - 15.1 mg·m^{-3} (6.51÷26.98). In the case of respired dust (alveolic fraction), the highest mean values were also noted in the tunnels under the elevators - 3.96 mg·m^{-3} (3.16÷4.96), during the dumping of grain into the grain hopper – admission of grain 1.46 mg·m^{-3} - (0.91÷4.22), manual cleaning of flour dust - 1.17 mg·m^{-3} and dumping of grain from the elevator's chamber to the mill 1.06 mg·m^{-3} - (0.14-3.30) [Buczaj A. 2008b].

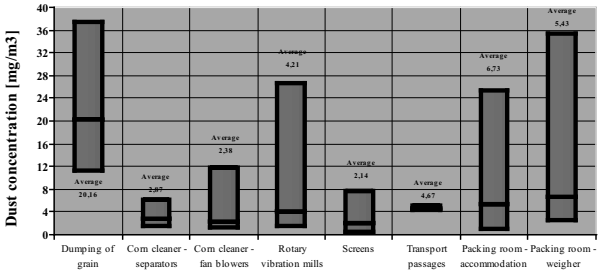

Fig. 1. Dust concentration at work environment sites in grain mills (mean values and range) [mg·m^{-3}]

In industrial mills the studies of dust occurring in the workers' respiratory zone while performing work activities at the workplaces of an elevator operator, miller and packer showed a high level of extra-thoracic fraction in

Table 1. Dust concentration at workplaces in grain mills (mean values and range) [mg·m^{-3}]

Workplace	Measurement of GRIMM 1.108 device		
	inhaled fraction	thoracic fraction	alveolic fraction
elevator operator	22,98 (9,13-47,4)	8,2 (1,86-17,3)	0,8 (1,9-3,5)
miller	3,71 (1,28-10,56)	1,34 (0,30-4,33)	0,18 (0,05-0,52)
packer	10,09 (4,06-73,64)	1,57 (0,64-14,6)	0,10 (0,04-1,43)
admission of grain	20,16 (11,20-37,5)	8,46 (5,72-19,26)	1,46 (0,91-4,22)
central switching station	0,40 (0,26-0,57)	0,20 (0,14-0,25)	0,07 (0,06-0,08)
dumping of grain from the elevator's chamber	15,1 (6,51-26,98)	6,26 (1,78-12,15)	1,06 (0,14-3,30)
separators	2,87 (1,61-6,05)	0,91 (0,29-1,97)	0,16 (0,03-0,41)
fan blowers	2,38 (1,21-11,71)	0,59 (0,29-1,35)	0,09 (0,05-0,36)
rotary vibrations mills	4,21 (1,49-26,73)	1,96 (1,07-4,33)	0,32 (0,11-0,99)
manual cleaning of flour dust	17,19 (7,12-28,60)	7,67 (3,80-11,09)	1,17 (0,8701,45)
transportation passages	4,67 (4,28-5,06)	2,69 (2,44-2,99)	0,79 (0,66-1,18)
cyclone filters	1,85 (1,59-2,18)	1,02 (0,94-1,16)	0,27 (0,24-0,30)
packing room - accommodations	5,43 (1,11-25,46)	1,45 (0,31-6,32)	0,16 (0,05-0,5)

inhaled dust. In the cleaning and packing departments the percentage contribution of the fraction withheld in the head region was the highest. This dust is deposited in the nasopharynx, from where it is removed due to the self-cleaning mechanisms, showing also a lower pathogenic affinity.

Measurements performed at the sites of the work environment in the mill while manual cleaning of dust, near cyclone filters and transportation passages showed that dust occurring at these sites contained a higher content of respired fraction, dust deposited in the thoracic-bronchial section, and also thoracic fraction dust penetrating beyond the pharynx, and therefore a higher exposure to fine particles of dust. In the central switching station the highest percentage of respirable dust was observed, accompanied by a relatively low percentage of extrathoracic fraction, which evidences the penetration there of the finest dust fraction.

The estimated level of the mean weighted concentration of both total and respirable dust for an 8-hour workday at a workplace of a miller in 3 mercantile industrial mills in the study did not exceed hygienic standards, while in one case the standard was only slightly exceeded which suggested the need to carry out additional examinations [Buczaj A. 2008b]. For the workplaces of a packer and elevator operator in all the industrial mills examined the MAC values for total dust were exceeded, while the MAC values for respired dust were not. Considering the exposure to total dust at workplaces of a packer and elevator operator a 2.5-fold and even 6.5-fold exceeding of the MAC values was noted.

FUNCTIONAL ASSUMPTIONS OF THE SYSTEM

The main task of the described and designed system of monitoring and surveillance of working conditions is the control of ventilation and dust cleaning systems in order to reduce the occurring elevated level of dustiness at key sites of the working environment down to the level below the MAC value. In addition, when an elevated level of dustiness occurs in individual rooms of the grain mill (exceeding the MAC value) the system, due to the alarm and access control systems, limits the access for employees not associated with work performed at a particular workplace. This task will be performed through the acquisition of measurement data collected by the supervision system from individual detection elements located in the rooms (climatic parameters) or directly in individual machines (technical parameters). The use of the model of an integrated system shared by the basic control system and by the supervising system for the same infrastructure elements will be the best solution to perform this task [Buczaj M., Sumorek A. 2011]. Such solution will make it possible to limit the costs associated with the use of an additional system (checking supervision system). This system will be additionally characterized by identical signals transmitted to the control and supervision system enabling the correct evaluation of the situation existing in individual objects or rooms. Fig. 2 presents the organizational scheme of the system.

The perfromance of the main task of the system (maintenance of the proper levels of dustiness at workplaces in the mill) is based on the control of executive elements of the system (exhaust fans with regulation flow system), based on the signals from the detection elements (dustiness detectors distributed in the rooms of the mnill and at workplaces). To make the correct operation of the system possible it is necessary to develop individual algorithms for control and construct the control application which would consider the specificity of the particular enterprise.

An additional function of the virtual supervision system increasing the functionality of such system consists in the potential acquisition of measurement data and their archiving as well as the possibility to apply the mathematical models and calculation algorithms in order to determine an optimal work schedule for individual devices. It is possible to provide the program with an additional panel enabling the transmission of information about the necessity to perform planned inspections of the devices with the specification of the parts required for this purpose. The advantage of such system over a standard solution consists in the fact that all necessary data will be displayed and available for the user at the same location on the computer screen in order to enable more complete control over production processes occurring in the grain mill.

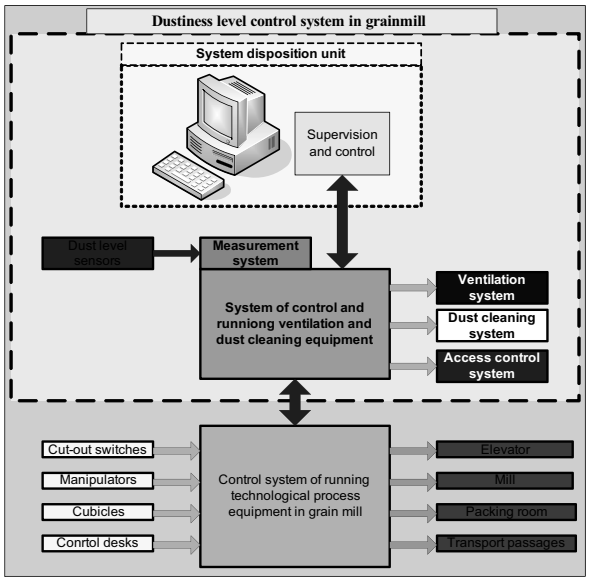

Fig. 2. Block organizational scheme of the system

In the proposed system of control of the level of dustiness in a grain mill the following main elements of the system should be mentioned (fig. 3):

– control unit – a computer by means of which the system is operated;
– disposition system – a selected device servicing and running the programme set by the operator (controllers, power supply and control systems, etc.);

– detection elements (detectors) – detectors of the level of dustiness installed at neuralgic sites in the enterprise which determine the current level of dustiness in a particular zone, shut door detectors in passages controlled by the system, etc.
– executive elements (actuators) – extractor ventilators and dust cleaning filters, and elements blocking access to the rooms controlled;
– elements mediating information exchange among the control systems present in the mill.

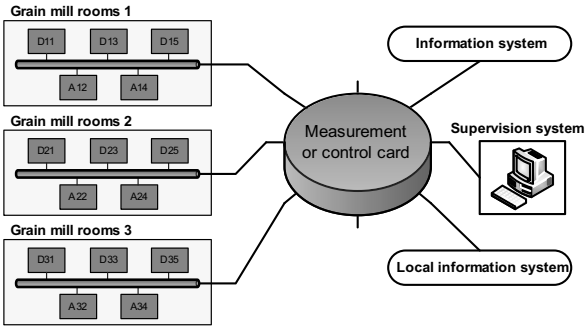

Fig. 3. Topology of the control grain dust supervision system in grain mills, D – detectors, A - actuators

In order to provide the correct operation of the system and perform the tasks associated with the complex servicing of all workplaces in the mill which are exposed to an increased level of dustiness, the system must be an integrated system. Such a system is characterized by a high information exchange between the individual elements of the system [Buczaj M. 2009].

This means that all elements of the system should cooperate with one another and exchange information concerning the current state of operating. Such requirements may be satisfied by the central disposition system. This does not mean that the system may be a dissipation system; however, it is important that the information concerning the state of appliances are constantly exchanged between individual elements of the system. In the solution proposed, the system is controlled from a designated workplace, but it may possess a number of control stations at key sites in the enterprise.

An additional function of the proposed system is its openness. This means that the system can cooperate with other systems in a grain mill, and in this way enable the improvement of work safety, not only due to the decrease in the risk of dustiness, but may also reduce other hazardous factors present at the workplace (e.g. noise).

The Labview programming environment was selected to perform the assumptions of the programme. The Labview environment enables the performance of complex funtions in the proceses of acquisition, archivization, procesing, and the analysis of the measurement data. This not only provides the possibility for free creation of programme structures of measurement and stimulation systems' useful in research projects, but also the creation of applications enabling the construction of modern control systems supervising technological processes. The task of the described system controlling ventilation and dust cleaning systems is to reduce the MAC values for grain and flour dust at selected workplaces in a grain mill.

SYSTEM OF CONTROL OF DUSTINESS LEVEL IN A GRAIN MILLS

The system of control of the dust level in a grain mill was developed based on the LabView programming environment. This environment possesses large capabilities of servicing technological processes, both with respect to measurements and control, and also individualized

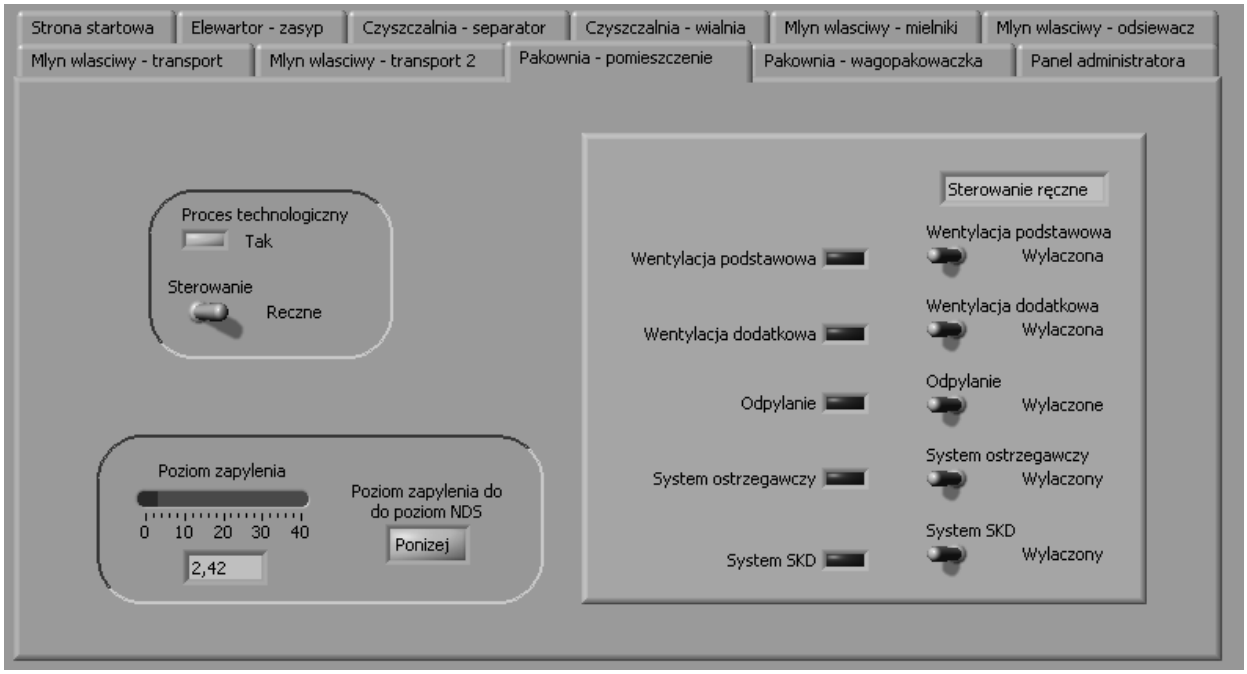

Fig. 4. User's interface of the system

approach to the process of creating systems operated by many users [Tłaczała, 2002]. According to authorizations, individual users may have various access authorization to the system. Due to the above-mentioned, the system is stable and resistant to operating by non-authorized persons. An additional advantage of the applications developed within the LabView program is their individuality. It is possible to use certain schemes, as well as to equip the programmes with individual solutions. This allows the adjustment of applications to sometimes dynamically changing situations in an enterprise (e.g. change of technology, change of the assortment produced, etc.).

The following elements may be distinguished in the programme managing and controlling the operation of the system:

– user's interface (fig. 4) – allows (according to authorization) control, change of configuration, or the control of operation of the system;
– organizational scheme (fig. 5) – internal connection between individual elements of the application enabling the performance of tasks set by the user on the control panel;
– I/0 service (operation of inlet and outlet devices) (fig. 6) – a system component responsible for the acquisition of data from detecting elements of the system and

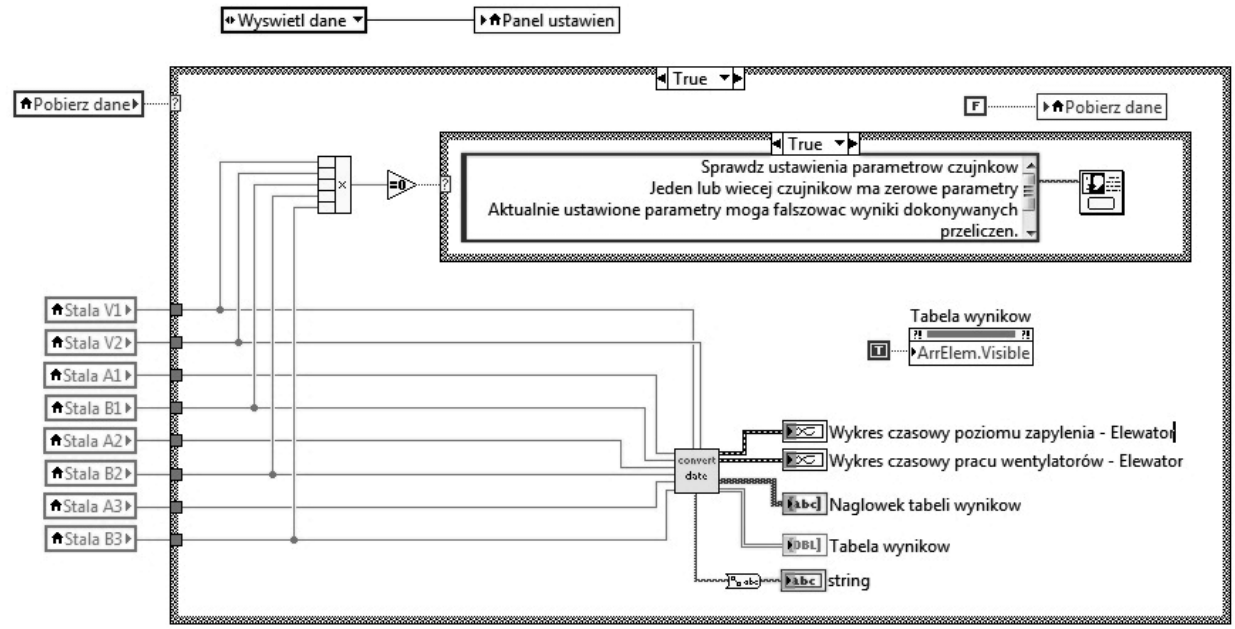

Fig. 5. The procedure of measurement date calibration – a part of the head program

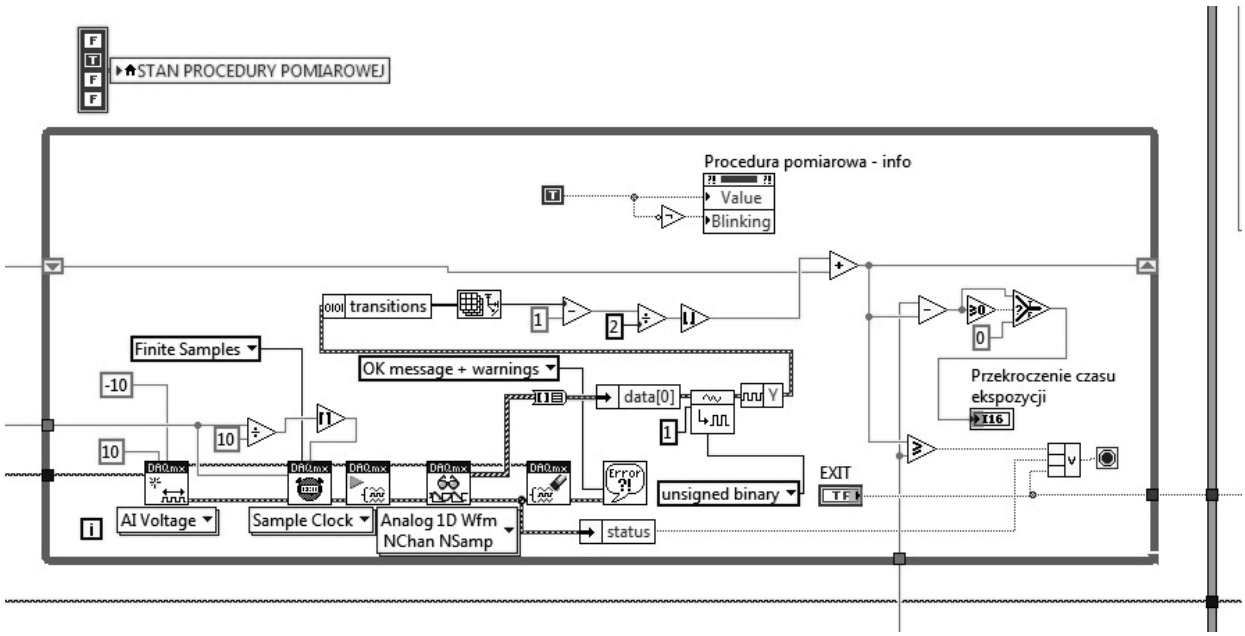

Fig. 6. One of the acquire measurement date procedure – a part of the head program

sending information to the devices controlling the operation of executive elements.

