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Increase of recycling efficiency of domestic waste of preliminary preparation of their dispersed fraction

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Abstract
Paper is devoted to efficiency increase of preparation process of dispersed fraction of domestic waste for the subsequent recycling by thermal methods. Necessity of preliminary preparation of dispersed fraction of domestic waste is proved. It is suggested to derive fine fraction from the total mass of the stored domestic waste and to expose them to preliminary preparation for increase of efficiency of their recycling.

Physical and mechanical properties of dispersed waste mixture are studied. The experimental researches of efficiency of granulation processes by such methods as pelletizing, granulation by compression and granulation in fluidized layer are conducted.
Dependence of the granules size on waste humidity and the gas flow rate for fluidisation is theoretically established and experimentally confirmed. Necessity of cyclic delivery of binder solution with regular intervals for providing of stationary operating mode of granulation of dispersed fraction of domestic waste in the device with fluidized layer of discontinuous operation is also theoretically established and experimentally proved.
The studied features of granulation of dispersed fraction of domestic waste by different methods will allow simplifying of choice of method and means of preliminary preparation of dispersed waste for different existing types of their recovery. Technology of heat treatment in chamber furnaces is considered as the most effective and ecologically rational method of recovery. The appropriate corrective amendments, which increase efficiency of such processing, are introduced in the existing technology of waste recycling in chamber furnaces on the basis of the conducted researches of methods of preliminary preparation of dispersed fraction.
Key words: DOMESTIC WASTE, DISPERSED FRACTION, RECOVERY, PRELIMINARY PREPARATION, GRANULATION, PELLETIZING, COMPACTION, FLUIDISATION, HEAT TREATMENT, CHAMBER FURNACE

Annually, in Ukraine about 15 million t of domestic waste are stored, and only about 10% of them are recycled and recovered. At present, more than 2 billion t of domestic waste are accumulated in the territory of Ukraine [1]. In the country, there are about 4 thousands registered and relatively equipped landfill sides [2]. At that, places of unapproved stocking of unassorted domestic waste are spontaneously formed near each settlement irrespective of its size. According to data of 2015, in Ukraine the area occupied by such waste is more than 2% of the whole territory of the country. The huge areas, which could be rationally used by reserved fund and are demanded in agriculture or city agglomerations, now are buried under layer of garbage and continue to be exposed to pollution and poisoning.

Despite the growing size of the problem, not enough attention is paid to it. The majority of known decisions are directed to separate collection of garbage, separation of valuable components, reduction of waste production in general and implementation of non-waste technologies [3]. However, there is open problem of reduction of territories of unapproved stocking of waste formed under the conditions of unseparable collection of garbage which is the reason of accumulation of dangerous chemicals, harmful bacteria and viruses of dangerous diseases.

Dispersed fraction of unassorted waste (the size of particles is up to 1 mm) as a part of the stored waste poses the greatest ecological danger. It is should be noticed that both organic and inorganic dispersed components pose specific danger. The organic dispersed component of waste contains toxic, chemically and biologically dangerous substances. Process of decay of organic component is followed by separation of methane-containing gas mixture that leads to frequent ignitions and fires in places of unapproved stocking of waste [4]. The inorganic dispersed component of waste in course of reversal process becomes the reason of arch formation in bunkers, sticking, hanging of particles, hard driving or blocking of moving elements of processing mechanisms, reduces efficiency of recovery process and reliability of recovery equipment. The ratio of organic and inorganic dispersed components in the stored waste is specific to each separate stored waste. Because of impossibility of division of organic and inorganic dispersible components of waste, such compound of dispersible waste becomes the main problem of scale industrial recycling of the stored waste. The compound of organic and inorganic dispersed fraction of waste does not undergo sorting, possesses complex rheological properties and represents the most ecologically dangerous component of waste in places of stocking. Fine particles of waste are spread quicker in reservoirs, penetrate into the soil simpler, are oxidized and dissolved more actively. Initially when stocking domestic waste, the fine component is about 10% of the whole waste.

Results of the conducted researches allowed establishing that under the influence of climatic factors and biochemical processes of decay in places of stocking, the fractional composition of waste is changed, at that, the share of ecologically aggressive fine fraction increases within 10 years from 7-10% to 70-80%.

