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Modelling of an impact of investment maintenance on the condition of economic protectability of industrial enterprises

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Abstract. There was substantiated the necessity of implementation of a modelling of an impact of investment maintenance on the condition of economic protectability of industrial enterprises with the participation of estimation of cost of investments and investment projects, the mechanism of purchase and sale of securities and conclusion of option contracts that allows to rationally manage the profitability of investment programs, fully ensuring the protectability of entrepreneurship of each subject of real sector of economics.

Key words: processes of investing, investment activities, industrial enterprises, economic protectability, valuation of investment projects, option contracts.

INTRODUCTION

Under the conditions of changing market, the environmental processes of investing are not subjected to sufficiently precise economic-mathematical prediction due to the fact that any investments by their nature of inflows are uneven both by time and by volume. This makes quantitative measurement-forecast of investments axiomatically subordinate to the law of probability distribution of the random value. However, the volume of investment inflow has always had a direct impact on the general level of investment maintenance of a number of business entities that needed them, since investment funds replenish working capital and are reflected on the condition of the economic protection of the given enterprise.

In this context there arises the necessity to conduct a modelling of an impact of investment maintenance on the quality of economic protectability of the business entity for implementation of effective management and control over investment processes and their profitability in the system of high-grade safety of entrepreneurship.

ANALYTICAL INSTRUMENTS

In most countries in recent years there has developed an uneasy economic situation in which the necessity to review the possibility of additional involvement of foreign direct investments in order to restore financial stability and to save sufficient level of economic protectability of industry that noticeably staggered in crisis conditions of world scale has become the urgent need for the real sector of the economics. In particular, in Ukraine the current situation as to inflow of investments is cardinally distorted - some outflow of foreign funds from the industry has been fixed [18]. The reason lies in both improper attention of the state to ensuring of the realization of statutory guarantees for foreign investors and in the deterioration of a number of economic parameters of strategically important domestic branches of industry that previously attracted investors by big dividends.

As is known, financial investments ensure investing of capital in various financial instruments of investment primarily in securities to receive income. They are independent kind of economic activities for enterprises and primary means of realization of external investing.

Analyzing the general financial-credit policy in the post-crisis period, we can conclude that some production and economic structures have stopped to prefer foreign investments due to the difficult financial condition and have started to cover all their needs from their own savings, reserve funds and domestic bank loans. However, these funds are not enough and under the rules of the market economy at this stage the preference should be given to namely external investments as to the main instrument of government maintenance of such financially unstable industrial enterprises that can become significant substitutes for insufficient domestic sources concerning profit earning and for efficient cost management.

Such domestic and foreign scientists as I.Blank [2], R.Castro, G.Clementi, G.MacDonald [4], B.Karpinskyi [5] etc. were engaged in the problems of the research of investments and investment maintenance of the market subjects. However, researches that would combine the analysis of efficiency and profitability of investments, investment projects at the enterprises with the measures to improve the condition of integrated economic protectability through effective quantitative modelling of the change of share price, effectiveness of optimal portfolio, mechanism of rational granting of premium for financial contracts, in particular, option ones, calculation of option prices have remained beyond their attention. As a matter of fact, the given article will be devoted to these issues.

SOURCE MATERIALS AND METHODS

It is necessary to understand that financial-credit and investment maintenance at crisis enterprises in full is impossible without primary activization at them of investment and innovation activities and increase of their investment attractiveness that requires the search of appropriate opportunities of acceleration of their economic growth on their own reproductive basis and improvement of the regulatory framework concerning regulation of economic activities. The problem of choice of sources of raising funds in a lack of own financial resources to ensure sufficient economic protection of enterprise is typical for crisis condition of economics, when production and economic structures are forced to turn to external resources, but do not get them by themselves, due to unstable financial condition, since the risk of not returning of investments and their ineffective use increases.

Rational combination of financing sources and strategic decisions relating to various projects of development of enterprises forms its financial-credit and investment strategy that has the direct impact on the economic security of the letter ones. According to [1], financial and credit and investment strategies can be based on a resource or targeted basis. Depending on the structure of the financing sources of the activities and development of enterprise as well as on the effectiveness of objectives and scopes of investment projects the following variants of selection of strategy are pointed out: using preferably own funds to invest limited number of small investment project; receiving state investments and loans; receiving financing from various sources on the basis of partnerships; use simultaneously all investment sources for the realization of one strategic project or only one kind of financial resources of all possible. In other words, economic development of industrial enterprises is always caused by the choice of a particular strategy of financing that is the basis of investment maintenance and is evaluated by the ultimate effectiveness of the process of functioning and profitability of investment program.

For most of industrial enterprises additional investments inflow is particularly necessary for renewal of the basic production assets, since production assets is a limitative factor for them that determines the production of finished products [10].

The experience of the developed countries of the world shows that the reproductive processes occur solely on the basis of investing. The more active it is, the faster paces of reproduction are and the more effective innovation transformations are. There is a wide range of methods to stimulate attraction of investments: accelerated depreciation, rational tax system, soft loans, the introduction of mechanisms of regulation of bank interest rates, encouragement of leasing [20]. Nowadays, as a rule, enterprises try to give preference to independent investing without intermediaries and to introduce rational policy of attraction of external resources, including favorable foreign investments [17, 21]. Preference is given to foreign direct investments among other external sources of financing, since they do not increase the indebtedness of the country that receives them but, quite on the contrary, stimulate export revenues and create conditions for further decrease of debt.

In this situation, real valuation of economic efficiency of investment projects where effectiveness of investment project should be considered as a transformed economic category that reflects its compliance with the goals and interests of the participants of the project and affect the quality of the general process of support of economic protectability at industrial enterprise becomes possible. Successful realization of investment project is always aimed at increase in profits of enterprise.

In general, investment projects are born only from the needs of individual production and economic structures, and the conditions of their viability always correspond to the investment policy and strategic goals of the state [15]. Timely quantitative valuation of investment projects is the guarantee of qualitative investment analysis that promotes correct selection of the most effective project, its improvement and risk minimization in the system ensuring of economic protectability of enterprise.

If there are made decisions on investing of funds that will be paying off during many years, the following is taken into account: change of demand for industrial products produced due to new investments, the size of interest rates and taxes that will affect expenses in investing, the future political and economic changes as well as inflationary depreciation of funds that affect the size of interest rates and price. In the case of inflation, there will be more future profits than the initial ones, so far as inflation affects price increases. At the same time the monetary cost of the investments will grow, therefore, to compare current investments with the investments of previous years it is necessary to use real investments, that is, taken in constant prices [17].

Financial and economic evaluation of investment projects occupies one of the central places in the process of modeling concerning substantiation and selection of possible variants of investing of funds in financial transactions with real assets [12]. Investment project at industrial enterprise should not be accepted for execution, if it does not provide return of invested funds at the expense of incomes from sales of industrial goods and profit earning that will ensure profitability of investments not lower than the desired level of production and economic structure and due to recoupment of investments within the period that will satisfy the given business entity. It means that it is suggested to evaluate investment projects at manufacturing enterprises comprehensively taking into account investment expenses that can be done either once or several times over quite a long period, and the initial investments in business entity must be considered both in terms of the possibility of obtaining profits and losses of enterprise, correcting its condition of economic protectability.

In general, estimation of cost of investments is affected by: valuation of their payback period; accounting rate of income on securities; net current value; internal rate of profitability and correlation coefficient of costs and incomes. In the period of significant inflation long-term capital investments will not be preferred because to provide loans and to invest money in securities for a long period of time is unprofitable because of the high risk of unstable economic situation, depreciation of money that will outstrip incomes, and because of the difficulties to predict interest rates in the future. Such capital investments usually have target character and may be preferential and connected with the financing of national programs. In such a case bank institutions should use the mechanism of allocation of loan not for the whole number of years and under mixed interests. In this situation, the payment amount or accreting amount will be calculated:

$$S = S_0 \times (1+i)^{t \times l} \times (1 + \Delta\, t \times i), \tag{1}$$

where: $t = t \times l + \Delta t$, S – the payment amount or accreting amount, hrn; S_0 _ initial loan amount received by the borrower, hrn; i – interest rate; $t \times l$ – the whole number of years; Δt – fractional residue; t – term of crediting of the enterprise, years.

If an increase of interest rate is expected, the following options are available [12]: 1) the rate under the agreement varies according to the growth of the average market rate, which, in its turn, changes depending on inflation; 2) the rate changes according to the terms of the loan agreement. Then the amount of repayment (S) will be calculated by the formula:

$$S = S_0 \times (1+i_1)^{t_1} \times (1+i_2)^{t_2} \ldots (1+i_k)^{t_k}, \tag{2}$$

where: i_1, i_2, ... i_k – successive values of interest rates; t_1, t_2, ... t_k – periods during which the corresponding rates are valid.

A special place concerning correction of investment activities today belongs to the issues concerning the optimality of portfolio of securities, estimation of cost of bonds and shares and determination of factors that influence their price and yield, and can be implemented in daily financial and economic activities of an industrial enterprise to ensure their necessary economic security now and for the future. The best option is such when the investor has an optimal portfolio of securities, that is, there is established an optimal correlation between risk and yield on dividends of securities. Although researches showed that the degree of risk of optimal portfolio will anyway be growing with increase of efficiency that is required and expected. If borrowed capital is present, it is possible to form a portfolio with any expected efficiency, but herewith the risk will be increasing indefinitely. If at some moment of time it is impossible to borrow money, then utmost expected efficiency of portfolio will match the efficiency at that moment of the most efficient security, all cash will be invested exactly in it. Most often portfolio of investor is diversified, which means that it represents a variety of securities: that is why both capital and risk will be allocated among all types of securities. Accordingly, the effectiveness of such optimal portfolio ($E_{opt}^{ЦП}$) can be expressed by the random value:

$$E_{opt}^{ЦП} = k_0 \times g_0 + \sum_{i=1}^{n} G_i \times k^*, \tag{3}$$

where: k_0 – share of investments with guaranteed efficiency g_0; G_i – random efficiency of the i-th risky security; k^* – scalar multiplier.

Simultaneously, particular attention should be paid to estimation of cost of a wide range of securities that are in circulation in the market, since their cost has also a direct impact on the security of economic protectability of business entities that own them. For bonds, for example, it is a must to take into account: coefficient of long-term debt to own capital, coefficient of profitability, coefficient of interest income taking into account dividends on preferred shares, coefficient of relation of working capital to short-term obligations, conditions of ensuring of bonds by mortgage, conditions of guarantees, maturity date etc.

As for mechanism of valuation of shares, valuation is carried out separately both for preferred and ordinary shares. Evaluation of ordinary shares is much more difficult in comparison with the valuation of bonds or preferred shares because the investor cannot always be sure of the amount of income, time limits of his payments and rate of profit. For bonds and preferred shares the only unknown variable is the accepted rate of profit. This approach is also suitable to determine the investment value of ordinary shares. But it is possible to give preference also to profit for discounting or to discount incomes which will receive dividends.

The most appropriate method that is used to determine the cost of ordinary shares is:

$$V_0 = \frac{D_1}{(1+g)^1} + \frac{D_2}{(1+g)^2} + \ldots + \frac{V_n}{(1+g)^n}, \tag{4}$$

where: V_0 – discounted value of shares; D_1, D_2, … – expected annual dividend payment to the n-th year; g – expected rate of profit; n – last year of holding period of investment; V_n – expected cost of the shares at the end of the year n.

An important criterion of estimation of the portfolio of securities is the general expected rate of profit on a portfolio. This indicator can be expressed as follows:

$$P^N = \sum_{i=1}^{n} a_i N_i^a + \sum_{j=1}^{k} o_j N_j^o, \quad (5)$$

where: P^{N} – total expected rate of profit on a portfolio of securities; N_i^a, N_j^o – expected rates of profit on shares and bonds; a_i, o_j – percentage (or proportion) of shares (bonds) in the portfolio of securities; n – number of shares in portfolio; k – number of bonds in portfolio.

However, much attention now is paid to option contracts and the opportunity to use them at industrial enterprises to manage at them financial and economic protectability. In general, option on a security is characterized by a certain maturity and exercise price. Option to purchase gives its owner the right to purchase a security at an exercise price, option for sale - the right to sell a security at an exercise price. The problem of efficient granting of premiums for option is one of the most difficult in the theory of development of the securities market. As for the European option, it is based on some assumptions that are taken from the experience of developed countries and are applied in practice. Firstly, the effectiveness of risk-free investments is determined by permanent force of growth so that the price of the investment will change in time according to the equation:

$$\frac{dS_0(t)}{S_0(t)} = Zdt, \quad (6)$$

where: $S_0(t)$ – price of investment; Z – force of growth of effective risk-free investments.

Secondly, the effectiveness of investment in any securities option issued will always be a random value and the price of security will change according to the stochastic equation:

$$\frac{dS(t)}{S(t)} = vdt + R^1, \quad (7)$$

where: $S(t)$ – price of a security that is set at the moment of payment of premiums; v – growth rate of the expected value of the efficiency of investment; R^1 – standard process with unit intensity.

If we denote a premium for option for sale as P_p^0, a premium for option to purchase as P_κ^0, and an exercise price after time interval T after the release of option as P_κ^0, then according to the theorem of parity of options [3] the following dependency s established between the premium for option to purchase and sale:

$$P_p^0 = P_\kappa^0 + P \times e^{-ZT} - S(t). \quad (8)$$

From this we can conclude: the higher the price of a security that the industrial enterprise owns, that is established at the time of payment of premiums, the lower the premium amount for option for sale is.

Option contracts allow you to limit the risk with a certain amount that is lost in the event of adverse development of events at business entity in the development of which funds are invested and their gaining herewith is potentially unlimited. Various assets are the basis of options contracts. In practice, option contracts can be concluded on shares, indices, interest securities, currencies, futures contracts, goods and more.

As is known, the contents of option lies in the fact that it provides one of the parties of the agreement a right of choice in the execution of contract or rejection of its execution, if it is disadvantageous [3, 11] and thus significantly destabilizes condition of economic security of the corresponding business entity if its actual costs significantly exceed the planned ones [6].

The problem of modelling of prices of options is the determination of the price that must be demanded for the purchase (or sale) of option. Resolution of this problem can greatly simplify the mechanism of management of the condition of economic protectiveness of the owner of this option or of that production and economic structure which wants to purchase it from an investor. Since it is impossible to predict accurately in advance the cost of the option at the moment of its expiry as P_κ^0, its use can be either beneficial or not.

Theoretically, to evaluate option is much easier than to simulate a situation that will be responsible for the condition of economic protectability of business entity that is interested in the contract. In practice it is difficult to assess the value of American option since American options, unlike the European ones, are characterized by the right of premature execution, that means that it is impossible to predict their ending date. Therefore, let us review a European option with pre-known ending date. Let us consider that shares are its basis and the dynamics of change of the share price during the validity of option is a random process. In order to more precisely evaluate the random event, in practice, we turn to the Bernoulli process [14].With its help it is possible to evaluate the dynamics of the price of shares during the validity of option which either increases with the probability q or decreases with the probability $(1 - q)$.This mechanism is the basis of binominal process.

If to denote share price at the moment of conclusion of option as A_0, then after some period of time in case of increase of dynamics of price the new share price will be $A_1 = A_0 \times k_1 \uparrow k_0 \downarrow$ and in case of decrease – $A_1 = A_0 \times k_0 \uparrow k_1 \downarrow$, where A_0 – initial share price; A_1 – share price in one time interval; $k \uparrow$ – growth of share price; $k \downarrow$ – falling of share price. According to the binomial process period of validity of the option is divided into sub periods where each period is characterized by possible growth or falling of share price and can be considered as a classical Bernoulli process.

Having conducted modelling of binomial process of change of share price for the duration of the option contract that is owned by enterprise for the period t you can establish additional control over the process of management of its level of economic security [8]. Moreover, if we assume that during the validity of European option on shares it is affected by a large number of factors: time of conclusion and end of option, dynamics of change of share price during this period, the presence of capital on the market except shares and other financial instruments, the presence of a continuous process of functioning of the capital market, the lack of opportunities of arbitrageur and taking into account the fact that the capital market is competitive, then, according to [14], the magnitude of the cash flows that are expected on option for sale at time t, will be equal to:

$$G_{k\uparrow} = \max(A_0 k \uparrow - P, 0) \text{ i } G_{k\downarrow} = \max(A_0 k \downarrow - P, 0), \quad (9)$$

where: P – option exercise fee.

Accordingly, for European option for sale the value of cash flows will be evaluated by the following equations:

$$P_{k\uparrow} = \max(P - A_0 k \uparrow, 0), \text{ якщо } A_1 = A_0 \text{i}$$

$$P_{k\downarrow} = \max(P - A_0 k \downarrow, 0), \text{ якщо } A_1 = A_0 k\downarrow. \quad (10)$$

For more precise valuation of options in practice it is suggested to calculate profitability of shares ($r_{k\uparrow}, r_{k\downarrow}$), which are the part of option and affect change of share price, so:

$$k \uparrow = 1 + r_{k\uparrow};\ k \downarrow = 1 + r_{k\downarrow}. \quad (11)$$

For valuation model of European option for sale, also using the binomial model, we can calculate the magnitude of cash flows that would directly affect the characteristics of option for sale after m growth of share price:

$$P^m = \max\left(P - A_0 k \uparrow^m k \downarrow^{n-m}, 0\right). \quad (12)$$

By controlling this process, it is possible to more efficiently determine the impact of the investment maintenance on condition of economic protectability of industrial enterprises, modeling forecasted dynamics of the rate of individual securities within the option contract.

Apart from that, the more increased the number of shares in the portfolio, the more complex the problem of valuation of European options will be. This will lead to a variety of changes in the rate of securities and will affect the price of options to purchase and for sale, which will lead to either losses or extra profitability of an industrial enterprise.

Also, the building of generalization of criteria of evaluation of investment projects at production and economic entities in the sphere of general investment activities which affects the general level of their economic security has become crucial [7, 9, 11]. When it is necessary to choose an investment project, it is recommended first of all to answer the question: what is the required amount of financial resources for an enterprise; where to find additional sources in the necessary amount and what their price is; to determine whether the investment pays off.

The main approaches to the evaluation of investment projects at industrial enterprises are [13, 19]:

1) calculation of the time cost of money (V_n) and their accounting in the valuation of investment projects:

$$V_n = \frac{D}{(1+r)^t}, \quad (13)$$

where: V_n – current cost (valuation of magnitude D from the position of the current time moment); D – income, that is planned to be received in the t-th year; r – discount factor;

2) calculation of the weighted average price of capital of investment project that is implemented in to industrial structure (SP_k):

$$SP_k = \sum_{j=1}^{t} p_j v_j, \quad (14)$$

where: p_j – price of the j-th source of funds; v_j – unit weight of the j-th source of funds in their total amount.

However, in general to evaluate the general potential of the project from a position of profitability and liquidity it is enough to analyze the following characteristics [16]:

1) dynamics of cash flows (funds) ($C_k(t)$), where parameter t shows, that a certain value C_k corresponds to each point of time:

$$C_k(t) = P_0 + A - B_I(\Delta), \quad (15)$$

where: P_0 – net profit on the investment project; A – amortization; $B_I(\Delta)$ – investment (capital) cost sand changes in working capital;

2) income if the project is implemented for one year ($D(I_1)$) –magnitude that indicates what should be the annual income from financial rent, that is equivalent to this investment project by income level:

$$D(I_1) = \frac{E_0}{a_{t_i}}, \quad (16)$$

where: E_0 – net brought effect of investment project; a_{t_i} – coefficient of financial rent;

3) calculation of the break-even point of investment project (valuation of reliability of the project).

RESULTS AND DISCUSSION

Thus, management in the sphere of the investment activities of industrial enterprises and integration of rational investment policy with scientific-research, production and commercial activities must become an essential element to ensure their economic security. In other words, to successfully develop a mechanism to ensure economic security of an industrial enterprise, an objective and precise financial and economic evaluation of its investment projects is necessary. It has been found that an investment project that is owned by an industrial enterprise and which affects the investment maintenance of its activities is a complex mechanism that operates according to a number of factors and parameters, which constantly and dynamically change and correct, through its effectiveness or ineffectiveness, the condition of its economic security, which directly complicates the process of modelling of this effect. There is a way-out from this situation if the final financial result of investment activities of an industrial enterprise is timely subjected to modeling through functional dependency on sufficient number of factors of micro- and macroeconomic character that govern investment calculations. This is recommended to be performed in a strict sequence, taking into account all the major valuation criteria of investment projects and, accordingly, the quality (quantitative) characteristics of the final results considering degree of uncertainty of recoupment of investments, that is, with the introduction of an additional factor of investment risk in order to more objectively diagnose the level of economic security of an enterprise in future.

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Mathematical model of dust cleaning process in centrifugal-inertial dust collector

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A b s t r a c t. The article is devoted to the problem of providing air cleaning from dust in various industries, using highly efficient apparatus, with the aim of bringing the volume of harmful emissions to the sanitary standards. The article presents new directions in creating of dust cleaning apparatus, based on the usage of centrifugal, inertial forces, by which the efficiency of dust collection could be significantly increased.

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

Statement of the problem. An extremely important factor that affects the territorial organization of all socio-economic life and production efficiency are ecological environmental conditions, which have significantly deteriorated in the past decades in Ukraine. One of the main factors that affect the ecological environment, is the development of industry in outdated technologies and related excessive urbanization of many areas. The fundamental tenets of sustainable human development are based on an understanding of the close relationship between environmental, economical and social problems, which in turn leads to the unification of scientific achievements of the leading specialists from academic institutions involving market problems and economic-environmental studies. Thus, it is not only and not so much about a new direction in environmental science, but also about a new direction in the overall system of worldview and understanding of the latest issues of man and nature interaction, the recognition of man's and society's places in the nature, their sustainable development. It appears, that the only way to improve technological and environmental safety is the ecological education of the whole society and improvement of algorithms of actions with emergency response, using management international standards, especially the ISO 14001 and ISO 9000 [1,2].

Techno-genic stress in Ukraine is characterized not only by high level of impact on the environment, but also by its variety. Fatal cases and injuries during accidents and emergency situations of techno-genic character in Ukraine occur 5-8 times more often than in other industrialized European countries, indicating serious shortcomings and state system's developmental impairments in environmental and technological safety progress. And in this number of issues a significant contribution is made by enterprises, which emit a tremendous amount of environmental harmful substances and dust. That is why the problem of cleaning air from dust is one of the main goals of environmentalists around the world. The main role in solving this problem is given to the development of highly efficient dust collectors.

The analysis of recent research shows a significant risk for the environment and human health from dust substances' emissions that worsen ecological environment, cause premature wear of industrial equipment as well as of housing and utility objects, harm human health. In 2012, the average concentration of dust (undifferentiated composition) exceeded environmental safety standards in 23 cities of Ukraine [3, 4].

At present, a particularly acute problem is that of capturing fine dust, which due to its low density is dissipated and moves over long distances with flows of air. Complication of dust cleaning systems along with raising demands on their performance requires the adoption of specific measures to develop a highly efficient dust collecting apparatus.

Raising requirements for clean air lead to the necessity of improving the means and apparatus of dust collecting [6-8]. The conducted analysis has proved that currently there is no apparatus capable of highly effective capture of fine fraction dust, while the need for its allocation out of dusty flow is imperative.

The purpose of this work is localization of environmental threat of air pollution from dust, generated by manufacturing industry, which causes negative consequences for the environment.

Exposition of basic material. Dust cleaning belongs to the aerodynamic classification category of problems. In the flow distribution a material's particle is affected by two forces: mass force and power of flow, in different directions. Mass force depends on the density, acceleration and volume, namely on the third degree of characteristic particle diameter. Power of flow, however, depends on the resistance coefficient, on the dynamic pressure, caused by the relative velocity between the particle and carrying medium and the particle's square cut. For the resistance coefficient the most important is Reynolds number [5]. Thus, in case of simplified division, if we neglect the transition area, two zones are formed: - at low Reynolds numbers for the power of flow Stokes' law is valid and at high ones - quadratic resistance law.

In the practice of mathematical modeling of processes of aerodynamic classification, the most widespread are the so-called deterministic and stochastic models. The basis of deterministic models makes an idea of the process as a motion of non-interacting particles in a stationary flow of gas. Deterministic models allow for evaluation of the basic factors' influence on several division characteristics (the equilibrium particle's size, in some cases - limit size), but do not allow to obtain the calculated expressions for distribution curves, whose creation is possible only on the basis of stochastic models of classification processes, taking into account the cumulative effect of environmental random impacts on each particle.

From foregoing material it is implied that both deterministic and stochastic models of processes' classification do not take into account the structure of turbulent dusty flow and material particles of different granulometry motion specificity. Currently, the theoretical basis for creation of dust collection apparatus is designed from the standpoint of airflow and single particle interaction without consideration of air velocity pulsating components and scale of vortex structures in flow's transporting medium, that must be considered to ensure the adequacy of mathematical models, which describe the work of equipment, including classification of materials.

The small-weight particles motion process under the action of centrifugal force in turbulent flow consists of two processes: the continuous motion of particles, in direction to cyclone wall inside pulsating moles, carrying them, and the chaotic as to direction, frequency and amplitude motion of particles along with pulsating fields, carrying them [9-12].

In the viscous sub-layer, directly adjacent to the wall, the role of viscous stresses is dominant in comparison with turbulent stresses. Therefore, decisive parameters in the viscous sub-layer are fluid's kinematic viscosity coefficient v and dynamic velocity (friction velocity) u *. Outside the area of viscous sub-layer the role of viscous stresses in the continuous medium is rather insignificant. As the simplest approximation of carrying flow's pulsating structure in the near-wall area let us take the simplest dual-zone model (Gusev and Zajchyk, 1991), consisting of the viscous sub-layer with zero intensity pulsations and turbulent zone with constant intensity pulsations:

$$\left\langle u'_i\, u'_j \right\rangle = A_{ij} u_*^2 H(y-\delta)., \qquad (1)$$

where: y - distance from the wall, A_{ij} - constants.