The proposed system of control of the level of dustiness in a grain mill may operate in an automatic mode, or manual mode controlled by the dispatcher from the main distribution centre, and in an emergency mode controlled by the user at a workplace. Such a solution not only makes it possible to optimize the operation of the system in normal conditions, but also allows the adjustment to the current demands in case of state of emergency, or risk for life and health of an employee.

Apart from managing and control of the operation of the system it may be equipped in the registration of events. This means that a history of the system operation is created, through to which it is easier to determine the causes of occurrence of states of emergency, and due to time registration it is possible to specify the periods of the planned conservation breaks.

CONCLUSIONS

Dust concentrations exceeding the MAC values which occur at the sites of the work environment in grain mills may constitute risk for the health of the employees exposed to them, therefore it is necessary to undertake actions in order to reduce workers' exposure to grain and flour dust. This should be obtained by the reduction of the emission of dust or by limitation for the employees of access to the rooms where high concentrations of dust occur which, in consequence, result in the exceeding of MAC values at an individual workplace.

The work environment in a grain mill is associated with the occurrence of many hazardous and troublesome factors at this work. The most important hazardous factor occurring in the work environment in grain mills is grain and flour dust. While penetrating into the airways, dust is settled and deposited in various sections of the respiratory system. The biological effect of dust depends, among other things, on its biological and mineral composition, size of particles, and amount of dust settled in individual regions of the respiratory system. Minimization of dust-related risk, and especially the reduction of the dust concentrations registered to the allowable values, should become a goal for the managerial staff in the mill.

Owing to the application of the virtual supervision system integrated with the autonomous control systems applied for the execution of the production and storage processes at grain mills it is possible to extend the scope of parameters and functions obtained by the user. Additionally the status of individual systems is monitored the supervision system and the user is provided with the complex access to information from one place.

Thanks to the application of LabVIEW software delivered by National Instruments, the access of the user is possible to advanced applications enabling the communication with external devices in several ways. In this system it is possible to use the serial and parallel ports, TCP/IP protocol as well as wireless connection with the devices. The last option increases the data transmission process efficiency. The systems are under uninterrupted control and the user is immediately informed thereof. Therefore the systems users are able to quickly localize the failure and to eliminate the defect source in case of a breakdown or danger status.

The system of dustiness control developed enables the measurement of dust concentration at specified sites of the work environment, and such a control of dust cleaning systems which would minimize risk occurring in the form of grain and flour dust.

The application of the LabView environment for the construction of the system allows the creation of systems adjusting themselves to the needs of an individual units and users. It provides a possibility to implement this system in a simple way to various units, e.g. change in the number of work sites, dust cleaning systems, etc.

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Economic and Mathematical modelling of factors affecting the formation of competitive capacity of milk processing production

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Summary. The main results of the study present a practicable attempt for conducting the economic and mathematical modeling of the probable effect of the factors on formation the milk processing production competitiveness as the main factor of formation the competitiveness of the very milk processing enterprise under conditions of Ukraine's membership in WTO and sharpening the world economic crisis.

Key words: competitiveness, economic and mathematical modelling, factors, milk processing enterprise.

INTRODUCTION

Aggravation of competition under conditions of economic crisis and saturation the milk products market of Ukraine with foreign products makes the problem of raising the level of competitiveness of domestic milk processing enterprises to be the urgent question of the day. One of the objective ways to raise the level of competitiveness of these enterprises is to raise the level of competitiveness of their products that in return is affected by a number of other factors. The problem is that there are no well elaborated techniques for mathematical modelling of probable effect of these factors today that is considered to be a good ground for a proper investigation in this area.

RESEARCH ANALYSIS AND PUBLICATIONS

Such economists as G.Azoev, V.Andriychuk, L.Balabanova, P.Berezivskyy, R.Hlibov, F.Horbonos, Yu.Hubeni, A.Zheleznyak, S.Kvasha, Yu.Korobiv, V.Kudlay, M.Malik, V.Mesel-Veselyak, O.Nuzhna, B.Paskhaver, Zh.Poplavska, L.ramenskyy, V.Reutov, P.Sabluk, B.Supikhanov, R.Phathutdinov, S.Shevelyova have paid much attention to the problem of raising the competitiveness of milk production enterprises recently. S.Vasylchak, N.Havryshko, N.Holomsha, R.Dudyak, M.Ilchuk, M.Parhomets, V.Savytska, V.Topikha, S.Shevelyova, O.Shpychak, et al. dedicated their studies to particular issues of milk production market as well as to elaborating the mechanisms for developing the milk production sub-complex of Ukraine. Marketing aspects of milk production have been given much attention in the scientific publications of M.Andrushko, G.Astratova, R.Dudyak R.Blum, Ye.Dolan, T.Kenig, B.Klepatsky, F.Kotler, M.Sakhatsky, D.Stoner, J.Holey. It is also worth mentioning the young researches such as N.Botvina, I.Bulakh, N.Dmytrenko, T.Dobrunik, A.Zheleznyak, V.Korchahina, O.Lytvynova, R.Lupak, V.Martynyuk, A.Nikolayeva, R.Oleksenko, N.Olkhovska, O.Prus, I.Tsymbalyuk and some others who study particular elements of competitiveness of milk production enterprises. The dynamic changes in the conditions of economic activities that took place in Ukraine when it joined the WTO and because of sharpening of the world crisis requires profound and extended study that would enable to optimize the economic activity of milk processing enterprises in order to enhance their competitiveness on the foreign and domestic markets. To obtain more accurate results when conducting the research it seems reasonable to consider the feasibility to apply the economic and mathematical methods of modelling the influence of different factors on the formation of the rate of this competitiveness.

MATERIALS AND METHODS OF RESEARCH

During the study, a variety of contemporary methods of scientific research have been applied, abstract and logical and monographic being the main ones. Applying these methods made possible to conduct revision of the materials and publications related to the problem of competitiveness of milk production enterprises of Agro-Industrial Complex under conditions of the world crisis.

Due to statistical and economic method of research the structural and dynamic tendencies of the development of regional milk production sub-complex have been evaluated. The method of scientific abstraction and the method of analysis and synthesis made possible to generalize the obtained information and to make conclusions that have been valuable for science and practice. The list of references includes the works of economic researchers who study the same problems as well as the relevant official statistical data. The principles of economic and mathematical modelling of economic processes and events have been applied in practice.

THE PURPOSE OF THE STUDY

The main purpose of this paper is to present the results of probable application of economic and mathematical modelling in order to study the effect of factors on formation of milk processing enterprises' competitiveness as the main factor for formation of competitiveness of this type of enterprises under conditions of Ukraine's membership in WTO and general economic crisis.

THE RESULTS AND DISCUSSIONS

The development of economy has always been accompanied by the competition that's why competition as a phenomenon has a very distinct historical character. «From the point of view of horizontal structure, control of one enterprise creates conditions for monopoly and functioning of a large number of totally independent companies under conditions of market coordination provides conditions for perfect competition» [19]. J.S.Mill wrote about competition that «taking into account that competition is the only regulator of prices, wages and rents it is a law all by itself and it sets the rules of its regulation» [2]. And a representative of neoclassic school A.Marshall defined competition as a competition «… between two persons that compete especially when selling or buying something» [1].

Considering competition as a specific rivalry in the surrounding of salesmen or in the surrounding of buyers among themselves for the place on the market or for conditions of purchasing or selling the product, A. Smith just formulated his famous principle of "invisible (hidden) hand" as a principle of competitive struggle and survival under market conditions [4].

All the history of economic development can be viewed as a history of competitive struggle [17]. The company is successful in competitive struggle due to its competitive advantages, which are treated by different scientists in different ways. The concept of competitive advantages was first developed by Professor M.Porter. In his works he thoroughly analyzed the factors that would provide the competitive advantage for the company when applying them [11].

Directions for formation the competitive advantages of a company in fact are the grounds for formation the desired level of its competitiveness that can be understood in two ways, i.e. as an economic category and as a characteristic of a particular enterprise.

Company's competitiveness as a category does not exist separately from other economic categories which characterize the company's conditions at a specific moment or describe the perspectives of company's development.

So, the efficiency of the enterprise (the efficiency here is more likely to be considered as a social economic category) will have a direct effect on competitive positions of this particular enterprise on the market and it will make these positions stronger, in other words competitiveness of the enterprise at this very moment is presented in its competitive position on the market.

In a very broad meaning M.Porter defines competitiveness as «possibility to win in a competition», and in economics «possession of qualities that provide advantages for the subject of economic competition», and «different objects by origin - types of products, enterprises and organizations, their groups…» [10, p.138] can possess these qualities. A somewhat similar approach was presented by R.Phathutdinov who considered competitiveness as «…characteristic of an object that describes degree of satisfaction of a certain demand in comparison with better analogues presented on this market» [15].

The results obtained when investigating the concept of "competitiveness" logically led us to necessity to consider "competitiveness" on different levels [20]. The hierarchy of the objects of competitiveness may logically have the following order:

– competitiveness of a commodity (service), (products);
– competitiveness of an enterprise;
– competitiveness of a branch (production);
– competitiveness of a country.

Moreover the content of the concept of competitiveness on each level has its distinguishing features.

Competitiveness of the enterprise can be defined as «its ability to compete successfully and to win» [16]. According to the functional approach when studying the enterprise's competitiveness, its level depends on the level of organizational work of all its divisions and services, and the operational efficiency of these subunits depends on the efficiency of the use of enterprise's resources, i.e. competitiveness of the enterprise is the function of all its internal resources [5]. In other words, competitiveness of the enterprise depends on a large number of internal and external factors that dictate the application of a systematic approach to investigation of their influence. [13]. «Certainly, there is a possibility of combination the efficient economic activity and effective competitiveness. But the enterprise may demonstrate competitive advantages on some market segments and have low economic indices. On the other hand, high economic efficiency of the enterprise does not provide competitive advantages» [19]. Though, «high competitiveness of the company is a condition to obtain high profit under market conditions» [18], «but in case when the production costs are as low as possible, when available resources are rationally used then domestic producers can start fighting for the markets for their products» [18].

On the basis of analysis of the content of above mentioned and other approaches regarding the very core of the subject of competitiveness of enterprise, taking into account the very rational thought that «competitiveness of economic object shows its capability» [8], and also that «competitiveness … can be evaluated only by means of comparison » [6]. we may formulate it as a category that demonstrates economic relations among enterprises regarding their capability to be presented on the market of the particular products due to their competitive advantages when compared to their competitors.There are grounds to define the competitiveness on the level of an enterprise as a capability of this enterprise to compete with the similar enterprise under any conditions. In other words, it means to be profitable for a long time on the market of similar products and to achieve goals using its competitive advantages due to a number of corresponding factors such as competitiveness of products, technologies and equipment, personnel, management and organization of business.

On the basis of conducted research we have come to the conclusion that the key factor of the competitiveness of the enterprise under any conditions is in fact the competitiveness of the products of this enterprise.

Regarding the competitive capacity of products there are different approaches. Milk is a unique food product, that has not been synthesized in the world by now. It has no analogues among the food products as to its content [12]. 40% of energy and protein a human receives from milk and milk products during his life [3]. American researcher К.Ekls wrote: ”Milk can substitute any product but there is no product that could substitute milk” [7]. Competitiveness of products is understood as a quality of this product to ensure a commercial success under conditions of competition [9]. Competitiveness regarding the particular kind of product involves its qualitative and price characteristics [14]. When analyzing the results of different approaches to the understanding the very meaning of product’s competitiveness in order to determine the milk competitiveness as an outcoming product of milk processing enterprise we can treat it as combination of its qualitative and valuable characteristics that make this product being capable to better meet the demands of customers in comparison with the same kind of products on the market under conditions of competition. The level of products’ competitiveness is made up of many factors, quality and price being the most essential ones. These factors are derivative from a big number of facts and processes, some of which can be mathematically modeled. These can be the level of high quality raw materials base and the quality of managing the material flows that both have effect on quality and price of the finished product and its position on the market.

The research has been conducted on the basis of regional milk production sub complex of AIC (Agro Industrial Complex) that within the whole administrative region include milk producers and milk processing enterprise.

The method of mathematical modelling for managing the material flows (in this case these are raw materials) under conditions of equal income of milk raw materials from the producers to the processing enterprise has been studied.

According to the standard and operational information we calculate the structure of transaction costs which include the transportation costs of the raw materials to the enterprise; costs for unloading and documentation; costs for expansion of raw materials base (as an option of economic relation); payment of managerial staff taking into account that constant costs for purchasing of raw materials for the given season (can be a year) account to a corresponding amount C_0 hrv per ton , and the costs for storing and refrigerating etc., – C_1 hrv per ton for a season.

In summer time milk processing enterprises mainly operate when they are relatively well supplied with raw materials which are delivered,

in constant intervals of time:

$$t = t_i - t_{i-1} = const, \tag{1}$$

In this approach:

$$t = \frac{T}{\eta}, \tag{2}$$

where: η – number of delivery of raw milk for the period T (days):

$$n = \frac{V}{q}, \tag{3}$$

where: q – average amount of milk per one delivery:

$$S_1 = C_0 n = \frac{1}{q} C_0 V = \frac{C_0 V}{q}, \tag{4}$$

$$S_2 = \frac{C_1 q T}{R}. \tag{5}$$

Organizational expenses (S_1) and the costs for storing and refrigerating milk at different stages of technological process (S_2).

Total amount of transaction costs for the whole season will make up:

$$S = S_1 + S_2 = \frac{1}{q} C_0 V + \frac{C_1 T}{2} q. \tag{6}$$

The enterprise is aimed to minimize these costs that can be calculated as follows:

$$S_{мін} = \sqrt{2 C_0 C_1 V T}, \tag{7}$$

and optimal meaning of $q_{опт}$ can be calculated in the following way:

$$q_{опт} = \sqrt{\frac{2 C_0 V}{C_1 T}}. \tag{8}$$

The necessary financial resources for covering costs for transportation and initial storing the raw milk can be

calculated with the formula (4) and (5), and the calculations show that their amount typically accounts to ½ of value $S_{\min}$.

The predicted values of raw milk amount on average per day for the period of the highest milking productivity of cows are recommended to be calculated with formula:

$$\overline{x} = \frac{q_{\min}}{t}. \tag{9}$$

In order to predict the necessary amount of transport means to supply the necessary amount and steady income of raw milk *($P_{вп}$)*, we need to apply the meaning of the number of trips of one vehicle, load carrying capacity and the average distance for delivery the milk to the processing enterprise:

$$N_a = \frac{\overline{x}}{kP_{вп}}. \tag{10}$$

In a similar way we can calculate the necessary amount of labor force applying standard labor costs for processing 1 ton of raw milk:

$$N_a = \overline{x}R. \tag{11}$$

To be able to analyze the tendencies for milk supply over the year and particular seasons, it is advisable to apply the statistical methods for processing these dynamic rates:

$$\overline{x}_i = \frac{x_{i-1} + x_i + x_{i+1}}{3}, (i = 1,...n), \tag{12}$$

where: x_i - 24 dol. volume of raw milk income,

$\overline{o}_3$ - adjusted meaning of 24 hr volume of raw milk income.

The results of calculations show that the volume of raw milk income over a number of seasons has been of parabolic character:

$$\overline{x}_i = a_0 + a_1 t + a_2 t^2, \tag{13}$$

where: t - unit time, then t = i=1, 2,..., η, and the duration of the season will amount $T = \eta$ days.

Parameters a_o, a_x, a_2 have been determined by application the method of the least squares:

$$\begin{cases} a_0 n + a_1 \sum t + a_2 \sum t^2 = \sum \overline{x}_i, \\ a_0 \sum t + a_1 \sum t^2 + a_2 \sum t^3 = \sum t\overline{x}_i, \\ a_0 \sum t^2 + a_1 \sum t^3 + a_2 \sum t^3 = \sum t^2 \overline{x}_i. \end{cases} \tag{14}$$

The system of regular equation as to a_o, a_1, a_2 is solved by applying the Cramer rule, and the obtained equation of regression allows to determine the calculated meanings of the average income of raw milk to the processing plant $\overline{o}_3$.

The calculations made on the basis of the data obtained from Joint Stock Company «Halychyna» in Radekhiv district, Lviv region, have proved the parabolic character of the dynamics of the raw milk volume income and confirmed the high value of the correlation coefficient (R=0,897). Thus, the equation for the tendency of raw milk income in 2009 applying this correlation coefficient is the following:

$$\overline{x}_t = -349,72 + 242,64t - 3,01t^2, \tag{15}$$

and in 2010 with the correlation coefficient R=0,979,

$$\overline{x}_t = -152,94 + 164,51t - 1,49t^2. \tag{16}$$

The conducted computations demonstrate that using only the one year period data there is no sense to apply the obtained equation regarding the tendency of raw milk supply because it is evident that the coefficients used have not been a function of sporadic factors and often these factors can be regulated (e.g. milking productivity of cows).

That's why it is advisable to consider the coefficient calculations a_o, a_1, a_2:

- taking into account the following factors:
- the expected volume of raw milk *V(т)*,
- volume of raw milk at the beginning of the season $t_0 = 0$ $\bar{o}_0$ (т),
- volume of raw milk in the end of the season $t_n = T$, $\bar{o}_n(T)$.

Initial data for the calculations of the values of the above mentioned volumes are the cows' productivity and outcome of milk from each herd and producer and the normative standards for processing every ton of raw milk.

So, at the moment of time $t_0 = 0$ applying the equation:

$$\overline{x}_0 = x_{t_0=0} = a_0 + a_1 \cdot 0 + a_2 \cdot 0 = a_0, \tag{17}$$

we: can calculate that $a_0 = \overline{x}_0$.