Physical and mechanical properties of dispersed fraction of the stored waste located in different climatic and environmental conditions, such as non-uni-

form morphological composition, humidity – 30 - 75%, bulk density – 300-350 kg/m^3, true density of mixture ≈ 1660 kg/m^3, do not allow implementation of scale industrial processing by any of the known thermal methods due to agglomerating of dispersible waste into warm and gas proof mass that determines necessity of preliminary preparation before processing. On the basis of experimental studies, it was suggested to derive the fine fraction of domestic waste from the total mass of stored waste and to expose them to preliminary preparation for increase of processing efficiency.

In this regard, the relevant scientific task is creation of technological basis for recovery of domestic waste on industrial basis and safe processing of their ecologically aggressive fine component by grounding of rational processes and parameters of granulation providing control of fractional and moist composition of the obtained product.

It was experimentally confirmed that processing of dispersed unassorted waste is possible in case of restriction of minimum fineness of processed material and humidity control that provides stabilizing in general of physical and mechanical properties of dispersed fraction. It is possible to achieve it in the course of material granulation. Granulation is formation of particles of material (granules) of the given fineness, shape and with the given properties. Process of granulation implies both grinding of large lumpy material and combining of fine particles of material. In the paper, the second case of granulation is considered.

The industry applies several methods of combining of fine materials into granules. The most widespread methods of granulation are different types of compaction, pelletizing of dispersed mass in the rotating devices and granulation in fluidized layer.

Granulation of dispersed fraction of domestic waste by method of pelletizing was studied by disk-shaped laboratory installation.

It was established that the stable pelletizing and formation of granules from dispersed waste can be observed only in case of achievement of relative humidity of 50% (in the presence of solution binding in material – 40 … 45%) by material. At that, free movement of particles on working surface of the device was possible in case of humidity of material no more than 35%. Therefore, material moistening and adding of binding solution should take place in course of granulation.

In case of granulation by pelletizing, granules with diameter of 5-10 mm were obtained. The average bulk density was about 400 kg/m^3, and did not depend on the size of formed granules. Distribution of granules-pellets strength corresponds to the classical theory of solid particles and is uniformly reduced with growth of the relative size of particles. Granules-pellets of dispersible waste were of brittle structure and were crumbled in the course of applied load. Mean value of strength of granules of dispersed fraction of waste obtained by pelletizing was about 0.04 MPa. Necessary time of pelletizing for obtaining granules of disperse phase of waste with such properties is 45-50 min.

Compression processing was considered as the stage of preliminary preparation of dispersed fraction of domestic waste for further processing. Compaction of dispersed material differs from other methods of granulation and more precisely guarantees such properties of finished products as size, shape, density etc [5].