Viscous sub-layer thickness δ is:

$$\delta = \delta + \frac{v}{u_*}, ...\delta_+ = const. \qquad (2)$$

It is also assumed, that the scale of turbulence near the wall has a constant value:

$$T_L = T_+ \frac{v}{u_*^2}, ...T_+ = const. \qquad (3)$$

Next we accept, that particles' averaged slide as to carrying flow is relatively small, so the influence of the effect of crossing trajectories for the period of particles' and turbulent whirlwinds' interaction can be neglected. Since we do not consider the reverse impact on carrying flow and particle collision, the equations system, which includes mass conservation equations, quantity of motion balance, for other moments of particles' velocity pulsations (dispersed phase turbulent stresses), the tensor of turbulent diffusion of particles splits: the concentration of Ф and intensity of transverse pulsations (v'^2_y) can be found independently from other hydrodynamic characteristics of the dispersed phase. For hydro-dynamically - developed flow, whose properties vary only in its normal direction, upon the absence of particles deposition, the following equations to determine Ф and Ф i (v'^2_y):

$$\Phi \frac{d\left\langle \upsilon'^2_y \right\rangle}{dy} + \left(\left\langle \upsilon'^2_y \right\rangle + g_u A_{yy} u_*^2 H(y-\delta) \right) \frac{d\Phi}{dy} = 0. \qquad (4)$$

In accordance with the experimental data it will take A_{yy} = 1 and proceed to dimensionless variables:

$$\tau_p^2 \frac{d}{dy}\left[\Phi \left(\left\langle \upsilon'^2_y \right\rangle + g_u A_{yy} u_*^2 H(y-\delta) \right) \frac{d\left\langle \upsilon'^2_y \right\rangle}{dy} \right] +$$

$$+ 2\Phi \left(f_u A_{yy} u_*^2 H(y-\delta) - \left\langle \upsilon'^2_y \right\rangle \right) = 0, \qquad (5)$$

$$\left\langle \upsilon'^2_{y_+} \right\rangle = \frac{\left\langle \upsilon'^2_y \right\rangle}{u_*^2}, \quad \lambda = \frac{y}{\delta} = \frac{y_+}{\delta_+}, \quad y_+ = \frac{y u_*}{v},$$

$$\tau_* = \frac{\tau_p u_*}{\delta} = \frac{\tau_+}{\delta_+}, \quad \tau_+ = \frac{\tau_p u_*^2}{v}.$$

Equations (3.13) and (3.14) in new variables take the form:

$$\Phi \frac{d\left\langle \upsilon'^2_{y_+} \right\rangle}{d\lambda} + \left(\left\langle \upsilon'^2_{y_+} \right\rangle + g_u H(\lambda - 1) \right) \frac{d\Phi}{d\lambda} = 0, \qquad (6)$$

$$\tau_*^2 \frac{d}{d\lambda}\left[\Phi\left(\langle \upsilon'^2_{y_+}\rangle + g_u H(\lambda-1)\right)\frac{d\langle \upsilon'^2_{y_+}\rangle}{d\lambda}\right] + 2\Phi\left(f_u H(\lambda-1) - \langle \upsilon'^2_{y_+}\rangle\right) = 0. \quad (7)$$

Boundary conditions for (6) and (7) upon the absence of particles' deposition on the wall, are set in the form:

$$\tau_* \frac{d\langle \upsilon'^2_{y_+}\rangle}{d\lambda} = 2\frac{1-e_y^2}{1+e_y^2}\left(\frac{2\langle \upsilon'^2_{y_+}\rangle}{\pi}\right)^{1/2} \text{ with } \lambda = 0;$$

$$\frac{d\langle \upsilon'^2_{y_+}\rangle}{d\lambda} = 0,\ \Phi\text{=1 with } \lambda = \infty. \quad (8)$$

Neglecting the influence of particles inertia during their interaction with turbulent whirlwinds, we put T_{Lp} equal to the Lagrangian scale, where we take $T_+ = \delta_+$. Then the involvement coefficients are:

$$f_u = \frac{1}{1+\tau_*},\quad g_u = \frac{1}{\tau_*(1+\tau_*)}.$$

Taking into account the (6), equation (7) can be transformed to the form:

$$\tau_*^2\left(\langle \upsilon'^2_{y_+}\rangle + g_u H(\lambda-1)\right)\frac{d^2\langle \upsilon'^2_{y_+}\rangle}{d\lambda^2} + 2\left(f_u H(\lambda-1) - \langle \upsilon'^2_{y_+}\rangle\right) = 0, \quad (9)$$

that allows to find (v'^{2}_{y+}) irrespective from Φ. Let us construct solution of the equation (3.18) in areas $0 < \lambda < 1$ и $1 < \lambda < \infty$, and then "staple" them.

In the area of viscous sub-layer ($0 < \lambda < 1$) equation (9) reduces to:

$$\langle \upsilon'^2_{y_+}\rangle\left(\frac{d^2\langle \upsilon'^2_{y_+}\rangle}{d\lambda^2} - \frac{2}{\tau_*^2}\right) = 0. \quad (10)$$

The solution of (10), considering (8) will be:

$$\langle \upsilon'^2_{y_+}\rangle = 0 \text{ with: } 0 < \lambda < \lambda_0,\quad \langle \upsilon'^2_{y_+}\rangle = \frac{(\lambda-\lambda_0)^2}{\tau_*^2}$$

$$\text{with: } \lambda_0 < \lambda < 1. \quad (11)$$

$$\langle \upsilon'^2_{y_+}\rangle = \langle \upsilon'^2_{y_+}(0)\rangle + \frac{2(1-e_y^2)}{\tau_*(1+e_y^2)}\left(\frac{2\langle \upsilon'^2_{y_+}(0)\rangle}{\pi}\right)^{1/2}\lambda + \frac{\lambda^2}{\tau_*^2}$$

$$\text{with: } 0 < \lambda < 1. \quad (12)$$

The solution of (11) takes place in case $\tau_* < \tau_{cr}$, and (12) is realized in case $\tau_* > \tau_{cr}$. Critical value τ_{cr} of inertia parameter τ_* is a bifurcation point and corresponds to the condition $\lambda_0 = 0$. In turbulent area ($1 < \lambda < \infty$,) the equation (3.18) is written as:

$$\tau_*^2 \frac{d^2\langle \upsilon'^2_{y_+}\rangle}{d\lambda^2} + \frac{2\left(f_u - \langle \upsilon'^2_{y_+}\rangle\right)}{\left(\langle \upsilon'^2_{y_+}\rangle + g_u\right)} = 0. \quad (13)$$

To construct the analytical solution, let us linearize (13) taking in the denominator of the second term: ($v'y^2$) = ($v'y^2$ (1)). As a result, we obtain the approximate solution:

$$\langle \upsilon'^2_{y_+}\rangle = \left(\langle \upsilon'^2_{y_+}(1)\rangle - f_u\right)\exp\left[-\frac{2^{1/2}(\lambda-1)}{\tau_*\left(\langle \upsilon'^2_{y_+}(1)\rangle + g_u\right)^{1/2}}\right] + f_u$$

$$\text{with: } 1 < \lambda < \infty. \quad (14)$$

Solutions' stapling terms in viscous and turbulent zones appear as:

$$\langle \upsilon'^2_{y_+}(1)\rangle\left(\frac{d\langle \upsilon'^2_{y_+}\rangle}{d\lambda}\right)_{1-0} = \left(\langle \upsilon'^2_{y_+}(1)\rangle + g_u\right)\left(\frac{d\langle \upsilon'^2_{y_+}\rangle}{d\lambda}\right)_{1+0}. \quad (15)$$

From (11), (14) i (15) and (15) we derive the ratio for finding out: (v'^{2}_{y+}(1)) and λ_0 at $\tau_* < \tau_{cr}$:

$$\lambda_0 = 1 - \tau_*\langle \upsilon'^2_{y_+}(1)\rangle^{1/2}. \quad (16)$$

From (12), (14) i (15) we derive the ratio for finding out (v'^{2}_{y+}(1)):

$$\left(f_u - \langle \upsilon'^2_{y_+}(1)\rangle\right)\left(\langle \upsilon'^2_{y_+}(1)\rangle + g_u\right)^{1/2} =$$

$$= \langle \upsilon'^2_{y_+}(1)\rangle\left[\frac{2^{1/2}}{\tau_*} + \frac{2(1-e_y^2)}{\pi^{1/2}(1+e_y^2)}\langle \upsilon'^2_{y_+}(0)\rangle^{1/2}\right],$$

$$\langle \upsilon'^2_{y_+}(0)\rangle^{1/2} = -\frac{1-e_y^2}{\tau_*(1+e_y^2)}\left(\frac{2}{\pi}\right)^{1/2} +$$

$$+\left[\frac{2(1-e_y^2)^2}{\pi(1+e_y^2)^2\tau_*^2} + \langle \upsilon'^2_{y_+}(1)\rangle - \frac{1}{\tau_*^2}\right]^{1/2}. \quad (17)$$

A critical parameter of inertia is determined from the ratio τ_{cr}^{2} (v'^{2}_{y+}(0 1, which does not depend on recovery momentum coefficient $\boldsymbol{e}_y$ and is equal to 2,81.

Distribution of particles concentration, that satisfies the condition Φ (∞) = 1, is determined by the integral of equation (6) and described by the expression:

$$\Phi = \begin{cases} \langle \upsilon'^2_{y_+}(1)\rangle\left[\tau_*\left(\langle \upsilon'^2_{y_+}(1)\rangle + g_u\right)\langle \upsilon'^2_{y_+}\rangle\right]^{-1} & .\lambda < 1, \\ \left[\tau_*\left(\langle \upsilon'^2_{y_+}\rangle + g_u\right)\right]^{-1} & \lambda > 1. \end{cases} \quad (18)$$

Figure 1 shows the distribution of transverse velocity pulsations (v'_{y+}) and the concentration of particles that correspond to [10, 11, 13, 15], [16] and [17] by elastic collisions with the wall: (e_y= 1), [10-13].

It is seen, that with increase of particles' inertia intensity of their speed pulsations increasingly deviates from the intensity pulsations in solid medium (1) and tends to a homogeneous distribution. The concentration of particles near the wall rises sharply, their accumulation in the viscous sub-layer area is observed. The phenomenon of accumulation of particles in inhomogeneous turbulent flows is explained by their turbulent migration (turboforez) from the area with high intensity of turbulent velocity pulsations to the area of low turbulence (particularly, to the viscous sub-layer on the surface that flows around). The theoretical interpretation of this phenomenon was given by Caporaloni et al (1975) and Reeks (1983).

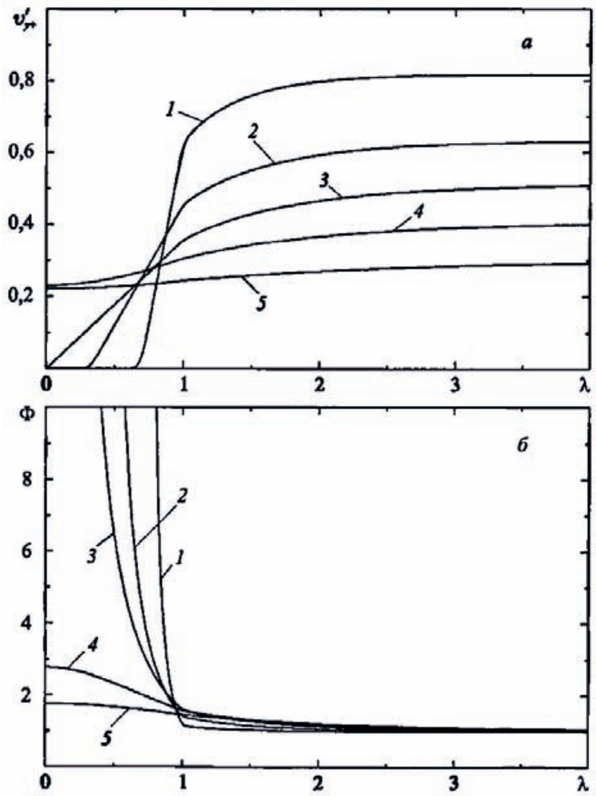


Fig. 1. The distribution of transverse velocity pulsations (a) and concentration (b) of particles in the near-wall area

Figure 2 illustrates the effect of particles' inertia on the values of velocity pulsations intensity and on concentration of particles on the wall.

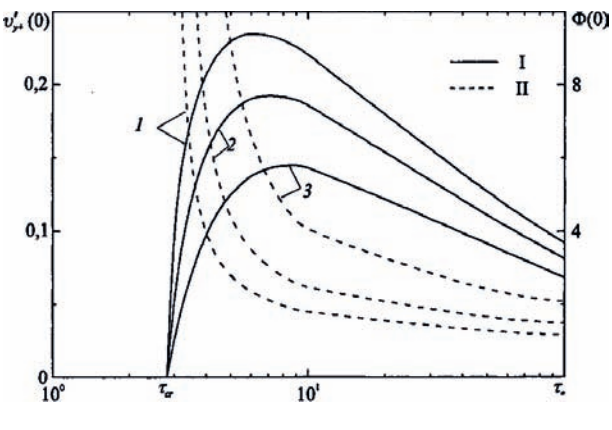


Fig. 2. The dependence of velocity fluctuations intensity (I) and particles' concentration (II) on the wall on the inertia parameter: 1 — e_y = 0,5; 2 — e_y = 0,8; 3 — e_y =- 1,0

As can be seen, pulsating energy of low inertial particles on the wall is zero, and the pulsations' intensity of inertial particles is different from zero. The effect of non-zero velocity pulsations on the viscous sub-layer and on the wall itself is due to diffusion mechanism of pulsations' transfer by mean of inertial particles from turbulent flow area. Attention is drawn to the availability of maximum in dependence of $v'_{y+}(0)$ from τ. Increasing of $v'_{y+}(0)$ along with rising of τ is explained by an increase of role of pulsations' diffusion transfer from turbulent area into the zone of viscous sub-layer. Reduction of $v'_{y+}(0)$ along with rising of τ after reaching the maximum is connected with decrease of intensity of velocity's pulsations in the dispersed phase, as more inertial parts are less engaged into turbulent motion of homogenous medium.

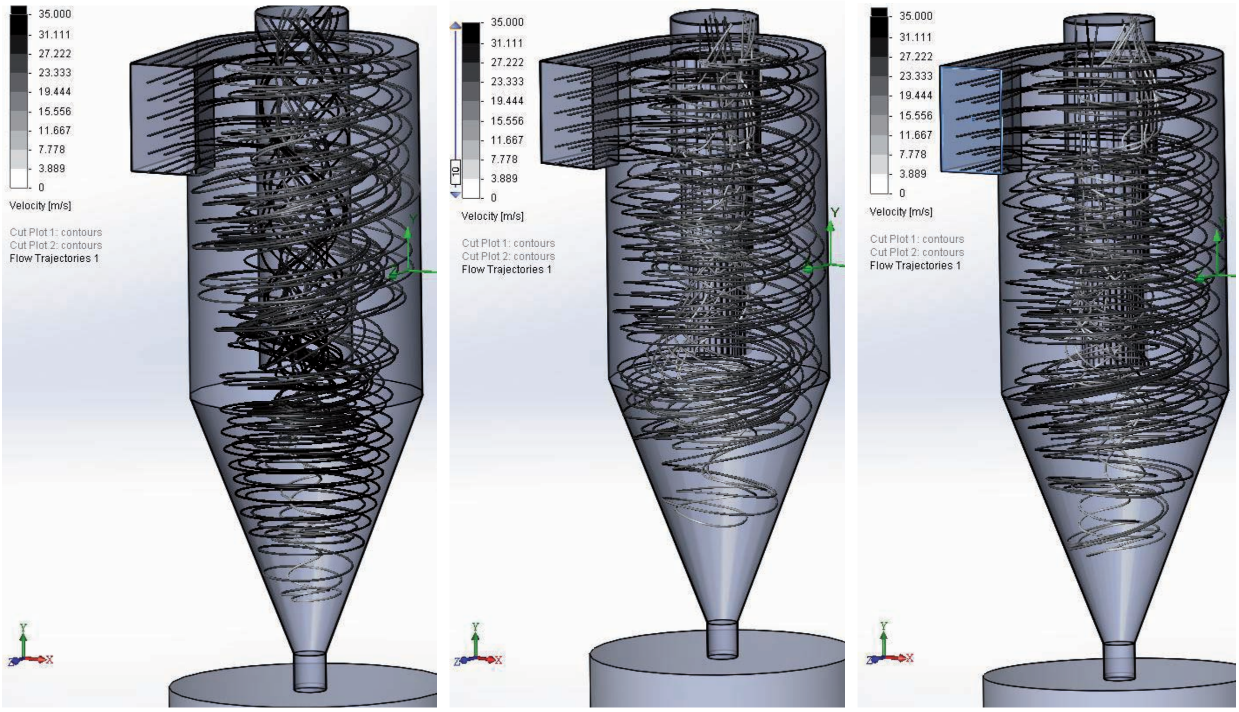
The concentration of particles on the wall tends to infinity $\tau < \tau_{cr}$ and tends to the unity at $\tau \to \infty$. With a decrease of impulse restitution coefficient e_y the intensity of pulsations falls, and the particles' accumulating effect in the viscous sub-layer slightly increases.

The analysis of pulsations' velocity intensity and of particles' concentration on the wall at different values of inertia parameter (particles' size) allow for a new design of inertial-centrifugal dust collector with changing angle of blinds attack as well as enables a more detailed study of air flow motion in an apparatus and the rejection of obviously failed designs at the stage of their development

Modeling will be conducted using the software package FlowVision from "TESYS" company [15]. For the research a solid model design with the following dimensions has been developed: diameter of cylindrical part – 0,5m; height of the cylindrical part – 0,75m; height of the conical part – 0,56m; dust outlet diameter – 0,07m; inlet height– 0,23m; inlet width – 0,15m; exhaust pipe diameter – 0,2m. Three variants of dust collector performance were considered. The first one - with three-cascade jalousie separator, with varying angle of blinds attack. Such jalousie separator is closed from the bottom side. The second one has the same blind's separator, but opens from the bottom side. If compared with traditional apparatus, the third model is performed with a traditional exhaust pipe.

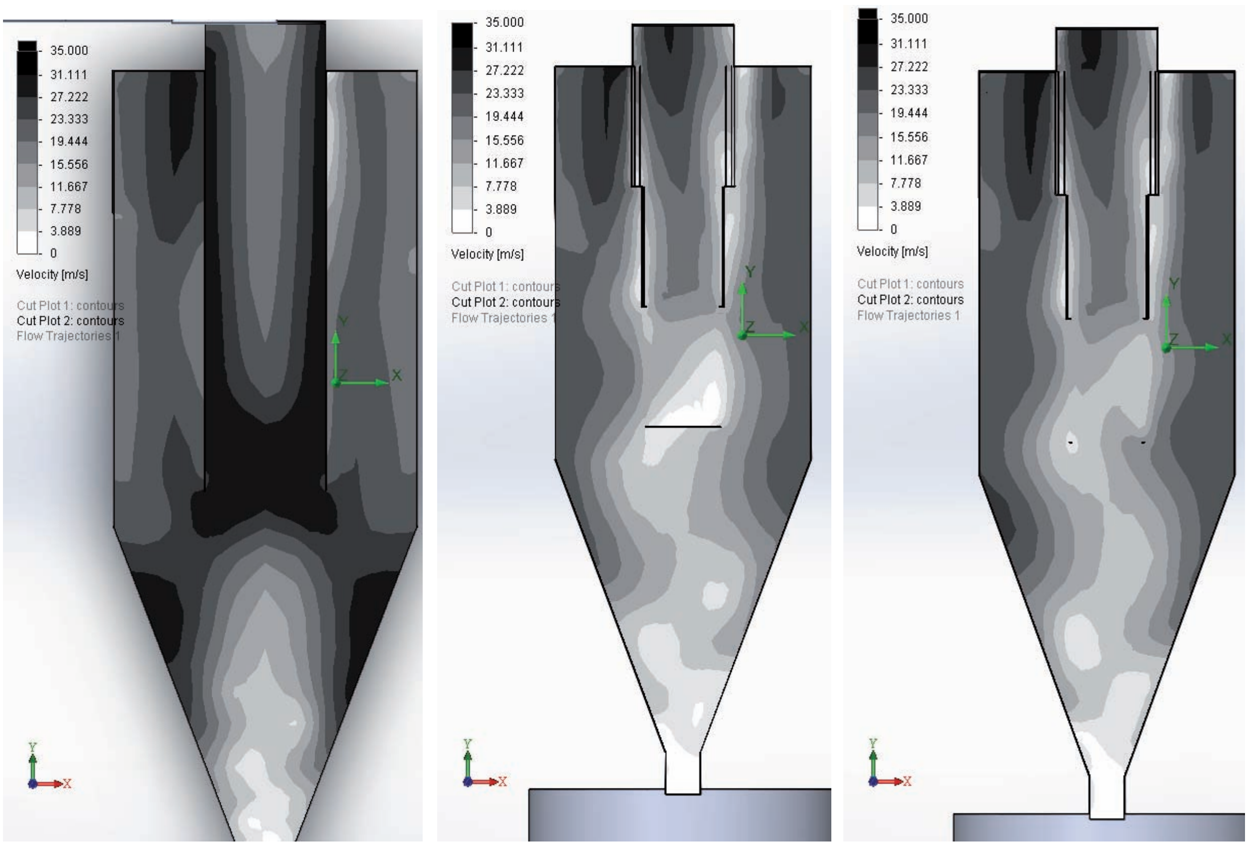
Figure 3 shows the trajectory of the air flows in apparatus of three designs.

The conducted analysis makes it possible to describe the aerodynamics of cyclone process in the new apparatus more precisely. Air flow gets into a dust collector through the tangential inlet pipe. Air flow velocity is 18m / s, which is the recommended value for this class of devices. Then the flow starts to rotate in the space between the exhaust pipe (Fig. **3**.a) or jalousie separator (Fig. 3 b, c) and the outer wall of the device, moving down. In the conical part of the device the flow makes a turn of 180 °, than rises and, continuing to rotate, goes out into the atmosphere. The negative feature of traditional cyclone with exhaust pipe is that near its lower edge air flows with high velocities are observed (Fig.3.a). Fine fast-response dust particles will be captured by these flows and, through the exhaust pipe, will get into the atmosphere. When jalousie separator is used, the air flow fills the cylindrical part of the device more evenly (Fig.3.b, c). In numerous publications a decisive influence of the cyclone's cylindrical part on the air purification



a b c

Fig. 3. Trajectories of air flow in a cyclone



a b c

Fig. 4. Distribution of airflow velocity' values

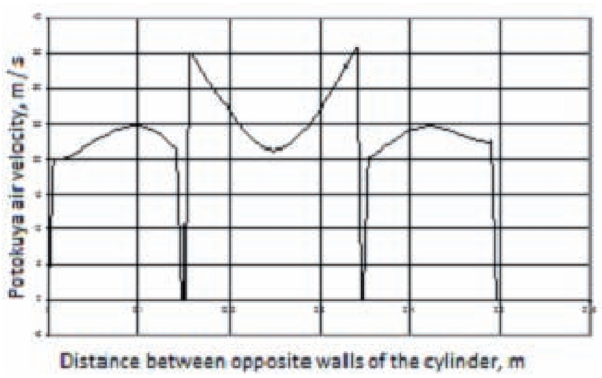
efficiency is indicated. Therefore, we will consider, what would be the distribution of airflow velocities and static pressure value in dust collector.

Figure 4 shows the distribution of the air flow absolute velocity's value at each section point, which passes through the cyclone axis. In the near-wall zone of the cyclone with jalousie separator the air flow velocity value is more uniform. Availability of traditional exhaust pipe causes numerous changes in velocity's value (Fig.2.a).

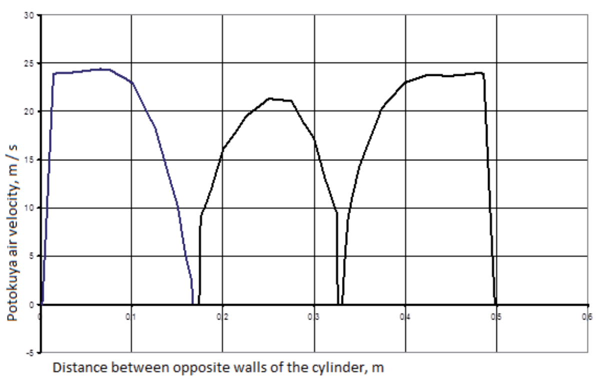
It is especially necessary to note the flow velocities in conical part. The use of jalousie separator of the developed design allows for a significant reduction of the value of air velocity in the cone. This will eliminate the ability of capturing dust particles by rising air flows and will help to improve the air purification efficiency [16,19].

Figure 5 shows the diagram of the airflow velocity changes in cross section, located in the middle of the cylindrical part of the apparatus. On the abscissa axis - the distance between opposite walls of the cylindrical part. For 0 the position on the left wall is accepted. The opposite wall corresponds to position 0.5 m. In the apparatus with traditional exhaust pipe air flow velocity value in separation zone varies in the range from 20 to 25m / s (Fig. 5 a). Close to cylindrical part walls and to exhaust pipe the velocity, due to adhesion, decreases to 0 m / s. In separation zone of apparatus with jalousie separator of suggested design f air low velocity is distributed more evenly (Fig. 4. b, c) and is about 24 m/s (Fig.5.b).

It is a positive fact that at its maximum level the obtained air velocity brings it close to the outer wall. Herewith the dust particle is affected by constact centrifugal force, which does not decrease with particle's moving away from the cyclone axis, as it is observed in the devices with traditional pipe.



a



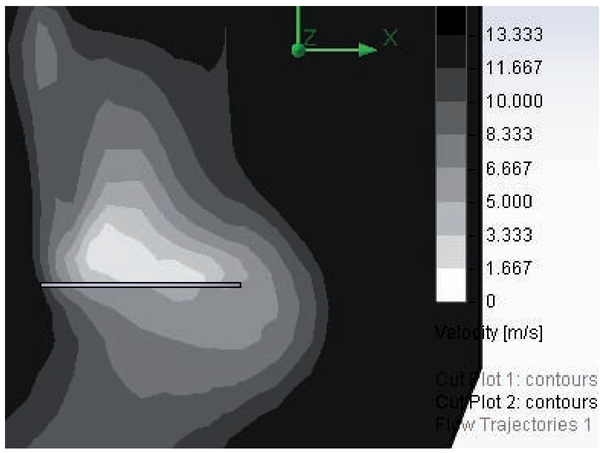
b

Fig. 5. Distribution of airflow velocity in horizontal section of cyclone

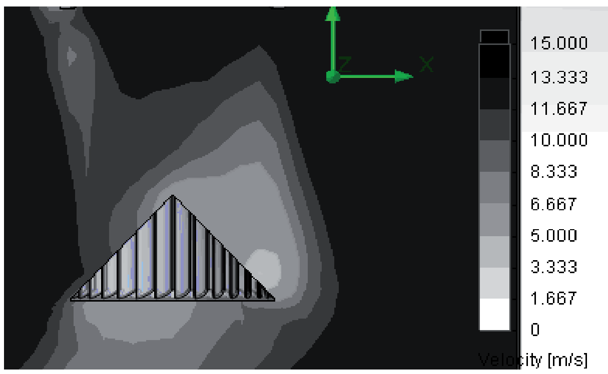
Application of jalousie separator of the developed design positively influences the air cleaning process. Air flow enters the separator throughout its height, and therefore plots of high velocity air do not form [17]. Due to the jalousie attack angle's change, throughout the whole height of jalousie separator the air flow velocity values are uniform and equal to about 3 m/s.