And at the time $t_n = T$:

$$\overline{x}_n = x_{i=T} = a_0 + a_1 T + a_2 T^2, \tag{18}$$

that is:

$$\overline{x}_n = a_0 + a_1 T + a_2 T^2.$$

The total volume of raw milk, that is transported for the time *[0,T]* will be:

$$V = \int_0^T (a_0 + a_1 t + a_2 t^2) dt = a_0^{\ T} + a_1 \frac{T^2}{2} + a_2 \frac{T^3}{3}. \tag{19}$$

By combining the equations (3.17), (3.18) and (3.19) into the system of equation in three unknown a_o, a_1, a_2 we can get:

$$\begin{cases} a_0 = \overline{x}_0 \\ a_1 = \dfrac{2}{T^2}\left[3V - T(2\overline{x}_0 + \overline{x}_n)\right] \\ a_2 = \dfrac{3}{T^3}\left[T(\overline{x}_0 + \overline{x}_n) - 2V\right]. \end{cases} \tag{20}$$

As a means of solution of such a system of equations it is advisable to consider the correlation:

$$\begin{cases} \overline{x}_n = a_0 \\ \overline{x}_n = a_0 + a_1 T + a_2 T^2 \\ V = a_0 T + a_1 \dfrac{T^2}{2} + a_2 \dfrac{T^3}{3}. \end{cases} \quad (21)$$

The average value of the volume of raw milk income at every moment of time t in the period $[0,T]$, can by calculated by means of the following equation:

$$\overline{x} = \overline{x}_0 + \frac{2}{T^2}\left[3V - T(2\overline{x}_0 + \overline{x}_n)\right].$$
$$t + \frac{3}{T^3}\left[T(\overline{x}_0 + \overline{x}_n) - 2V\right]t^2. \quad (22)$$

In case of applying the presented method of calculations in other enterprises you must apply the corresponding variation coefficient to correct the meaning:

$$\delta = \frac{\zeta}{x}, \quad (23)$$

where: x is the average volume of raw milk supply for 24 hrs over the season calculated with method of the least squares;

ζ – mean square deviation of random variable x_n,

ζ – mean square deviation of random variable x_n.

The value ζ can remain unvarying over the future period in case of negligible changes of values of its random factors. But in case of required correction of one of the important criteria the change of coefficients a_0, a_1, a_2 will be obligatory , that will cause the automatic reviewing of criteria meanings:

$$\overline{x}_0^{'} = \overline{x}_t;\ \overline{x}_n = \overline{x}_T, \qquad t=0\ \ T=T', \qquad V' = (V - \sum_{t=1}^{t} \overline{x}_t).$$

Corrections mean taking into account the volumes that have already been stored up by the moment of time í (even in the form of dry milk).

The conducted corrections of calculations will in turn have effect on the volumes and rates of the whole amount of works fulfilled in the enterprise.

In the same way we can calculate the future amount of necessary vehicles and workers under condition of available calculated standards and application of Poisson's law, i.e. distribution law of random variable:

$$P_k(t) = \frac{\lambda^k e^{-\lambda t}}{k!}, \quad (24)$$

κ – number of vehicles κ = 0,1,2,....;

$P_k(t)$ – probable κ-income of vehicles per unit of time t;

e - – Napierian base (e = 2,71828).

κ – number of vehicles κ = 0,1,2,....;

$P_k(t)$ – probability κ- of vehicles' per unit of time t;

e – Napierian base (e = 2,71828).

The time for service of one vehicle is calculated in the same way:

$$P = (\tau)t) = e^{-\mu t}, \quad (25)$$

where: $P(\tau > t)$ – probable excess of time t time interval τ between regular trips of vehicles.

The conditions presented in mathematical modelling are much harder than they can be in real life thus providing a certain "safety factor" for estimation the operation of the system.

With the aim of further mathematical formulation of considered dependences we indicate: the average number of vehicle units as λ; the average number of vehicle units that are unloaded per unit of time – as μ:

$$\mu = \frac{1}{\overline{t}_{обс.}}, \quad (26)$$

where: $t_{обс}$ – the average time for servicing one vehicle unit;

μ - number of unloading places;

$a = \dfrac{\lambda}{\mu}$ - loading level of enterprise.

Then:

– probability value that all milk pick up points are out of operation:

$$P_0 = \left[\sum_{k=0}^{n} \frac{a^k}{k!}\right]^{-1}, \quad (27)$$

– probability value that κ milk pick up points perform unloading of vehicles:

$$P_k = \frac{a^k}{k!} \cdot P_0, \qquad (1 \le k \le n) \quad (28)$$

– the average number of unloading places in milk pick up points:

$$N_3 = \sum_{k=1}^{n} k P_k, \quad (29)$$

– number of unused places at the operational milk pick up points:

$$N_{ïð} = n - N_3, \quad (30)$$

– milk pick up point working index:

$$k_{пр} = \frac{N_{пр}}{n} \cdot 100\%, \quad (31)$$

– coefficient of idle periods in a milk pick up point:

$$k_3 = \frac{N_3}{n} \cdot 100\%, \quad (32)$$

– idle periods probability before unloading:

$$P_{оч} = \frac{a^n}{n!} P_0, \quad (33)$$

– average number of vehicles standing idle before unloading:

$$\bar{m} = \lambda \cdot P_{оч}. \quad (34)$$

Then the total amount of financial losses of milk processing enterprise as a system will include losses from idle hours of vehicles and losses from underuse of operational milk pick up points:

$$S = \bar{m}C_T + N_{пр}\, C_б, \quad (35)$$

where: C_T – is money equivalent of the value of standing idle of a vehicle unit, hrv/dol.; $C_в$ – is money equivalent of the value of underuse of one operational milk pick up point, hrv/dol.

Let's estimate the operation of milk pick up points of a Joint Stock Company «Halychyna»:

– income intensity of vehicles with raw milk, λ = 5 units/dol,
– the average time for unloading of one vehicle unit at MPP (milk pick up point), $t_{обс}$ = 5 minuts, i.e. μ = 10 units/dol,
– the value of idle hours of one vehicle unit make out C_T = 105 hrv/dol,
– the value of underuse the operational capacity of one MPP, $C_в$=215 hrv/dol.

The most wide spread conditions for using the operational capacities of milk pick up points are the ones that correspond to n = 5, 6,7,8,9 and 10.

Then, for example, when $n = 7$ the losses of enterprise make out S_7 =2146,3 hrv/dol. When we set up two more milk pick up points at each enterprise, that is n = 9, then losses from inefficient unloading make out S_9 =1446,3 hrv/dol, and the economy cuts per hour will be $\Delta S = S_7 - S_9$ = 700 hrv/dol.

CONCLUSIONS

The hierarchy character of dependences between the level of competitive capacity of the enterprise and its products and different rates of factors of this level specifies the structure and block character of economical and mathematical model in order to optimize this level of products' competitiveness taking into account the organizational and legal type of economic activity of the producer. Application of the economical and mathematical modeling for providing the products' competitiveness must become an integral part and instrument of the system for controlling its level. The suggested approach for analyzing MPE (milk processing enterprise) operation makes possible to apply the mathematical model for more effective management than under real conditions. Making regulations and adjusting the presented and formal indices, studying possible results we provide conditions for development of automated monitoring system aimed at making managerial decisions regarding the organization of MPE business and milk processing enterprise in general to ensure the higher level of their competitiveness.

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Nonequilibrium state of engineering systems

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A b s t r a c t. We present a characteristic of nonequilibrium phenomena and describe a method of determining the interdependence of thermodynamic forces and irreversible processes caused by them.

K e y w o r d s: nonequilibrium state, unstable systems, thermodynamic

Any engineering system has a certain technological structure, i.e., consists of a series of interrelated elements. Each structure on a certain j-th level is characterized by some collection of variables. In the twentieth century, due to profound experimental and theoretical investigations, the notions of physical laws have become wider. We should mention here, firstly, the discovery of nonequilibrium structures arising as a result of irreversible processes, where system relations are established naturally of themselves, secondly, the idea of the constructive role of time following from the discovery of nonequilibrium structures, and thirdly, the appearance of new postulates concerning dynamic, unstable systems. These discoveries have changed our concept of determinism [1].

It should be emphasized that at present the proposition of enthropy increment is by no means reduced to an increase in disorder because order and disorder appearance is explained by new, unique phenomena [3]. If the situation under study is far from and exist simultaneously, then, order and disorder prove to be tightly connected: one of them includes the other.

Our perception of nature becomes dualistic, and the basic concept in this perception is the idea of nonequilibrium state [2]. The matter is of nonequilibrium

status not only leading to order and disorder, but also making it possible to detect an equilibrium, then differential equations modeling this or that natural process become nonlinear, and analysis of a nonlinear equation, as a rule, is not reduced to a single type of solution. In this connection, a new solution can lead to changes in the space-time interpretation of the object or phenomenon under consideration.

Studying the interrelations between different physical phenomena does not cancel the phenomenological laws, existing within the framework of each phenomenon, but enables one to evaluate heuristically the possibilities of refinement and generalization of these laws and to understand their meaning more profoundly. These postulates are based on the principles of nonequilibrium thermodynamics [4...6], where the Onsager – Casimir reciprocal relation, established experimentally, has a fundamental character. This proposition, which can be called the fourth law of thermodynamics [7], is especially important in the modeling of real gas mixtures.

As the determining (rheological) relations supplementing the system of equations of heat and mass transfer, it is customary to apply the phenomenological relations of irreversible processes (Onsager relations):

$$I_k = \sum_{k=1}^{N} L_{kl} X_l, k = 1, 2, ..., N, \quad (1)$$

where: N is the number of independent physical processes and L_{kl} is the matrix of phenomenological (kinetic) coefficients, connecting the fluxes L_k and thermodynamic forces X_l.

The fluxes and thermodynamic forces in (1) are, in the general case, tensor quantities of any rank. The physical meaning of kinetic coefficients can be clarified, within the framework of molecular-kinetic theory.

The number of nonzero kinetic coefficients in (1) is bounded by the Curie principle [4], according to which the components of fluxes (i.e., components of vectors along the coordinate axes) will depend not of all components of the thermodynamic forces. For example, in the case of an isolated system, processes of different tensor dimensionality do not interact between themselves. In addition, within the framework of Onsager relations,

the Onsager – Casimir symmetry relations (the so-called reciprocity principle) are taken as an independent postulate [7]:

$$L_{kl}(B,\Omega) = \varepsilon_{kl}\varepsilon_{lk}L_{lk}(-B,-\Omega). \quad (2)$$

Here: B is the magnetic induction, Ω is the angular velocity of rotation of the system, $\varepsilon_k = 1$ for even (energy, concentration) and $\varepsilon_k = -1$ for uneven (momentum density) microscopic parameters (even or uneven functions of particle velocities). For an isotropic nonrotating system in the absence of external magnetic field, the symmetry relation (2) takes a simpler form:

$$L_{kl} = L_{lk}, \quad (3)$$

where: L_{ki} are scalar quantities.

We may consider the symmetry relations (2) and (3) as an empirically reliableaxiom, which is corroborated within the framework of statistical mechanics and by experimental data.

It should be emphasized that, in analyzing the hydrodynamic as well as the heat and mass transfer processes, the phenomenological approach (based on the postulates of nonequilibrium thermodynamics) enables one to obtain the defining relationships for the thermodynamic fluxes as well as algebraic formulas connecting the coefficients of molecular transfer and convenient for calculations.

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Influence of pollutions on the thermal characteristics, heat efficiency and optimal dimensions of tubes with londitudinal fins

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Abstract. In this report the results of experimental investigation on the influence of pollution on heat characteristics of tube with longitudinal fins are presented. The thickness of polluting on the finned surface in different time moments is measured. The dynamic of growth for polluted thickness is determined. As follows from experiments, the profile of polluting along the height of fins is near to trapezoidal. The temperature distributions in fins and total heat flux conducted by finned wall at the different time moments are found. The presence of pollution on the finned surface leads to change of temperature distribution in fins which substantially differ from the similar distributions for "clean" fins. The questions connected with the choice of the optimum dimensions of fins being polluted are discussed. It is shown that the optimum dimensions of fins are dependent on the value Biot number of polluting.

Key words: pollution, fin, tube, temperature

INTRODUCTION

In the process of exploitation of finned heat exchanges, which work in polluted environment there is affected their heat efficiency. It is caused by precipitation of pollution on the extended surface. The profile of this pollution along the fin height may be complicated and the influence of pollution on the thermal characteristics of finned surface can be considerable.

By the modelling of heat transfer processes in the fins with pollution or coating which possess a low heat conductivity it was shown [1, 2], that in this case the thermal characteristics of finned surface have a considerable distinction from the characteristics of "clean" surfaces. For example, the temperature distributions in fins with pollution are characterized by great differences from the similar distributions for fins without polluting. Besides, the presence of pollution on the finned surface lead to the necessity of taking into account the influence of pollution on the choice of the optimum dimensions of fins [1,2].

In this report there are presented the results of experimental investigations in which the processes of growth of the pollution on the finned surface and influence of pollution on the temperature distributions, heat efficiency of fins and summary heat flux from tubes with the longitudinal fins were studied. Also, the questions are studied connected with the calculated heat transfer methods and the choice of fin optimum dimensions for conditions of pollution of the extended surface.

EXPERIMENTAL APPARATUS AND PROCEDURES

There was created the experimental set up for investigation of influence the pollution on heat transfer conditions in tubes with longitudinal fins (Fig. 1). As a source for production of the waste gases with the polluted components, a diesel-fed engine was used having the power of 48 kWt, which worked using the fuel-oil. The experimental test section consists of the finned tube, which is contained within the outside tube (system "tube in tube"). The heating surfaces of this section had the next dimensions: outside tube diameter – 89 mm, inside tube diameter – 30 mm, length of tube – 2500 mm; fin height – 20 mm; fin thickness – 1 mm; number fins on the tube – 12.

The experiments were carried out in three directions:

1) Carrying out of balance tests.
2) Measuring the temperature of heat carriers in the channel inside a pipe, and leading into a pipe, in the wall of pipe and along the fin height in the different sections of test section.
3) Determination of the thickness, and thermal and physical properties of pollution.

In balance tests the expenditure of exhaust-gas and water, and output temperatures of gas and water were determined. Also the aerodynamic resistance in gas highway was determined.

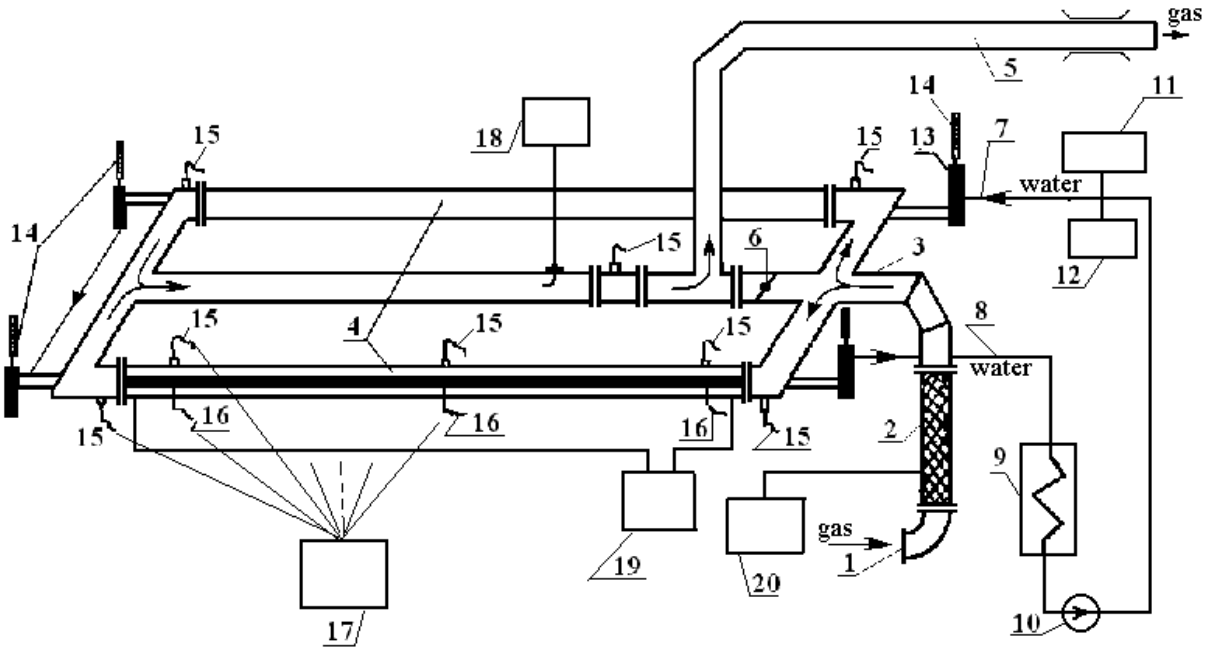

Fig. 1. Scheme of the experimental set up: 1 – inlet tube; 2 – flexible junction; 3 – gas collector; 4 – experimental sections; 5 – outlet tube; 6 – regulation valve; 7 – arrangement for bringing cold water up; 8 – arrangement for the leading of hot water; 9 – system for the cooling of hot water; 10 – circular pump; 11 – device for the measurement of water expenditure; 12 – device for the measurement of the pressure of water; 13 – thermometer for the measurement of the temperature of water; 14 – cartridge-case of thermometer; 15--16 – thermocouples; 17 – device for the measurement of temperatures; 18 – device for the measurement of gas expenditure; 19 – device for the measurement of the change of gas pressure in the experimental section; 20 – device for the measurement of gas pressure

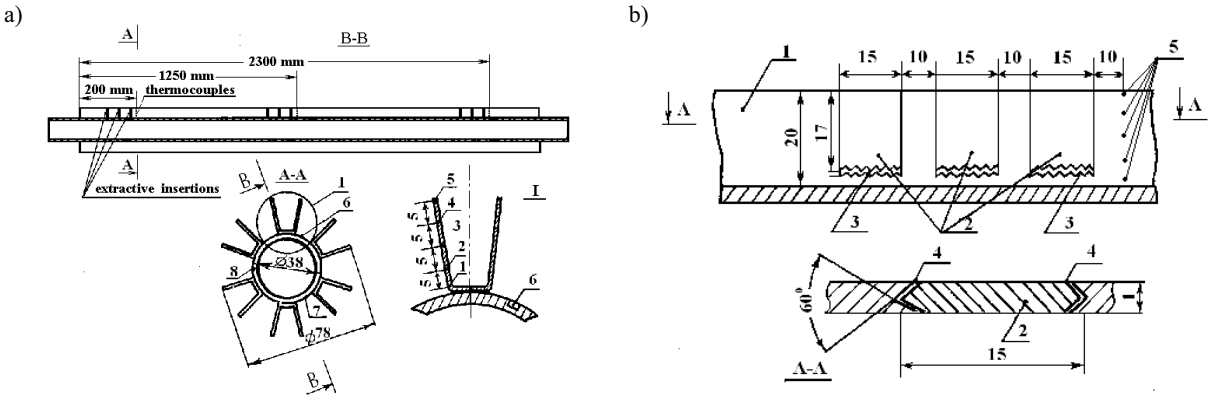

Fig. 2. Experimental section: a) longitudinal and cross section of finned tube, 1-8 – thermocouples along the fin height and on the tube; b) area of fin with insertions for the determination of the thickness and profile of pollution, 1 – fin; 2 – insertions of the type «swallow tail»; 3 – toothed base of insertions; 4 – junction of the insertion with fin; 5 – thermocouples

Table 1. Expenditure and temperature of heat carriers

Name values	Dimension	Stage I	Stage II	Stage III	Stage IV
Time	hour	4	72	144	216
Gas expenditure	kg/hour	215	207	206	205
Temperature of gas input output	°C	 294.9 91.6	 294.2 110.3	 295.0 124.4	 296,5 128,5
Water expenditure	kg/hour	3670	3700	3470	3710
Temperature of water input output	°C	 57.6 60.3	 56.6 58.6	 50.7 53.1	 54,0 56,2

For the realisation of works three sections of the finned pipe were prepared for the distances $L_1 = 200$, $L_2 = 1250$ and $L_3 = 2300$ from the beginning of fins (Figure 2). In these sections for the measuring of temperatures in the finned pipe thermocouples were set - in the pipe under the fin, in the middle part of the pipe between the fins and also a few thermocouples along the height of fin with the distance of 5 mm between them (Fig. 2a).