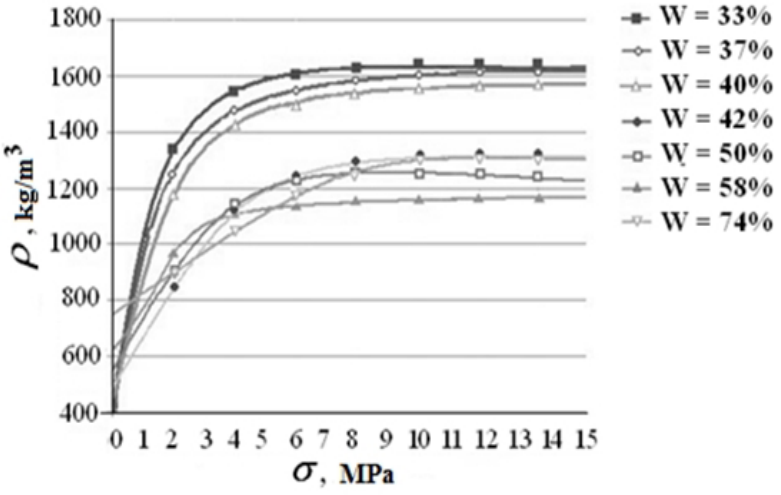
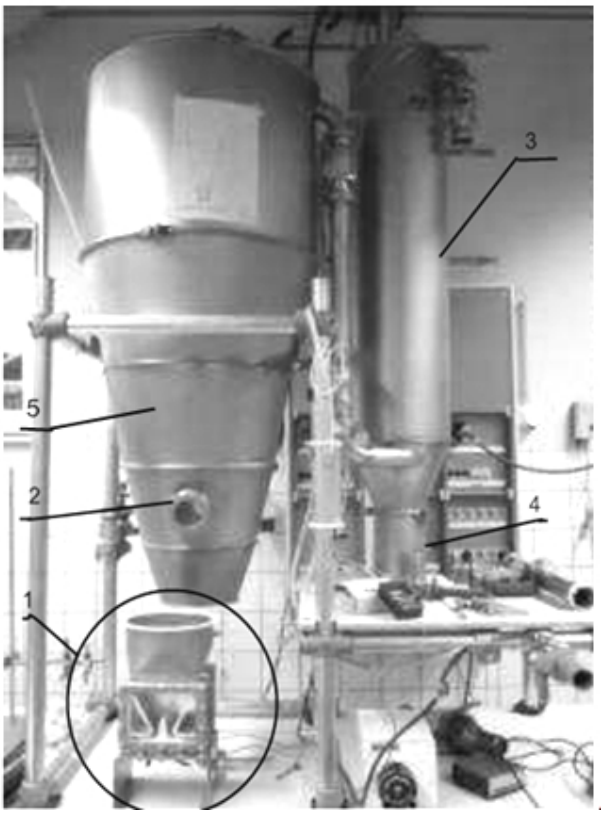


Figure 1. Compression curves of compaction of dispersed fraction of waste of various humidity (developed by the author)

The experimental researches on compaction of dispersed fraction of domestic waste were conducted on the special instrument for compression tests of Donetsk National Technical University. On the basis of compression tests of the studied material, compression curves of compaction process of dispersed fraction of waste for tests of various humidity (Figure 1) were built.

From diagrams of growth of briquettes bulk density in case of pressure increment of compaction, it is possible to draw a conclusion that effective compaction of dispersed fraction of domestic waste is possible in case of humidity up to 40% inclusive. The use of more wet raw materials for compaction will lead to formation of less dense and less solid briquettes that will be reflected in efficiency of further operation. Therefore, when compaction of dispersed material, which humidity exceeds 40%, there is necessity of preliminary drying.



1 - feed part of machine; 2 - observation window; 3 - vertical forcing pipe; 4 - filter; 5 - operating zone of machine

Figure 2. The granulator device of discontinuous operation with fluidized layer of German Technical University Hamburg University of Technology (TUHH) of institute of Solid process engineering and particle technology (SPE)

Granulation in fluidized layer is a process in case of which particles of the solid static mass interact and integrate into larger granules. This static mass under the influence of gas flow passes into pseudostate similar to a state of liquid mass.

In relation to domestic waste, such type of preliminary preparation is applied for the first time. It was experimentally established that granulation of small-sized fractions of domestic waste in fluidized layer possess a row of advantages comparing with other methods of granulation. This approach makes it possible to solve several main problems of recycling of dispersed waste simultaneously; namely, the possibility of drying by fluidizing gas makes it simpler to use excessively humid material, and continuity and closeness of process reduce negative impact of dangerous wastes on people and environment. Isolation of such process and circularity of flow motion of fluidizing gas allows isolating and catching the majority of harmful and dangerous substances [6].

The experimental researches of granulation in the machine with fluidized layer were conducted on laboratory installation of discontinuous operation (Figure 2).

Process of granulation in the device fluidized by layer differs from other methods of granulation by rather complex hardware basis and large number of controlled parameters [7]. On the one hand, it complicates control of this process making certain demands to the equipment, material and operator. On the other hand, a large number of controlled parameters makes it possible to control granulation process deeply and in details that in turn gives the chance to process complex granular masses [8]. Non-identified dispersed fraction of waste can be also referred to such material.

For providing of dispersed and humidity conditions of product, parameters of supply of fluidizing gas in the granulator device were established experimentally; stable fluidizing of dispersed fraction of waste with the relative humidity 20… 40% is provided in case of air flow in the range of 80 … 100 m^3/h.