In the cyclone with bottom closed jalousie separator airflow velocities close to 0 m / s are observed. This will contribute to accumulation of fine dust in these areas. To eliminate this phenomenon it is recommended to perform the conical bottom of jalousie separator. Distribution of air flow velocities near such bottom is shown in Figure 4.b. 4.6

In separational zone of the cyclone with conventional exhaust pipe, the static pressure drop is about 2000 Pa (Fig.7.a). Using jalousie separator of the suggested design reduces pressure drop to 350 Pa (Fig.7.b, c). Reducing static pressure drop helps to reduce the amount of air involved in secondary flows. This creates the preconditions to increase dust collector's efficiency.



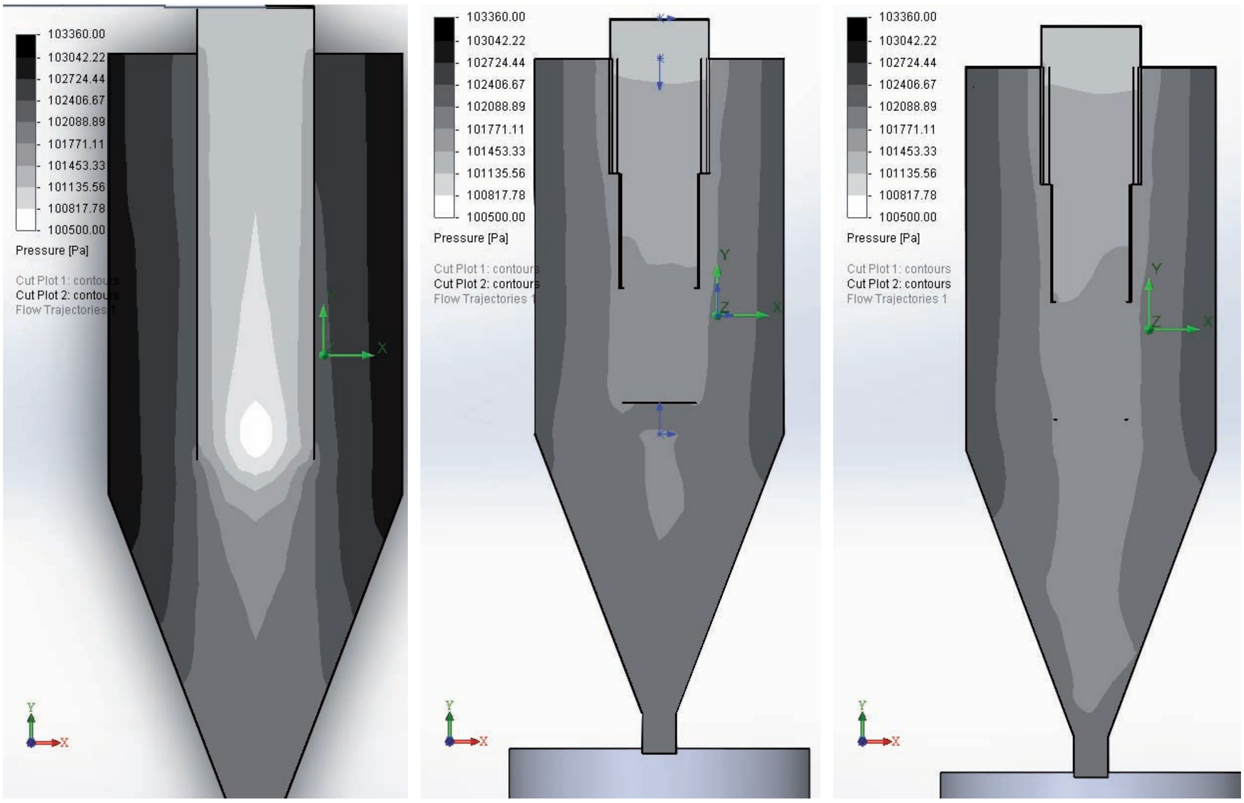
a



b

Fig. 6. Air flow's speed values near the bottom of jalousie separator

Conclusions. By creating a range of dust collectors we managed to obtain a significant increase (6 - 8%) of fine dust catching efficiency (8 and 16) 10^{-6}m, if compared with the standard - Cyclone CN-11along with reducing



a **b** **c**

Fig. 7. Distribution of static pressure values

the hydraulic resistance and metal consumption (smaller dimensions). The first type apparatus, where the small increase of performance have been achieved, anyway at 1-2% is of higher efficiency than standard unit [18-20].

Having created a range of dust collecting apparatus, we were able to meet the needs of a number of industries (in compliance with the requirements of MCL), hence depending on the dust type and technological conditions of production, the most appropriate for these requirements type of dust collector, for which we have created an automated system (using a computer), can be chosen.

Currently, the implementation of a number of suggested dust collectors to be used in wood processing, rubber waste's processing, cement production, manufacturing industry, is taking place.

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The problem of highly effective cleaning of air from dust

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Abstract. This 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 of conforming to the 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 improve significantly the dust catching efficacy.

Key words: dust catching, air cleaning, pollution, centrifugal, cyclone

Problem definition. The present ecological situation in Ukraine (excessive concentration of environmental threat productions, outdated and inefficient nature of protection equipment at the closing stages of technological chains, engineering system insecurity, low level of enterprises' efficiency in the increased environmental risk conditions etc.) determines the urgency of constant utmost attention to the activities aimed at ecological security of the country. Heavy concentration of agriculture and industry has caused disastrous air, water and soil pollution. Present ecological change scales have created a real hazard to public health and pose a threat to the life of Ukraine citizens. The state of health of society is one of the basic environmental quality criteria. In the population common sicknesses rate those diseases are prevalent which are the result of anthropogenic environmental pollution, particularly of atmospheric air contamination. Impartial medical data indicate the constantly growing influence of ecological factors on the physical potential of our society.

Upon the whole, ecological situation in Ukraine can be characterized as crisis. In 2012 the average annual dust concentration (undifferentiated with respect to composition) exceeded the ecological safety standards in 23 Ukrainian cities. [1,2]. According to the Ministry of Statistics (State Statistics Service of Ukraine) information, in 2012 total volume of hazardous substances emissions into the atmosphere accounted for 6,04 mln t, at that 4,16 mln t – from stationary sources of pollution, and 1,88 mln t – from traffic (non-stationary sources).

The data of official state statistics and from other special researches indicate that environmental changes are closely related to the state of health of the population. Dust lungs pathology, first of all pneumoconiosis and chronic dust bronchitis, have been ranking high traditionally in the structure of population professional morbidity for many decades. And so in 2012 in Ukraine the highest proportion manifested itself of pneumoconiosis and chronic bronchitis at 27,5% (710 cases) and 21,8% (564 cases) per 100 thousand citizens. The diseases of allergenic origin are typical of the most ecologically dependent types of pathology. In comparison to 2011, in 2012 the incidence of bronchial asthma among Ukrainian population increased from 423,3 to 458,2 cases per 100 thousands of citizens, i.e. by 8,4%. There is a direct close correlation between the atmospheric pollution levels caused by allergenic action substances (dust) and the incidence of bronchial asthma among Ukrainian population.

For many years the initial population sickness rate in Lviv Oblast' have been higher than the average one Ukraine-wide, and even higher than in Donetsk-Dnipro region. As it has been shown by the results of the researches [4], in the conditions of Lviv Oblast', even against the background of medical aid level increasing (twofold), there is a growth of general sickness rate among the adults by 18%, and among the children by 7%, which is closely related to the environmental pollution level. Dust emissions have dramatically worsened the ecological state of the environment. For this reason, recently in all countries of the world much more attention has been devoted to the issue of dust emissions under various technological processes.

It is essential to discover correlation between atmospheric pollution in the regions of Ukraine and population sickness rate growth, also to perform the present dust cleaning apparatuses analysis and to suggest high-performance dust catchers for air from dust cleaning.

Therefore, the task of our researches was to formulate the theory of dusty gas stream flow in the apparatus casing and on its significance for the choice of optimal dust cleaning apparatuses structure.

Recent Research Analysis. The analysis of famous dry dust cleaning methods has shown that despite high-performance catching of coarsely dispersed dust particles, they cannot provide fine-dispersed fraction cleaning by more than 85%, and a number of constructive improvements leads to a considerable complication of dust cleaning schemes.

The greatest achievements in centrifugal catching of solid particles from gas flow are marked in the part of apparatus implementation (engineering), but not scientific elaborations, [3-6] which is explained, on the one hand, by the accumulation of industrial apparatuses operation long experience, and on the other – by the considerable complication of description of certain phenomena and properties of heterogeneous systems: rigid body – gas in centrifugal field,

Literary sources analysis allows us to draw a number of general conclusions concerning our research: aerodynamics data have a solely experimental nature; there are no theoretical connections whatever, which would allow to generalize the collected experimental material and to detect the major defining the "screws" in aerodynamic properties; if there were such connections, we could dispense with experiments in every specific case, and their availability would be a solid foundation of different screws selection and computation methods. It is essential to devise different constructions in the "screw" use of optimum variants from the viewpoint of security and economic efficiency of regulation; computational methods must in terms of quantity take into consideration the interference conditions of all the ventilation system elements; the ultimate goal of the research must be the getting of simple and infallible "screws" for computation and selection methods.

Main Research Material Statement. Air from dust scrubbers efficacy and economical efficiency is most frequently determined by the right choice of all the automatic regulation elements. The main part of such regulation tasks is connected with amount changes of the air, which go through different branches and separate system elements [8].The control device is an element for incoming flow swirl – a "screw" of different constructions.

The data availability about aerodynamic properties of the "screw" is the necessary prerequisite for the right choice of the elements for incoming flow swirl (the "screw") in conformity with specific regulation conditions. In practice, the designing of cases, when they are chosen to match the size of air ducts and equipment in the "screws" installing places, are not infrequent

In the suggested by us dust catcher construction the conchoidal inlet is just the example of direct placement of such a "screw" in the dust catcher inlet.

Aerodynamic properties materials often have experimental nature and cannot be generalized for other constructions. In the works devoted to "screws" computation, the acquired experimental data apply to any constructions. At the same time their practical use conditions, including reciprocal influence of "screws" and other system elements, with which they co-operate, [9-13] are left out of account. The existing "screws" methods and recommendations are either complicated, or have a very general nature.

The multiplicity of "screws" constructions dictates the need for such solutions that may allow conducting computations sufficiently simply and with good reasons for it, depending on specific regulation conditions.

The rectangular and straight "screws" engineered today, which are intended for full industrial production, structurally differs from those, whose aerodynamic properties are known. For this reason, the fact that American companies recommending their products demonstrate a radically different selection and computation techniques, is of interest.

Aerodynamic "screws" properties are expressed by their inner and working characteristics. Inner aerodynamic "screw" characteristic is determined by the relation:

$$\zeta = f(\alpha), \tag{1}$$

where: ζ– "crew" resistance coefficient; α – trailer dead angle, deg.

Since we open the "screw" in order to increase consumption, the pressure on the "screw" differential is decreasing, and pressure loss in air duct is increasing proportionally to the velocity square of the air, which goes through either naturally or the "screw" characteristic should be considered in correlation with the characteristic of the system, in which it is used [15,18]. This characteristic, which is essential for regulation processes computation, is called the working aerodynamic characteristic. Its formation by known inner aerodynamic characteristic can be executed by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\Delta H_1}{\Delta H_0} \cdot \frac{\xi_{p,y} + \xi_0}{\xi_{p,y} + \xi_1}}, \tag{2}$$

where: υ_0, ΔH_0, ζ_0 – air consumption, pressure loss in the section, which is adjusted, and open "screw" resistance coefficient α=0, respectively; υ_1, ΔH_1, ζ_1 – the same in any of "screw" trailer intermediate positions; $\zeta_{p.y.}$ – section, which is adjusted, resistance coefficient, attributed to the velocity in the "screw" cut.

Practically, the "screws" are used for the consumption control in the branches by constant general drop and: ΔH1/ΔH0=1. Thus working "screw" characteristic computation is made by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\xi_{p,y} + \xi_0}{\xi_{p,y} + \xi_1}}. \quad (3)$$

If in formula (3) the close "screw" resistance coefficient $\zeta_з$, is taken into consideration, $\frac{v_1}{v_0}$ v_1/v_0 will express the so-called air-sweeping, or the amount of air, that go through the close "screw" with respect to the overall consumption through the open "screw". It is obvious that air-sweeping through the "screw" is the function of total resistance of the section, which is adjusted. The stronger resistance is, the air-sweeping is more intensive for one and the same "screw".

The graph of Figure 1 represents the quantity of air-sweeping through the close "screw" computational dependence on the section, which is adjusted, resistance coefficient $\zeta_{р.л}$. In addition to that, the meanings of $\zeta_{р.л}$ are applied to the velocity in the flow area of the "screw", which adjust. According to the graph data, air-sweepings depending on the adjusted resistance of the section and the installed "screw" size, may differ considerably, and thus they cannot characterize the "screws" embodiment quality.

The "screw" resistance coefficient at its closing is the basic quantity, which determines the tightness of "screw" closing. Perfectly executed "screw" has $\zeta_з$, real "screws" – finite quantity $\zeta_з$.

If we are to characterize air-sweeping, as it is practically accepted, by the percentage from total consumption when the "screw" is open, it should be considered by equation $\zeta_{р.у.}$=0 , and the air-sweeping should be calculated by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\xi_0}{\xi_1}}. \quad (4)$$

At the same time, the minimum air-sweeping quantities will be obtained. For any installation these quantities will be higher.

It is known that for the regulation convenience it is necessary to adjust the consumption relative change dependence on the relative "screw" thread to, most of all, the approximate to the rectilinear [17,19,20].

The evaluation of maximum force (moment) for "screw" drive is the necessary condition of the actuating mechanism power right selection. The strongest force on the actuating mechanism will be the case, when:

$$M_п = M_{дин} + M_{гв} \text{ , } kgm \quad (5)$$

where: $M_п$ "screw" drive moment, *kgm*; $M_{дин} = cbF\Delta H$ – rotational moment which arises from the action asymmetry of current intensities, flowing with respect to "screw" axis (the resultant of these forces does not lie on the "screw" axis, but is situated at some distance from it, which depends on the rotation angle of the "screw" and its form); c – empirical coefficient, dependent on the rotation angle and the form of the "screw"; b – "screw" width in the perpendicular to rotation axis direction, m; F – "screw" area, m^2; ΔH – the pressure differential on the "screw", kg/m^2; M_{cm} – the force, required on the "screw" rotation in the still air, *kgm*.

Relation (5) allows us to find the nearest quantity of the forces on the actuating mechanism by experimental evaluation M_{cm} and c for this "screw" construction.

In the practice of engineering, in most cases the air motion, through different obstacles, apertures etc, resistances quantities is conventionally characterized by resistance coefficient. General formulae of resistance take the form of:

$$\Delta H = \zeta \frac{\gamma\omega^2}{2g} \text{ Па.}, \quad (6)$$

where : ω – air velocity in the "screw" flow area, *m/sec*; γ – air specific weight, kg/m^2.

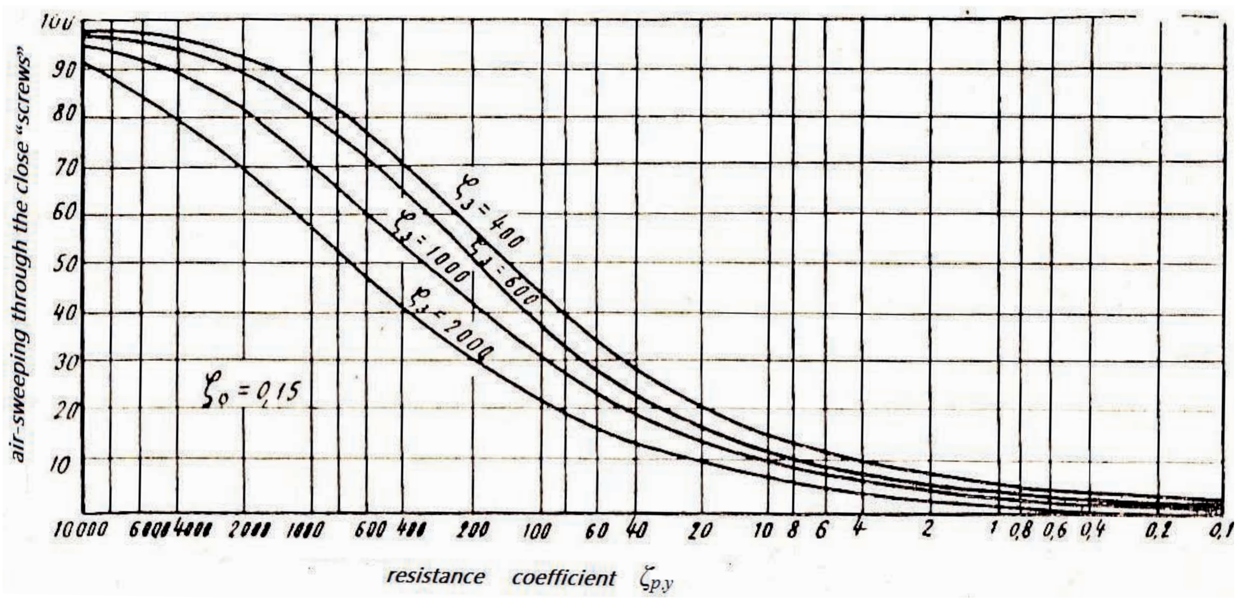

Fig 1. The dependence of air-sweepings through the close "screws"

Such formula form is conditioned by the quadratic dependence between motion resistance of the air and its velocity, which occurs by turbulent motion, when the inertial forces, arising in the flow, dominate the viscous forces. Such an air motion mode is commonly observed, when different obstacles encountered on the motion path are flown around.

In its general form the resistance coefficient consists of the friction resistance coefficient and the form loss coefficient. In the case under our review the first coefficient quantity because of the "screw" trailer narrow width is low in contrast with the second one, which takes the "screw" choking effect into consideration. That is why, in all the subsequent reflections, the form loss quantities determined from the difference of pressure loss between the cuts with the fields of velocity, which evens, before the "screw" and after it, are the only issue [22]. The effect of closely located elbow pieces or obstructions, disturbing the equal velocity distribution, is specifically examined.

It is known that resistance coefficients are independent of both Reynolds *Re* and Mach numbers *Ma*. As a rule this dependence is not observed, when Reynolds number is large (turbulent motion). Its character is determined by the nascent state of flow separation and vortex formation and their subsequent development. The more severely the flow in local resistance is deformed, by the smaller *Re* numbers the vortex and separation are formed, and thus we observe the quadratic resistance law. The "screws" are usually used for the consumption regulation in the air ducts of large sizes, that is why their sizes are also large in most cases. As a result, we may assert that the automated modeling condition should be adhered to for the majority of the folding «screws» at the considerable air flow velocities. More detailed research of this issue was not set as this paper object.

The resistance coefficient dependence on the Mach number begins to appear approximately when $Ma > 0,6$. Since the air velocities in air dumps are incommensurable with the sound velocity, we may consider that the "screw" resistance coefficients are independent of *Ma*.

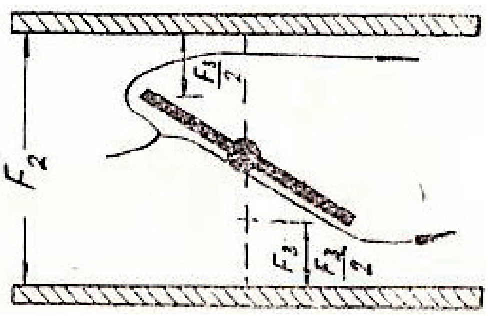

Fig 2. The air flow around the "screw" schema

Thus, these coefficients must be the functions of only geometrical parameters of the "screw". The latter are determined by the "screw" installing angles, their number and the form, and also by the "screw" design (rectangular, round, opposed).

This parameter part creates one or another conditions for the air flow motion through the folding "screw" and stipulates its resistance coefficient quantity. When the air flows between the "screw" folds, the air stream narrows from air duct full cut F_2 to some free cross-sectional area plane F_3, which is generated by a certain "screw" folds installing (Figure 2). Simultaneously, the flow deviates from the rectilinear direction, while at some distance after the "screw" its inverse deviation or air duct length leveling occurs.

The availability of velocity differences in the narrow and wide cross-section results in the flow separation and vortex formation, which stipulates irreversible energy consumption. In essence, the phenomena, occurring in the examined case, are analogous to the case of the stream sudden expansion by abrupt change of cross-section for air passage and can be estimated by the dependences (7) and (8):

$$\zeta = \left(\frac{F_2}{F_{3\varepsilon}} - 1 \right)_2, \quad (7)$$

$$\zeta = \left(\frac{1}{n^{\varepsilon}} - 1 \right)_2, \quad (8)$$

where: ε – the coefficient of stream contraction, which is the result of motion inertia; $n=F_3/F_2$ – free area between the "screw" to air duct's cross-section area ratio.

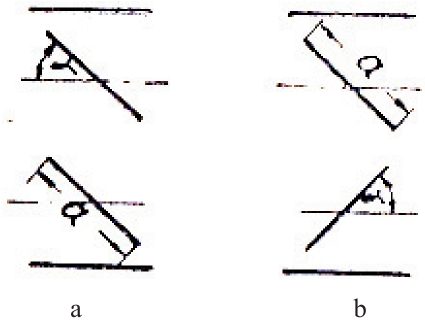

Fig. 3. Parallel and opposed "screws" schema: a – parallel, b - opposed

Coefficient ε – the function of installing angle of the "screws", their design and relative positions.

Correspondingly, "screws" aerodynamic characteristics of different designs are to be different. Their inner aerodynamic characteristics construction, i.e. the determination of resistance coefficients by different "screws" installing angles, comes to the quantities n and ε finding.

The value ε cannot be definitely determined as depending on the "screw" design, as the character of stream flows is various. Appealing to Figure 3, we may mentally divide the air flow, approaching the "screw", into three parallel branches with different resistances by constant general drop. The flow character and, correspondingly, also the contraction coefficients are different in different branches. The legitimacy of such division is corroborated by the studies on the hydraulic flume in order to check the air flow between the "screw" folds and behind it authentic picture.

Thus, the "sudden expansion" of the flow from the aperture, generated by fold edge and "screw" frame plate, to the intersection, which is approximately equal to the fold width, occurs in higher and lower branches (Figure 3; b). The phenomena character may be written down by the dependence:

$$\zeta'' = k_{n.p}\left[\frac{\alpha\cdot b}{\frac{a\cdot b}{2}(1-\sin\alpha)\cdot\varepsilon_0}-1\right]^2 = k_{e.g}\left(\frac{2}{n\cdot\varepsilon_0}-1\right)_2, \quad (9)$$

where: α and b – "screw" frame width and length, *m*: $k_{e.g.}$ – extension graduation coefficient, or resistance coefficients relation by gradual and sudden extension; ε_0 – compression coefficient, determined by "screw" folds design.

The flow character of the stream between the folds, angularly related to each other (Figure 3; a), can be described by the dependence as extension from the pressed opening:

$$\xi' = \left[1-\frac{\frac{ab}{2}(1-\sin\alpha)\varepsilon'\varepsilon_0}{ab}\right]^2 = \left(1-\frac{n\varepsilon'\varepsilon_0}{2}\right)^2, \quad (10)$$

where ε' – compression coefficient by flow from the pressed opening, which can be determined with the help of reference book.

The phenomena, occurring air flow between parallel folds (Figure 3; a), can be described by the dependence:

$$\xi''' = \left(\frac{1}{n''\varepsilon_1\varepsilon_0''}-1\right)^2, \quad (11)$$

where: ε_0'' – coefficient, which takes incidental corner losses between the folds, and also incidental vortex formation on the edge into consideration; ε_1 - compression coefficient by flow from the pressed opening, which can be determined with the help of reference book information. In contrast to ε' it does not take account of the intrusion into the bore softening.

According to the known dependence for parallel branches by constant general drop we can write down:

for opposed and single-winged "screws":

$$\frac{m}{\sqrt{\xi}} = \frac{m\frac{n}{2}}{\sqrt{\xi'}} + \frac{m\left(1-\frac{n}{2}\right)}{\sqrt{\xi''}}, \quad (12)$$

for parallel "screws":

$$\frac{m}{\sqrt{\xi}} = \frac{\frac{n}{2}}{\sqrt{\xi'}} + \frac{1-\frac{n}{2}}{\sqrt{\xi''}} + \frac{m-1}{\sqrt{\xi'''}}, \quad (13)$$

in the general view:

$$\xi = \frac{m}{\dfrac{n}{2\left(1-\dfrac{n\varepsilon'\varepsilon_0}{2}\right)} + \dfrac{1-\dfrac{n}{2}}{\left(\dfrac{2}{n\varepsilon_0}-1\right)\sqrt{k_{np}}} + \dfrac{m-1}{\left(\dfrac{1}{n''\varepsilon_1\varepsilon_0''}-1\right)}}. \quad (14)$$

Dependence (14) can be spread on angular displacement interval 20<α<70º. It is obvious that by α=0÷10º and α=80÷90º the stream flow laws, different from the one examined above, come into effect. These laws require special study.

For ζ_0 determination of close "screws" we can apply Idelchik formula, which relates to rod lattices. In the accepted by us nomenclature this dependence has the following appearance:

$$\zeta_0 = \beta\left(\frac{1}{n_0}-1\right)_{4/3}, \quad (15)$$

where: β – trial coefficient, which depends on the "screw" form.