With the purpose of determination of the thickness as well as the thermal and physical properties of pollution on the fin, insertions were made of the type «swallow tail» with toothed base (Fig. 2b). On each of the three sections on the length of pipe three insertions were made. This gave the possibility to take the insertions out in different time moments. To provide a reliable contact between the insertions and the fin, an aluminium foil was used. In different moments of time, the measurement of expenditures, pressures, temperatures was conducted and the collection of insertions was performed. Further, the thickness of pollution was measured for the different heights of the fin, weighing the insertions with pollution, afterwards the coefficient of heat conductivity was calculated for the samples of pollution.

The measurements were conducted for the time period right up to the completion of stabilising of the thickness of polluted layer. Such measurements were conducted in in a few stages:

I. tests with a clean surface period of time),
II. in 72 hours (3 days) the work of setting,
III. in 144 hours (6 days) the work of setting,
IV. in 216 hours (9 days) the work of setting,
V. in 288 hours (12 days) the work of setting.

RESULTS AND DISCUSSION

As the conducted measurements showed, after 216-220 hours (9 days) the thickness of pollution on the surface of the finned pipe was stabilised. The results of the measurement of expenditure for gas and heat carriers, their temperatures on and beyond the experimental section for different time periods are presented in Table 1.

In Table 2 the results of the measurement of the thickness of pollution are presented for different sections along the length of finned pipe and along the height of fin for different distances from the fin base. Besides, in Table 2

Table 2. Thickness of pollution on the surface along the fin height for the different sections

Name values	Dimension	Stage II			Stage III			Stage IV		
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
Gas expenditure	kg/hour	207			206			205		
Temperature of gas	°C	288	190	124	290	204	129	291	205	131
Thickness of pollution along the height of fin 0,15h 0,25h 0,5h 0,75h h	mm	 0.88 0.82 0.67 0.54 0.49	 0.60 0.5 0.35 0.26 0.23	 0.22 0.22 0.18 0.12 0.08	 1.35 1.25 1.08 0.95 0.87	 1.12 1.08 0.89 0.74 0.60	 0.53 0.35 0.30 0.25	 1.65 1.60 1.35 1.25 1.15	 1.45 1.25 1.10 1.00	 0.90 0.88 0.78 0.72 0.67
Average thickness of pollution along the height of fin	mm	0.75	0.40	0.17	1.13	0.90	0.38	1.40	1.26	0.80
Average increase of pollution	mm	0.75	0.40	0.17	0.38	0.50	0.21	0.27	0.36	0.42

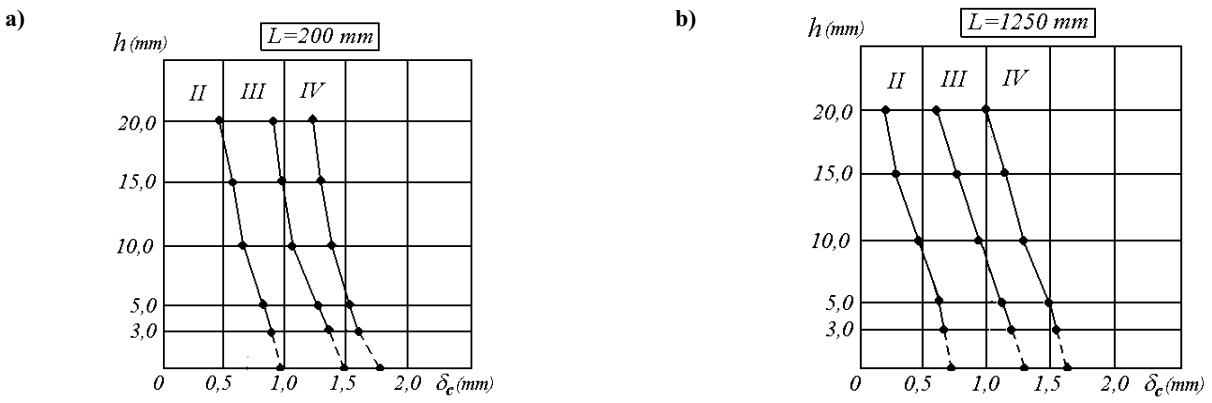

Fig. 3. The distribution of thickness of pollution along the fin height in the different cross-sections of the fin: a) $L = 200$ mm; b) $L = 1250$ mm

the average thickness and average increase of thickness of pollution along the height of fin are presented for the different sections of a pipe. As follows from the measurement, the thickness of pollution increases on the measure approaching the fin base, and that of pollution along the height of fin for all sections is near to trapezoidal (Fig. 3). The thickness of pollution is decreased along the length of fin (Fig. 4). The dynamics of change of the pollution thickness on the fin in time is presented in Fig. 5. From this figure it follows, that for the initial periods of time the most intensive growth of deposit. With time the speed of increase falls and it is not increased in future, therefore there follows the stabilisation of deposit thickness. This process is typical for all the sections along the length of pipe. However, the processes of stabilisation of pollution have some displacement at times (later in the process) while approaching the areas of finned surface.

Characteristically, on the initial areas of finned pipe the increase of depositsis is substantially greater than on the areas.

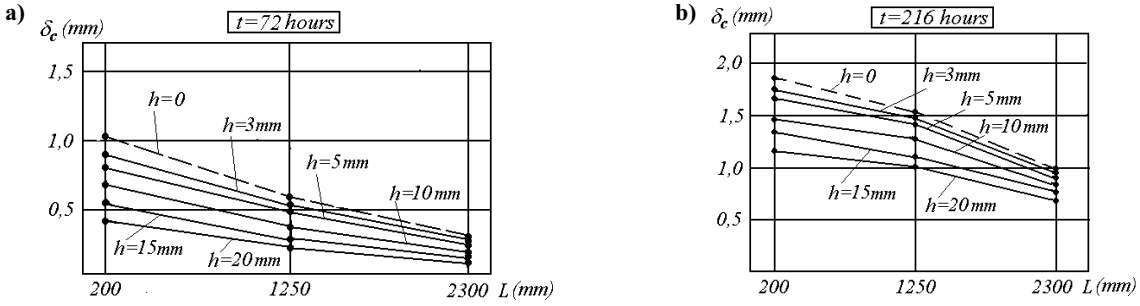

Fig. 4. The distribution of thickness of pollution along the fin length in the different cross-sections on the height of fin: a) $t=72$ hours; b) $t=216$ hours

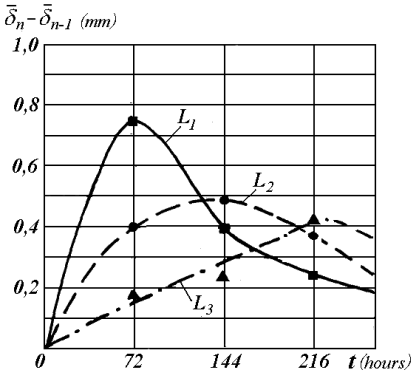

Fig. 5. The dynamics of change of average pollution thickness on a fin (=II, III, IV – number of stage)

The measurement of the coefficient of heat conductivity for the material of pollution was conducted. It turned out that this value is near to $\lambda_c = 0.11$ Wt/m ^{0}C. Some deviations from this value are caused by the changes in the structure of pollution during its growth on the finned surface at different time moments. In the initial periods of time they have a more dense structure, and with time soot pollution has a more fragile structure, and its thermal and physical properties are changed. The measurement showed that the maximal deviations from the middle value 0.11 Wt/m ^{0}C did not exceed 10%.

The results of the measurement of the temperature of pipe and fins, in the different points on the height on the different sections along the length of finned pipe, are presented in Table 3. The typical temperature distributions along the height of fin, in one of sections for different time moments are shown in Fig. 6. As follows from the figure, the temperature distribution in the fins at the presence of pollution substantially differs from the distribution for fins without pollution. The presence of deposits on the finned surface leads to a more uniform

Table 3. The temperature of fin along the height for the different sections along the length of pipe

Name values	Stage I			Stage II			Stage III			Stage IV		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Gas expenditure, kg/hour	215			207			206			205		
Temperature of gas, °C	282	154	91	288	190	124	290	204	129	291	205	131
Temperature of tube, °C	65	62	60	59	59	58	54	54	52	57	56	55
Temperature of fin along the height, °C												
0,15h	65	62	60	59	59	58	54	54	52	57	56	55
0,25h	102	87	64	67	64	60	65	60	53	67	60	57
0,5h	117	93	65	82	69	62	76	64	57	78	66	60
0,75h	140	98	66	95	77	64	92	74	60	99	75	63
H	187	122	76	126	93	72	118	86	86	120	89	70

distribution of temperature along the height of fins - the more so, the thicker the deposits.

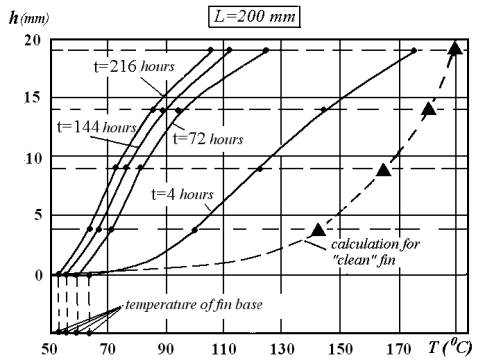

Fig. 6. The temperature distributions along the height of fin for the section $L=200$ mm in the different time periods

Using the balance measurement of the expenditures and temperatures for gas and water heat carriers, the total heat flux leading from finned tube in the different moments of time was calculated. The results of the calculation are presented in Fig. 8. As follows from Figure 7, the presence of pollution on the surface of finned pipe leads to a considerable decrease of the total heat flux, which consists of nearly 30%.

The numeral modelling of heat transfer in pipes with longitudinal fins at the presence of pollution on the external surface was conducted. The results are valid for the temperature distribution and heat efficiency of finned tubes with deposits at using the simplified, two-dimensional and conjugated model. The comparison of results found in these models with experimental data showed

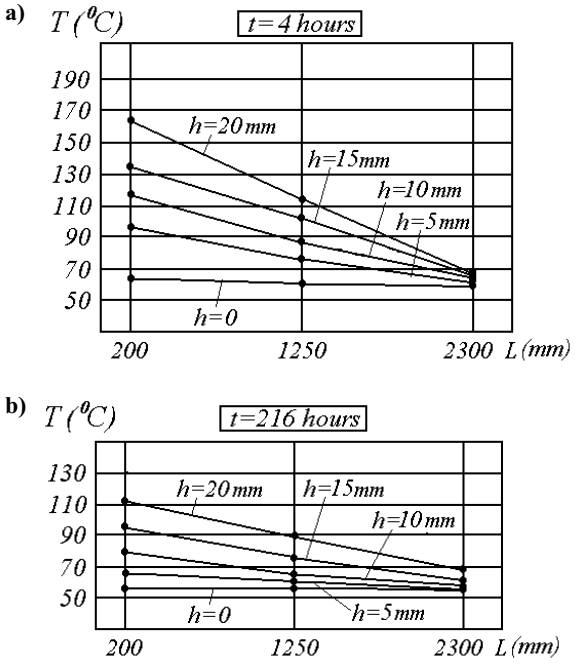

Fig. 7. The temperature distributions along the length of fin for the different sections of the fin height: a) $t=4$ hours; b) $t=216$ hours

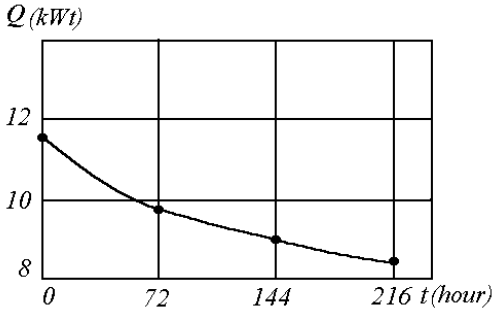

Fig. 8. The total heat flux leading from finned tube in the different periods of time

their coincidence in a satisfactory way. The maximal errors in the calculations do not exceed 15%.

The important question at the design of heat-exchanges working in a polluted environment is the choice of the optimal fins. The paper [2] provides the formulas for the calculation of the optimum thickness and height of longitudinal fins with pollution or coating:

$$\delta_{f,opt} = 0,632\frac{1+Bi_c}{\alpha\lambda_c}\left(\frac{Q_f}{T_0-T_g}\right)^2, \quad (1)$$

$$h_{f,opt} = 0,7979\frac{1+Bi_c}{\alpha}\left(\frac{Q_f}{T_0-T_g}\right), \quad (2)$$

where: α is heat transfer coefficient, h_f, δ_f - accordingly, height and thickness of fin, δ_c is the thickness of pollution or coating, T_0 is the temperature of fin base, Tg is the temperature of external heat carrier, $B_{ic}=\alpha\delta_c/\lambda_c$ is the Biot number of pollution, Q_f - heat flux of the fin.

As follows from the expressions (1), (2) an optimum height and thickness of fins depends on the Biot number of pollution. These are increased with the growth of Biot number. With such conditon the optimum thickness and height of fins is by1,5 time higher compared with the optimum of «clean» fins. The influence of nonuniformity of pollution along the fin height on the optimum fin dimensions may be taken into account, using the correct coefficients [2].

The crucial issue is the correct choice of the optimum of fins for heat exchanges with extended surfaces which subject to pollution would enable an improvement of the mass and dimensional characteristics of such heat exchanges.

CONCLUSIONS

1) Dynamic of change the thickness of pollution on the surface of finned pipe is determined. It was found out that the maximum speed of the growth the thickness of pollution takes place on the initial section of finned surface. In the course of time the thickness of pollution is stabilised, besides the process of stabilisation is later nearer the end of a finned pipe. Profile of pollution along

the height of fins is close to the trapezoidal profile for all the sections along the length of longitudinal fin.

2) The temperature distributions in a finned tube for the different moments of time are measured. It is found that the presence of pollution on the finned surface leads to a more uniform distribution of temperature along the height of fins, compared with the temperature distribution of a "clean" finned surface. This uniformity of the temperature distribution is the higher, the greater the thickness of pollution. The presence of pollution on the surface of a finned pipe leads to a considerable decrease of the total heat flux.

3) The optimum dimensions of polluted fins depend on the Biot number of pollution and increase with the growth of this value. For the studied condition the optimum height and thickness of longitudinal fins may exceed by 1,5 time the optimum dimensions of "clean" fins.

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A model of an energy efficient building automation system

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Abstract. A good building is characterized by structural and installation flexibility. Its another important feature consists in adaptability i.e. in potential subdivisions and modification of the functions owing to the fact that the type of activity conducted in a building object may be changed in course of its service life. There are several market requirements to be met by a building. The basic requirements are: the profit for the owner and developer, effective use of available space, low maintenance costs and possibility to generate profits. It is possible to determine the principles of engineering (POE) for a building on the basis of an assessment of quality of the already existing buildings. The following quality categories are determined in the framework of this method: technical, functional, behavioural, organizational and economic category. The users of the building as well as their needs and location in the building and the needs of this building are further elements to be considered.

The purpose of the present article is to establish a definition of an intelligent building and to present a model of building automation system in this type of building as well as to present the examples illustrating the use of computer in order to reduce electric energy consumption. The issues associated with the designing of energy efficient systems in the scope of building management have also been discussed.

Key words: energy efficiency, programming, building system, intelligent building, electric system.

INTRODUCTION

The eagerness to increase the comfort of the user and to reduce the maintenance costs was the guiding principle for te development of intelligent building. The construction of a building efficiently responding to human needs has become possible thanks to the development in the scope of information technology and automatic control engineering. The human effort aiming at the improvement of living conditions is one of the factors determining the development of new technologies in the scope of electric systems. Unfortunately there are often new problems caused by more and more advanced technologies in the scope of household appliances facilitating everyday life of their users.

The electric energy demand is increased as a result of new energy receivers occurring in the building system. A building which seemed to be an energy efficient object at its commission, becomes a source of increasing expenditures.

Therefore the versatility of the building and its openness to future changes is extremely important. The varying family situation of its users is another essential factor to be considered owing to changes in the house: children are born, their parents get older and need certain facilitation in the operation of the building systems.

Nowadays, the form of the employment of the users is sometimes changed and it becomes necessary to arrange some new rooms not considered before in the building, e.g. an office, laboratory or a doctor's or dentist's office. The reconstruction or extension of an existing house is often very expensive and arduous. Therefore the decision on the type of electric system to be applied in the building should be made as early as in its designing phase.

Unless this perspective is considered by the designer and/or investor at this moment, increasing energy consumption may become problematic after several years in case of an average functionality of the building.

There is a series of solutions elaborated for electric systems in order to increase the functionality of buildings [2, 3, 4, 5, 6]. Their scope encompasses the approach based upon control engineering solutions in conventional systems as well as upon introduction of intelligent building elements. The state-of-art building systems make it possible to organize the operation of many devices in a better manner and to optimise their power supply. The operation of many devices can be programmed according to the needs and habits of the users. Therefore it is possible to improve the comfort and to achieve potential savings.

The specialized software is often necessary in order to prepare the design and to start the automation systems.

APPLICATION OF COMPUTER ENGINEERING IN DESIGN

The enterprises have to cope with difficult tasks in the scope of planning and production control to meet the requirements of contemporary market. There are two types of production processes: i.e. continuous production processes and discrete production processes [13].

The continuous production processes are characterized by the manufacturing of a product in a continuous manner, most often by means of chemical, physical or mechanical processes.

The discrete production processes are characterized by the manufacturing of products consisting of elements which are produced individually in accordance with individual process plans (Fig. 1).

There are three basic types of production: mass, series and piece production.

A characteristic feature of the mass production consists in the manufacturing of very large quantities of standard products. The design or technological revisions are insignificant.

The series production is characterized by the medium scale of production and medium number of product variants. These products are manufactured in small lots.

The piece production is characterized by large number of products variants; the products are manufactured in small lots or as pieces.

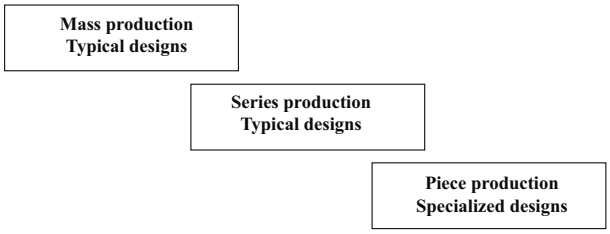


Fig. 1. Designing as a discrete production process

Depending on the type of an investment, the design of automatic control of the building can be interpreted as a kind of production. The designing may be associated with the tasks which are applied in very large number of the projects thereafter; which corresponds to mass production. Sometimes it is associated with the issues resembling serial production or the designer creates his/her own solutions. The following groups of functions are performed by the designer of the building automation systems in accordance with the type of solutions being elaborated:

– New systems,
– Modernized systems,
– Variant systems.