The granules obtained in consequence of this process tended to regular spherical shape and were of the small size ($d_{eku} \approx 3.099$ mm). Such size of material particles allows providing necessary level of gasification and sufficient amount of contact sintering points. The granules obtained by fluidizing also possess high level of porosity (≈ 63%), hence, providing the particle with big response surface necessary for efficient involvement in chemical processes (Figure 3).

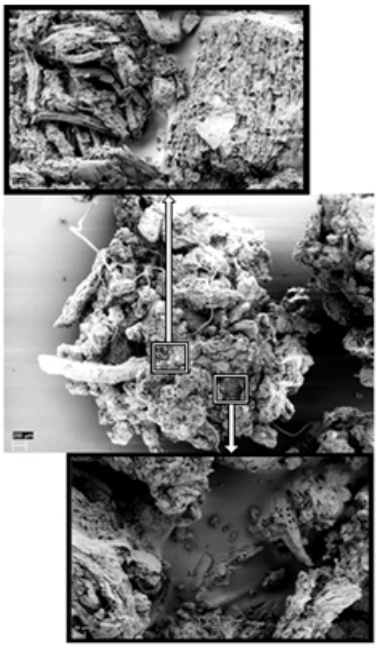


Figure 3. The granule of dispersed waste obtained in the device with fluidized layer. Pictures of REM x50 and x500 (developed by the author)

It was experimentally established that for support of the stable mode of fluidizing of dispersed fraction of waste, it is necessary to use material with the relative humidity no more than 25…35%. Humidity necessary for stable fluidizing can be achieved by means of preliminary atmospheric drying.

For regulation of granulation process of bulk in the device with fluidized layer, an important role is played by such parameters as fluidizing gas flow, current humidity of material and size of granules. The amount of moisture in material affects adhesive power conducing aggregation of material particles, and thereby, increase in the size of granules. The fluidizing gas flow provides suspension of particles conducing their intensive interaction and, thereby, granulation. At the same time, fluidizing gas flow dries up the liquid on particles surface reducing humidity of material. The size of particles increases with increase in humidity, however, particles of the bigger size for suspension require greater air flow.

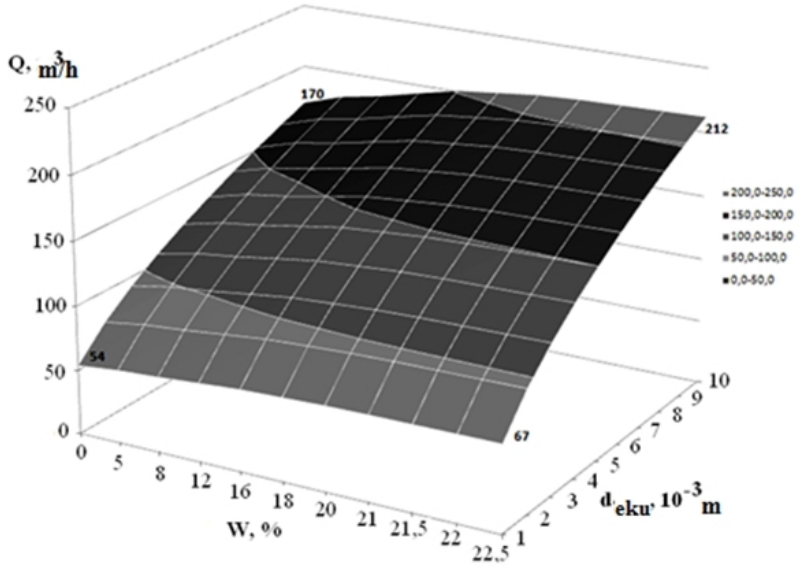
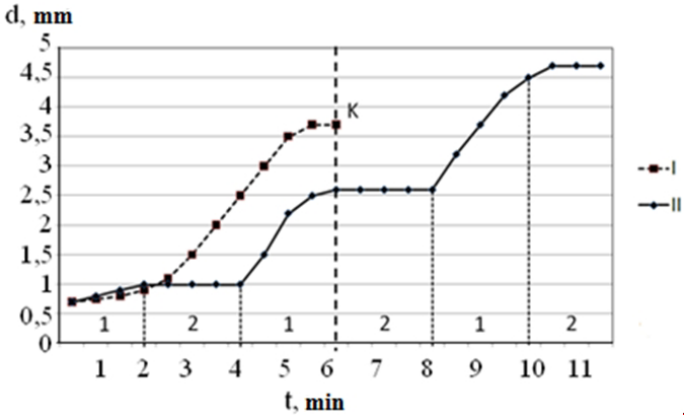