Close "screws" resistance coefficients can be only experimentally obtained because of the fact that their quantities are determined only by "screw" fold construction and their realization quality. Resistance coefficients at the fold rotation angles close to 10º and 70º can be obtained only be means of the nearest values interpolation correspondingly when: α=0 and α=20º, and also α=70º and α=90º.

Thus, for computation by the dependences (14) and (15) the coefficient quantities *n*, *n''*, *ε1*, *ε'*, $k_{e.g}$ can be taken according to the known theoretical data, and ε_0, ε'', β – must be obtained as a result of the experiment. For their determination we have used experimental data on the resistance coefficients of rectangular opposed and parallel "screws" of different designs [1 – 3], and also the results of our own experiments. The technical information about these "screws" is provided in Table 1. 8 experimental arrangements were researched.

The pressure loss, caused by the "screw" installing, was determined by the expression:

$$\Delta H = (H_{\Pi}^{AA} - H_{\Pi}^{BB}) + \Delta h,\ \Pi a., \quad (16)$$

where: H_{Π}^{AA}, H_{Π}^{BB} – total pressures in the cross-sections AA and BB, *mm*; Δh – incidental losses, related to cross-sectional AA air duct length flow leveling, *Pa*.

Resistance coefficient is estimated by formula (6).

Since the researches were conducted on "screws" full-scale specimens, we did not manage to reach full leveling of the flow behind the "screw" because it is necessary to have long tangents of air ducts. The quantity *Δh* was estimated by Idelchik formula for losses computation by the impact in the flow with the uneven velocities profile.

Table 1.

"Screw" type	"Screw" designation	Cross-sectional area, m^2	The number of sides
Rectangular Opposed	P 700 X 500 P 1 000 X 1 000	0,35 1,0 2,43	3 6 11
Rectangular Parallel	PO 700 X 500 PO 1 000 X 1000	0,35 1,0	3 6
Round Parallel	Д 440 Д 885 Д 1 200	0,152 0,615 1,13	1 2 5

For this case:

$$\Delta h = \left(\frac{1}{n^2} + N_1 - \frac{2M_1}{n}\right)\frac{w_1^2}{2g}\gamma, \quad (17)$$

where: N_1 – the coefficient of kinetic energy in bottle neck:

$$N_1 = \frac{1}{F_1}\int\left(\frac{w_\tau}{w_1}\right)^3 \cdot dF, \quad (18)$$

M_1 – the coefficient of momentum in bottle neck:

$$M_1 = \frac{1}{F_1}\int\left(\frac{w_\tau}{w_1}\right)_2 \cdot dF, \quad (19)$$

F_1 – the most narrow cross-section area, m^2; w_τ – local actual velocity, *m/sec*; w_1 – average velocity in bottle neck, *m/sec*.

The quantities N_1, M_1, w_1 can be estimated, when we know the velocity shape in a certain selected cross-section AA on the flow extension side. The performed analysis of velocity fields, obtained at different angles of "screw" closing, shows that the velocity profile for this case can be described by the equation of such type:

$$w = A + B\sin\left(\varphi + \omega\frac{2y}{b}\right), \quad (20)$$

where: y - cross-sectional distance from air duct horizontal axis, *m*; b – air duct cross sectional height, *m*; A, B, φ, ω – empirical coefficients.

The solution of integrals N_1, M_1 for the function of the type (20) turn out to be complicated and cumbersome formulae, and because of this they are not given. When n, N_1, M_1, w_1 are known, we can estimate the value Δh by formula (17).

The measurement technique includes the following. For each of the "screw" fold rotation angles (from 0 to 90º in every 5º) the velocity fields in the selected cross-sections before and after the "screw" were taken off. All the measurements were conducted from the ventilator suction side. The possibility to control rotational speed allowed us to select different speed rates, convenient for measurements.

The experiments showed that the velocity distribution to the "screw" (cross-section BB) approximated to the profile for a fully developed flow, which occurs in long pipes and canals.

On the side and top walls of air duct in 100 – 150 mm the holes 1 mm in diameter were drilled, to which from the outside the tubes 3 mm in diameter were soldered. All the tubes were joined with each other by means of rubber and glass tubes and connected to the micro-manometer.

The correctness of static, dynamic and full resistances measurements was verified by their summation in every air duct cross-sectional point, placed 20-40 mm apart. The value of cross-sectional average velocities was verified with loss average velocity, estimated by a collector [21, 23].

The fundamental setup schema for "screws" by their full closing air-sweeping values determination is shown in figure 4. The loss measurement was conducted in tube q, the vacuum one – in camera 2. According to this information absolute air-sweeping values and also the quantities ξ were determined.

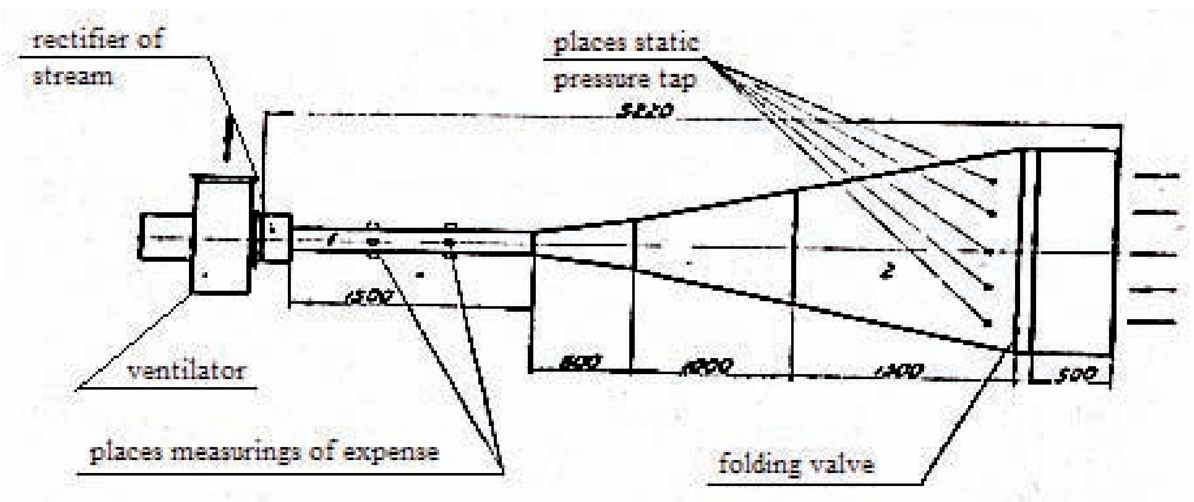

Fig 4. Experimental setup for the air-sweeping by the close "screw" schema

Table 2.

"Screw" fold rotation angle	Cross-sectional average velocity, m/sec	Wide and narrow cross-sections area ratio	Kinetic energy coefficient	Momentum coefficient	Unit resistance coefficient, related to the velocity in the "screw" flow open area
40º	10,1	0,9	0,04	1,32	0.4
60º	9	0,8	2,65	1,45	0,82
75º	6,3	0,6	5,14	2,17	1,9

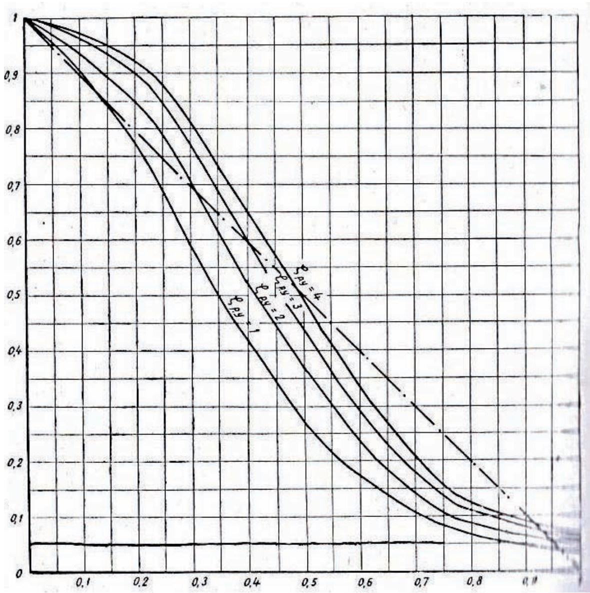

Fig. 5. The opposed "screws" performance aerodynamic characteristics

The generalization of our own experiments results and literary data allows for a recommendation of experimental coefficients' values measurements.

On the basis of inner aerodynamic characteristics, the "screws" performance aerodynamic characteristics, whose example is provided in figure 5, were constructed by formula (3). When we control air losses by means of twofold "screw", air flow inlet occurs at some angle on the "screw" folds. This circumstance stipulates specific distinction of twofold "screws" aerodynamic characteristics from the straightway one. In the case in question the mutual merge quantitatively depends on sizes ratio of twofold "screws" sections, their configuration and "screw" folds installing angles.

As mentioned above, the final force on the "screw" drive consists of M_{dyn} and M_{st} (5). The evaluation of M_{st} was carried out in the experimental way on the "screws", at the same time the lever, fastened on the driving fold axis, made the folds turn. Appropriate lever forces and shoulder lengths ℓ are listed in Table 3. The quantities $M_п$ were determined in the same way, and the maximum value for all "screw" types was fixed by $\alpha = 75º$.

Table 3.

"Screw" designations	Lever forces, kg	Lever shoulders length ℓ, m	Mst, kgm	A number of folds	Mst on one fold, kgm
Р 500 Х 700	1,4	0,042	0,059	3	0,02
Р 1000 Х 1000	0,4	0,397	0,159	6	0,0265
У 1000 Х 1000	1,8	0.075	0,135	6	0,023
У 1350 Х 1800	0,8	0,397	0,318	11	0,029
Д 440	0,3	0,065	0,02	1	0,02
Д 885	3,3	0,031	0,099	3	-
Д 1200	4,8	0,031	0,15	5	-

To sum up Table 3 data, formula (5) can be represented in the form, for rectangular parallel and opposed "screws" with streamlined folds:

$$M_п = 4,3 \bullet 10\text{-}4\xi\alpha{=}75ºFw_2 + 0,025\ m,\ kgm, \quad (21)$$

for round screws with flat folds:

$$M_п = 6,7 \bullet 10\text{-}4\xi\alpha{=}75ºFw_2 + pm,\ kgm, \quad (22)$$

where: p – coefficient, which characterizes M_{st} on one fold and depends on the production quality of swivel blocks and fold weight.

It is significant that the quantity *cb*, which determine the distance of the application point of the resultant from the fold axis, for flat round fold it appeared to be approximately half as large, than for the streamline rectangular fold. That is why, we can concede that by the streamlined fold form, fewer forces on the movement are needed under other equal conditions, than by the flat one.

Thus, the dependences (21) and (22) allow us in the consumption way to determine forces for "screw" drive, which have folds, and equal to the examined, by different sizes and "screws" operating conditions.

For the study of aerodynamic processes, occurring in the cyclone by incoming air flow rotation around its own axis, subsequent researches were conducted in two directions; the first consisted in the research of the constructed apparatus aerodynamics by means of computer modeling, the second – in the characteristics study of the dust catcher on the test bench, which was described in chapter 3.

For the study of aerodynamic processes, occurring in the dust catcher engineered construction and for the parameter optimization for experimental researches substantiation, we have constructed the three-dimensional solid model of the dust catcher (Figure 6). In the cyclone upstream end we have placed the apparatus, the "screw" (Figure 7), primary purpose of which is to spin the incoming air stream round the nipple. The rotational frequency depends on the angle α (Figure 9) of the "screw" blades location.

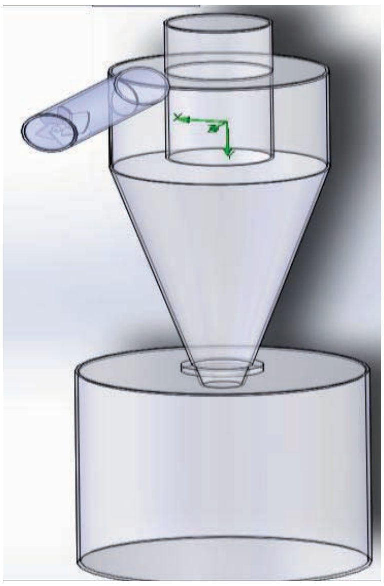

Fig. 6. Separator solid model

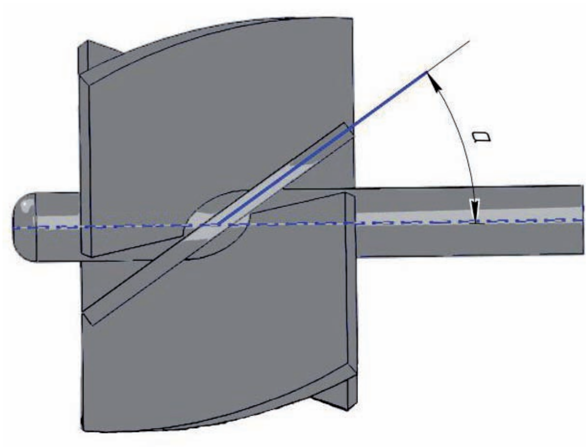

Fig. 7. Element for incoming flow spinning, the "screw'

Apparatus aerodynamic processes analysis was conducted with the i use of FlowVision, and also on the basis of the developed mathematical model, relying on the use of Navier–Stokes equations, which are described in the non-stationary formulation, mass, momentum and energy of the environment conservation laws. Furthermore, low elements state equation, and also the empiric relations of viscosity and these environment elements thermal conductivity on the temperature were applied. The turbulent, laminar and transitional (the transition between the laminar and the turbulent is determined by the critical Reynolds number value) flows are modeled by these equations. For the turbulent flows modeling (they most often occur in the engineering practice) mentioned Navier–Stokes equations were averaged by Reynolds criterion, i.e. they used the averaged on a small time scale turbulence influence on flow characteristics, and the big scale temporary changes of averaged on a small scale and by short time of gas-dynamic flow characteristics constituents (pressure, velocities, temperature) were taken into consideration by the introduction of appropriate time derivatives. As a result the equations had complementary terms – tension be Reynolds criterion.

As a consequence of mathematical modeling it was proved that by the flow rotation frequency increasing in the upstream and around its own axis, the cyclone hydraulic resistance is increasing [24]. At a blade angle of inclination, which is 15º, the apparatus hydraulic resistance practically is twice as strong as the cyclone resistance without incoming flow rotation. It is essential to study what influence on the cyclonage processes aerodynamics and the efficiency of the dusted flow clearing the incoming flow rotation has. Pro hac vice they conducted the researches at blade angle of inclination in the interval between 0 and 35º 5º Thus, they proposed the apparatus construction, the general view of which is presented in Figure 6.

The Resume And Perspectives of Subsequent Researches. At the "Electron" Production Association a test-industrial unit with a capacity rate of 600 m^3/sec for the dust suction from grinding machines, which consists of a casing, fastened on a grinder, a centrifugal-inertial dust catcher with a chevron separator, in the upstream end of which a "screw" was installed (Figure 9). It was constructed and mounted from scratch. The tool maintenance department machines connection to the ventilation system, suggested by us, allowed for an increase of general dust cleaning efficiency to 98,6%, changing hydraulic resistance and dimensions in addition to this, that is confirmed by application and test acts, and this opens up new vistas for suggested construction application and allows for a decrease of negative industrial atmospheric effusion and reduction of the threat of global consequences for future generations by means of advanced serious engineer decisions on the prevention of fine aerosol emissions.

The suggested by the authors apparatuses have found a wide use in plastic and mechanic metal working, in the building materials production when producing the bitumised perlite, ceramic tile, cement, bituminous concrete, sulfur, mud powder, saturnine red, furnace charge, potassium-magnesium, vinyl chloride, wood and metal chips, and they showed high performance at low power inputs.

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Time of exposure to grain processing disinfection in strong electric fields

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A b s t r a c t . A prototype installation is presented developed at the Department of Electric and Electro Technology of the National University of Life and Environmental Sciences of Ukraine, in which, with appropriate electric field intensity in air inclusions partial grain mass discharges are occurring and, accordingly, throughout the volume of products ozone is formed, the concentration of which is governed by the electric field. The results of investigation of barley moisture effect on ozone concentration in the grain mass under the action of a strong electric field are discussed and a nomogram is developed for determining the time required for an effective dose of antiseptic treatment of barley.

K e y w o r d s : Strong electric field decontamination processing, grain weight, nomogram, treatment dose, ozone treatment exposure, humidity.

INTRODUCTION

The purpose of grain microflora disinfection can be attained by chemical, biological and physical methods. Nowadays grain processing is carried out mainly by chemical means. But along with the achievement of positive results, the use of chemicals has several negative consequences, including environmental pollution by pesticides and their accumulation in soil and in plant products that pose a threat to human and animal health, as well as the complexity of the performance of work [1, 2]. There are also a number of diseases against which chemicals cannot provide the proper effect. This primarily refers to Fusarial diseases and mold fungi that develop during storage. Besides, chemical methods cannot be used in the processing of food supply of grains.

Given these circumstances, in the advanced countries of the world environmentally clean agricultural production is actively developed, by reducing the use of pesticides and alternative methods of plant processing. First of all, it focuses on electrical methods, providing electromagnetic, ionizing, light, ultraviolet, laser, and other seed processing [3, 4, 5]. However, these methods do not have industrial use because of the insufficient clear reproducibility of the results and low efficiency in the fight against disease-causing agents of seeds, some of them being very energy-intensive.

One promising trend developing in the recent years has been the use of strong electric fields for preseeding processing of seed crops in order to stimulate growth processes and processing of the crop during storage in order to neutralize surface microflora [6, 7].

Therefore, the development of a method for determining operating parameters for decontamination processing of grain in the electric field of high voltage for use in a production environment is an urgent task.

MATERIALS AND METHODS

In recent years, at the Department of Electric and Electro Technology at the National University of Life and

Fig. 1. Appearance settings for the processing of cereals in the electric field of high intensity

Environmental Sciences of Ukraine research has been carried out on the application of strong electric fields for preseeding stimulation of seeds and grain handling disinfecting storage [8, 9, 10]. The research resulted a prototype installation, the look of which is shown in Fig. 1.

At the developed installation the grain mass is poured into the processing chamber where it is between high voltage electrodes. The appearance of the treatment chamber is shown in Fig. 2.

Fig. 2. Appearance of camera processing

At a corresponding electric field in the volume of products partial discharges occur in air inclusions where the uneven distribution electric field intensity is the maximum [11, 12]. With the increase of the applied voltage, ionization occurs in large amounts of air inclusions, and the momentum of the discharge of air inclusions in the following will be more than in the previous ones.

It will also increase the intensity of the ionization in the inclusions where it started at a lower intensity. With the passage of the ionization processes, in the whole volume of production ozone forms, which is known for its bactericidal properties [13, 14, 15, 16, 17]. The concentration of ozone depends on the electric field and moisture of the grain mass [18].

RESULTS AND DISCUSSION

As a result of experimental studies an effective dose has been found of disinfecting treatment [19], which is dependent on exposure time and ozone concentration. Determination of the ozone concentration in grain mass involves the time necessary to obtain the effective dose. In a production environment the problem of determining the dose is complicated, since it needs the measurements of ozone complex and laborious processes requiring additional equipment. Therefore, it became necessary to develop an alternative and easy way to determine the dose of grain processing, depending on the known parameters of the crop, such as humidity.

Moisture determines the dielectric properties of grain mass, which significantly affect the discharge processes in it under an electric field of high intensity, and hence the concentration of ozone.

To investigate the influence of humidity on the concentration of ozone, barley variety «Don'ts» was used of the moisture ranging from 12.2% to 17.2%. In the studies dielectric plate of polyethylene was used with the thickness of 0.5 mm, the distance between the electrodes was 3 cm, height mixture of barley 6 cm [20]. The voltage at the electrodes was 16 kV. The results are shown in Table 1.

Table 1. Studies of dependence of ozone concentration in the grain weight of its moisture

№ п/п	1	2	3	4	5	6	7
W, %	12,2	13,5	14	14,5	15,9	16,7	17,2
K, мг/м^3	101,4	592,8	697,4	644,3	487,5	362,1	217,3

The analysis of experimental studies presented in Table. 1. shows that the maximum of ozone concentration is achieved with conditioned grain moisture 14-14,5%. This can be explained by the ability of grain mass to move from the state of the insulator to the conductor, depending on humidity. So, at 12% moisture corn is in the state of an insulator and the number of ions in the interstitial fluid is very small. In this state, the grain mass partial discharges occur infrequently and therefore ozone concentration is low. With increasing humidity, the number of ions in the intercellular fluid of grains increases, which contributes to the formation of the electric field in the air inclusions and thus the passage of intense bit processes. Therefore, there is a growth of ozone concentration to moisture content 14.5%. With further increase in moisture, content of ions continues to grow, conduction current begins to flow through the grain mass, which prevents the accumulation of charge in the air inclusions. The intensity of partial discharges is reduced. Thus after humidity of 15%, a gradual reducing of the ozone concentration is observed.

As a result of the research the mathematical dependence $K_o=f(W)$ is described. Analytical expression $K_o=f(W)$ obtained on a PC using software is represented by the expression:

$$K_o = a + b \cdot W - c \cdot W^2 + d \cdot W^3, \qquad (1)$$

where: a = -52834; b = 9891; c = 600; d = 11,88 - coefficients for barley grain mass.

Also to construct a nomogram it was necessary to establish the dependence for determining the exposure time at various concentrations of ozone, which is necessary to ensure processing of 2940 doses (mg·m^3)/min, providing 90% neutralization of harmful microorganisms. [19] The dependence is established given in Fig. 3. Parameters are defined for the developed setup, with 3 cm distance between electrodes, dielectric plates of polyethylene thickness of 0.5 mm and the voltage across electrodes 16 kV.

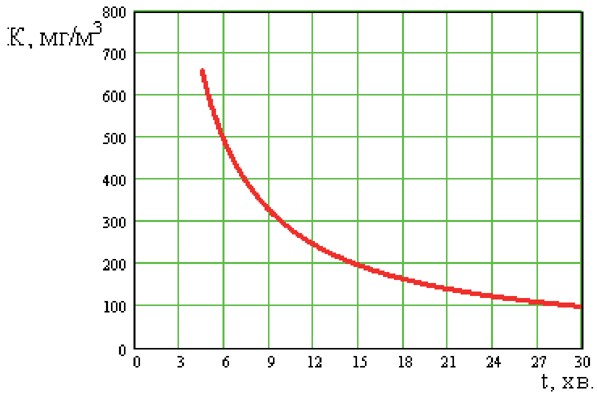

Fig. 3. The dependence of time of exposure at various concentrations of ozone, which is necessary to ensure 2940 mg dose processing of m3/min

Using the above relationship (Fig. 3) and the mathematical dependency of ozone concentration in the grain mass at the field strength 5.3 kV / cm from the moisture content (1), a nomogram was constructed , which is presented in Fig. 4.

For a given nomogram we can determine the time required to ensure an effective dose of decontamination during the processing of barley grain mass at a certain value of its moisture.

CONCLUSIONS

The effective disinfection of grain in the electric field of high intensity, with the necessary dose of processing, depends on the ozone concentration and exposure time. Measurement of ozone concentration is a difficult and time-consuming process requiring additional equipment. Therefore, a nomogram was developed, using which it is possible to determine the exposure time that is necessary to ensure the effective dose of antiseptic processing of barley grain mass (2940 (mg·m^3)/min) with relation to the barley humidity.

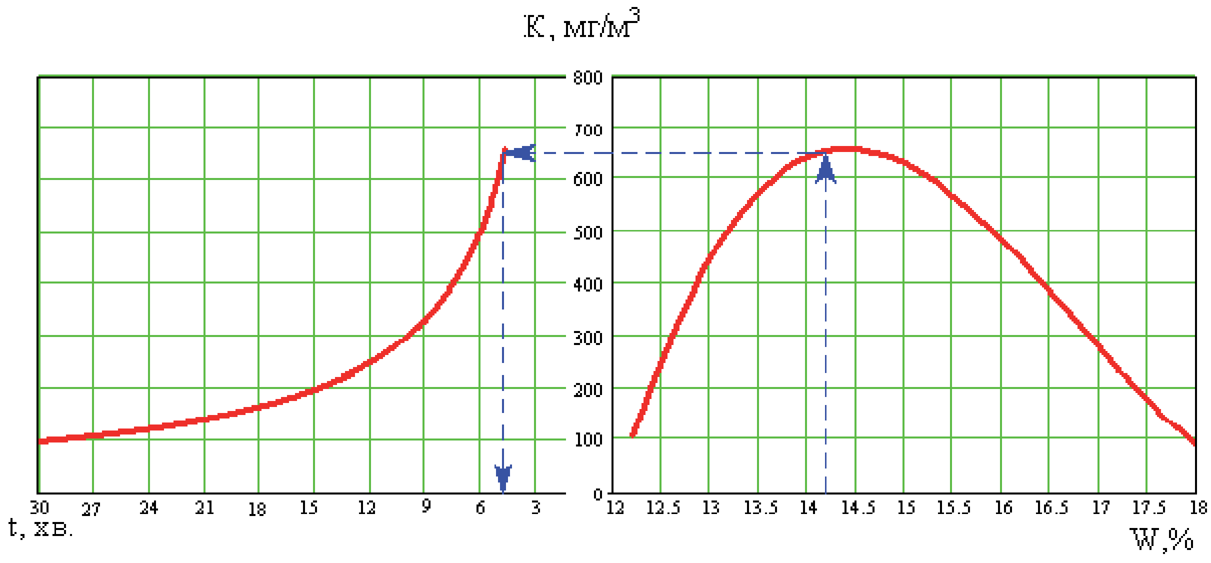

Fig. 4. Nomogram for determining exposure time of barley grain in a production environment

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Effect of polarization molecules reagents of the burning reaction on the efficiency of equipment for thermogeneration

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Abstract. The aspects of physical and chemical nature of oxidizing-reduction processes of burning were investigated. The communication of efficiency of fuel equipments with polarizing and activating of molecules-reagents was exposed. Application of molecules electro-activation for optimization of the chemical reactions at burning passed at incineration of gaseous hydrocarbon fuels in the oxidizing air environment was grounded experimentally.

Key words: energy efficiency, burning, electric field, high voltage, activation, polarization.