The complete design process consists of three phases:

– Concept design,
– Engineering,
– Preparation of documentation.

Depending on the group of systems being considered, certain phases of design process may be completed in limited scope.

The activities performed by the designer in individual design phases are illustrated in Table 1. In case

Table 1. The activities performed by the designer in individual phases of building systems designing

Group of systems			Design phase	The activities performed by the designer	Applied programs
New system	Modernized system	Variant system	Concept design	Preparation of requirements	Text editor, Spreadsheet CAD 2D,
				Preparation of concept variants	
				Preparation of system topology	
				Assessment of solution selection	
			Engineering	Consultation with investor	Text editor, Spreadsheet, Tools
				Preliminary assumptions	
				Preliminary calculations	
				Optimisation of system topology	
				Building permit design	
				Detailed engineering	
			Preparation of documentation	Formal and legal documents	Text editor, Tools, CAD 2D
				The scope of works to be performed	
				Technical description and calculations	
				Bill of quantities and installation tables	
				Graphical part	

of state of art systems, the designer also acts as a person programming and running the building automation system.

The designer of electric systems should use a work station equipped with hardware and appropriate specialized software. The software encompasses a text editor and several programs aiding the calculations carried out in course of design activities.

The important criteria to be considered by the designer in software selection are: possibility to create diagrams, to design systems basing upon architectural blueprints in dwg format as well as to support the selection and calculations of system elements.

A new role of PC appeared with the introduction of the new building systems e.g. KNX. The computer became a tool required to start up the devices. Therefore a portable computer is necessary for the designer/ installer to enable his convenient displacement in the building in course of their starting.

The structure of the designer's work station depends on the functions and tasks to be performed by the designer. The final definition of requirements regarding the size of computer and its configuration depends on installed software and tasks to be performed by the designer. The basic equipment of the station is illustrated in Fig. 2.

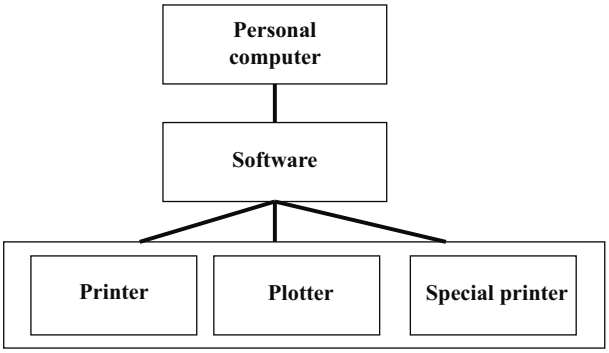


Fig. 2. Basic elements of the electric systems designer's work station

A personal computer is the basic element of the station. The computer should be equipped with highly efficient processor as well as high capacity memory and good graphical card. Furthermore the station should be provided with good quality printer, because a colour printout makes it possible to facilitate the localization of the systems in the building and to avoid collisions between them. The use of plotter is required in case of printout of large formats.

A MODEL OF SYSTEMS IN AN INTELLIGENT BUILDING

The systems integration is an extremely important issue in contemporary buildings [1, 3, 8, 9, 10, 12].

A model of systems in an intelligent building has been designed in order to enable the analysis of the issue associated with devices integration in KNX system. The work at this station consists of the following phases:

- Preparation of system design and creation of schematic connection diagram.
- Connections of selected devices.
- Determination of systems topology in the building.
- Introduction of bus devices and assignment their physical addresses in ETS4 program.
- Systems programming by means of ETS4 program.
- Systems starting.
- Verification of systems functioning for the compliance with preliminary assumptions.

Design of laboratory station is equipped with elements constituting the components of each building system (Fig. 3).

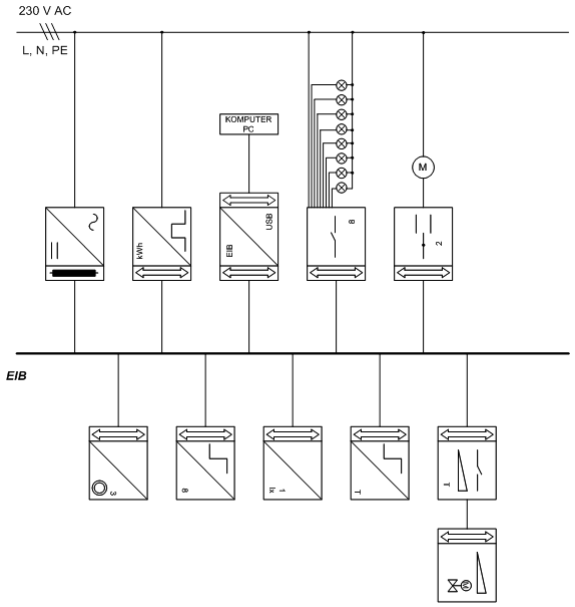
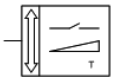
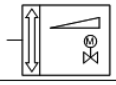
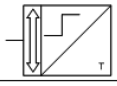
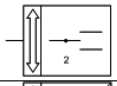
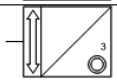
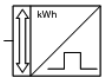


Fig. 3. Block diagram of laboratory station design

1	**EIB 320 mA power pack**	
2	**RS 232 interface**	EIB / RS 232
3	**USB interface**	EIB / USB
4	**8x4A switching ON actuator**	8
5	**8-fold 24VDC binary input**	8
6	**Illumination sensor**	1 lx

7	**Cancealed heating actuator**	
8	**Heating valve actuator**	
9	**Room thermostat**	
10	**Dual shutters controller**	
11	**Triple Busch-Triton pushbutton**	
12	**Electric energy meter**	

This station makes it possible to build the systems enabling the lighting, heating and shutters control. Furthermore the station is provided with an electric energy meter to enable the checking and testing of power consumption for individual elements of the system which has been built.

The following system operation simulations are possible by means of created model of the building:

– ***Lighting control***

The design and construction of the system enabling the control of two groups of lamps: the lamps are turned on and off in an independent manner. The illumination sensor should be used to send a telegram switching the corresponding groups of lamps; this telegram is sent to the bus if the preset threshold values of illumination measured in lx are exceeded.

– ***Heating control***

The design and construction of the system enabling the control of heating: the created system should enable the heating control in three modes: comfort, stand by and night operation mode.

– ***Shutters control***

The design and construction of the system enabling the control of shutters: the created system should enable the control of two groups of shutters independent of each other. One of them will be controlled upwards or downwards by prolonged depression of the pushbutton. Another group of the shutters will be provided with possibility to stop their movement time any time by short depression of the pushbutton.

The systems specified above should be provided with an electric energy meter to enable the checking of power consumption for individual devices.

The system makes it also possible to select an interface to be used for PC connection to the system. The connection is possible by means of RS 232 or USB interface.

The computer constituting a component of the station is equipped with ETS4 program to enable the preparation of the building automation system design, the system starting and execution of the building systems operation simulations.

CONCLUSIONS

The following conclusions can be made on the basis of considerations contained in the present article:

1. The testing of KNX system elements is possible by means of designed model of an intelligent building.
2. Its principal task is to analyse the integration of devices other than elements of this system.
3. Energy saving is the principal goal to be achieved.
4. The simulations of the lighting, heating and shutters control are possible at this station.
5. The electric energy meter enabling the monitoring of energy consumption during the executed experiments is an essential component of the station.
6. An important advantage of this project is the possibility to design and to implement various configurations of bus devices connections, because there are no permanent connections between the station modules. Therefore a wider scope of KNX system testing is possible through the creation of systems combining the lighting, heating and shutters control.
7. Further extension of the station in the form of new bus devices is also possible.
8. In order to enable full representation of possibility of optimised energy consumption in KNX system, this station should be provided with elements of a conventional electric system including energy meter in future. Thanks to created hybrid model, it will be possible to compare both the systems and to demonstrate possible savings in a more complete manner.

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Scientific and technical preconditions of electric field application at plants protection

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Abstract. The questions of application of nutrient solutions in an electric field, which contribute to the stimulation of plant growth, reduce electrical and raw losses.

Key words: electric field, electric charge, dispersity, surface tension, nutrient solutions, plants.

INTRODUCTION

Application of traditional technologies for plants protection, and first of all, by means of spraying of the differently applied aerosols plays an important role in the agricultural production, especially in the field of hothouse vegetable-growing. Such technologies embrace the process of additional unroot plants fertilizing, sprinkling and pollination with different nourishing and antidotic solutions, disinfestation and disinfection of enclosed spaces etc., which largely contribute to the creation of favourable terms for development and growth of plants.

However, in the course of such technologies analysis in the light of modern requirements, it becomes possible to ascertain, that these technologies are characterized in terms of high losses of working solutions, inequality of sedimentation on green mass of plants, create comparatively bad terms for absorption of solutions by the surface of plants, increase the losses of energy and water, promote ecological restrictions.

Practical applications reveal that in the course of traditional technologies exploitation, a high polydispersity of spraying is observed (from 30 up to 700 μm (micrometres)), the ratio of the useful settling of working solutions on green mass does not exceed (25-35)%, the inequality of sedimentation arrives at (45-60)% with norm, according to international standards, being set at the level of 15 %.

High polydispersity of spraying contributes to appearing of the phenomenon that large drops (>300..350 μm) do not hold back on a surface and fall on soil, drops (<15...50 μm) are either taken by air, or, having high volatility, evaporate and only part of drops of working solutions with diameter of (50..200) μm (not more than 30-35 %) arrives at the surface of green mass.

The performance of existing methods is largely determined by the possibility of specific terms creation for maintenance of drops of working solutions on all surfaces of green mass of plants, including the reverse part, which would accelerate the process of penetration of substances in the tissues of plants. Unfortunately, at application of these methods, results cannot be examined as positive. For instance, the inequality of sedimentation from both parties of surface of leaves arrives at (55-60)%, that is explained by sedimentation effect on the leaves of drops only under the action of attractive and inertia powers and presence of the so-called ”hollows” here.

The foregoing features of existing methods as well as the defects which take place during their realization especially with the increasing value of plants protection and requirements to energy-and-resources saving, stipulate the necessity of development of new technological processes as well as the engineering and constructive decisions or improvements of the already applied technologies.

MATERIALS AND METHODS

Basing on the theory adhesion [5] it is possible to ascertain that the penetration of operating substances in tissue of plants is normally carried out only in the liquid state and determined by the phenomenon of humidity, i.e. by pin cooperation on a limit: a solid (leaves, green mass) - liquid (working solution). Thus the retention of drops correlates with the phenomenon of moistening, which has a primary value in the processes of plants defence. It is known that the best molecular cooperation which determines humidity takes place under the next condition [4]:

$$\sigma_{s.b.} \geq \sigma_{w.s}, \quad (1)$$

where: $\sigma_{s.b.}$, $\sigma_{w.s.}$ - surface-tension of accordingly solid body and working solution.

The products of plant-growing are characterized by the considerable range of humidity and considerable vibrations of surface-tension. For example, green mass of bow, carrot, cabbage have the moisture content : $\Theta = 120...170°$ and surface-tension: $\sigma = (65…75)\ N{\cdot}m{\cdot}10^{-3}$. Moreover, some plants have a difficult structure of epidermis, microlevel inequality, presence of lanate fibres, that contributes to the diminishing of humidity.

Taking into account that many of working solutions have a considerable surface-tension (>75 $N{\cdot}m{\cdot}10^{-3}$) and, first of all, due to the fact that they present hydrogens solutions, possibility of moistening diminishes (1).

It is experimentally set that a surface-tension of working solutions must be within the limits of (30…40) $N{\cdot}m{\cdot}10^{-3}$, with the moisture content being set < 90°. Undoubtedly, the achievement of such values in case of application of traditional technologies causes considerable difficulties, generally it is practically impossible.

The solution for this problem may be found either by means of implementing of substantial changes in compounding of existent working solutions, by previous treatment of surface of green mass with the aim of humidity level control and management and surface-tension or development of fundamentally new decisions, which would stipulate not only the implementation of condition (1) but also even sedimentation on the surface of plants with minimum losses which is not still provided by currently existing technologies. The first couple of the above mentioned decisions, in our view, can solely contribute to the increase of price and further complication of process of treatment, introduction of additional technological operations etc. and cannot be examined as perspective and competitive. The most prospective technology of protection and cultivation of plants, in our view, especially for a hothouse vegetable-growing may be considered the application of electric-field, i.e. electrostatic method of spraying, which expediency is stipulated by physical essence, possibility of losses diminishing in quantity of working solutions up to (8-10)%.

The main feature of electrostatic method is that the charged particles of working solutions (pesticides, nourishing solutions etc.), moving along the lines of force of electric-field which is in turn created by the system of electrodes: a crowning electrode (nebulizer) and sedimentated electrode (plant) are evenly precipitated both on overhead and on the bottom (reverse) surface of leaves.

Previous experimental researches [4] in the sphere of nourishing solutions deposition on leafy mass of plants (growing in flowerpots) showed that on an overhead and reverse surfaces, sedimentation arrives at (90-92)% and (75-85)% accordingly. The conferring of the liquid to the solution of high potential (40..60 kW) on the crowning edge of nebulizer contributes to diminishing of surface-tension of drops of liquid, their durability and sizes, that in turn, stipulates the increase of spreading process and creation of the even placing of solution on the moistening surface of plants.

Thus a surface-tension is determined by the following expression [3]:

$$\sigma_{st} = \sigma_d - \frac{\varepsilon_k \cdot \varepsilon_o \cdot \bigcup^2}{4r_d} \quad (2)$$

where: σ_d - surface-tension of drop of liquid; ε_k - an inductivity of liquid; ε_o - an inductivity of vacuum; r_d - a radius of drop of liquid; U - electric potential of drop.

High potential on the crowning edge of nebulizer increases the specific electric charge of drops of solution, which in turn stipulates the creation of a more developed surface of drops and as a result greater contact with the surface of plants, increasing the spreading of all leafy (vegetable) cover, its maintenance on the surface.

An electrostatic method facilitates the change of dispersion of drops (by 1,2…10 times). Thus, according to [4], there is a connection between the surface-tension and sizes of drops.

$$r_p = r_0 e^{-\frac{4\pi\sigma_p \cdot \mu_p \cdot \mu_\Pi \cdot N \cdot L}{\rho_p \cdot \varepsilon_0 \varepsilon_p RTE^2 r_0}}. \quad (3)$$

RESULTS AND DISCUSSION

Analysing expressions (2, 3) it is possible to assert that the change of surface-tension (σ_{pp}) and radius (r) of drop of working solution in the electric field takes place similarly and determined by the value of electric potential of drop (U^2). This, in turn, gives grounds to do an important conclusion: the losses of mass of working solutions are proportional to the surface-tension and tension of electric-field, which is the power description of the field and determines the trajectory of motion i.e.:

$$\Delta m_{ws} \approx \sigma_{pp} \cdot \frac{1}{E^2}, \quad (4)$$

where: Δm_{ws} – losses of working solution; E – voltage of electric field.

Expression (4) has a conclusive value at the determining of the modes of treatment of plants and at developments of structural parameters of electrostatic installations for plants protection, highlights meaningfulness of parameters E and fully accedes to principles of motion and charging of particles in the electric field.

Relations (2, 3, 4) stipulate the terms not only for the receipt of the homogeneous and monodispersible spraying but also for adjusting a process with determination of optimal sizes of drops of working solutions subject to the concrete state of plants and agrotechnical demands.

It is experimentally set that at application of working solutions in the electric field, for example, the aquatic solutions of mineral fertilizers, a size of drops must be

70… 120 μm, spraying (monodispersion) homogeneity presents ≥75-82 %.

The indicated parameters contribute to the even sedimentation on the green mass of plants, create favourable terms for the effective spreading on their surface and penetration in tissues of plants. The previous results showed that such treatment stimulated the increase of the productivity for 8-12 %.

High economic (diminishing of charges of working solutions), functional (physical grounds, equality of deposition and sedimentation) and ergonomics (diminishing of energy losses, increase of productivity, protection of environment) advantages of electrostatic method in comparison to existing technologies stipulate its efficiency, processing ability and perspective.

However, there are problems, such as an absence of the single theory of penetration of working solutions in tissues of plants, presence of contradictions in the presentation of physical aspects of processes of charging, motion and sedimentation in the electrostatic field of aquatic solutions of working substances on green mass of plants, the heterogeneous level of researches, empiric character of some conclusions, restrain development and introduction of modern developments.

Development of this direction, for example, in home plant growing, is restrained by inadequacy of level of scientific and technical, technological and designer decisions, absence of producing of corresponding technological equipment and, first of all, small high-voltage sources and nebulizers, parameters and physical possibilities of which would meet the requirements, that are inherent to the processes of plants protection and contributed to the practical realization of hothouse vegetable-growing.

The indicated scientific and technical aspects of the problem and advantages of application of electric field, as a working instrument for deposition of nourishing and antidotal preparations in the course of plants protection, in our view, must contribute to the appearance of attention and interest to the considered questions from research and technical workers, who are engaged in the problems of energy and resource saving in plant growing.

CONCLUSIONS

Application of such a perfect method as electrostatic approach stipulates high efficiency and creates more favourable terms for plants protection in a wide range according to the existing agri-technical requirements.

Development and realization of the method, without regard to its economic and technological advantages, in the national agrarian production is restrained by practical absence of researches of suitable quality and especially insufficient attention to the developments in the sphere of creation and production of special electrotechnical equipment.

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CFD modelling of combustion in HCCI engine using avl fire software

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Abstract. HCCI (Homogenous Charge Compression Ignition) combustion system is now one of the most promising solutions used in piston engines. The paper presents the results of three-dimensional modeling of combustion in the single-cylinder HCCI engine powered with Diesel fuel. 3D modeling was performed in AVL Fire code. The basic combustion parameters including start of the ignition (SOI), burn duration (BD), indicated pressure (pi) and nitric oxide (NO) and soot (Soot) emissions were analyzed. The modeling results show that combustion process in HCCI engine compared to a conventional engine with compression ignition is characterized by an earlier ignition (SOI) and shorter burn duration (BD). The impossibility of controlling HCCI combustion process leads to deterioration of engine performance and increased emissions of harmful exhaust gas components. Calculations showed that for the same equivalence ratio of burn mixture, uncontrolled HCCI combustion compared to a controlled combustion in engine with fuel injection operated is characterized by higher NO emission and reduced Soot emission.

Key words: homogenous charge compression ignition (HCCI), exhaust gas recirculation (EGR), heat release rate (HRR), start of the ignition (SOI), burn duration (BD), injection timing (IT), conventional compression ignition engine (CI), indicated pressure (pi), nitric oxide (NO).