Figure 4. Dependence of process parameters of fluidizing in case of granulation of dispersed fraction of domestic waste (developed by the author)

It was theoretically established and experimentally proved the mutual logarithmic dependence of the size of granules (d_{eku}) on humidity of domestic waste (W) and gas flow (Q) on fluidizing (Figure 4). Such dependence is characteristic of the range of humidity of material of 0 … 25% and the gas flow of 80 … 100 m^3/h in the device of volume ≈3 m^3 .

Also necessity of cyclic delivery of solution of binding material with uniform intervals of delivery was proved experimentally. It allows prevention of unwanted aggregation of particles of dispersed fraction of waste, accumulation of material and drops of binding solution on walls of operating device, and also provides uniform drying of particles in the course of granulation and, respectively, formation of solid granule (Figure 5).

Parameters of supply cyclicity of binding for obtaining optimum strength of granules, in case of which the ratio between supply period of binding liquid and idle fluidizing is 1:1-1:1.2 in average at total duration of intervals of 1.5-2.5 minutes for general time of granulation till 20 minutes, are established.



I – diagram of particles growth in fluidized layer with continuous feed of binding; K –line of critical sticking of material in case of continuous feed binding, granulation process stop; II - diagram of growth of particles with cyclic delivery of binding with an interval of two minutes;
1 – fluidizing stage with supply of binding; 2 – fluidizing stage without supply of binding

Figure 5. Dynamics of increase in the size of granules in fluidized layer in case of continuous and cyclic feed of binding with uniform intervals

Table. Results of granulation of dispersed fraction of waste by different methods

Basic equipment of granulation	Plate granulator	Stamp press	Fluidized layer
Average equivalent diameter of particles, mm	7,5	*Fixed value*	3,099
Granule strength, MPa	0,034	0,3	0,26
Duration of granulation process, min	45…50	5…7	10…12
Necessity of further drying	*Yes*	*No*	*Yes*

High level of strength of agglomerates formed in the granulator with fluidized layer, their high density and low finale humidity allow application of these granules in many processing diagrams. As an example of recovery of dispersed fraction of waste, the technology of thermolysis-energetic recuperation developed by Donetsk National Technical University (Figure 6) is considered [9].

The following principles are the basis for technology of thermo-recuperation:

1) Technology basis is thermolysis of organic part of waste.

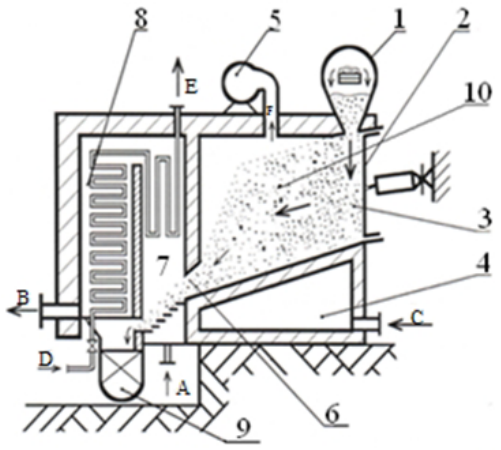
2) Large scale of industrial plants and high technology productivity. Possibility of use of the existing hardware basis of coke-chemical enterprises.

3) Complex nature of recycling. Recovery of organic component, volatile product entrapment, thermal energy obtaining.

4) Recovery of unassorted organic waste. Compounding of mixtures of industrial and domestic solid and liquid wastes.

5) Controllability and flexibility of processes.

6) Complete tightness of the thermolysis equipment, complete cycle of processing, and consequently, high level of ecological safety.