INTRODUCTION

The efficiency of fuel and energy resources use determines the development level of economies and population welfare in the world. Also, the time of resources exhaustion of the traditional fossil fuels (both found out, and prognosis) are measured by a few tens years [6,12,17]. Lengthening of the term of using of these fuels is important both from the point of view of time for researches on new methods and equipment for the obtainment of energy, and from the point of view of an increase of period of their use in the chemical and food industries and reduction of negative influence on the environment. A rise of efficiency of energy generating equipments in that direction of development of incineration technologies [15] which will prolong the period of using of the fossil hydrocarbon fuels is of current and timely interest.

Because of the basic quantity of thermal and other energy types we get at incineration of traditional and nontraditional fuels, it follows to focus attention at the burning process. A burning process is an exothermic oxidizing-reduction chemical reaction. For the rise of efficiency of heat generation at the use of hydrocarbon fuels it is necessary to achieve optimization of chemical reactions of burning and promote plenitude of the fuel burning.

Purpose of researches - to learn physical and chemical nature of oxidizing-reduction burning processes and to correlate the fuel options efficiency with the structure and activity levels of molecules-reagents for the optimization of burning chemical reactions at incineration of gaseous hydrocarbon fuels in the oxidizing air environment.

THEORETICAL GROUNDING

The rise of energy efficiency of fuel equipments is based on the use of the basic aspect of chemical kinetics theory - Arrenius law [4,9,16]. These law characterizes possibility and speed of chemical reactions between molecules-reagents. The theoretical and experimental researches showed the possibility of rise of incineration efficiency of gaseous hydrocarbon fuels in air by electro-activating of molecules-reagents of burning reaction. In theory [3,14,19], energy efficiency of fuel equipment at incineration of hydrocarbon fuel in air can be promoted across the acting on the components of burning reaction by the high-voltage pulsating uneven electric field of high voltage (HVPUEF).

The experimental researches of electro-activation of molecules-reagents by the burning reaction of propane and natural gas in air showed the possibility of practical realization of the offered method in the fuel equipments of different types for the gaseous hydrocarbon fuels [13].

The basic descriptions of molecules gaseous alkanes are shown in [18]. From this source it is evident that an increase of molecular mass of gaseous hydrocarbons is straight proportionally related to their basic descriptions - density, heat productivity and the specific expenditure of air (oxygen) for incineration. At the same time there is an inversely proportional dependence between the molecular mass and temperature of burning. This dependence, in our opinion, can be explained by the hydrocarbonic molecules structure and their polarization.

The molecules polarization consists in the distribution of general electronic cloud in space. If s-connection in diatomic molecule with the identical atoms takes place, an electronic cloud is distributed symmetrically in relation to the kernels of both atoms [1,11]. By the connections between the atoms of different elements, a charge of electronic cloud is distributed between atoms asymmetrically (geteropolar connection).

Under act of external electromagnetic field or field of neighbouring atoms, the displacement of electronic cloud density process takes place [2,8,10,20]. This process is named polarization of molecules. The polarized molecules have electronic clouds with different spatial density of charge. Polarity of molecular connections relies on their length and difference of atom electro-negativities, which form connections. The larger this difference, the greater polarity of molecules. Polar molecules contain the two opposite signs charges, that are located on the definite distance and are named dipol. Dipol is characterization of the dipole moment. The dipole moment of molecule is a vectorial value and equals a vectorial sum of all dipole moments of separate connections and unshared electronic pair in molecule. The dipole moment is calculated as product of charge and distance between the centers of opposite charges. A dipole moment is measured in debay (D); 1D = 3,33.10-30 C•m (Coulombs x metr). For the most molecules with the simple covalent connections the size of dipole moment is within the range 2...4 D.

The total polarized of molecule has three components [7]: atomic, electronic and orientating:

$$P = P_{at} + P_{el} + P_{or} \tag{1}$$

In formula (1), P_{at} characterizes displacement of atomic kernels toward the negative end of dipol, P_{el} - displacement of electrons to positive pole of dipol , and P_{or} characterizes the orientation of molecules in the electric field. An electronic constituent of polarized P_{el} makes an insignificant part of the general polarized. An orientation constituent P_{or} considerably diminishes with the rise of temperature.

A magnitude of polarized can be defined after the definition of dielectric permeability of matter (ε) on formula Clauzious-Mosotti:

$$P = \frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{M}{\rho} = \frac{4}{3} \pi N_A \alpha, \tag{2}$$

where:
M – molecular mass of matter (g·mol^{-1}),
ρ – density of matter (g·sm^{-3}),
N_A – Avogadro number (6,02·10^{23} mol^{-1}),
α – molecules polarization (sm^3).

If a matter is complex, that is it consists of a any components with polarizations α_i and by volume concentrations N_i, a formula Claouzius-Mosotti will have a kind:

$$\frac{\varepsilon - 1}{\varepsilon + 2} = \frac{4}{3} \pi \left[N_1 \alpha_1 + N_2 \alpha_2 + \cdots + N_k \alpha_k \right]. \tag{3}$$

Polarized P is determined by formula:

$$P = \frac{4M}{3\rho} \pi \left[N_1 \alpha_1 + N_2 \alpha_2 + \cdots + N_k \alpha_k \right]. \tag{4}$$

Sometimes the polarized names dynamic polarization, because it arises up under action of external field and relies on the structure of molecule and from size and direction of external field.

Polarized, as a measure of polarizing power of molecule, relies on mobility of electrons. So, p-electrons are more mobile than s-electrons. Therefore, molecules with π-connections are easier to polarize than molecules with σ-connections.

In our opinion, the larger degree of polarity of molecules, the more they are added to influencing of external electric field, acquired in this field of the proper kinetic energy and they are easier added to activating. The more the structure is similar in molecule to unipolar one, the heavier it is activated by the external factors.

The experimental researches of efficiency of the fuel burning under electro-activating influence by the high-voltage uneven electric field on molecules of gaseous hydrocarbons (propane and natural gas) and of air oxygen was conducted.

Spatial structures of molecules of methane CH_4 and propane C_3H_8 can also be presented as models [7,11]. Figure 1 presents a model of methane molecule. The form of molecule methane is tetraedr with the valency corners H-C-H even 109°28'. A molecule of methane is symmetric, and unipolar (nonpolarized).

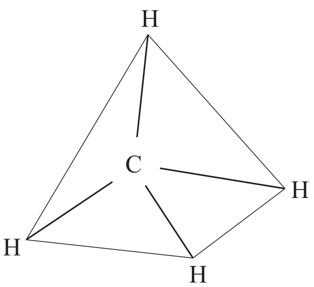

Fig. 1. Spatial structure of methane molecule

From our viewpoint, symmetry of methane molecule does not respond to transition of its electrons on the energy excitations levels .

The spatial structure of propane molecule – C_3H_8 has a crank form (Fig.2).

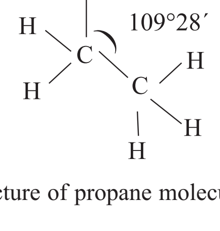

Fig. 2. Spatial structure of propane molecule

A molecule of propane has the asymmetrical distributing of electronic orbitals, that is it is geteropolar. This, in our opinion, allows with the less energetic expenditures to polarize the molecules of propane and translate them on excitation levels.

Atoms of carbon in molecules with the ramified chains differ by the type of having with other carbon atoms. With the increase of carbon atoms number in molecules the probability is multiplied and the fork of hydrocarbon chains is increased. A quantity of hydrocarbons isomers grows with the increase of quantity of atoms of carbon in the molecule.

The influence of polarity on the activating molecules can be their temperature of inflammation. The gas methane has autoignition temperature even 545, ethane - 530, propane - 504, and butane - 430 °C. In obedience to these data, evidently, the greater alkane polarization, the lower autoignition temperatures are.

MATERIALS AND METHODS OF RESEARCH

The experimental research on the efficiency of electro-activating of burning reaction molecules-reagents is presented by three series of experiments.

In the first series the research is conducted on the influence of HVPUEF separately on air and propane, and simultaneously on both components.

The first series of experiments included the following variants:

– incineration without electro-activation (control) ;
– incineration with electro-activation of air;
– incineration with electro-activation of propane;
– incineration with electro-activation of air and propane simultaneously.

In the first series of experimental researches 1,0 l of water was heated from 20 °C to 40 °C. In both experiments impulses of electric field were explored in the range of frequencies from 0 to 200 Hz. The impulses of electric field were explored in the range of frequencies from 0 to 140 Hz. The efficiency of electro-activation of components of burning reaction was estimated on the exceeding of time of heating of water without activating of burning reaction components above time under their activating. The first experiment was repeated three times. Results of the first experiment are shown in Fig. 3.

In the second and third series of experiments the influence HVPUEF was explored on the molecules-reagents of burning reaction at incineration of propane and natural gas in the air. In both experiments impulses of electric field were explored in the range of frequencies from 0 to 200 Hz. The efficiency of action of impulsive electric field with different frequency at incineration of propane and natural gas was estimated by time heating 0,7 l of water from 20 to 40 °C. The second and third experiments were repeated three times.

The variants of the second experiment of research were as follows:

1. Without high-voltage impulsive signal.
2. With activation - on the electrode system in the channel of air the impulsive mainly negative voltage is given, and on the electrode system in the channel of propane - impulsive mainly positive voltage (- - on air + - on propane).
3. With activation (+ - on air + - on propane).
4. With activation (+ - on air, - - on propane).
5. With activation (- - on air, - - on propane).
6. With activation (+ - on air), propane - without straightening.

Efficiency of influence HVPUEF on the components of burning reaction was estimated on differences at time between the experimental variants and control (without electro-activating of molecules). Results of the second experiment are presented in Fig. 4.

In the third experiment the estimation was conducted of electro-activating efficiency of molecules of natural gas and air. In the first variant of this experiment the research of activation was conducted only on air, in the second variant - general activating of air and natural gas.

Efficiency of electro-activating was estimated on contraction of heating time of water. Results of the third experiment are shown in Fig. 5.

RESULTS AND DISCUSSION

Experimental results obtained in the first series of experiments have shown that electro-activating of reaction components of burning of propane in the environment of air comparatively to controls variant substantially abbreviates time of heating of 1 litre water in all variants. Calculated $LSD_{0,05}$=4,33. The electro-activation of propane in the pulsating high voltage field with frequency 80 Hz allowed to warm water at the expenditure 11,3 % less fuel than in the control. The most positive effect (reduction of expenditure of fuel on 21,5÷22,0 %) is observed at action on both components of oxidizing-reduction exothermic reaction of burning by the high-voltage pulsating uneven electric field with frequency 100÷120 Hz. In the last variant of the first experimental series it is possible to mark realization of principle of superposition on the compatible influencing of activating of burning reaction of components.

Results obtained in the first experiment have proved the substantial abbreviation of time of heating of water during electro-activating of air and propane in the electric field of high tension practically in all variants. For all variants of research maximums of decline of time of heating of water were marked at the use of impulses with frequency 100÷120 Hz. The most positive effect (decline of time of heating on 22,1÷19,0 %) was found in the indicated range of frequencies for variant with the serve on the electrode systems of impulses of high tension without straightening. Calculated for the second experiment $LSD_{0,05}$=3,31 has given ground to consideration of substantial differences between the results of different variants.

Results of the first and second experiments are similar and show that most efficiency of incineration of propane in mid air is observed during electro-activation of both components of reaction of burning without straightening on frequency HVPUEF from 100 to 120 Hz.

From the result of the third experiment it is evident, that activating HVPUEF of natural gas and air abbreviates the water heating time in both variants of research. During activation of air for the high-voltage impulses with frequency 100 Hz the time of water heating was reduced by 11,1 %. During the general activation of natural gas and air the time of water heating was reduced by 12,0 %. Calculated for the third experiment $LSD_{0,05}$=2,46 testifies about unimportance of differences between both variants of experience practically for range of explored frequencies. This unimportant difference is explained, from our point of view, that in variant with the simultaneous activating both component of reaction of burning effective there was only activation of air. Payment in the general efficiency of reaction of burning of the activated natural gas was insignificant. It is possible also to make a conclusion about that in the second variant of the third experiment the parameters of electric field did not allow the sufficient measure to conduct activation of molecules of natural gas. So, by the fact that maintenance in the natural gas of methane makes 89÷99 % [10], in our opinion, it is explained that the obtained result shows ineffective influence of HVPUEF on the gomeopolar molecules of methane. Therefore, the difference in the degree of electro-activation of molecules of propane and methane can be explained by the structure and polarization of molecules.

CONCLUSIONS

1. Theoretically and experimentally the possibility was proved of increasing fuel efficiency equipments on gaseous hydrocarbon fuel molecules in the activation of the combustion reactants under high-voltage pulsed uneven electric field.
2. When activating molecules reagents chemical reactions, it is important to take into account their degree of polarity.

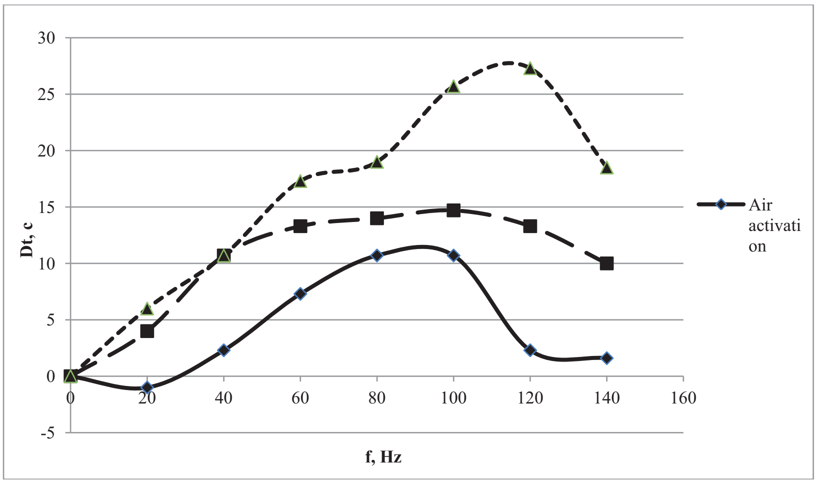

Fig. 3. Dependence of the reduction of water heating time on frequency impulses at electro-activation of propane and air (experiment 1)

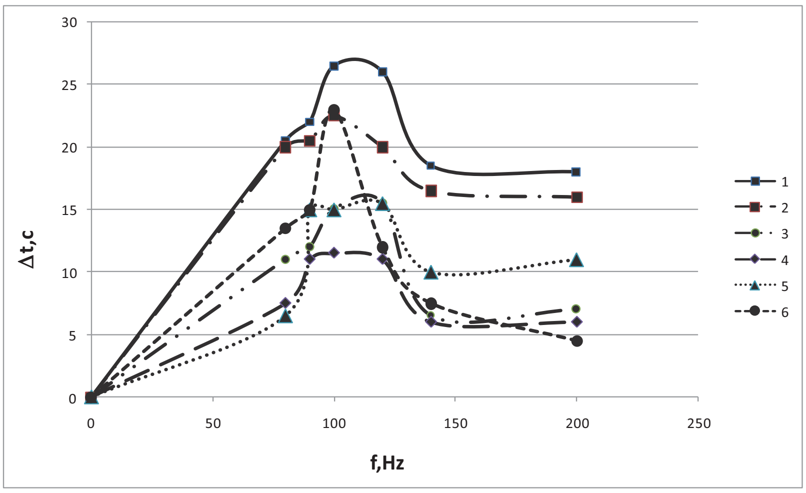

Fig. 4. Dependence of time reduction of water heating on frequency impulses for different variants of electro-activation of propane and air (experiment 2)

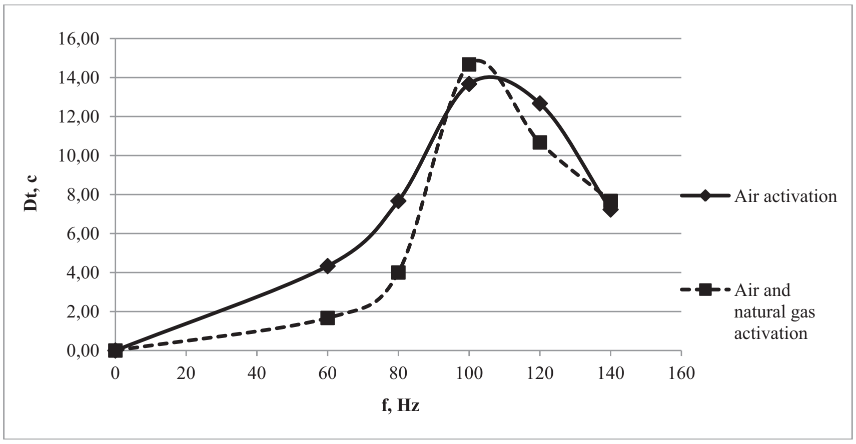

Fig. 5. Dependence of decline magnitude of water heating time on frequency impulses during electro-activation of natural gas and air (experiment 3)

3. The experimental results confirm the theoretical conclusions about the important role of polarization of molecules for their electroactivation.

4. Research should be continued on impact of high pulsed uneven electric field on molecule reagents at the combustion of natural gas (methane) in the air.

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Impact voltage deviation on the technological characteristics of crushers

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A b s t r a c t. The results of research on the influence of voltage deviation on the technological characteristics and energy losses in electric drive of the crusher are presented. Dependence of the productivity, of specific consumption of energy and grinding module on the voltage are established.

K e y w o r d s: crusher, electric drive, voltage deviation, productivity, specific consumption of energy, power loss, the grinding module.

INTRODUCTION

Voltage deviation from normalized values leads to inflicted losses from disruption of processes, reduced service life of electrical equipment, rising costs or loss of electricity supply, for example in emergency situations [1–7].

Economic losses, caused by the poor quality of electricity, have two components: the electromagnetic and technology. Electromagnetic component is determined mainly by the loss of active power and change in the life of electrical insulation. Technological component is caused by the influence of energy quality on productivity of technologic plants and the cost of products [8].

Allowable voltage deviation in Ukraine and Russia is ± 5%, and the maximum permissible deviation of ± 10 % [9]. In the European Community RMS deviation voltage should be within ± 10 % [10–12].

However, the actual voltage deflection in Ukraine and Russia is much higher than the permissible value. The range of voltage variation is 15–28 % of the nominal [13].

Voltage deviation causes a change in the angular speed of the electric motor, which causes a change of technological characteristics of working machines.

As a result of experimental studies prof. I. Revenko found that the speed of hammers is the most significant factor in a crusher [14]. Increasing the angular speed of the rotor increases the intensity of crushing grinding due to increased deformation and fracture of particles of the processed material, which with increasing strain behave like a brittle body. However, the practical application of increasing the intensity of grinding by increasing the speed of the rotor is limited by crushing capacity of installed sieve.

Therefore, the angular speed of the rotor at crushing shredding process can be divided into three characteristic periods [14]. In the initial period the growth of speed causes increase in grinding, resulting in reduced energy process, and productivity increases. In most profitable workflow period, which corresponds to a change in the speed range from minimum intensity until the maximum performance crusher, the crusher operates with high performance, ensuring a good quality of shredding. But bandwidth sieve begins to affect the speed of the surface layer of the processed material crushing chamber, which affects productivity and causes growth of energy consumption for grinding material. In the third, critical period energy expenditure for further increase in the speed does not lead to increased productivity or a sufficient degree of comminution, and excessive chafing of the product is caused.

The purpose of research was to establish the influence of voltage deviation on the technological characteristics and energy losses in the electric drive of crushers.

MATERIALS AND METHODS

The analysis of changes in angular speed of electric drives with voltage deflection was carried out using the theory of electric drives related to electromechanical properties of asynchronous motors, driving characteristics of working machinery, and the use of mathematical modelling.

Laboratory studies were conducted on the experimental setup, performed on the basis of universal crusher

KDU-2 [15]. Clover and lupine hay were used as the processed material.

In experimental studies the voltage on the motor was replaced by autotransformer, while measuring the rotational speed of the shaft by tachometer. The change of technological parameters of crusher from voltage deviation was defined, using the technological characteristics of crusher and the experimental dependence of angular speed on voltage.

The influence of voltage deviation on the energy loss in electric drives was determined using the theory of electric drives related to electromechanical properties of asynchronous motors, energetics of electric drives and application of mathematical modelling.

RESULTS AND DISCUSSION

In the steady state the asynchronous motor operates on the working area of mechanical properties that can be considered linear [16]:

$$M_{д} = \beta_{д}(\omega_0 - \omega), \tag{1}$$

where: $M_{д}$ – moment of the motor, N·m, $\beta_{д}$ – stiffness of the mechanical characteristics of the motor, N·m·s, ω_0 – synchronous angular speed, s^{-1}, ω – given angular speed, s^{-1}.

At voltage deviation the mechanical characteristics of the motor in the work area can be described by the equation:

$$M_{д} = \beta_{д} U_*^2(\omega_0 - \omega), \tag{2}$$

where: $U_* = U/U_н$ – voltage relative units.

Mechanical characteristics of crushers is described by the equation [17, 18]:

$$M_c = M_0 + (M_{сн} - M_0)\left(\frac{\omega}{\omega_н}\right)^2, \tag{3}$$

where: M_c – moment of static resistances of working machine, N·m, at a given angular speed; M_0 – initial moment, N·m; $M_{сн}$ –moment of static resistance, N·m, at nominal angular speed; ω i $\omega_н$ – given and the nominal value of angular speed, s^{-1}.

In the steady state:

$$\beta_{д} U_*^2(\omega_0 - \omega) = M_0 + (M_{сн} - M_0)\left(\frac{\omega}{\omega_н}\right)^2, \tag{4}$$

or

$$\beta_{д} U_*^2(\omega_0 - \omega_н\omega_*) = M_0 + (M_{сн} - M_0)\omega_*^2, \tag{5}$$

where: $\omega_* = \omega/\omega_н$ – angular speed in relative units.

After transformations we obtain:

$$U_* = \sqrt{\frac{M_0 + (M_{сн} - M_0)\omega_*^2}{\beta_{д}(\omega_0 - \omega_н\omega_*)}}. \tag{6}$$

As follows from (6), the angular speed of crusher by changing the voltage varies by a complicated algorithm.

If we neglect the initial moment $M_0 = 0$, we obtain:

$$U_* = \sqrt{\frac{M_{сн}\omega_*^2}{\beta_{д}(\omega_0 - \omega_н\omega_*)}}. \tag{7}$$

Because

$$M_{сн} = K_з M_{дн}, \tag{8}$$

where: $K_з$ – load factor of the motor,

$$\beta_{д} = \frac{M_{дн}}{\omega_0 - \omega_н} = \frac{M_{дн}}{\omega_0 s_н}, \tag{9}$$

where: $s_н$ – nominal motor slip,
the expression (7) can be written as:

$$U_* = \sqrt{\frac{K_з\omega_*^2 s_н}{s}} = \frac{1-s}{1-s_н}\sqrt{\frac{K_з s_н}{s}}. \tag{10}$$

Auditing changes of angular speed of crusher's motor with a nominal slip 0.02, 0.05 and 0.1 at the voltage deviation are shown in Fig. 1.

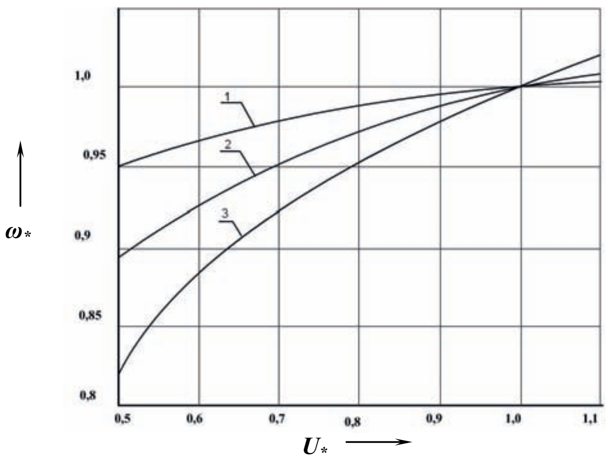

Fig. 1. Changing of the angular speed of the crusher's motor from voltage at nominal motor slip: 1 – 0.02, 2 – 0.05, 3 – 0.1

Since the voltage deviation causes a change in angular speed of crushers, their productivity, specific energy consumption and grinding module change as well.

The dependences of specific energy consumption and productivity of the crusher KDU-2 on voltage for clover hay are shown in Fig. 2, and lupine hay – in Fig. 3. Dependence of grinding module on the voltage is shown in Fig. 4.

The studies found that the productivity of crushers decreases with increasing and with decreasing voltage from the nominal value. The specific energy consumption at lower voltages decreases, but the grinding module increases nonlinearly. When the voltage increases, the unit cost of energy does not lead to increased productivity or degree of comminution, and causes only excessive chafing of the product.

The voltage deviation also causes a change in active power losses in electric drive of crusher.

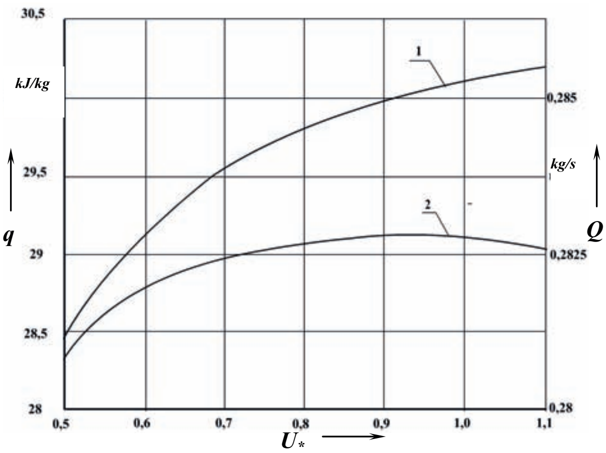

Fig. 2. Dependence of specific energy consumption (1) and productivity (2) of the crusher KDU-2 from voltage for clover hay

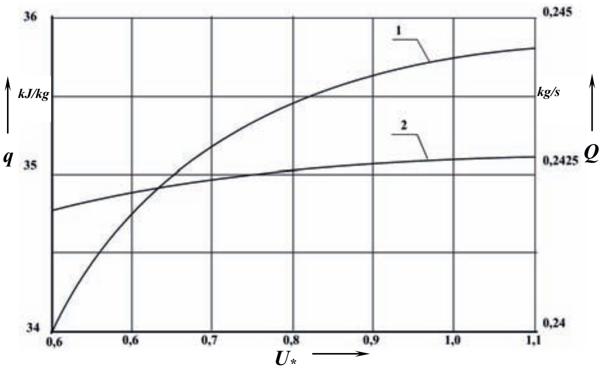

Fig. 3. Dependence of specific energy consumption (1) and productivity (2) of the crusher KDU-2 from voltage for lupine hay

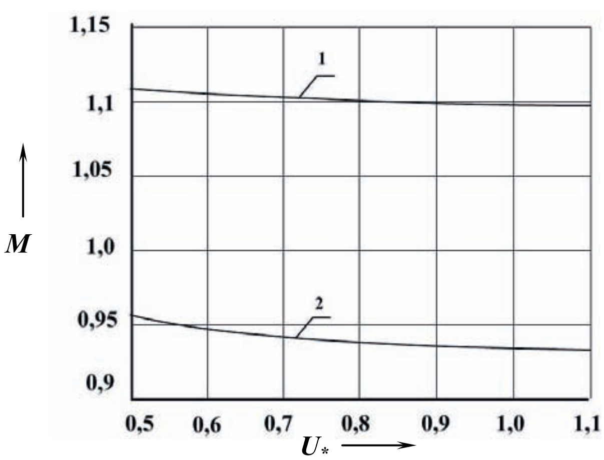

Fig. 4. Dependence of grinding module from the voltage: 1 – lupine hay, 2 – clover hay

Mechanical losses are determined by the approximate formula:

$$\Delta P_{м} = \Delta P_{м.н}\left(\frac{\omega}{\omega_{н}}\right)^{2}, \qquad (12)$$

where: $\Delta P_{м.н}$ – mechanical losses at nominal speed.