INTRODUCTION

HCCI (Homogenous Charge Compression Ignition) combustion system is now one of the most promising solutions used in piston engines. It combines the best features of spark ignition engines and compression ignition engines, and is characterized by low NO_x and PM emissions and high efficiency. So far conducted research on HCCI engine not solved the problem of control of moment of autoignition of homogeneous mixture supplied to engine and duration of the combustion process. The presented work concerns the numerical study of the combustion process of homogeneous mixtures in HCCI engine. The basic combustion parameters including start of the ignition (SOI), burn duration (BD), indicated pressure (p_i) and nitric oxide (NO) and soot (Soot) emissions were analyzed. Modelling in the AVL Fire was carried out. The aim of modelling was to get acquainted with the course of HCCI combustion process and compare the basic parameters of the uncontrolled HCCI combustion with controlled combustion in a conventional engine with compression ignition.

THE EXISTING STATE OF RESEARCH

Development works on combustion, emissions of harmful exhaust gas components and controlled autoignition in HCCI system s well as application of the system in a real engine are conducted in many research centers and universities around the world. The work [1] briefly describes the history of origin, worldwide research work results, advantages and problems following from specific combustion process, typical for HCCI engines which are so different from the well known and widely used spark and diesel engines. More than twenty years left since the HCCI concept was first proposed and demonstrated and steady progress has been made in developing the technology. Previous and current research works in the world have indicated that the engine working in HCCI mode can be supplied by means of different fuels at extremely low emissions and high efficiencies. Homogeneous charge compression ignition (HCCI) engine technology has received increasing attention in recent years due to its intrinsic benefits in terms of high efficiency and low NO_x and Soot emissions [2]. However, unresolved issues include combustion phasing (i.e., the control of the start and duration of combustion), high carbon monoxide and unburnt hydrocarbon emissions, limited load-speed operating window, and transition to spark-ignited combustion at high loads. Several strategies

for mixture control have been devised and are currently being considered to help overcome these difficulties. These include diverse fuel injection schemes such as port fuel injection and single or multistage direct injection (DI or MDI), as well as external exhaust gas recirculation (EGR), variable valve timing, and variable compression ratio. Homogeneous charge compression ignitron (HCCI) is nowadays a leading trend in the development of gasoline internal combustion engines. The application of this novel combustion system will allow for compliance with future legislations concerning the exhaust emissions including carbon dioxide. The paper [3] presents a design and implementation of a research engine with a direct fuel injection and the capability of HCCI combustion via an internal gas recirculation and negative valves overlap (NVO). The technical approach used in the engine allowed and autonomous HCCI operation at variable loads and engine speed without the need of a spark discharge. Experiments were conducted at a wide range of valve timings providing data which allowed as assessment of a volumetric efficiency and exhaust gas recirculation (EGR) rate. Permissible range of air excess coefficient, providing stable and repeatable operation has also been identified. The use of direct gasoline injection benefited in the improvement of the start of the combustion (SOC) and heat release rate control via the injection timing. The objectives of the study [4] is to clarify ignition characteristics, the combustion process, the knock limit and the misfire limit of natural gas mixed with a small amount of dimethyl ether (DME) in a HCCI engine. In the combustion test, natural gas and small amount of DME were charged into the suction air homogeneously. The equivalence ratio of natural gas was increased to find the knock limit or the misfire limit of the HCCI test engine under a constant DME amount. The effect of the natural gas addition on suppression of the low temperature reaction of DME, and the effects of the DME amount and the intake temperature on the reaction rates, the knock limit of the DME/natural gas mixture, and the operation load range of the HCCI engine were investigated experimentally. The paper [5] presents results of the research carried out on the impact of initial temperature and combustible mixture composition on work of engine based on the HCCI principle. The researchers found that there is a specific value of the mixture initial temperature (approximately 200°C). When it is reached, further temperature rise does not cause any distinct increase of combustion process maximum pressure, pressure buildup rate and self-ignition delay. This initial temperature value slightly depends on combustible mixture composition. Work [6] investigates the basic combustion parameters including start of the ignition, burn duration, cycle-to-cycle variation, and carbon monoxide (CO), unburned hydrocarbon (UHC), and nitric oxide (NO_x) emissions of homogeneous charge compression ignition engines fueled with primary reference fuels and their mixtures. Two primary reference fuels, n-heptane and iso-octane, and their blends were evaluated. The experimental results show that, in the first-stage combustion, the start of ignition retards, the maximum heat release rate decreases, and the pressure rising and the temperature rising during the first-stage combustion decrease with the increase of the research octane number. Furthermore, the cumulative heat release in the first-stage combustion is strongly dependent on the concentration of n-heptane in the mixture. The start of ignition of the second-stage combustion is linear with the start of ignition of the first-stage. The combustion duration of the second-stage combustion decreases with the increase of the equivalence ration (inverse of the excess air factors) and the decrease of the octane number. The cycle-to-cycle variation improved with the decrease of the octane number. In [7], which is a continuation of [6], the influence of exhaust gas recirculation (EGR) rate, intake charge temperature, coolant temperature, and engine speed on the HCCI combustion characteristics and its emissions were evaluated. The experimental results indicate that the ignition timing of the first-stage combustion and second-stage combustion retard, and the combustion duration prolongs with the introduction of cooled EGR. At the same time, the HCCI combustion using high cetane number fuels can tolerate with a higher EGR rate, but only 45% EGR rate at 1800 rpm. Furthermore, there is a moderate effect of EGR rate on CO and UHC emissions for HCCI combustion engines fueled with n-heptane, but a distinct effect on emissions for higher octane number fuels. Moreover, the combustion phase advances, and the combustion duration shorten with the increase of intake charge temperature and the coolant out temperature, and the decrease of the engine speed. At last, it can be found that the intake charge temperature gives the most sensitive influence on the HCCI combustion characteristics.

In this paper, by using the advanced combustion simulation package AVL Fire, HCCI combustion process in test engine were investigated and analyzed numerically. The basic combustion parameters including start of the ignition timing (SOI), burn duration (BD), indicated pressure (p_i) and nitric oxide (NO) and soot emissions (Soot) of a single-cylinder (HCCI) engine powered with diesel fuel were analyzed.

In recent years the numerical modelling investigations using more and more advanced mathematical models have been intensively developing. The development of numerical modelling is reinforced with increasing computational power that allows modelling of not only flow processes but also combustion in 3D [8, 13]. One of more advanced numerical models used for combustion process in piston engines modelling is AVL Fire [14]. In 2009 Institute of Thermal Machinery of Czestochowa University of Technology began University Partnership Program with AVL List GmbH Company and to modelling thermal cycle of IC engines using AVL Fire software [15, 21]. The Fire software belongs to contemporary programs which are used for modelling of thermal cycles of internal combustion engines. AVL Fire allows modelling of a flow and thermal processes that occur in the intake manifold, the combustion chamber of IC engine and the exhaust pipe with a catalyst and a particulate filter. This programme

enables the calculation of transport phenomena, mixing, ignition and turbulent combustion in internal combustion engine. Homogeneous and inhomogeneous combustion mixtures in spark ignition and compression ignition engines can be modeled using this software as well. The kinetics of the chemical reactions phenomena is described by combustion models that take into account the oxidation processes in high temperatures. Several models apply to auto ignition processes including HCCI combustion. AVL Fire allows modelling of knock processes that occurs in the combustion chamber of IC engine. This program allows building three-dimensional computational grids, characterizes the boundary conditions of surfaces and initial conditions of simulation. The postprocessor gives a possibility to visualize the results.

TEST ENGINE AND MODEL ASSUMPTIONS

Modelling of the thermal cycle of the HCCI engine in the AVL Fire program was carried out. The object of the investigations was a modernized diesel engine 1hc102 Andoria fueled with diesel fuel. As a result of the modernization the shape of the combustion chamber was modified. The compression ratio has not changed and was equal to 17.5. The engine was operated at a constant speed of 1800 rpm. The engine is a stationary, two-valve unit with a horizontal cylinder configuration. The cooling system of engine is the evaporation of the water jacket. Table 1 presents the main engine parameters, initial conditions and Fire sub-models.

Table 1. Modelling parameter

Engine parameters	
Type	Water-cooled, 4 stroke
Number of cylinder	1
Displacement volume	918 cm^3
Engine speed	1800 rpm
Bore×stroke	100×120 mm
Connecting-rod length	216 mm
Squish	2.5 mm
Compression ratio	17.5:1
Injection timing (conventional engine)	14,12,10, 8, 6 deg BTDC
Initial conditions	
Initial pressure for 180 deg BTDC	0.9 MPa
Initial temperature for 180 deg BTDC	340 K
Equivalence ratio	0.5
Fuel	Diesel
AVL Fire sub-models	
Turbulence model	k-zeta-f
Combustion models	Eddy Breakup Model
Ignition models	Diesel (conventional engine CI) HCCI Shell Model (HCCI engine)
NO formation model	Extended Zeldovich Model
Soot formation model	Frolov Kinetic Model

On the basis of the real dimensions of the experimental engine a three-dimensional mesh of engine combustion chamber was built (Figure 1). The mesh of the modeled combustion chamber of the 1hc102 modernized test engine consisted of nearly 32000 computation cells. Two-layered wall boundary layer was considered.

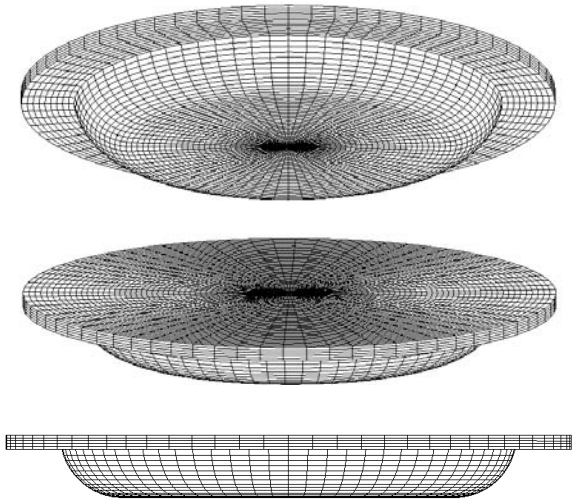

Fig. 1. The computational mesh for combustion chamber of the test engine

Computations were conducted for the angle range from 180 deg before top dead centre (BTDC) to 180 deg after top dead centre (ATDC). Calculations included the study of a HCCI engine and conventional compression ignition engine CI. HCCI engine and conventional engine was fueled with a mixture of diesel-air equivalence ratio of 0.5. The modelling of a conventional combustion process was conducted for five of injection timing: 14, 12, 10, 8 and 6 deg before top dead center for which there was no knock combustion [22, 26]. HCCI combustion process was not controlled and preceded spontaneously. On the basis of the pressure data obtained from modeling indicated pressure p_i was calculated. The indicated pressure is one of the parameters determining the performance of a combustion engine. The calculated indicated pressures do not include certain losses both in the combustion process as well as the flow losses and blow-bys.

RESULTS OF CALCULATION

Figure 2 shows a comparison history of diesel fuel combustion between the HCCI engine and conventional compression ignition engine CI. Some basic combustion parameters of the combustion process in HCCI and conventional engine CI are also shown in this figure. HRR_{max} is defined as the maximum value of heat release rate in combustion process. The timing of SOI (start of ignition) is defined as that point on the HRR graph at which the rate of heat release rate exceeds 0.5 J/deg, as shown in Figure 2 [27]. The BD (burn duration) is defined as the combustion duration, which is the distance between the crank angle of SOI and crank angle corresponding to

20% of the magnitude of peak of heat release rate on the falling side of the curve [6]. Characteristics show a large difference between the HCCI engine and a conventional engine in the ignition timing, maximum heat release rate, maximum pressure and temperature. In the case of the conventional engine, the ignition occurs near TDC because the ignition timing can be controlled by the fuel injection timing, while, in the case of the HCCI engine which does not have a mechanism to control combustion, the ignition occurs earlier than in the case of the conventional compression ignition engine.

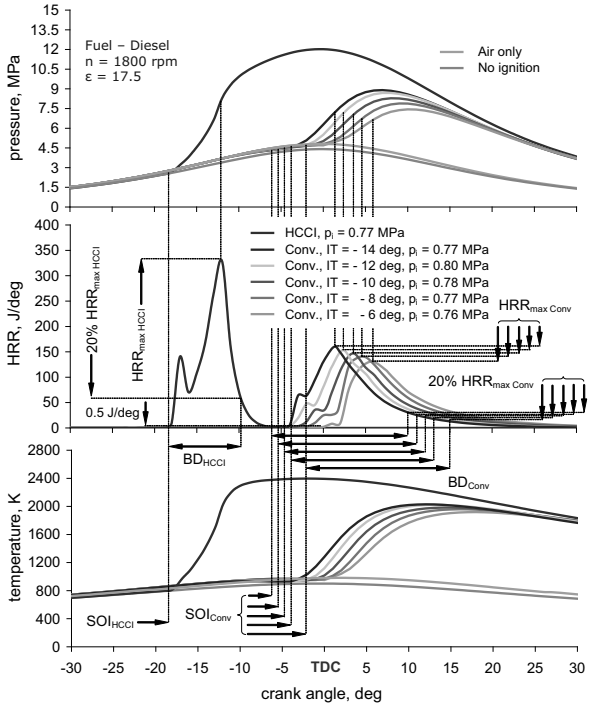

Fig. 2. Comparison of the history of the diesel fuel combustion between HCCI and conventional compression ignition engine CI

As shown in the heat release curves, diesel fuel in HCCI clearly shows two-stage combustion phenomena, that is, the low-temperature reaction and high-temperature reaction. The two-stage combustion mechanism is typical of diesel fuel and also occurs with lighter fuels, such as kerosene. In the case of this type of combustion, at 760 - 880K, about (5-15) deg CA before principal and fast heat release, cold blue flames appear and preliminary heat release occurs [29]. The results of modelling show that for a conventional engine powered by mixture of er = 0.5, the most optimal of injection timing angle (IT) is angle equal to 10 deg before TDC. For this injection angle the maximum indicated pressure achieved equals to 0.78 MPa. In the HCCI engine, with er = 0.5, the maximum indicated pressure achieved similar value equals to 0.77 MPa. Figure 2 and Table 2 shows, that combustion process in HCCI engine compared to a conventional engine is characterized by an earlier ignition (SOI) and shorter burn duration (BD).

Table 2. Selected results of the modeled combustion process

	IT deg	p_i MPa	SOI deg	BD deg	NO_x ppm	Soot mg/m^3
Conv.	-14	0.77	-7	17	425	1.25
Conv.	-12	0.80	-6	17	380	4.28
Conv.	-10	0.78	-5	18	358	6.45
Conv.	-8	0.77	-4	19	327	9.63
Conv.	-6	0.76	-2	19	285	16.58
HCCI	-	0.77	-18	9	1067	1.5e-06

Temperature distribution in the working area of conventional CI engine and HCCI engine for er = 0.5 is depicted in Figure 3. At 8 deg before TDC in conventional engine is realized ignition of diesel fuel injected. At the same time, in HCCI engine, the combustion process is already taking place in the entire volume of the combustion chamber.

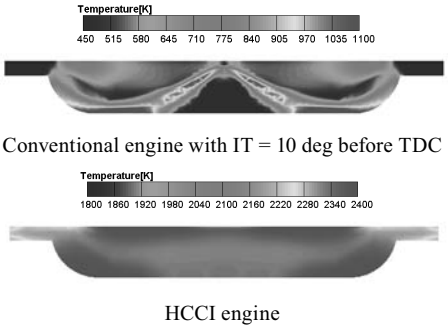

Fig. 3. Temperature distribution in combustion chamber of the conventional CI engine and HCCI engine for er = 0.5 at 8 deg before TDC

HCCI engine characterized by a higher NO emissions and lower Soot emissions compared to conventional engine CI (Table 2, Figure 4 and 5). Uncontrolled HCCI combustion is characterized by higher emission of the nitric oxide and lower emissions of the soot than it is in the case of a controlled combustion in a fuel injected engine.

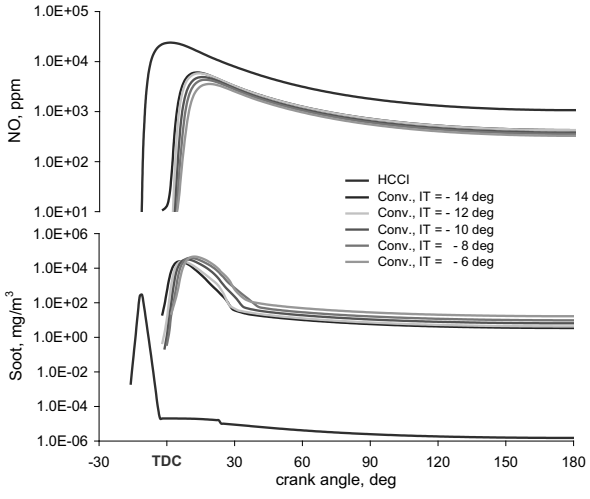

Fig. 4. Nitric oxide and Soot emission of conventional CI engine in comparison with emission of HCCI engine

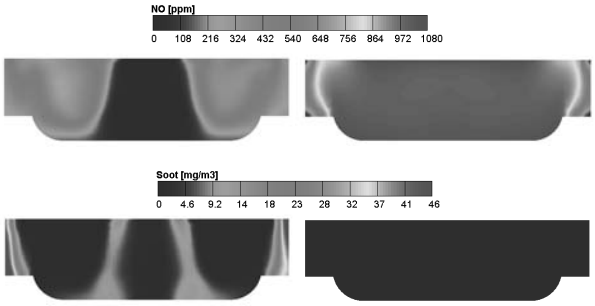

Fig. 5. NO and Soot concentration in combustion chamber of conventional CI engine and HCCI engine for er = 0.5 at 40 deg after TDC

CONCLUSIONS

This paper discussed the effect of EGR rate on HCCI combustion parameters and NO emissions. Based on these discussions, some conclusions may be drawn.

1. HCCI combustion process compared to a conventional compression ignition engine is characterized by an earlier ignition (SOI) and shorter burn duration (BD).
2. Compared to the CI engine, too early ignition of uncontrolled HCCI combustion leads to an increase in the maximum values of pressure, temperature and heat release rate in the cylinder. Higher pressures, however, cause no increase in indicated pressure (p_i), which is the utility parameter and shows the engine performance.
3. Uncontrolled HCCI combustion is characterized by higher emission of the nitrogen oxide (NO) and lower emission of the soot (Soot) than it is in the case of a controlled combustion in fuel injected engine.
4. Control of ignition and combustion process in HCCI engine can be an effective method of reducing emissions of NO [30]. The most commonly used systems of HCCI process control include Variable Valve Timing (VVT), external and internal EGR, Variable Compression Ratio (VCR) and a system of cooling and heating of inlet charge.

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Explore the potential use of cast ductile iron (ADI) on the working parts of machines working in municipal wastewater treatment plant

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Abstract. The theoretical part of the study discloses the genesis of the research which originated from a possibility of replacing the so far used expensive machine parts with parts cheaper and yet offering similar quality and performance life. A short characteristic of the machine was given where the main operating parts made so far from steel were replaced with parts made from cast iron. The equipment and its main applications were described.