The steel losses from eddy currents and hysteresis are determined by the formula:

$$\Delta P_{cm} = \Delta P_{cm1} + \Delta P_{cm2} \approx \Delta P_{cm1н}\left(\frac{U}{U_{н}}\right)^{2}\left(\frac{f_1}{f_{1н}}\right)^{1,3}\left(1+s^{1,3}\right), \qquad (13)$$

where: – steel losses of the stator at nominal values of frequency and voltage.

At the voltage deviation $f_1 = f_{1н}$ and the expression (13) has the form:

$$\Delta P_{cm} \approx \Delta P_{cm1н} U_*^2\left(1+s^{1,3}\right). \qquad (14)$$

To drive of crushers used motors with stiff mechanical characteristics, so the first factor in the expression (10) is close to unity. Then the voltage deviation:

$$U_* \approx \sqrt{\frac{K_з s_н}{s}}, \qquad (15)$$

and steel losses:

$$\Delta P_{cm} \approx \Delta P_{cm1н}\left(U_*^2 + \frac{K_з^{1,3} s_н^{1,3}}{U_*^{0,6}}\right). \qquad (16)$$

As follows from (12), the voltage deviation is not significantly affected by steel losses of asynchronous motor.

Variable power losses in asynchronous motor are determined by the expression [20]:

$$\Delta P_v = \Delta P_{v2} + \Delta P_{v1} = \left(1+\frac{R_1}{R_2^{/}}\right) M_{д}\omega_0 s, \qquad (17)$$

where: ΔP_{v2}, ΔP_{v1} – variable power losses in the circles of the rotor and stator, W; R_1 – rotor winding resistance, Ohm; R'_2 – rotor winding resistance, reduced to the stator windings, Ohm; $M_д$ – moment of the motor, N · m; ω_0 – synchronous angular speed, s^{-1}; s – motor slip.

Expression (17) with (2) and (15) can be written as:

$$\Delta P_v = \left(1+\frac{R_1}{R_2^{/}}\right)\beta_д U_*^2\omega_0^2 s^2 = \left(1+\frac{R_1}{R_2^{/}}\right)\frac{\beta_д\omega_0^2 s_н^2}{K_з^2 U_*^2}, \qquad (18)$$

or

$$\Delta P = \Delta P_н / U_*^2, \qquad (19)$$

where: $\Delta P_н$ – variable loss at rated voltage.

Thus, variable power losses in electric drive of crusher are inversely proportional to the square of the voltage. At higher voltages the losses are reduced compared with the nominal, but at the growing variable loss. At lower voltage power losses increase.

CONCLUSIONS

At voltage deviation the angular speed of crushers varies by a complex algorithm, which causes the change of productivity, specific energy consumption and grinding module. Based on the studies found, if the voltage drop to 20 % , productivity of crushers is reduced by 2 % and the grinding module increases. This reduces specific energy consumption by 5 % and energy losses increase in electric drive by 1.5 times.

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Interaction free energy of small particles in an elektrolyte solution

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Abstract. A solution has been constructed of the Debye-Huckel equation for system spheres with arbitrary radii and surface charges or potentials in electrolyte solutions. A general theoretical method for description of inter-particle interaction within such systems has been elaborated. The practically important case of two spheres has been considered in detail. Finite closed formulae to calculation of interaction energy of two spherical particles with constant surface charges have been obtained from general expressions within zero approximation. The known relationships of Deryagin-Landaw-Lifshits-Overbeek theory follow from our formulae in the limit cases.

Key words: Debye-Huckell equation, particles in electrolyte, pair interaction.

INTRODUCTION

Through studying ion-electrostatic interaction in systems of inorganic nanoparticles and biological cells in electrolyte solution the basic problems of calculation of the energy and forces interaction between cells and particles arise. This problem is closely connected with the problem of the electric double layer free energy of interaction between two spherical particles suspended in an aqueous electrolyte dispersion medium. From early works [1] a great attention is paid to this problem [2-7], and it is the actual question [6] until now, especially, under consideration of interaction of inorganic small particles with biological cells or microorganisms. Interaction of double diffuse layers is usually calculated on the basis of Deryaguin ‘s approximation. But the use of this approach can lead to incorrect results in some cases, as it was noted in [2,4].

The practical important case of two spheres is considered in detail. We fulfill the special transformation of the obtained systems. It gives the opportunity to separate the groups of connected coefficients in the infinite systems. This procedure essentially simplifies the practical solution of the problem. From general expressions the closed formulae to calculate the interaction energy of two particles with constant surface charge are received in a zero approximation. The known relations of other authors follow from our formulae as a particular case if certain conditions are fulfilled [1,2].

STATEMENT OF PROBLEM

A system of N spherical particles in an electrolyte solution with permittivity ε_m is considered. Radius of the particles is denoted as α_k, and their permittivity is denoted as ε_k $k = 1,2, \ldots, j, \ldots, N$. We link the local polar spherical coordinates (r_k, θ_k, φ_k) with centers of the particles (r_k is a polar radius, θ_k is an azimuth angle, φ_k is a polar angle). An arrangement of two arbitrarily chosen particles from the ensemble is shown in Figure 1, where the correspondent coordinates are indicated. Global coordinates (x, y, z) of observation point P are determined by vectors $\mathbf{r}_k$, $\mathbf{r}_j$ in the local coordinates connection, and distance between centers of the spheres $R_{kj} = |\mathbf{R}_{kj}|$, where $\mathbf{R}_{kj} = \mathbf{r}_k - \mathbf{r}_j$.

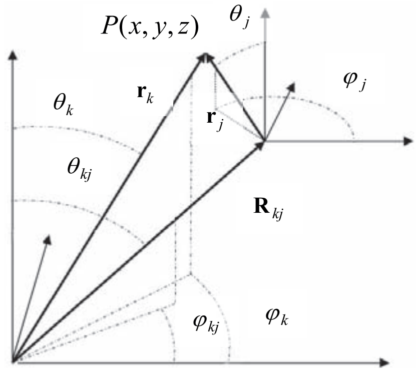

Fig. 1. The local coordinates connection

The potential corresponding to the internal and external domains of the spheres' surfaces are marked relatively by overscripts "<" and ">". In the external domain the potential $\varphi^>$ appears to be a sum of potentials $\phi_k^> = \phi_k^>(r_k, \theta_k, \phi_k)$, created by every sphere, i.e. $\phi^> = \sum_{k=1}^{N} \phi_k^>$ providing that any external field is absent. In the electrostatic approximation every potential $\phi_k^>$ ($k = 1, 2, ..., N$) is a solution of the Debye-Huckell equation (1), and potentials inside the spheres $\phi_k^< = \phi_k^<(r_k, \theta_k, \phi_k)$ the solutions of the Laplace equation (2) correspondingly:

$$\Delta\phi_k^> - \kappa^2 \phi_k^> = 0, \tag{1}$$

$$\Delta\varphi_k^< = 0. \tag{2}$$

Boundary conditions on the surface of the k-th sphere at $r_k = a_k$ can be formulated in different ways. We consider the case when the densities of surface charges are adjusted, so we have:

$$\phi_k^< = \phi^>, \quad \varepsilon_k \frac{\partial \varphi_k^<}{\partial r_k} - \varepsilon_m \frac{\partial \varphi^>}{\partial r_k} = 4\pi\sigma_k. \tag{3}$$

The boundary conditions (3) reflect a continuity of potentials and electric inductions on the surfaces of spheres, and densities of surface charges can be general functions of local coordinates $\sigma_k = \sigma_k(\theta_1, \phi_k)$. As usual, it is necessary to add conditions of potentials' limits:

$$\phi_k^> \to 0 \textbf{при } r_k^> \to \infty \textbf{ и } \phi_k^< < \infty \textbf{ при } r_k^> \to 0. \tag{4}$$

THE PROBLEM SOLUTION FOR SYSTEM OF N SPHERES

To solve the problem we used the expansions of solutions by series in the spherical functions $Y_{lm}(\theta_k, \varphi_k)$, $l = 0, 1, 2, ..., m = -l, -l+1, ..., 0, 1, 2, ..., l$. We assume that the system of the spherical functions is normalized. Inside and outside of the spheres the expansions appear to be:

$$\phi_k^< = \sum_{l,m} A_{lm}^{(k)} r_k^l Y_{lm}(\theta_k, \phi_k), \tag{5}$$

$$\phi_k^> = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} B_{lm}^{(k)} k_l(\kappa r_k) Y_{lm}(\theta_k, \phi_k). \tag{6}$$

In (6) the modified spherical Bessel functions of third kind $k_l(z)$ [10] are used.

Total potential in the surrounding media can be written as follows:

$$\phi^> = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} B_{lm}^{(k)} [k_l(\kappa r_k)] Y_{lm}(\theta_k, \phi_k) + \\ + \sum_{j=1}^{N}{}' \left[\sum_{l_j=0}^{\infty} \sum_{m_j=-l_j}^{l_j} B_{l_j m_j}^{(j)} [k_{l_j}(\kappa r_j)] Y_{l_j m_j}(\theta_j, \phi_j) \right], \tag{7}$$

where the stroke near the sum means that the term with subscripts $j = k$ is excluded. The sum subscripts l_j, m_j underline that they can vary independently from subscripts l, m which correspond to k -th sphere.

The problem consists in determination of unknown coefficients $A\%\backslash$ B™ in the expansions of potentials (5), (6) from boundary conditions (3). To write the boundary conditions, expressions for potentials and their derivatives in other local coordinates are needed. For the solution of the problem we use the addition theorems [10]. At this, we transform the product of the spherical Bessel functions by scalar spherical functions to a product of the modified spherical Bessel functions by the scalar spherical functions. Moreover, the properties of 3-j Wigner symbols are taken into account and the transition to coefficients of Klebsh-Gordon $C_{l\,m\,l'\,m'}^{l''\,m''}$ [8, 9]. As result, we get the following formula for the products $k_l(\kappa r_j) Y_{lm}(\theta_j, \phi_j)$ at the condition $r_k < |\mathbf{r}_j - \mathbf{r}_k|$:

$$k_l(\kappa r_j) Y_{lm}(\theta_j, \phi_j) = \sum_{l'=0}^{\infty}, \\ \sum_{m'=-l'}^{l'} (-1)^{l'-m'} Y_{l'm'}(\theta_k, \phi_k)\, i_{l'}(\kappa r_k), \\ \sum_{l''=|l-l'|}^{l+l'} Y_{l'',m-m'}(\theta_{jk}, \phi_{jk}) k_{l''}(\kappa R_{jk}) \phi_{m\,-m'\,m-m'}^{l\,l'\,l''}, \tag{8}$$

where:

$$\varphi_{m\,-m'\,m-m'}^{l\,l'\,l''} = \left[4\pi(2l+1)(2l'+1)/(2l''+1)\right]^{1/2}. \\ C_{l\,0\,l'\,0}^{l''\,0} C_{l\,m\,l'\,-m'}^{l''\,m-m'}, \tag{9}$$

and θ_{jk}, ϕ_{jk}, $\mathbf{R}_{jk}$ are shown in Fig. 1. It is seen that the modified spherical Bessel function of the first kind $i_l(z)$ [10] appeared in our expression (8).

Now we can write the expression for total potential with using addition theorem (8) in the local coordinates linked with the k -th sphere:

$$\phi^> = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} B_{lm}^{(k)} k_l(\kappa r_k) Y_{lm}(\theta_k, \phi_k) + \\ + \sum_{j=1}^{N}{}' \sum_{l_j=0}^{\infty} \sum_{m_j=-l_j}^{l_j} B_{l_j m_j}^{(j)} \sum_{l_j'=0}^{\infty} \cdot \\ \cdot \sum_{m_j'=-l_j'}^{l_j'} (-1)^{l_j'-m_j'} Y_{l_j' m_j'}(\theta_k, \phi_k)\, i_{l_j'}(\kappa r_k) \cdot \\ \cdot \left\{ \sum_{l_j''} Y_{l_j'', m_j - m_j'}(\theta_{jk}, \phi_{jk}) k_{l_j''}(\kappa R_{jk}) \phi_{m_j\,-m_j'\,m_j-m_j'}^{l_j\,l_j'\,l_j''} \right\}, \tag{10}$$

and because the variables are separated we can found derivatives by the radial coordinates directly from (10), and then calculate their value on the surface of the k-th sphere. The expansions of the potentials and their derivatives we substitute to the boundary conditions (3). As a result, we have the system of *2N* functional equations. Then we multiply the obtained equations by the complex conjugate functions $Y_{lm}^{*}(\theta_k, \varphi_k)$ and integrate over the surface of the sphere. The procedure leads to a family of infinite systems of algebraic linear equations. As the spherical harmonics are orthogonal functions, and we assume that they are normalized, we have the following values for the integrals (δ_{ij} is the Kronnecker symbol):

$$\int_0^{2\pi} d\phi \int_0^{\pi} Y_{lm} * (\theta, \phi) Y_{l'm'}(\theta, \phi) \sin\theta d\theta = \delta_{ll'} \delta_{mm'}. \quad (11)$$

So, in summation by indexes l_j', m_j' the terms with subscripts $l_j' = l$, $m_j' = m$ are left only, and we get the following systems:

$$a_k^l A_{lm}^{(k)} = B_{lm}^{(k)} k_l(\kappa a_k) +$$
$$+(-1)^{l-m} i_l(\kappa a_k) \sum_{j=1}^{N}{}' \sum_{l_j=0}^{\infty} \sum_{m_j=-l_j}^{l_j} B_{l_j m_j}^{(j)}$$
$$\left\{ \sum_{l_j''} Y_{l_j'', m_j - m_j'}(\theta_{jk}, \phi_{jk}) k_{l''}(\kappa R_{jk}) \phi_{m_j\ -m_j'\ m_j - m_j'}^{l_j\ l_j'\ l_j''} \right\} = f_{lm}^{(k)}, \quad (12)$$

$$B_{lm}^{(k)} + \alpha_{lm}^{(k)} (-1)^{l-m} \sum_{j=1}^{N}{}' \sum_{l_j=0}^{\infty} \sum_{m_j=-l_j}^{l_j} B_{l_j m_j}^{(j)} \cdot$$
$$\cdot \left\{ \sum_{l_j''} Y_{l_j'', m_j - m_j'}(\theta_{jk}, \varphi_{jk}) k_{l_j''}(\kappa R_{jk}) \varphi_{m_j\ -m_j'\ m_j - m_j'}^{l_j\ l_j'\ l_j''} \right\}, \quad (13)$$

where: $\sigma_{lm}^{(k)}$ are the expansions' coefficients of the surface charges in the spherical functions, and the notations are introduced

$$\alpha_{lm}^{(k)} = \frac{\varepsilon_k l i_l(\kappa a_k) - \varepsilon_m \kappa a_k i'_l(\kappa a_k)}{\varepsilon_k l k_l(\kappa a_k) - \varepsilon_m \kappa a_k k'_l(\kappa a_k)},$$
$$f_{lm}^{(k)} = \frac{4\pi a_k \sigma_{lm}^{(k)}}{\varepsilon_k l k_l(\kappa a_k) - \varepsilon_m \kappa a_k k'_l(\kappa a_k)}. \quad (14)$$

The primes mean a differentiation of functions by their arguments. It should be noted that for the constant densities of surface charges we have $\sigma_{lm}^{(k)} = \sqrt{4\pi} \sigma_k \delta_{l0} \delta_{m0}$.

As result, we have the aggregate of *N* connected infinite systems of linear algebraic equations. The systems contain only the coefficients $B_{lm}^{(k)}$ of external potentials and they completely solve the problem of N spheres interaction.

ION-ELECTROSTATIC ENERGY OF INTERACTION OF TWO PARTICLES

Now we consider the problem of interaction of two spheres in detail on the basis of general relationships. The line crossing the centers of spheres is taken as the axe z. The shortest distance between spheres we denote as *H,* and so the distance between centers of spheres is $d = H + a_1 + a_2$. For the Debye-Huckell approximation to the double layer free energy $F = F_{tj}$ of a pair interaction of the *i*-th and the *j*-th spheres for the known densities of the surface charges can be found using formula [3, 4]:

$$F = \frac{1}{2} [\int_{s_i} \sigma_i(P_i) \phi_i(P_i) dS_i + \int_{s_j} \sigma_j(P_j) \phi_i(P_i) dS_j],$$
$$(i, j = 1, 2; i \neq j). \quad (15)$$

The potential energy *V* of the double layer interaction is given by the equality $V = F - F_0$ [5], where F_0 is the free energy for two single spheres, and if the densities σ_1 and σ_2 are constants:

$$F_0 = \frac{8\pi^2 a_1^3 \sigma_1^2}{\varepsilon_m (1 + \kappa a_1)} + \frac{8\pi^2 a_2^3 \sigma_2^2}{\varepsilon_m (1 + \kappa a_2)}. \quad (16)$$

Integrating in (15) is executed over the surface of the correspondent sphere, and because the potentials on the surfaces of the spheres are equal inside and outside the spheres, we can use either of potentials' representations. If the surface charges are constant, integration leads to calculations of the spherical functions integrals over the total surfaces of the spheres. Then we have:

$$\int_{S_j} Y_{lm} dS_j = (a_j^2 \sqrt{4\pi}) \delta_{l0} \delta_{m0}, \quad (17)$$

and after integrating (16), taking into account the expansions (5), we have the simple expression for the free energy:

$$F = \sqrt{\pi} [\sigma_i a_i^2 A_{00}^{(i)} + \sigma_j a_j^2 A_{00}^{(j)}]. \quad (18)$$

So, to find the energy of pair interaction, only the first coefficients of series expansions $A_{00}^{(k)}$, $B_{00}^{(k)}$ are needed, but, as the matter of fact, their value is to be determined from the indefinite systems.

In this case, the problem is axis-symmetrical, and the system for determination of the potentials' coefficients looks like:

$$A_{00}^{(i)} = B_{00}^{(i)} k_0(\kappa a_i) + i_0(\kappa a_i) \quad B$$
$$\sum_{l'} B_{l'0}^{(j)} (-1)^{l'} (2l'+1)^{1/2} k_{l'}(\kappa d), \quad i$$
$$i, j = 1, 2; i \neq j, \quad (19)$$

$$B_{00}^{(i)} + \alpha_0^{(i)} \sum_{l'} B_{l'0}^{(j)} (2l'+1)^{1/2} k_{l'}(\kappa d) = f_0^{(i)}, \quad (20)$$

$$B_{l0}^{(i)} + \alpha_l^{(i)} (-1)^l (2l+1)^{1/2} \sum_{l', l''} B_{l'0}^{(j)} (2l'+1)^{1/2} (-1)^{l''} k_{l'}(\kappa \qquad l \qquad =$$
$$k_{l''}(\kappa d) \left(C_{l'0l0}^{l''0} \right)^2 = 0. \quad (21)$$

We take into account that the spheres are placed on the axe *z*, and in (12), (13) the functions $Y_{lm}(\theta, \phi)$ at $\theta = \pi$ have the value $Y_{lm}(\pi, \varphi) = \delta_{m0} (-1)^l \sqrt{(2l+1)/(4\pi)}$ [11].

The obtained system allows further simplification, because there is an opportunity to separate the coefficients $B_{l0}^{(k)}, B_{l0}^{(j)}$ and to get independent systems for every sphere. For all that, only the right parts of the systems define the connection between spheres.

ZERO APPROXIMATION FOR TWO SPHERES

The simplest case takes place if we keep only one term in the expansions of potentials, i.e. if $l'=m'=0$ (a zero approximation). If the terms of higher order in comparison with the quantity $k_0^2(\kappa d)$ are neglected, the formula for the potential energy of interaction $V(d)$ can be derived:

$$V(H)=F-F_0=\frac{8\pi^2 a_1^3}{1+\kappa a_1}\frac{\sigma_1\sigma_2}{\varepsilon_m}\cdot$$
$$\cdot\frac{k_0(\kappa d)}{z_1^2 k_0(\kappa a_1)k_1(\kappa a_2)}\left[(\kappa a_2)^2 i_0(\kappa a_2)k_1(\kappa a_2)+(\kappa a_1)^2 i_1(\kappa a_1)k_0(\kappa a_1)\right]+$$
$$+\frac{8\pi^2 a_2^3}{1+\kappa a_2}\frac{\sigma_1\sigma_2}{\varepsilon_m}\frac{k_0(\kappa d)}{(\kappa a_2)^2 k_0(\kappa a_2)k_1(\kappa a_1)}\cdot$$
$$\cdot\left[(\kappa a_1)^2 i_0(\kappa a_1)k_1(\kappa a_1)+(\kappa a_2)^2 i_1(\kappa a_2)k_0(\kappa a_2)\right]. \quad (22)$$

In the formula (22) the modified spherical Bessel functions of the first order $k_1(z)=-k_0{}'(z)$, $i_1(z)=i_0{}'(z)$ $(k_0(z)=(\pi/2)\exp(-z)/z$, $i_0(z)=shz/z)$ are used [17].

When the distances between spheres are large at $d\to\infty$ and $k_0(\kappa d)\to 0$, general formulae are simplified, and we obtain the formula (16).

Now we consider the spheres when $a_1 = a_2 = a$ and $\sigma_1 \neq \sigma_2$. At the condition $a_1 = a_2 = a$ the corresponding formula takes the form:

$$V(H)=\frac{16\pi^2 a^3\sigma_1\sigma_2}{\varepsilon_m(1+\kappa a)^2}\frac{a}{H+2a}e^{-\kappa H}+$$
$$+\frac{4\pi^2 a^3(\sigma_1^2+\sigma_2^2)}{\varepsilon_m(1+\kappa a)^3}\left[(\kappa a-1)+(\kappa a+1)e^{-2\kappa a}\right]\cdot$$
$$\cdot\left(\frac{a}{H+2a}\right)^2 e^{-2\kappa H}. \quad (23)$$

To comparison we write out the formulae Hiroyuki Oshima [5], which had been derived as an approximation for large radii and small separation. At the condition $a_1 = a_2 = a$ the correspondent formula takes the form:

$$V_{HO}(H)=\frac{4\pi^2 a}{\varepsilon_m\kappa^2}\frac{H+a}{H+2a}\left[-(\sigma_1^2+\sigma_2^2)\ln(1-A^2)+2\sigma_1\sigma_2\ln\frac{1+A}{1-A}\right], \quad (24)$$

where: $A=\left(a/(a+H)\right)\exp(-\kappa H)$.

If $\sigma_1 = \sigma_2 = \sigma$, it follows from (24) that:

$$V_{HO}(H)=-F_0\frac{(1+\kappa a)}{(\kappa a)^2}\cdot\frac{H+a}{H+2a}\ln\left(1-\frac{a}{H+a}e^{-\kappa H}\right), \quad (25)$$

where: in this case $F_0=16\pi^2 a^3\sigma^2/[\varepsilon_m(1+\kappa a)]$.

The Derjaguin's metod [1] gives the following simple expression for the same case:

$$V_D=-F_0\frac{(1+\kappa a)}{(\kappa a)^2}\ln(1-e^{-\kappa H}). \quad (26)$$

If we neglect the second term in our formula (23), it takes the form:

$$V(H)=F_0\frac{1}{1+\kappa a}\frac{a}{H+2a}e^{-\kappa H}. \quad (27)$$

We see, at $\kappa H \to 0$, then $V_D \to \infty$. It means that formula (26) can give incorrect results at small κH values. The analogous situation takes place for relationship (25), too. When $\kappa H >> 1$ and $\kappa a >> 1$, after expanding the logarithms to correspondent series and keeping the first

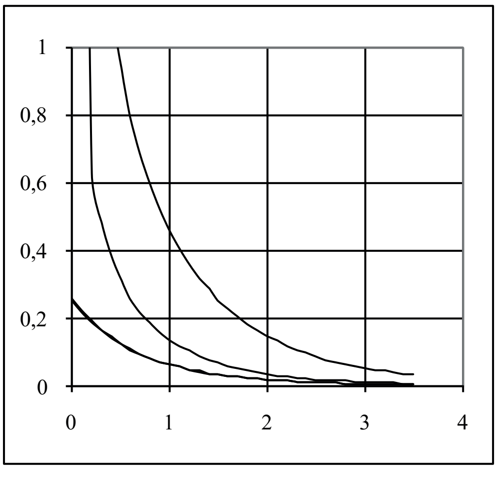

Fig. 2. Interactions' energy $V^* = V/V_0$ of two identical spheres with the constant charges versus κH at $\kappa a = 1$

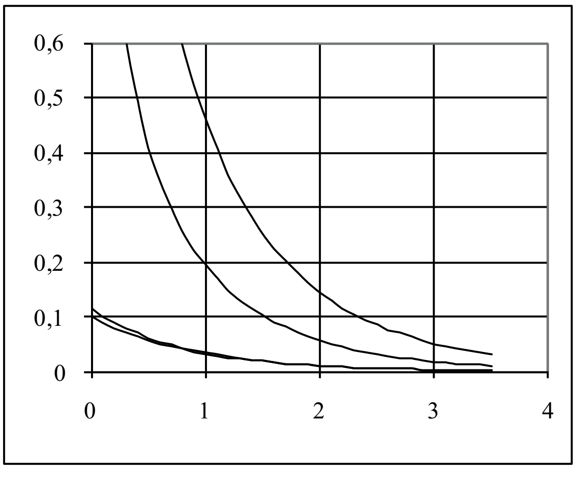

Fig. 3. Interactions' energy $V^* = V/V_0$ of two identical spheres with the constant charges versus κH at $\kappa a = 4$

1 – Derjaguin approximation; 2 – Hiroyuki Oshima approximation; 3 – our simplest zero approximation; 4 – our improved zero approximation.

terms of the series we get the same expressions from formulae (25), (27).

NUMERICAL RESULTS

We obtain closed formulae with results of another author in the limit cases, but our results are more general and they can be improved if the next approximation is taken into account. Some results of the worked out calculation are presented in Fig. 2 and Fig. 3.

We consider the case of adjusted densities of surfaces charges. We determine dependences of non-dimensional interaction energy , where $V_0 = 16\pi^2 a^3 \sigma^2 / (\varepsilon_m (1+\kappa a))$, for two identical spheres with constant and equal charges versus parameter κH at κa = 1 (Fig. 2) and at κa = 4 (Fig. 3).

It follows from this data that at $\kappa H > 3$ formulae H. Oshima (25) and our formulae for zero approximation give the neighbor values, but Derjaguin's formula gives a too high value. All the results begin to agree at large values of parameter κH. Our results strongly differ from results of Hiroyuki Oshima and Derjaguin, especially at very small values of κH, because and $V_D \to \infty$ and $V_{HO} \to \infty$, when $\kappa H \to 0$.

CONCLUSIONS

The exact solution for interaction of a system of small spherical particles in electrolyte is obtained. On the basis of the exact solutions the handily closed formulae for calculating ion-electrostatic energy of two spheres are derived. Our results correspond to the results of other authors in simple cases and generalized ones in range of small values parameter κa. In this article we have considered the case when surfaces' charges are given, but the problem of spherical particles interaction with giving surface potentials can be solved similarly.

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Ukraine's prospects in development of marine mineral deposits

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Abstract. It is shown that the known reserves of marine minerals, including polymetallic nodules hydrates, marine sapropels, etc., will last the humanity for thousands of years. International cooperation and broad cooperation of companies and enterprises of maritime mining are needed to conduct the search, along with research and operation of deep mining complexes. This will allow us to prepare for the commercial development of marine deposits of mineral and energy resources in the near future.

Key words: offshore fields, minerals, gas hydrates, marine sapropel, biofuels, mining complexes

INTRODUCTION

Until recently it was believed that, in the foreseeable future, the international community would face a total shortage of energy and mineral resources, given that reserves in the mainland are limited. Therefore, for more than half a century, attention has been directed to an intensive study of the resources concentrated in the sea [1].

According to experts, approximately 500 billion dollars are spent on oceans research annually. At present, the ocean waters house more than 40 drilling ships and 200 drilling rigs with drilling to a maximum depth of 12 km.

Marine Geology has ceased to be a purely romantic science. A new stage in its development is due, above all, to the discovery of large oil and gas fields on the continental slope, which, compared with the shelf remain virtually unstudied. At the end of the last century, we began preparing for the industrial development of deep-water fields with metalliferous material: polymetallic nodules, containing Mn, Ni, Cu, Co, Mo, Zn, and energy resources - gas hydrates (methane in the solid state).

According to preliminary estimates, the total reserves of gas hydrates in the oceans make up 12...76×10^{19} m^3, polymetallic nodules - 300 billion tons (only in the Pacific Ocean - 165 billion tons). Ferromanganese metal ore: Mn - 30%; Ni - 1,3%; Cu - 1.2%: from - 0.2% to nearly 30 useful components, stocks of which are constantly increasing [2].

Thus, the annual accumulation of manganese nodules is approximately 3 times greater than the consumption of the world's industry in the same period of time, the accumulation of cobalt and zirconium is even greater (respectively 4.5 and 5 times). This means that the stocks of mineral resources in the oceans can still last for hundreds and thousands of years.

DEVELOPMENT OF UNDERWATER FIELDS

In the 1990-s. the Soviet Union and the United States carried out experiments to test the dredge (disturber) for modeling the process of nodule mining and identifying the negative impact on the environment. Japan tested unit collection PN at depth of 2200 m in the center of the north-western Pacific Ocean. China, India, South Korea and other countries - sites owners [3] have also actively conducted research .

The expected timing of commencement of commercial production is as follows: gas hydrates - the second, and PN - the third decade of the XXI century. The country that will be better prepared in the scientific and technical point of view by this time, i.e. will find a reliable way to access to raw materials from subsea fields, will win the competition.

Since 2006, Canada, Norway, the U.S. and Japan have begun piloting commercial development of fundamentally new and fabulously wealthy (166×10^{17} m3 of methane) hydrocarbon energy source - metanogidrata, which in the form of "combustible ice" (112×10^{17} m3 CH_4) and "methane ice" (54×10^{17} m^3 CH_4) lie in the depths of permafrost regions of mainland-island land in sediments by 93...95% of the world's oceans.

With total world oil and gas reaching 2804×10^9 m3 (4 billion m3 of oil and 2800 billion m3 of natural gas), they can suffice for mankind for nearly 6 million years. Even if the predictions come true by 10%, still the objective - to provide reliable access to the deposits of gas hydrates and the development of industrial technology of their production - justifies the means.

BLACK SEA REGION RESOURCES

In recent years, the Black Sea region became a zone of special attention as a potential source of marine minerals, and not only for the Black Sea countries. [4].

In the Black Sea region geological reserves have been found of gas hydrates (solid gas) 25...30 trillion m^3; sapropelic muds (agrochemical raw materials) - $3.2...10^{11}$ m^3; fine sands - up to 100 billion tons, fresh water (common stock) - 178 million m^3 per year; gold placers - 100 ... 150 tons, limestone - unlimited, spa mud - 70 million m^3; sulfur - a few billion tons, there are also reserves of iron ore on the shelf south of the Kerch Peninsula with iron content 35...39%, etc. [5].

In addition, with the construction of oil and gas pipelines, the bottom of the Black Sea is increasingly becoming a building site. Therefore, issues of security, including the environmental safety, involving the works and exploitation, are in the foreground. [6]

SEABED PROGRAM DEVELOPMENT

The development of ocean resources related to government priorities of Ukraine is considered as a necessary condition for the development of scientific, technological and industrial potential of the country.

In 1993, Ukraine adopted a “national program of research and resources of the Azov-Black Sea shelf and other regions of the World Ocean for the period until 2000” [7]. It was attended by over 60 companies and organizations of various Ministries and Departments of the NAS of Ukraine, Ministry of Education of Ukraine. Work across the country has been coordinated by the “National Agency for Marine Research and Technology” (NAMIT), reporting directly to the Cabinet of Ministers of Ukraine. The leadin builder of hardware for the marine sub-sector of mining was identified as NIPIOKENMASH Institute (now former) in Dnepropetrovsk.

During this period, a considerable amount of work was done on the study of mineral resources of the seabed and the creation of means for their development. Unfortunately, up to now they have not been claimed in full and, of course, out of date. In our country, many areas of technical developments on the project pilot sample mining installations for mining PMK in the oceans.

Due to the economic crisis in the second half of the 90’s., the problem of development of marine resources has fallen out of the priorities. There are no own boats (OB), equipped with special modern research complexes in Ukraine. Termination of funding and the lack of real support from the government has led to the loss of the leading position, the breaking of scientific and industrial relations, destroying experimental base, design documentation, and as a consequence, to a lag of domestic equipment and technologies from the world’s average.

INTERNATIONAL COOPERATION

Starting in 1995, Ukraine has to negotiate with the international organization Interoceanmetal (IOM) to accede to the Agreement on the establishment of a joint organization for work on prospecting, exploration and preparation for the commercial development of ferromanganese nodules. The first members of the consortium, formed in 1987, were members of the CMEA countries: Bulgaria, China, Cuba, Poland, the USSR and Czechoslovakia. Subsequently, negotiations were suspended and frozen in 2004 by the Ukrainian side.

Status “pending expectations” industrial development subsea led to an apparent lag of Ukraine advanced countries. And this - the loss of markets of high technology products and dependence on foreign suppliers of strategically important raw materials scarce.

In 2006 the “National program of mineral resources of Ukraine till 2010” was adopted [8], which is part of the preparation for the development of future seabed defined objectives:

- Search in the Black and Azov seas for hydrocarbons, sapropel, building materials and learning gold mineralization;
- Search and exploration in the oceans for polymetallic nodules, testing equipment and technologies for extraction and processing.

Unfortunately, after many years of inactivity, in 2006 the American company “Vanco International Ltd.” won an open competition and the government entered into an agreement to explore and develop oil and gas field Kerch area of 13 km^2 of Ukrainian shelf at depths of 300 to 2000 m.

On leased land, the latest drill ship will be exploited, whose one-day work costs over 1.2 million $ USA. The total investment of the company in 30 years is to exceed $ 15 billion. Although the first right to purchase shares “wreath” in the production of hydrocarbons, according to the contract, belongs to the Ukrainian side - they will have to buy likely at world prices, and domestic researchers are unlikely to get access to the leased land.

Preparing for the subsea development requires significant investment and long-term planning.

PROSPECTS FOR THE DEVELOPMENT OF MARINE RESOURCES

And yet, despite the negative trend of recent years, Ukraine has the necessary prerequisites for the restoration of its scientific, technical and technological capacity.

According to the results of previous cruises, the "Professor Vodyanitsky", "Kiev" and others performed extensive research on the geology and marine sapropel for agricultural, industrial and environmental purposes. It has been found that the use of mineral mixtures based on sapropel reduces weight dose of fertilizers by 17 times.

Biofuels fever that gripped the world, requires increased acreage and increased efficiency. Increase in the production of biofuels can solve a number of economic (higher energy prices), political (independence from the supplier countries) and environmental (not polluting the atmosphere) problems.

Proved, the Black Sea sapropel muds increase the efficiency of crop and it is obvious that they will be in demand. And agriculture can become very profitable for Ukraine, which will increase its role in the international arena, as the breadbasket of Europe.

Sapropel application also showed good tread properties on infected radionuclides. They have a term used in construction, medicine and other fields.

Industrial development of deposits of sand in deep terraces shelf can solve the problem of the expected shortage of this raw material in Europe. This is especially true in view of the ring road around the Black Sea, the length of 7500 km.

The study of volcanic gas is of particular interest. It is assumed that the extent of this type of gas release in the Black Sea is estimated as at least hundreds of billion m^3.

COMPETITIVENESS AND THE POTENTIAL OF COUNTRIES

In conditions of market relations it is extremely important to keep up with world-class R & D, which threatens the loss of competitiveness of domestic producers. Gradually, there comes to understanding the need of the national policy on mineral resources of the Azov-Black Sea basin and the oceans. Its performance, in the foreseeable future, could lead to a change in the geopolitical situation in the region and in the world.

The examples are not far to seek: today it is oil and gas, tomorrow - hydrates and strategically important raw materials for the steel industry, without which you cannot get a quality metal, then - the development of agrochemical raw materials which will enable the solution of the more and more acute in recent years problem of food shortage.

In 2008, the National Security and Defense Council of Ukraine adopted a decision "On Measures for the Development of Ukraine as a Maritime State" [9]. With its appearance talks with "Interoceanmetal" were resumed not only on the level of technical expertise, but also on the State level. It is hoped that with the development of the Maritime Doctrine of Ukraine adopted in 2011 and the new "National Program of Mineral Resources of Ukraine till 2030" [10], our situation will change.

Subsea technology is not less complex and global than space one. Constantly evolving, it requires a tremendous knowledge of all areas of fundamental and applied science. Therefore, developed countries are investing heavily in training for commercial development of metalliferous and energy resources, exploration of new fields, and corresponding training.

In this area, as in any other activity, there is a tremendous need for scientific and technical support of products, development of new ideas, development and implementation of innovative projects, copyright protection in the sale of intellectual property rights (licenses). New technologies have become so sophisticated, costs for their approbation even at the level of pilot samples, especially for deep-water conditions, so important, competition in the market of high-tech products so tight, that it is difficult to rely on individual success [11]. Thus, the cooperation and collaboration of enterprises and firms within the project can be the basis of real success.

In our country, fairly strong scientific potential has remained - in the institutes of the NAS of Ukraine, in universities, in industrial research institutes, enterprises and organizations. Success in this case is: advanced domestic science schools, meeting modern requirements research base, to form a sufficiently strong field of mechanical engineering, with significant reserves. All this allows us to be in demand in the emerging market for marine technologies of mining and metallurgical structure.

Today, investing in research and production, usually returns are expected almost immediately. However, projects on the problem in this category must take time to achieve their profitability. Exploration and development of mineral deposits on land sometimes takes much longer, but the results can by far outweigh the costs (oil, offshore gas, nickel, diamonds, land and so on). Such issues cannot be ignored, because in the area of sea mining at the level of industrial designs, virtually all is to be created for the first time.

CONCLUSIONS

The development of complex projects in joint international programs, support of innovative projects are the most effective and realistic ways for Ukraine to join the leading countries, which are involved in the preparation for commercial development of offshore mineral and energy resources.

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Geoinformation technology for spatial inventory of greenhouse gas emissions: electricity and heat generation in Poland

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Abstract. One of the main features of energy production in Poland is high dependence on consumption of coal and lignite, which results in significant emissions of greenhouse gases (GHGs) to the atmosphere. This article presents the geoinformation technology and spatial analysis of GHG emissions from fossil fuel burned by power and combined power and heat plants. These plants are considered as emission sources of a point type. As input data, official regional statistics about consumption of fossil fuel for electricity and heat production are used. In addition, main characteristics of power and power/heat plants are collected from official web-sites. Based on the developed model, numerical experiments have been carried out for the territory of Poland. The results of spatial modeling are presented in the form of thematic maps.

Key words: modeling, geoinformation technology, greenhouse gas emissions, electricity production, combined heat and power production, fossil fuel.

INTRODUCTION

Technological development moves ahead, making our life more and more comfortable. As a downside, the global temperature increases and global climate change becomes irreversible [7, 13, 27]. International scientific community has proved that the increase of greenhouse gases (GHGs) in the atmosphere is the main reason of the increase in average global temperature and significant global climate change [5, 10, 15, 16].

The energy sector is the biggest contributor of GHG emissions to the atmosphere [3, 4, 16]. In the developed countries, it accounts for almost 90% of total carbon dioxide emissions and 75% of total GHG emissions. According to the classification of emission sources created by the Intergovernmental Panel on Climate Change (IPCC), the category "*1.A.1.a. Electricity and Heat Production*" belongs to the energy sector [1]. It is further divided into three subcategories, as shown in Fig. 1.

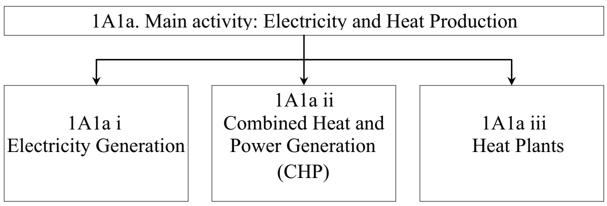


Fig. 1. Subcategories of the category "1.A.1.a"

In the modern world the majority of human activities require electricity and heat supply. Electricity and heat generation are based mainly on the combustion of fossil fuels, such as coal, natural gas or fuel oil. This leads to significant increase in GHGs emissions. Therefore, numerous incentives are introduced in order to reduce the use of fossil fuels, and instead increase a share of renewable sources in total energy production. Despite these efforts, fossil fuels remain the main source of energy.

Spatial inventory of GHG emissions improves the estimates of effectiveness of greenhouse gas emission reduction measures [2, 3, 9]. It identifies greenhouse gas sources and sinks at the level of individual regions, not only at the national (country) level. Therefore, countries are encouraged to develop their own spatial models to assess the processes of GHGs emission/absorption [17].

The first results of spatial analysis of GHGs caused by fossil fuel burned by power and power/heat plants in separate Polish regions were presented in [14]. This paper describes the mathematical model for spatial analysis of GHGs, and the experiments were carried out only for eastern Poland.

In the present paper we modify the model introduced in [14] by considering the amount of fossil fuels burned and known for each plant. This study focuses on two categories of sources: (1) Electricity Generation and (2) Combined Heat and Power Generation. We develop spatial inventory of GHGs of power and combined power and heat plants for whole Poland. For verification of results, we compared calculated emissions of point sources with corresponding data reported by each power plant.

FEATURES OF ELECTRICITY AND HEAT GENERATION IN POLAND

Poland annually produces greenhouse gas inventory reports according to the international obligations introduced by the Kyoto Protocol to the United Nations Framework Convention on Climate Change - UNFCCC. The latest inventory report [18] shows that the category "1.A.1.a. Public Electricity and Heat Production" is the largest contributor of emissions. It covers over 53.1 % of total GHG emissions in energy sector [18].

The energy sector in Poland highly depends on coal. Almost 62% of the electricity and heat production is based on combustion of coal as the main source of energy. Lignite is the second important fossil fuel used for electricity and heat production; it covers around 30% of total electricity in Poland [28]. Power plants that consume lignite usually are located close to miners of this fossil fuel.

The category "1.A.1.a" covers two types of power plants: "Zawodowe" (power/heat plants for general usage) and "Przemysłowe" (power plants for industry) [8,12]. This study is focused on power and heat plants classified as "Zawodowe". The power/heat plants which are classified as "Przemysłowe" belong to another category of emission sources (Manufacturing industries and building).

MODELLING GHG EMISSIONS FROM ELECTRICITY AND HEAT GENERATION

Input data required for spatial modeling of GHG emissions from electricity or combined power and heat generation include the following:

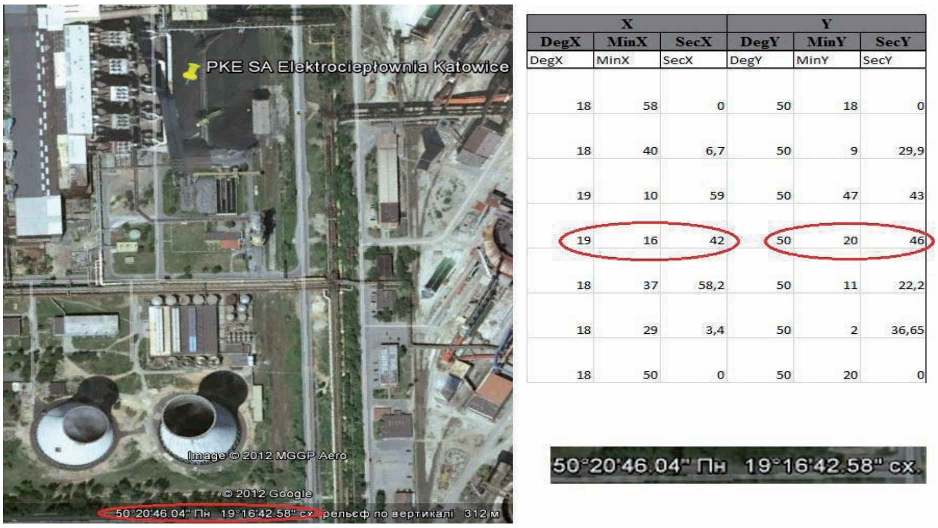
- consumption of different types of fossil fuels; this is available only on a voivodeship level,
- characteristics of plants and their coordinates.

Consumption of fossil fuels. Since 2008 the statistics data on coal consumption is reported as a total amount used by both types of plants – "Occupational" ("Zawodowe") and " Industrial" ("Przemysłowe"). To get the information only about coal consumption of "Occupational" plants, we assume that the proportion of fuel consumed by "Occupational" and "Industrial" plants remains the same as in 2007.

Figure 1 illustrates the thematic map of consumption of coal and natural gas for power and heat production by "Occupational" plants. This map was built using fuel consumption and the digital map of Polish voivodeships.

Plants as emission sources. The power plants producing electricity and heat are considered to be huge sources of a point-type [4]. We created a database with detailed information on characteristics of these plants. The database includes a set of precise geographic coordinates that were extracted from web-sources using the plug-in "Google Earth". An example of this process is shown in Fig. 2.

Fig. 1. Consumption of coal and natural gas for power and heat production at voivodeship level for the year 2010, th. TJ



X			Y		
DegX	MinX	SecX	DegY	MinY	SecY
DegX	MinX	SecX	DegY	MinY	SecY
18	58	0	50	18	0
18	40	6,7	50	9	29,9
19	10	59	50	47	43
19	16	42	50	20	46
18	37	58,2	50	11	22,2
18	29	3,4	50	2	36,65
18	50	0	50	20	0

Fig. 2. Extraction of coordinates of a power / heat plant using the plug-in "Google Earth"

Naturally, a territorial distribution of power/heat plants in Poland depends on economic activity, and thus it is uneven. For instance, Silesian voivodeship is the main industrial region of the country with numerous power plants.

Based on the coordinates of power plants, a digital map of electricity generation plants was created, using GIS tools (see Fig. 3).

Fig. 3. The created map of power / heat plants of Poland

Emission estimates. Carbon dioxide is the main GHG emitted by energy sources. Emissions of carbon dioxide are formed as a result of burning of carbon contained in fossil fuels [11, 16]. It causes also a release of a large amount of thermal energy, which is directly or indirectly used to produce mechanical energy (often to produce electricity).

For a spatial analysis, one needs to know exact fuel consumption at each point source, and this kind of information is not available from official statistics. However, with certain parameters, such as a structure of fossil fuel consumption and general power, the data on fuel consumed can be disaggregated into individual point sources within a voivodeship.

The emission of g-th gas from an elementary object (a single plant) is calculated based on its usage of fuels accounting for respective calorific values and emission factors, in accordance with the formula:

$$E_g^{En}\left(\xi_{En,n_p}\right) = \sum_{f \in F} Q_f^{En}\left(\xi_{En,n_p}\right) K_{g,f}^{En}\ C_f\left(\xi_{En,n_p}\right), \quad (1)$$

where: $E_g^{En}\left(\xi_{En,n_p}\right)$ is the emission of the g-th GHG from fuel burning of a point source ξ_{En,n_p}, $n_p = \overline{1, N_{En,p}}$; $N_{En,p}$ is the number of emission sources in an administrative unit R_{1,n_1}, $R_{1,n_1} \in \tilde{R}_1$, and R_{1,n_1} is an administrative unit of the "first level" (voivodeship); $\tilde{R}_1$ is the set of administrative units; f is a fuel type, $f \in F$; F is a set of fuel types (coal, lignite, natural gas, mazut); ξ_{En,n_p} is a point-type emission source (power/heat plant), $\xi_{En,n_p} \in \Xi_{En}$; Ξ_{En} is a set of point-type emission sources on the administrative unit R_{1,n_1}; $K_{g,f}^{En}$ is the emission factor of the g-th gas from burning the f-th fuel type in Energy sector (1.A.1.a "Main Activity Electricity and Heat Production"); $C_f\left(\xi_{En,n_p}\right)$ is the calorific value of the f-th fuel type for point-type source (these parameters differs for each point source; the main reason of it is a technological process of plants [26]), $Q_f^{En}\left(\xi_{En,n_p}\right)$ is the amount of the f-th fuel type consumed by a point-type source ξ_{En,n_p} in R_{1,n_1} administrative unit.

The parameter $Q_f^{En}\left(\xi_{En,n_p}\right)$ is calculated for each power/heat plant with the formula:

$$Q_f^{En}\left(\xi_{En,n_p}\right) = \frac{D_f^{En} - \sum_k D_{k,f}^{En}}{\sum_{i=1}^{N_{En,p}} W\left(\xi_{En,i}\right) - \sum_{n_k} W\left(\xi_{En,n_k}\right)} W\left(\xi_{En,n_p}\right),$$

$$n_p = \overline{1, N_{En,p}}, \quad (2)$$

where: D_f^{En} is the amount of the f-th fuel for electricity and heat production in administrative unit (voivodeship)

R_{1,n_1}; $D_{k,f}^{En}$ is the known amount of fuel used by a point-type source ξ_{En,n_k}; $W\left(\xi_{En,i}\right)$ is the overall power of a power/heat station; $W\left(\xi_{En,n_k}\right)$ is the overall power of power/heat station with known amount of fuel used. Overall power of a plant is the main parameter used for fossil fuel disaggregation, since power (combined power and heat) plants cannot produce more electricity (electricity and heat) than it is technically feasible.

For the ξ_{En,n_p}-th plant, the total GHG emissions in CO_2 equivalent are calculated as a sum of the g-th gas emissions multiplied by their respective global warming potential:

$$E_{\Sigma}^{En}(\xi_{En,n_p}) = \sum_{g \in G} E_g^{En}(\xi_{En,n_p})\, W_g,\ n_p = \overline{1, N_{En,p}}, \quad (3)$$

where: $E_{\Sigma}^{En}(\xi_{En,n_p})$ is the GHG emission in CO_2 equivalent by point-type source ξ_{En,n_p}; W_g is the global warming potential [6].

COMPUTER REALIZATION

Geoinformation tools were developed using MapInfo and corresponding programming language MapBasic. Calculations are based on the mathematical model (1)-(3) to provide spatial analysis of GHG emissions from power/heat plants of Poland.

For computer modeling, a specialized database was created as input data. It includes the following components: (i) consumption of fossil fuel by power and heat plants at voivodeship level [28]; (ii) list of public power plants and their characteristics; (iii) coordinates of public power plants with additional statistical data [25]; (iv) emission factors [26]; (v) remarks and references.

The results are presented in the form of thematic maps. As an example, Fig. 4 demonstrates the total emission from electricity and heat production in Poland at the level of separate plants. It includes a sum of emissions of all GHGs multiplied by global warming potentials. The same results but aggregated to the level of voivodeships are presented in Fig. 5.

Silesia (Śląskie) voivodeship is a region with the largest GHG emissions from energy production[21, 23, 24]. Two out of ten biggest Polish power plants (Elektrownia Rybnik, Elektrownia Jaworzno) are located there, see Fig. 6 and Fig. 7,a. In terms of GHG emissions from power plants, Mazowieckie voivodeship [20, 22, 24] is one of the biggest emitters. In Mazowieckie voivodeship there are eight power plants, and two of them are in the list of the largest emitters (Kozienice Plant, Siekierki Power Plant), see Fig. 6 and Fig. 7 b.