In the research part of the study several types of alloys were proposed. Their use is expected to ensure the required performance life of parts combined with price reduction. A short characteristic of the proposed material was given. A technology of making moulds for the said machine parts was developed. Using this technology, the respective moulds were made and poured next with three cast alloys.

One of the proposed materials was subjected to four types of the heat treatment, two alloys used as reference materials were left in as-cast state. The castings were fettled and weighed. The hardness of the cast materials was measured.

The working (turning) parts were delivered for operation to a sewage-treatment plant where, after assembly in a turning machine, the performance tests were conducted.

Key words: environmental protection; innovative foundry materials and technologies; wear-resistant alloys; mechanical properties.

THE AIM AND SCOPE OF THE STUDY

The present study was initiated by one of the sewage-treatment plants vividly interested in the possibility of replacing the so far used working parts of a turning machine with parts cheaper but of similar performance life.

Hence the main aim of the present work was making a trial lot of castings operating as parts of the machine for turning of triangle heaps (the turning paddles) using a material of the properties comparable with materials used so far but enabling a reduced cost of the manufacture of these parts. In our activities carried out so far, quite often we faced the situations when a "weak" link in the operating equipment was the quality of some operating parts of machines and equipment and their high price. The example are ploughshares used by agricultural industry and bushings in mechanical coal miners. When these parts started to be made of proper materials, it has finally become possible to successfully match their long performance life with low cost of manufacture.

A SHORT CHARACTERISTIC OF THE MACHINE

The investigated machine (Fig.1) is used for the turning of typical triangular heaps.

Fig. 1. The turning machine

When the machine is operating, two scrapers placed before the frame are pushing the turned stock from the wheel tracks to the inside where it is taken over by the revolving rotor and thrown backwards. This process also serves for the disintegration of large lumps. Since the

processed material is in most cases thrown centrally, a new well-aerated heap is formed.

Optionally, the machine can be equipped with an installation for wetting of the heaps with water, ejected from ducts connected to a water feeding system or to a storage reservoir. Depending on the type of the turning machine, it is moving on wheels or caterpillars.

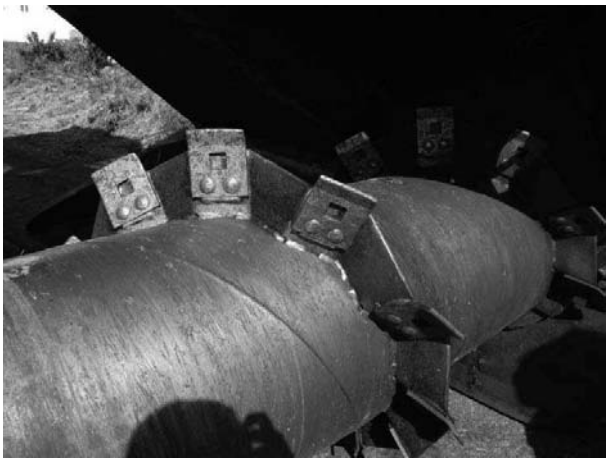

Fig. 2. Paddles on a rotor of the turning machine

As mentioned previously, the working elements of the turning machines are rotors with paddles fixed on the external surface - the so called turning paddles (Fig. 2).

The said machines are used in sewage-treatment plants and on municipal waste dump fields. One of the main tasks of the turning machine is mixing of organic matters, like straw, grass, hey, etc. with semi-liquid stock, obtained during the municipal waste treatment, and then with soil and refining additives to produce mineral fertilizers used in agricultural industry.

Below, an example of overall dimensions and operating parameters of a turning machine is given, overall dimensions of the machine:
- width – 5200 mm,
- length – 3200 mm,
- height – 3400 mm,

overall dimensions of the rotor:
- width – 4300 mm,
- diameter – 1000 mm,
- dimensions of a paddle – 148 x 120 x 10 mm

operating parameters of the machine:
- maximum rotational speed of the rotor – 240 1/min,
- accessories of the rotor – 8 combs – 44 tools (turning paddles),
- feed rate – up to 50 m/min,
- turning capacity – (300 – 3000) m^3/h.

DISCUSSION OF RESULTS

GENERAL

To know the operating conditions of the machine for the turning of triangular heaps, the main working parts of which are the paddles discussed in this article, a sewage-treatment plant where this machine is used was visited.

The turning machine was installed in the sewage-treatment plant. A practical display of its operation under the standard operating conditions was arranged. The display demonstrated the conditions and the capabilities of the machine.

The practical display and the technical specification helped us understand the conditions that the material used for the directly operating parts of the machine, i.e. the turning paddles, should satisfy. The conditions are very demanding. First of all, the material should be characterised by high mechanical properties, like the tensile strength, ductility, hardness and abrasion wear resistance. It should, moreover, offer adequate corrosion resistance, taking into consideration the environmental conditions of its future operation.

Taking the above into consideration, as well as the specification of the material used so far (manganese cast steel), the work on the choice of the best material and technology for the casting of the turning paddles was started.

THE SCOPE OF THE RESEARCH

- Choice of moulding technology and mould making process.

The sewage-treatment plant interested in the new cast material for the turning paddles provided us with a brand-new specimen of the paddle, which served us as a pattern for the die used in the proposed technology of mould-making (the technology of lost wax patterns). In the rubber die several wax patterns of the required configuration were made. After combining the patterns in clusters, the ceramic mould was fabricated by the successive application of six ceramic layers.

The ceramic slurry in which the pattern clusters were immersed was composed of Ekosil binder and silica flour in the ratio of 1:2. As a loose dry ceramic material for the successive layers we used first the fine-grained silica sand, and next coarse-grained one. After the drying of the last ceramic coating, the wax patterns were melted out in a pressure autoclave in the atmosphere of steam overheated to the temperature of 120°C.

One single cluster prepared for pouring was composed of four patterns of the paddles. Altogether 12 mould clusters were made.

The clusters were placed in metal boxes and supported with sand.

- Selection of cast material, melting process and heat treatment

When selecting the cast material for the turning paddles, the high mechanical properties, i.e. hardness and tensile strength combined with relatively high ductility and abrasion wear resistance were mainly taken into consideration.

The following alloy types were considered:

– ADI after different types of heat treatment – the main material,
– high-alloyed cast steel – the reference material.

Melts were carried out in an induction furnace of 60 kg capacity made by Radyne. Two melts of spheroidal graphite cast iron were prepared. The chemical composition of the cast iron is given in Table 1.

Two grades of cast steel were melted., one melt for each cast steel grade. The chemical composition of the cast steel is given in Table 2. From the cast iron melts, 32 castings of the chemical composition given in Table 3 were made.

Two cast steel melts were also conducted, making 4 cast pieces from each melt. The cast steel had the chemical composition as given in Table 4.

The paddles cast from s.g. iron were next subjected to a heat treatment to obtain the ADI structure. The heat treatment regime as given in Table 5 below was adopted.

A set of cast paddles is shown in Fig. 3.

Fig. 3. A set of cast paddles

The paddles cast from steel were not heat treated. A photo of a single paddle is shown in Figure 4.

Table 1. The chemical composition of the cast iron

S.g. iron melt	Chemical composition in %,					
	C	Si	Mn	Mg	Ni	Cu
	3,50-3,60	2,50-2,90	0,30-0,50	0,060	1,10-1,30	0,50-0,70

Table 2. The chemical composition of the cast steel

Melt No.	C	Si	Mn	P	S	Ni	Cr	Mo	N	Al
No. 1	0,30	0,30	16,0	0,008	0,014	-	18,0	-	0,70	-
No. 2	0,10	1,00	0,60	0,008	0,015	4,80	25,0	2,20	0,70	0,15

Table 3. The chemical composition of the cast iron melts

Melt No.	Paddle No.	Chemical composition in %,							
		C	Si	Mn	P	S	Mg	Ni	Cu
1	1-16	3,60	2,75	0,35	0,06	0,01	0,070	1,15	0,57
2	17-32	3,70	2,90	0,27	0,055	0,005	0,09	1,35	0,43

Table 4. The chemical composition of the cast steel melts

Paddle No.	C	Si	Mn	P	S	Ni	Cr	Mo	N	Al
33-36	0,32	0,30	≅18,0	0,01	0,010	0,10	16,2	-	0,60	-
37-40	0,055	0,95	1,3	0,010	0,010	4,60	23,70	2,00	0,60	0,15

Table 5. The adopted heat treatment regime

Casting No.	Temp. austenitising [° C]	Time austenitising [hours]	Temp. salt bath [° C]	Holding time [hours]
1-8	930	3	280	4
9-16	930	2	340	2
17-24	930	2	300	2
25-32	930	2	320	2

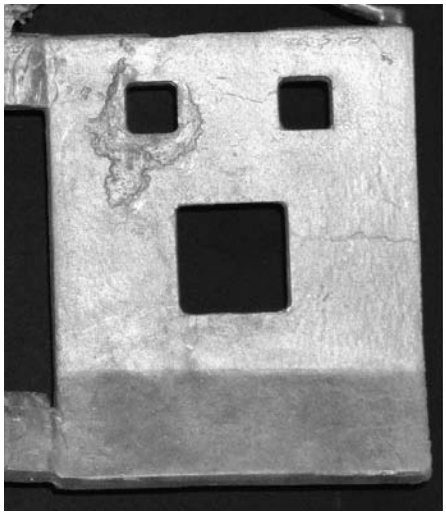

Fig. 4. Photo of a single paddle

- Mechanical tests of the castings and quality assessment

At this stage of the studies, testing of mechanical properties consisted in the measurement of the casting hardness taken on the working surfaces of paddles cast from ADI. The measurements were taken with a stationary hardness tester.

The results of the hardness measurements taken on ADI castings are given in Table 6.

The results of the hardness measurements taken on steel castings are compiled in Table 7.

The quality assessment included the visual inspection of the external surfaces of paddles (to check them for the presence of surface defects) and X-raying of castings.

The visual inspection of the casting surfaces did not reveal the presence of any defects which would disqualify the castings; only small pinholes and veins were noticed and were removed.

The X-ray inspection did not reveal any internal defects that would disqualify the castings.

- Performance tests

The research program included making the following castings of the turning paddles:

a. from ADI – 32 pieces,

b. from alloyed steel – 8 pieces

Castings were handed over for performance tests carried out in a sewage-treatment plant where they were assembled in a machine for turning of triangle heaps, and where their positions on a rotor were periodically changed according to a standard schedule of operation. Before assembly the paddles were weighed to check them later for the loss of weight during performance tests.

During the initial period of operation (four months and about 400 motohours) one paddle made from the cast iron was totally damaged. The remaining castings revealed standard wear and tear and remained in operation. The Institute will be informed on the results of the performance tests made by the user upon completing of the tests. So far, a set of paddles has been reported to operate for a mean time of 800 motohours.

CONCLUSIONS

TENTATIVE ECONOMIC ANALYSIS

From the information supplied by the sewage-treatment plant where the performance tests were carried out it follows that the price of 1 kg of the proprietary paddles operating in a heap-turning machine is 50 PLN. The estimated cost of making 1 kg of castings in small-lot production from the proposed cast material (ADI) and using the proposed moulding technology should amount to about 40 PLN/kg. If the technology of moulding in e.g. sodium silicate sands is adopted, the cost per piece in small-lot production will be cut down to about 30 PLN/kg.

So, assuming a similar performance life of parts, it should be possible to reduce the cost of the paddle manufacture by approximately (20-40)%.

Table 6. The results of the hardness measurements taken on ADI castings

Casting No.	Temp. salt bath [° C]	Results of hardness measurements [HRC]	Mean hardness values [HRC]
1-8	280	35,33,33, 40,36,40	36
9-16	300	36,29,28,32,34,29,31	31
17-24	320	20,19,21,20,20,20	20
25-32	340	26,32,29,26,35,26	29

Table 7. The results of the hardness measurements taken on steel castings

Casting No.	Results of hardness measurements [HRC]	Mean hardness values [HRC]
33-36	37,39,41,38,40	39
37-40	30,32,29,27,30	30

SUMMARY

The outcome of the research was manufacture of a pilot lot of cast turning paddles operating as a main element in the machine for turning of triangular heaps, used in both sewage-treatment plants and in the municipal waste dump fields.

The tests and examinations made so far have proved an extended life of the proposed new cast materials and advantages resulting from the proposed technology of manufacture.

Using this material in small-lot production it is possible to reduce the cost of the working parts by about 20-40%.

The next conclusions will be drawn upon completing of the performance tests and complex material examinations.

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Theoretical and experimental ground of the fuel energy efficiency improvement by an activation of the burning reaction molecules-reagents

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A b s t r a c t. In theory and experimentally a method of fuel options energy efficiency rise due to an activation of burning reaction molecules-reagents under high voltage electric field action is grounded. A variant of the technical realization of the offered method is described.

K e y w o r d s: high voltage, electric field, activation, energy efficiency, RedOx.

INTRODUCTION

The economy of fuel and energy resources due to the rise of efficiency of the use of power equipment is one of the basic tasks of modern science and production. Accordingly, a greater expenditure of power equipment per unit of products has a greater negative specific influence on environment. Therefore, a rise of the power equipment use efficiency is valid both for economy in general and, by necessity, for every industry from the viewpoint of economic and ecological efficiency of their functioning.

At present, traditional fossil power equipment is the basic energy source of practically all the economies of the world. Thermal energy sources are traditional and they supply to the most traditional power equipment. Thermal energy is created in te process of fossil fuels incineration in the oxidizing gas environment, that is at the motion of oxidizing-restoration chemical reactions. Therefore, at the use of power equipments optimization is an important task of the motion of chemical reactions.

The process of molecules-reagents activation at burning exothermic reactions is an object of our theoretical and experimental researches.

The technical and technological researches aim at the optimization of burning reaction of hydrocarbon fuels in the air under the high tension electric field.

The article presents the results of theoretical and experimental studies the target of which is the efficiency of motion of exothermic reactions of burning on the example of incineration of hydrocarbon gaseous fuel in mid-air under high voltage electric field.

MATERIALS AND METHODS

The fuel heating value and temperature of flame are basic fuel properties. The fuel heating value (specific burning warmth) is the quantity of warmth (MJ/kg), which is selected at the complete burning of 1 kg of hard or liquid fuel, or 1 m^3 of gaseous fuel. In practice, it is possible to distinguish higher Q_h^f and lower Q_l^f heating value of fuel [1]. A higher heating value is the description of fuel at its complete burning and condensations of the well-educated aquatic pair during burning. So, as in the real terms an aquatic pair is thrown out in the atmosphere, therefore in the heating engineering computations and reference literature under the term heating value of fuel we understand a lower heating value of fuel, in which the warmth of aquatic pair condensation is taken into account. The important question is whether it is possible to change the heating value of every traditional power equipment, or non-traditional one, of a strictly definite and constant size, by means of the proper technologies in the direction of increase.

Processes of generation of warmth are linked, mainly, with the reducing- oxidizing (RedOx) exothermic burning reactions. For the optimization of these processes it is expedient to consider them from the viewpoint of the chemical kinetics theory. The dependence of reactionary properties of the chemical system on the inlying energy, structure and atomic and molecular reagents composition is the basic question of modern theory of chemical kinetics.

Still in 1889 Arenious created the law of chemical kinetics [2], known as the law of his name. This law expresses the possibility of motion of chemical reactions between molecules-reagents. He links the constant of speed

of reaction with energy of activating (E_A), which characterizes the power state of molecule and is written down as:

$$k = k_0 \cdot e^{-\frac{E_A}{RT}}, \quad (1)$$

where: k_0 - preexponential constant; R - gas constant, even 1,987 cal/grad·mol; T - temperature in the degrees of Kelvin scale, °K; e - basis of natural logarithms.

To find an activating energy, reaction speed is caat a different temperature and for every value of speed constant. After taking the logarithm of both parts of formula (1) get a formula:

$$\ln k = \ln k_0 - \frac{E_A}{RT}. \quad (2)$$

For a greater comfort of computations decimal logarithms are used:

$$\lg k = \lg k_0 - \frac{E_A}{4,575T}, \quad (3)$$

where: the number 1/4,575 - module of translation of natural decimal logarithms, increased by R = 1,987.

Energy of activation can be defined with the formula

$$E_A = (\lg k_0 - \lg k)4,575T. \quad (4)$$

From formula (4) it is evident, that the energy of activation of molecules relies straight proportionally on temperature.

A process of activation of the molecular system consists in the transformation of power state of electrons on the higher power level.

The explanation of the given process can be illustrated by means of power diagram of atom (molecules) in Fig.1

A process of excitation of atom (molecules) consists in transition under action of power factor of one or a few valency electrons from the stationary shell in atom (molecule) on higher excitation levels.

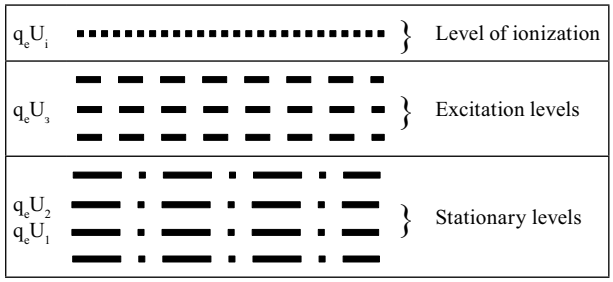

Fig. 1. Power diagram of atom

To release an electron from a molecule of methane, one should get the quantum energy lower than 12.6 eV [3], for ethane and propane – 11.5 eV, for oxygen molecules - 15.5 eV [4] - the quantum of energy lower than the energy of ionization, but sufficient to transfer an electron in an excited state. For computations we take the value of quantum energy of activation molecules about 5% lower than the energy of ionization.

Molecules activation by light is the result of inelastic collision of molecules and quantum of light [5]. With sufficient quantum energy of electromagnetic radiation, electrons move from molecule stationary energy levels to excitation levels. This quantum energy of light (E_l) is calculated by the formula:

$$E_l = h_o \nu, \quad (5)$$

where: h_o – Planck's constant ($6,626 \cdot 10^{-34} \cdot$ J c); ν - electromagnetic wave frequency (Hz).

The frequency was calculated of electromagnetic radiation needed to activate the aforementioned molecules and the results were put into Table 1.

As seen from the obtained results, for the activation of molecules the so called vacuum ultraviolet rays can be used with a wavelength within 100 nm or less. Getting radiation with such parameters in normal states is problematic. Therefore, photoactivation of molecules without special training parameters of the environment is not effective.

After our working hypothesis, for activating of molecules-reagents, except for thermal, it is possible to use other outsourcings with energy. If external energy sources are constant and secure the source of pulsating energy, frequency of which answers resonance frequency of molecules of reagents, it is possible to attain an effect of their translation in the active voice with the substantially lower power expenditure. Complementing the formula (4) by the effect of action on molecules-reagents we will get other factors:

$$E_A = E_{AT} - E_{A3} = [(\lg k_0 - \lg k)4,575T] - Wb, \quad (6)$$

where: W - energy obtained from outsourcings; b - coefficient of the use of external energy by molecules-reagents.