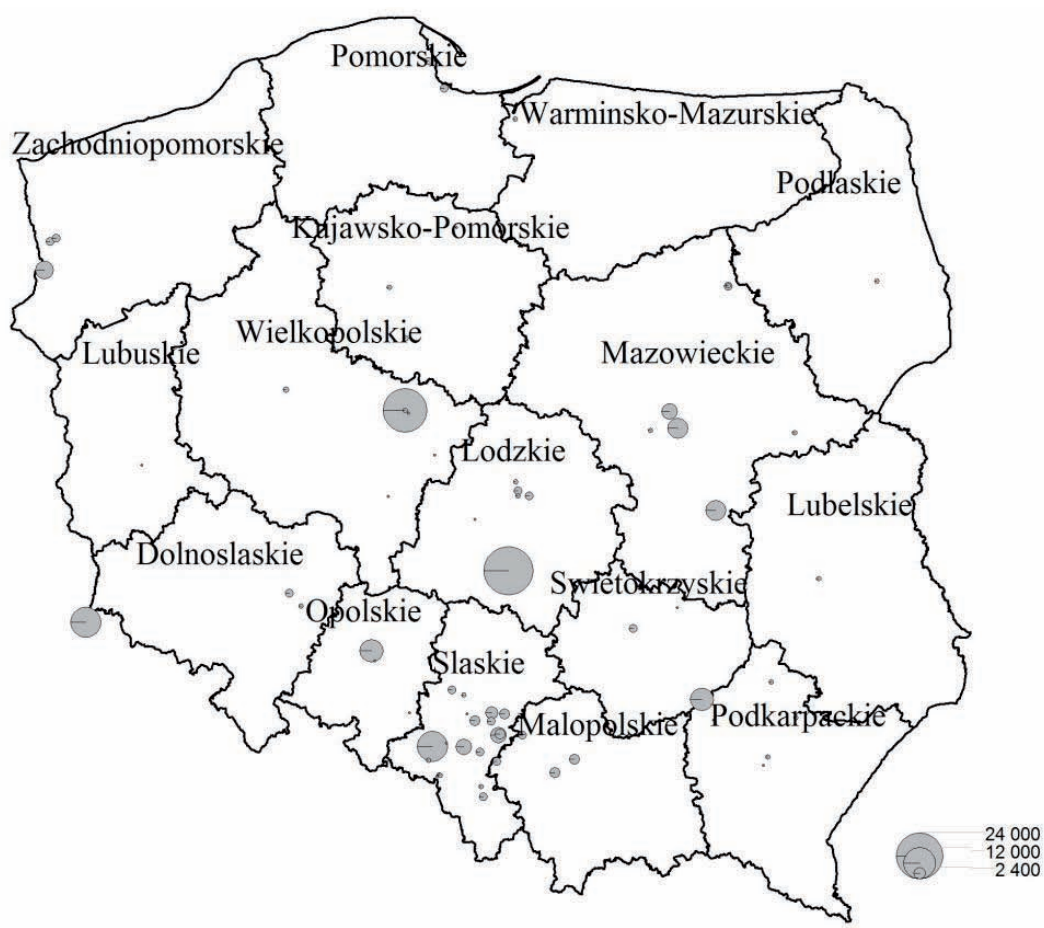


Fig. 4. Total emissions from electricity and heat production at the level of plants (2010, th. tones CO_2-equivalent)

Fig. 5. Total emissions from electricity and heat production at the level of voivodeships (2010, th. tones CO_2-equivalent)

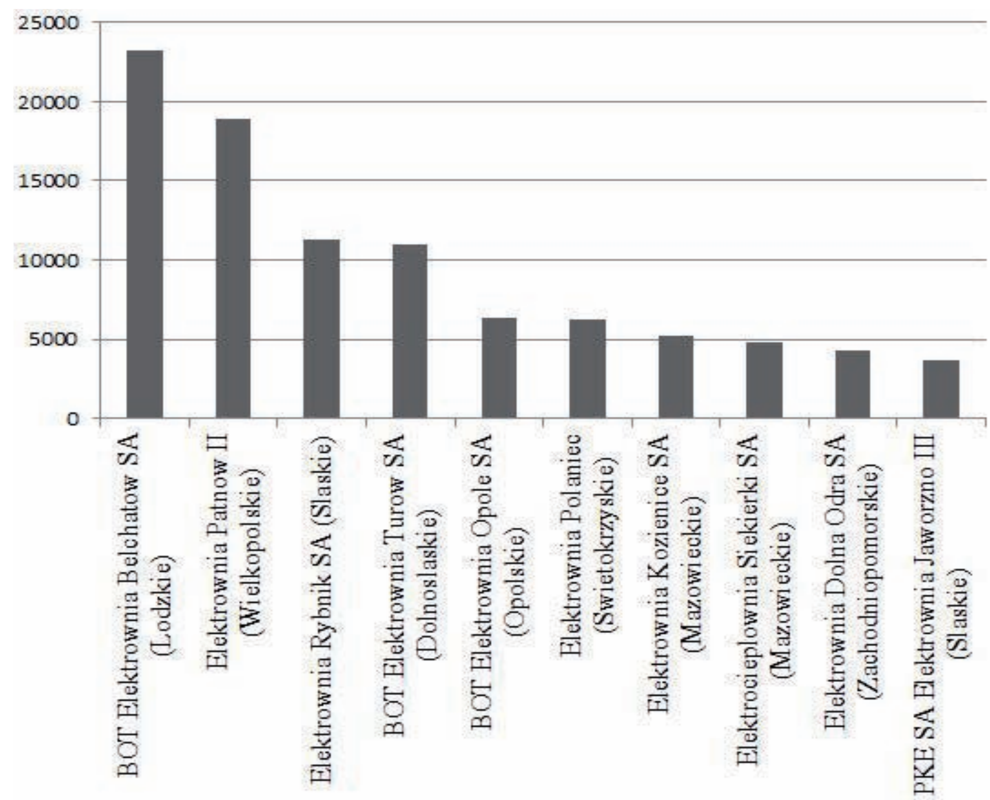
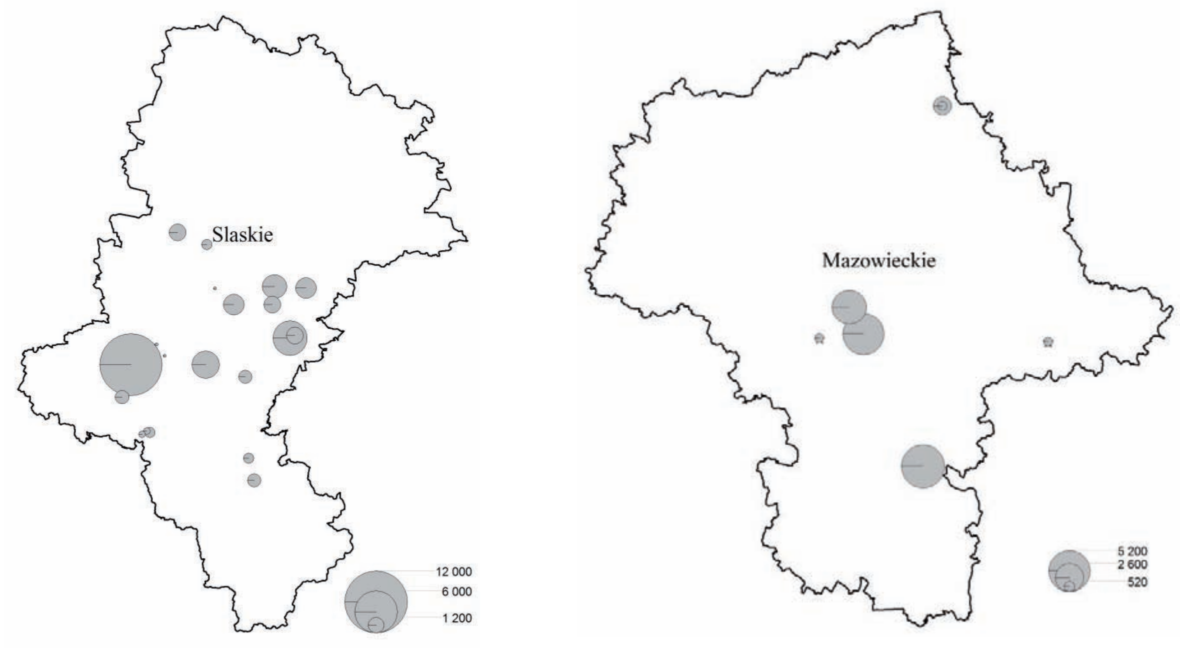


Fig. 6. The biggest point sources of emissions – power/heat plants (2010, th. tones of CO_2-equivalent)



a b

Fig. 7. Total emissions from electricity production in Silesia (a) and Mazowieckie (b) voivodeships (2010, th. tones of CO_2-equivalent)

The next step after computer realization is a verification of obtained results. Some power plants and combined power/heat plants publish data on their annual emissions on web-sites. We compared the results of our model with the official data published by plants. For example, in Lower Silesian voivodeship there are three power and heat stations. One of them "BOT Turow SA Power Plant" is the biggest emitter that covers more than 70% of all GHG emissions in the voivodeship [19]. In this case, the difference between the model results and official numbers from the environment report does not exceed 4 %, see Fig. 8.

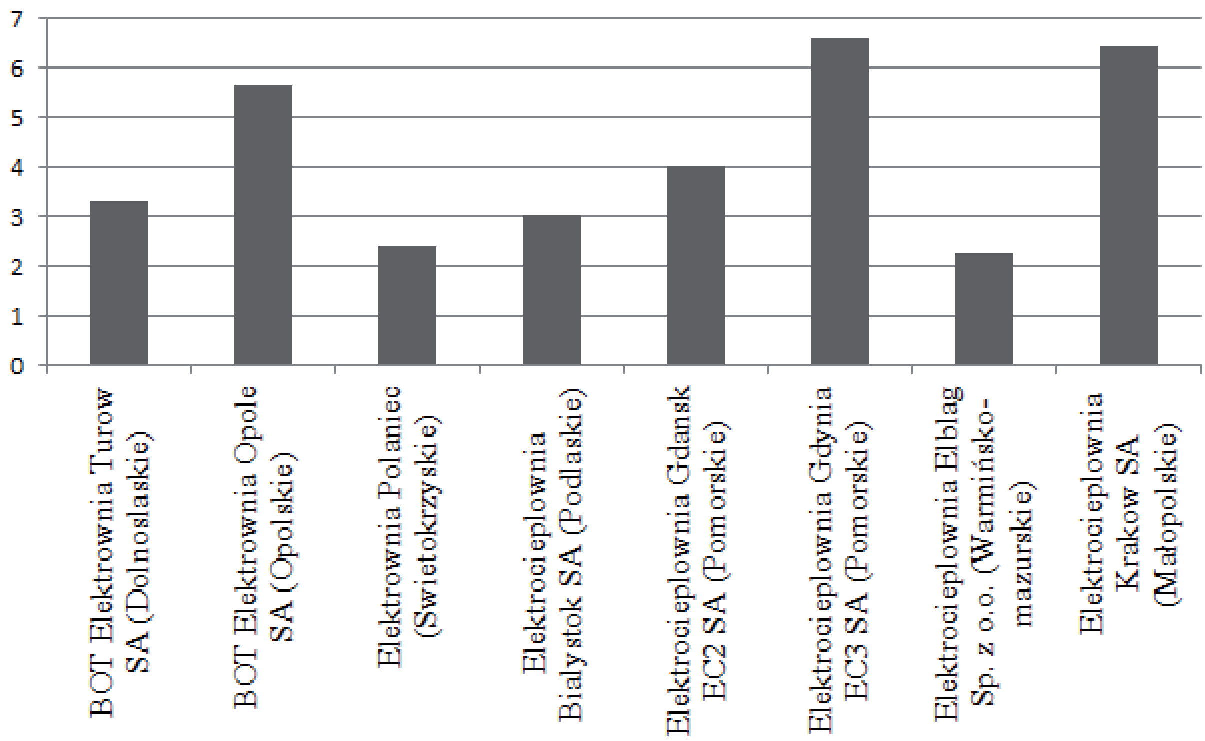


Fig. 8. Difference between official data that are published on power / heat plant sites and calculated from distributed data (2010, %)

CONCLUSIONS

Electricity and heat generation is one of the main energy categories in Poland, accounting for 43.5 % of total GHG emissions. This paper provides the spatial analysis of annual GHG emissions from fossil fuel burning in power and power/heat plants. The emission estimates are based on official statistics about consumption of fossil fuels for electricity, power/heat production, and data on electricity, electricity/heat generation by each plant. In order to spatially allocate the emission sources, geographical location of the main power and power/heat plants as point-type emission sources have been identified, and corresponding digital map of power plants has been created using GIS tools. The numerical experiments on spatial modeling of GHG emissions were carried out by implementing the developed geoinformation technology. Obtained results can be presented in the form of digital maps with georeferrenced information on sources of emissions. For example, spatially resolved carbon dioxide emissions and corresponding thematic map clearly emphasize that the largest emitter of CO_2 is the power plant – BOT Elektrownia Bełchatów SA located in Lodz voivodeship. Nevertheless, Silesian voivodeship is an unquestionable leader of GHG emissions from electricity production. The difference between the model results and official numbers included in the environment report does not exceed 3-7 %.

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Personal potential of manager as a prerequisite of realization of managerial potential of enterprise

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A b s t r a c t . Crucial role of management is proved in realizing the potential of enterprise management system. The essence of the concept of "managerial staff" based on establishing key characteristics of managerial work is specified. The necessity of consideration of personal potential managers and their competencies as prerequisites of managerial capacity of the enterprise is justified. The necessity is pointed out of mastering managers' socio-psychological instruments of influence on the staff with the aim to develop their personal potential.

K e y w o r d s : enterprise, control system, administrative potential, managerial staff, personality potential, competence.

PROBLEM, ANALYSIS OF RESEARCH AND PUBLICATIONS

Research prerequisites were to realize the potential of enterprise management system, under which it was suggested to understand the possibilities of effective management of functioning and development of the enterprise, which requires the definition of reserves and improvement of its component such as management capacity.

According to the author's research on the establishment of general scientific notion "potential" [1, 2] and determination of the structure of the potential enterprise management system [3], under the management capacity the possibilities are understood offering effective activities of management, so that employees at all levels of government are involved in the preparation, adoption and implementation of management decisions. The subjective nature of this component of the total system capacity management is due to individual preferences, experience, intuition of decision makers, and is an integral factor in decision-making. Clearly, reducing this subjectivity can contribute to improving the objective possibilities of enterprise management system (codification of knowledge, raising methodological, organizational and logistics management, quality information for management processes, the use of mathematical models and methods of decision-making, etc.). But, at the same time, subjectivity manager as the person who decides is an integral part of the management company: ultimately, the state as objective (information and technical and structural and functional blocks), and so combined (unit training, adoption and implementation of management decisions) components, selected according to the author's approach to the structure of the potential enterprise management system, directly dependent on the knowledge, skills, intellectual ability, initiative and experience of management. It is no coincidence that the most investigated approaches to establishing the nature of "potential enterprise management system" identify potential management system with management potential as the ability of management to carry out its activities, by the way, causing this terminological uncertainty in studies [4, 5, 6].

The exclusive role of management capacity to implement the overall system capacity is due to the fact that management actually interprets management information, identifies sources of gathering and processing facilities, determines the timing of tasks, selects the best alternative management solutions, sets the direction of motion data streams, is responsible for creating communications system, manages resources, determines the distribution of rights and responsibilities in the organizational structure of the management system, guides, including (consciously or unconsciously) their own preferences, based on their experience, trusts their own intuition based on their formal and informal relations and others. Consequently, to upgrade reserves capacity, enterprise management system should look primarily to increase the efficiency of management as a subjective component of management processes.

The aim of the article is to establish the prerequisites of managerial capacity as a defining component of the total system's capacity management.

THE MAIN MATERIAL AND RESULTS

Additional difficulties arise in this context, due, in particular, to the lack of a common understanding of the concept of "managerial staff " ("administrative manager", "management personnel", "managers", "workers control").

In our view, specification of the content of the concept of "managerial staff" and synonymous concepts can help to use it as criteria unification of specific characteristics (features) that are inherent in administrative work, and allow relatively easily to identify its relation to other types of work in the organization (enterprise). These characteristics are expressed:

- in the nature of the work (administrative work – mostly mental, is creative, important in the management of labor – setting goals, developing methods and techniques to achieve them, the organization of joint activities of employees);
- in the subject of work – information is particularly subject to administrative work, making managers who make the decisions necessary to change the state of the managed object;
- used in media (tools is a means of working with information);
- results (the result is measured by the achievement of goals).

It should be noted that the majority of scientists whose works are devoted to the problems of management rarely take into account the presence of the distinguishing features of managerial work in establishing the essence of the concept of "managerial staff". The following analysis shows definitions of "managerial staff" and it synonymous concepts, the results of which are presented in Table 1.

As shown in Table 1, often the definition is limited to fixing the fact of belonging to a certain category of employees staff management, governance, administration of enterprises and others [7, 8], without providing answers to questions regarding the nature of managers who can separate this category of employees from other employees of the enterprise (organization, institution). Trying to identify the content of managerial work, mostly realized by rebuilt management functions, work (tasks, issues) to be fulfilled (solution). Additionally, we note that none of the definitions weighs the creative, intellectual nature of managerial work as its distinguishing features. Preferably, there is no indication for informational and management [7, 8, 9, 11, 12, 14], while the same information is particularly subject to administrative work, and its transformation using appropriate means - a prerequisite for decision making in the management of enterprise. Thus, we believe that an essential feature of the administrative work is its informative nature, that necessarily involves the collection, processing, transfer, use and creation of new management information.

In light of the above considerations the following definition can be formulated: company management – are its employees, whose work is creative and informational in nature and focused on specific management functions, or who perform work in technical support management to achieve business objectives. Under the definition given in [3], the total system's capacity management (subjective component management) is due to individual abilities and socio-psychological skills of the management.

Exploring the prerequisites for the formation and development of managerial capacity in enterprise management system as potential managerial personnel it should be noted that, ultimately, this potential does not arise "from the air", as it is determined by individual capabilities of individual workers that depends on their personal potential. This simple fact leads to the need for considering the concept of "personal potential employee", under which the following can be understood:

- degree of professionally significant qualities and characteristics of the person providing the successful implementation of employee labor problems and efficient solution of production problems [16],
- system properties of individuals that are the foundation of professional personal development and provide the appropriate level of achievement in training and follow-up [17],
- existing human talents, interests, and the internal settings and intentions that may find their realization in the professional field for the appropriate conditions and organizational context [18],
- biosocial tier system consisting of professional activity as a result of conversion of natural advance payments in individual professional skills [19],
- special, capable of self-development system of internal renewable resources employee who appear in the results of one's professional activity [20].

Without rejecting the possibility of interpretation of the concept of "personal potential employee" under the above definition, we formulate a definition of "personal potential manager" in accordance with the results obtained by the authors regarding the establishment of general scientific notion "potential", which is used in particular by providing a definition of "system potential management "[3]. Namely, under the personal manager will be understood the potential opportunities for effective implementation of employee management, due to the presence of the relevant individual abilities and social and psychological problems. First of all, we mean the ability of a manager to think creatively, outside the box to solve the task facing him, effective decisions. Only a person with creative thinking, creativity, appropriate behavior, the necessary theoretical and practical knowledge that is relevant competencies, directly through the implementation of the labor process is able to change the manufacturing process, cause the structural change towards humanization and specialization of labor, creating additional value. Accordingly, competence management can be seen as a key factor that causes the implementation of enterprise management capacity.

Analysis of common definitions of "competence", presented in [21], shows that appropriate competencies are understood as a set of interrelated personality traits based on professional (special) knowledge, values and

Table 1. Analysis of definitions of "managerial staff " and its synonymous concepts[1]

Source	The concept to be determined	Definition	Having reference to the distinctive features of managerial work			
			The nature of work	Subject labor	Means of labor	Results of labor
Modern Dictionary of Economics [7]	Managerial staff	Employees of management, employees who belong to the administration of the firm, company, organization , office workers , the management of enterprises, institutions	-	-	-	-
Great accounting dictionary [8]	Managerial staff	Workers engaged in management of the economy and public administration: the heads of enterprises, institutions, organizations and their deputies, heads of departments who are not employed directly in manufacturing, chief specialists engaged in the managerial staff	-	-	-	-
M.M. Glazov, I.P. Fyrova, O.M. Istomina [9]	Managerial staff	Category of workers who directly perform management functions or perform work in technical support management	+	-	-	-
T.Y. Bazarova, B.L. Eryomina [10]	Managerial staff	Workers who decide administrative coordination issues in the enterprise and its business units, keep records and provide information	+	+	-	-
International Labour Organization [11]	Managerial personnel	Part of a broader category of workers , which in addition includes managers and other professionals	-	-	-	-
V.R. Vesnin [12]	Administrative staff	Part of company's staff whose job is to organize other staff activity, management of production, administrative, financial, accounting, research and other functions	+	-	-	-
O.V. Chumachenko, T.S. Shulgina [15]	Managerial staff	Members whose duties involve managing or doing the job of technical support of the management, the main results of this activity are: creation of new information; change of its form or content; detection of the problem of company activity; preparation and decision-making process; realization and control for the execution of the commands	+	-	+	+
O.P. Egorshin [13]	Managerial personnel	People, who do the labor activity during the process of production management and do the transformation of information with the help of technical managerial equipment, whose main activities are: studying the problem of management, creation of new information, change of its content or form, preparation of managerial decisions and after the decision of the head of the company the most effective variant - realization and control of the process	+	+	+	+
M.V. Voitolovsky, O.M. Kalinina [14]	Managerial personnel	Staff, the labor activity of which is directed for the concrete managerial functions	+	-	-	-

skills, intellectually and personally conditioned experience of social and professional life rights that are set in relation to the decision of a range of professional tasks. These personal qualities include an employee's readiness to mobilize knowledge and external resources to ensure the effective operation of an organization, and willingness to work effectively in situations of uncertainty. Directly regarding competencies, enterprise's managerial representatives, as thoroughly specified in the D.K. Voronkov, along with their basic professional knowledge, increasingly have the need for competencies associated with the mastery of social and psychological tools to influence the activity of personnel [22, p. 294]. For this, they must master the functions of a mentor, coach, learn to diagnose organizational culture and socio-psychological climate measure intellectual capital collective and individual subordinates, to provide social and professional adaptation of new employees, delegate functions to subordinates

[1] Made using [15, c. 58]

based not only on their knowledge but also personal potential of others.

Therefore, for effective professional work managers have to master a wide variety of skills that can be considered as the basis of the formation and development of personal potential of the managerial staff. In turn, the realization of personal potential of managers is a prerequisite for the development of the management capacity of enterprises as a combination of personal potential of the employees and of management system. Finally, the implementation of managerial potential capacity will promote the overall capacity of enterprise management system, under which, as already noted, it is proposed to understand the possibilities of effective management of operation and development. Thus, the competencies of employees of management system is the basis, which is the necessary initial condition for realization of the potential of enterprise management system (Fig. 1).

Note that along with the acquisition of basic professional knowledge by managers, as unconditioned basis of their competence, it is important to develop skills associated with mastering social psychological instruments of influence on activity staff. Theory and practice of evidence have shown that the potential leader should greatly enhance knowledge and skills in the field of Socionics - the science of human perception of information from the outside world and information interaction among people. Possessing that, director of technology provides effective search for viable options for the allocation of functions between subordinates modeling for the most intensive information flow in business communication with their sociotypes. Optimal distribution of roles according to the features of sociotypes and key skill levels as well as types of solutions depending on the particular social type is presented in Table 2, 3 [22, p. 295].

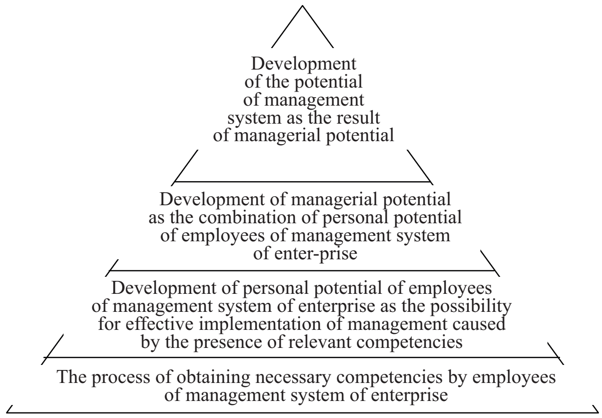

Fig. 1. The role of competence of managerial staff in ensuring the capacity building of management system of enterprise

Considering the features sociotypes, the distribution of roles in a team provide rapid accumulation of information in the enterprise management system, enhancing

Table. 2. Distribution of roles according to the features of sociotypes

Component of joint activity	Role	Sociotype
Cognitive	Newbie with „fresh" point of view	Inventor, Entrepreneur
	Adviser (judge)	Critic , Analyst
Practical	The Head	Marshall , Administrator,
	Designer of solutions	Enthusiast , Politician
	Practitioner Host	Controller , Master
Emotionally communicative	Scout of resources	Psychologist, Coach
	Soul of group	Mediator, Lyric
	Closer	Humanist, Guardian

Table 3. Sociotypes, key skills , levels and types of solutions

Types of decisions	Key skills	Variant of sociotype	
		optimal	satisfactional
level 1 (routine)	Strict adherence to procedures, reasonable assessment of the situation, humane leadership, supervision, motivation	Marshall, Administrator	Politician, Enthusiast
level 2 (selective)	Formulation of objectives, tactical planning, analysis of information	Master, Controller	Mediator, Bodyguard
level 3 (adaptation)	Identifying problems, systematic solutions, analyzing the possible risk, the creation of working groups	Analytic, Critic	Lyric, Humanist
level 4 (innovation)	Creative management, strategic planning, systems development	Entrepreneur, Inventor	Psychologist, Mentor

the soundness of decisions taken, and will improve the efficiency of their performance.

CONCLUSIONS

A key role in realizing the potential of management system of an enterprise is played by the managerial staff, under which it is proposed to understand the potential set of personal potential of employees of the management system of an enterprise. The interpretation of the concept of "personal potential" as opportunities for effective implementation of employee management, suggests that the causing factor of managerial potential of management system of enterprise are the competences of managerial staff. Development of competences related to managerial staff, in particular, to the mastery of social and psychological instruments of influence on the activity of workers is a prerequisite for improving the efficiency of its operations and, consequently, of the total potential of the system of enterprise management.

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