From formula (6) it is evident that thermal energy of activation can be lowered due to the use of other sources of molecules activation.

Table 1. Options of electromagnetic radiation activation

Molecule	Ionization energy, eV	Activation energy			Light frequency, Hz	Electromagnetic wave length, nm
		eV	J / molecula	J / mol		
Methane	12,6	11,91	$19,08 \cdot 10^{-19}$	$11,48 \cdot 10^5$	$2,87 \cdot 10^{15}$	104
Ethane	11,5	10,87	$17,41 \cdot 10^{-19}$	$10,48 \cdot 10^5$	$2,63 \cdot 10^{15}$	114
Propane	11,5	10,87	$17,41 \cdot 10^{-19}$	$10,48 \cdot 10^5$	$2,63 \cdot 10^{15}$	114
Oxygen	15,5	14,65	$23,47 \cdot 10^{-19}$	$14,12 \cdot 10^5$	$3,54 \cdot 10^{15}$	85

To the external energy sources for the activation of molecules-reagents it is possible to take, for example, electromagnetic radiation or irradiation by the stream of the charged particles. In [6] a method is described of obtainment of molecules with the set properties of chemical communications. It consists in operations on a molecule with no less than two degrees of freedom, electromagnetic radiation or stream of the charged particles, which translate a molecule from one quantum power to another. The electromagnetic stream and infra-red laser radiation will initialize and increase the reactionary power of matters [7]. The positive influence of heterogeneous stationary electric field on the flowline of the reaction of burning is described in [8,9].

From all the possible methods of molecules activation we selected the components of RedOx burning reaction for the research on electro-activating. The liquid gas propane was chosen as the reducing component, and the oxygen of air as an oxidant.

The developed experimental unit served the research on influencing efficiency of high-voltage pulsating electric field on the oxidant and fuel at incineration of propane. A functional diagram of the experimental unit is shown in Fig. 2.

The experimental unit works as follows. By the separate channels gaseous fuel and air enter the gas burner. On its way to the gas-ring oxidant in the electrode system 1 and fuel in the electrode system 2 are added to the activating action of the high-voltage pulsating electric field. Each of the electrode systems has a corpus in its composition, made from the dielectric material; entrance and initial opening; general electrode, executed as a metallic plate; and needle-shaped electrodes, placed to the general electrode athwart, which have different length with the purpose of the most effective carrying of fuel and oxidant. The frequency of electric field impulses is changed in the range 20-120 Hertz. The choice of the operations modes of the experimental unit was carried out by means of switches SA1 - SA4.

The oscillogram of the initial signal of sound generator (U_1) and oscillograms of initial signals of generator of high pulsating voltage (U_2) of the experimental equipment are shown in Fig. 3.

The research of efficiency of electro-activation on the oxidant and fuel at the incineration of propane was conducted in the variants:

1) - incineration without electro-activating (control);
2) - incineration with electro-activating of air;
3) - incineration with electro-activating of propane;
4) - incineration with electro-activating of air and propane together.

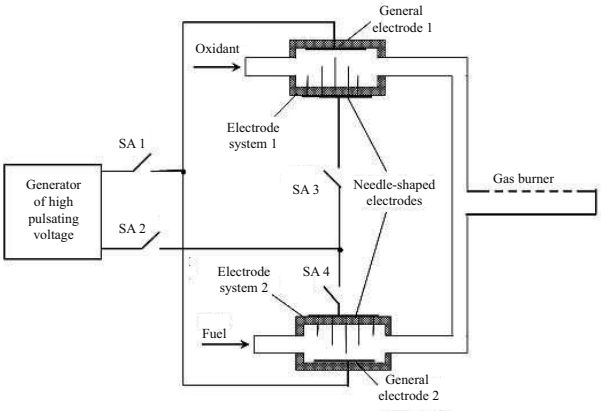

Fig. 2. The functional scheme of the experimental unit

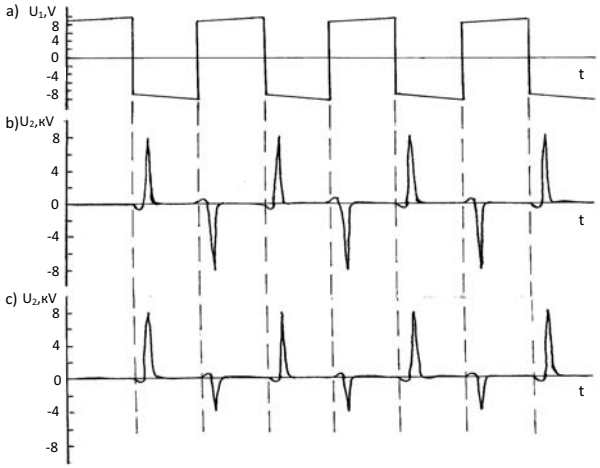

Fig. 3. Oscillograms of sound generator initial signal (a), Oscillogram of entrance signal of the electrode systems without straightening (b) and with straightening (c)

RESULTS AND DISCUSSION

The efficiency of electro-activating was tested by the time of heating 1,0 liter of water from 20 °C to 40 °C.

Table 2. Influencing of electro-activation of burning reaction components at the time of water heating

Method of incineration of fuel	Time of heating of water (c) at frequency of electric field, Hz						
	0	20	40	60	80	100	120
Without electro-activating (control)	124,0	-	-	-	-	-	-
With electro-activating of air	-	125,0	121,7	116,7	113,3	113,3	121,7
With electro-activating of propanou	-	120,0	113,3	110,7	110,0	112,3	110,7
With electro-activating of air and propanou	-	110,0	113,3	106,7	105,0	98,3	96,7
LSD							4,33

There were three repetitions of the experiment. The research results are given in Table 2.

The obtained experimental results show that electro-activation of burning exothermic reaction components of propane in mid-air reduces the heating time of 1 litre of water in an old tub practically in all variants of research. The most positive effect is observed at the action on both of the components of reaction of burning of high-voltage pulsating electric field with frequency 100-120 Hertz.

CONCLUSIONS

1. Activation of molecules-components of burning reaction by the high-voltage pulsating electric field results in the reduction of expenditure of fuel.

2. The highest efficiency of electro-activation (about 22 %) is obtained at the frequency of high-voltage pulsating electric field 120 Hertz and the activation of both the components of burning reaction.

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Measuring equipment and software products in vibrodiagnostics

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Abstract. Master data are expounded on the nature of vibration of electric machines and possibility of exposure of their defects with application of vibrodiagnostic methods.

Key words: vibration, vibrocontrol, vibrometer, vibroanalyzer, diagnostic information, monitoring.

INTRODUCTION

At present the device providing is one of the most current problems of vibrodiagnostic which needs an urgent decision.

As known, a vibration and noise is natural processes in machines and equipment, and they are under the action of the dynamic efforts of investigation on their wear and various defects. Indisputably, vibration shows by itself an informing and effective diagnostic parameter, as swaying forces arise up directly in the place of defect, and a machine is "transparent" for a vibration[3, 5]. An important circumstance here is that vibrodiagnostic can be conducted directly in place, without sorting out and stopping of the equipment.

It should be noted that diagnostics following a vibration allows to find out the various defects of electric machines - disbalance, malalignment and out-of-parallelism of billows, loss of inflexibility and weakening of supports, precipice of wall screws, violation of geometry of line of vala and different defects of bearings knots, including problems with grease.

On the basis of the obtained information it is possible to optimize te planning of permanent and capital repair, increase the TBO period, cut down expenses on the purchase of repair parts and expense materials. Vibrodiagnostics can be valid for one occasion or periodic monitoring or deep survey.

Measurement of intensity of vibration after the standards of ISO can be executed by the row of portable diagnostic devices, and also with the use of the stationary diagnostic systems together with the spectrology of vibration, measurement of shock impulses, by the spectrology of shock impulses and other measuring functions.

The state of equipment is diagnosed on the basis of the widely bar measurements of vibration with the delivery of middle quadratic values of parameters. The measurements are conducted in three directions: horizontal, vertical, axial. The best result is obtained reliant on the state of the diagnostic equipment.

After measuring, the intensity of vibration by ISO takes forms of presentation equipment in the color code system for traffic light "green, yellow, red" along with the issue of numerical measurement results.

Presupposition troubleshooting for machine vibration parameters is that vibration of the working machine may convey variable information on its condition. To use the program of vibrocontrol maintenance is essential that this information is properly taken from vibration signal.

Machinery vibration analyses (vibration spectrum analyzers) are divided into four main groups:

Single-channel or two-channel devices for vibration control, analysis of the shape and spectral content of signals, including vibrations, sustainable modes of equipment;

Single-channel or two-channel devices for vibration control, monitoring and diagnostics (including software) machinery and equipment with extended frequency and dynamic range, and wider range of algorithms signal analysis;

Multichannel devices or devices with high-speed switch channels, for parallel measurement and analysis of vibration machines in transient conditions of work, in particular, approach-stopway.

Cross-parallel devices for continuous recording of vibration and other processes with further detailed analysis of the recorded signals.

Development of basic principles and technical diagnostics of mechanical systems for the vibroacoustic characteristics accounted for the second half of the twentieth century. The principles were closely vibrational spectrum analyzer implementation vibration. Now the analyzer is the storage media of self-powered and low weight, wide range of problems solved vibrometrical, that can exchange information with computer systems "deep" analysis using expert systems.

Analysis functionality of vibroanalizator was the subject of the work of several Russian experts and scientists - DV Sokolova (for "Promservis); AV Barkow, NA Barkow and PP Jakobson (for "CCA"); VA Rusova ("Select Center), firm representing developers of vibrodiagnostics systems, including spectrum analyzers vibration.

Vibration analyzer must meet the following requirements:
– versatility and multiple registration options;
– ease of use and portability;
– the ability to collect data - measuring results;
– informative indicator screen;
– expert program of informational character (embedded and external).

The basis of measurement and analysis of vibration signals are three types of devices that perform different operations:
– vibration sensor that converts vibrations to electrical signal;
– filter that selects the signal components in the required frequency domain;
– detector to measure the amplitude (power) of the selected component.

The filter can be designed as an electronic device, may be acoustic, for example - the resonator, or mechanical, for example - an intermediate plate, established between the sensor and the object of measurement.

Other devices include various combinations of these types depending on which information technology they use. The most crucial element of the collection of data is sensor vibration, which turns mechanical vibrations into an electrical signal. For many years different sensors of different types were successfully used. The most reliable among them today is the accelerometer, which also provides high accuracy of transformation. The most common type is the accelerometer with integrated charge amplifier, to which power comes from data assembler (or analyzer) on the same wire as the measured signal.

The most frequently used means of measurement are those realized on the basis of computer technology: analyzers forms, spectral analyzers and envelope spectrum analyzers, whose structure is shown in Figure 1. Features of waveform analyzer vibration and noise (Fig. 1, a) consist in measuring amplitudes and phases of individual signal components and comparative analysis of forming separate areas signal at the beginning and end, determined by the angle of rotation of the shaft. Such analyzers are widely used for diagnosing machinery of reciprocating-type and the rotors in the process of balancing. Spectrum analyzer (Fig. 1, b) using the same type of items can reduce vibration signal processing. Introduction to this scheme of the spectrum envelope detector enables to detect damage of rolling bearings and mechanical elements in the early stages (Fig. 1, c).

Analyzers are issued that implement the features of personal computers (Fig. 1 d). Such measurement and analysis of the signals do not differ in sizes and are used in the laboratory or bench conditions. Development of construction vibration analyzer is inextricably linked with the development of computer technology and

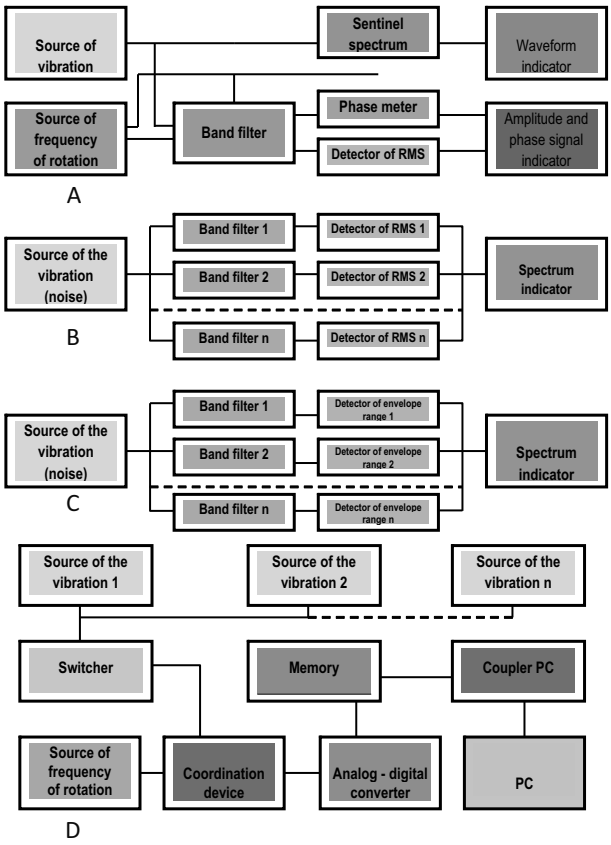

Fig. 1. Structural schemes of analyzers used in vibrodiagnostics: A - a waveform of vibration and noise, B - spectrum signals of vibration and noise; C - the range of the spectrum envelope detector vibration; D - range of analog - digital converter (ADC) and a personal computer(PC)

it focuses primarily on reducing the size, increasing memory capacity and the functions performed.

Vibration Spectrum Analyzers have the following possibilities:
– to analyze the temporal characteristics of signals and signal analysis time sweep (oscilloscope mode),
– spectral analysis of vibration - a division of vibration frequency components in a wide frequency range with a choice of frequency bands,
– spectral analysis of envelope of high frequency vibration signals with the possibility of restructuring the medium frequency band filter and limits the choice of different frequency range,
– provide sufficient resolution to 1600 lines / spectrum,

– provide the average values for the spectral characteristics,
– evaluation of vibration emission signal - definition of peak-factor,
– determine the overall level of vibration in the band are set in vibration control standards,
– perform measurements on the route,
– are able to transfer the accumulated measurements to a computer for further processing.

Additional features that must characterize the devices are self-balancing rotor bearings, availability of graphic LCD display, measurements downloadable by the route from your computer.

Portable vibrometer 795M-107V is designed to measure parameters (vibroacceleration, vibrospeeds and vibromoving) of working equipment in the frequency range from 2Hz to 10KHz and spectral analysis of vibration signals.

The device has a USB interface to connect to a PC.

Vibration Analyzer PROTON-EXPERT is a portable vibromeasuring complex with the function of dynamic balancing, implemented on the latest generation microprocessors, which can deal with many tasks of modern vibrocontrol and vibrodiagnostics.

The device has two built-in amplifiers for sensors such as ICP ® and charge sensors. Moreover it is possible to connect any other external sensors via adapters (up to 1000 channels). Availability of all necessary research functions (envelope spectrum, the general level, the peak - a factor amplitude / phase, range, acceleration / ran, etc.) extended frequency range device (0,1-25 600) Hz, integrated program of balancing, design reliability and high precision metrological characteristics make the spectrum analyzer indispensable tool of modern specialist vibrodiagnostics, repair and adjusting.

The device has a large low-temperature liquid crystal display with high resolution and backlighting.

Multi-channel simultaneous vibration signal analyzer and recorder (vibroanalyzer) Atlant-8 is a modern device designed for solving the most difficult tasks in fault diagnosis of equipment. The basis vibroanalyzer is a laptop that combines the functions of registration signal processing, storage. Function of the vibration signal processing, filtering and synchronous digital conversion are implemented in an external unit. Connected to this unit Vibration probe and index phase are used in balancing. Application of computer for signal processing removes almost all the limitations of conventional portable equipment vibrocontrol - small number of input channels, low speed, limited memory. The possibility of continuous registration of signals for tens of seconds or minutes can be used for such devices for registration of transients in the equipment as vibration control mechanisms are slow processes.

Stationary control system «VDR-8 includes a base unit and a set of sensors. The device "VDR-8" (Vibro Data Recorder) belongs to a class of modern electronic recorder-vibration signal analyzers, which additionally includes the functions of the expert fault diagnosis of machinery and equipment. The main purpose of "VDR-8" is the organization of patient monitoring parameters and diagnostics maintenance of pumps, fans, compressors.

The device solves the complex problem of monitoring equipment, as it will record vibrations, temperature and process parameters. Following treatment of primary information "VDR-8 can include anxious and alarm system, diagnose defects in equipment, developing, plan dates for the repair.

The presence of embedded device channel temperature control and process parameters allows parametric perform diagnostics of equipment. This expert system in diagnosing has new properties such as possibility of operational control of the flow of the pump unit efficiency rating, the organization's work with a minimum energy consumption.

Software "Atlant " is a program for diagnosing technical condition.

The software includes the following components:

– "Atlant" - a database of equipment, including technological and organizational hierarchy equipment at the enterprise, passports for diagnostic equipment, a database of all completed vibromeasure. This is the main piece of software that allows various types of diagnostic tests based on the same vibromeasure. User performs measure vibration on the equipment, so that you can perform any type of diagnostic calculations without additional measurements;

– Pallada+ - closed automated expert system development firm Vibro Center is designed to vibrodiagnostics condition of the equipment for the spectra of vibration signal. The system can diagnose dozens of different defects. The unique capabilities of this system include the possibility of removing heat from center in the complex equipment.

Program "Aurora" – is a combination of a database on equipment with unique properties for the expert system that provides: assessment of the current state of the unit - the general condition of the equipment is estimated by the measured vibration level as «good», «satisfactory» and «unsatisfactory». The program answers the basic questions that should solve the system of service facilities: Can you operate this machine? If possible, what is its remaining life? Why the vibration unit? When do you need to plan and carry out repairs that need to prepare for it?

Determination of defect – one needs to practice enough to know that vibration has increased. In most cases you need to know the cause of the vibration. Only this allows to plan renovation work at the right time to service. The program has a built-in expert system for searching for the cause of increased vibration measurements based on the general level vibrospeeds. Based on a minimum of information it allows sufficient reliability to diagnose 15 types of faults, including: a center indicating the plane of shear, bending rolls, no balances, axial shifts, wear of bearings, weakening their attachment, defects of the belt gear and others.

CONCLUSIONS

Proper instrumentation providing measurements of vibration is the key to obtaining accurate diagnostic information in determining the technical condition of machines and aggregates.

While choosing appropriate measurement instrument, one should first consider the tasks that are supposed to be decided by vibroacoustic diagnostics.

In problem solving and monitoring of process equipment, including submersible electropump units, multifunctional vibration analyzers must be used adapted to the work with computers, to the archiving of measurements and their operational processes.

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