1 - system of charging; 2 – pressing and pushing device; 3 - thermolysis furnace; 4 - heating system of furnace; 5 - system of volatile discharge; 6 - inclined passage; 7 - fire chamber; 8 - boiler unit; 9 - system of ash disposal; 10 - material sintering zone
A - air supply in fire chamber; B - furnace gases for purification; C – supply of gas and air for heating of the furnace; D - water supply in boiler unit; E - discharge of steam to the turbine; F - discharge of chemical products for recycling

Figure 6. Schematic diagram of installation of thermolysis-energetic recuperation of waste [9]

Fundamental distinguish of this technology from other thermal methods of processing is division of heat-carrying agent and processed weight that leads to the minimum formation of volatiles containing dioxines [10]. At the same time, the volatile components, which are formed during thermolysis, are less polluted than when burning, inasmuch as the process is carried with compacting of the initial raw materials. It is provided with repressing of bulk mass of waste after charging in the furnace in the course of its layered sintering that almost completely excludes formation of dust fractions in gas products.

Recovery of waste by coking puts certain requirements to material. It is theoretically justified and experimentally proved that by analogy with coke-chemical production, thermolysis of waste particles is possible only at certain granulometric composition of particle with the size <1 mm - 25-27%, 1-3 mm - 40-45%,> 3 mm - 28-35%. It is caused by certain ratio of large and small-sized particles of material for achievement of the maximum bulk density, which is conductive to the better sintering, at the same time providing sufficient gasification of material during thermolysis. The size of granules of dispersed fraction of waste obtained in case of granulation in the device with fluidized layer ($d_{eku} \approx 3$ mm) is comparable to the necessary size of furnace charge for effective sintering in chamber furnaces, and allows providing of necessary level of gasification and enough contact sintering points. Thus, it is possible to draw a conclusion that the granules of dispersed fraction of domestic waste obtained in case of granulation in the device with fluidized layer are suitable for their further processing by thermal methods including in technology of thermal-recuperation in chamber furnaces. The granules of dispersible fraction of waste obtained in fluidized layer can be also used as the component in carbon furnace charge without coke quality loss. Efficiency of such processing was experimentally confirmed on the hardware basis of PJSC "Avdeevka Coke Plant".

The preliminary evaluation of economic effect of such recycling method application under the conditions of our state has shown the following results:

- the cost of industrial complex of productivity on the initial raw materials of 2 mil. tons per year is 20 mil. c.u.;
- construction period – 1.5-2 years;
- profit of the project – 8-10 mil. c.u./ year;
- payback period – 2-3 years.

Practical implementation of this technology is supposed to be on platforms and with use of infrastructure and personnel of the existing coke-chemical plants allowing application their potential. Thus, relevant scientific problem of creation of technological basis for elimination of stored waste on an industrial basis and safe recycling of their ecologically aggressive fine components due to grounding of rational processes and parameters of granulation providing control of fractional and moist composition of the obtained product is solved in the paper.

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Investigation of strength and corrosion resistance properties of combined packaging materials for metal products

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Abstract
In the paper, strength and corrosion resistance properties of combined packing materials for protection of steel products are studied. It is established that in case of steel products application, the most unfavorable temperature range is the interval (30-40)˚C when growth of vapor transmission rate of packing materials is observed and access of water vapors to metal surface increases. The packing papers containing vapor-phase inhibitors of corrosion have protective effect under the conditions of the increased relative humidity: the index of corrosion does not exceed 5.0 g/m^2.
Key words: COMBINED PACKING MATERIALS, DEFORMATION AND STRENGTH PROPERTIES, CORROSION RESISTANCE PROPERTIES, HUMIDITY, STEEL PRODUCTS

Introduction

Today and in the foreseeable future, metal remains the main constructional material of which different products are made. The main problem of metal products during application, storage and transportation under different conditions is their corrosion [1-2]. According to the experts, corrosion in a year destroys from 25 to 30% of annual output of ferrous metals. It specifies primary importance of problem of metals corrosion prevention, and therefore, big significance of search of optimum packing materials for anticorrosive protection of metals.

The progressive direction in corrosion prevention is development of the packing materials containing inhibitors of corrosion [3-6]. In recent years, this problem has risen especially seriously due to extension of export of steel products. In some cases, the products are transported in open wagons or by sea through the regions with humid tropical climate that is the favorable medium for corrosion processes.

On the one hand, perfect package for steel products should totally exclude access of water vapors and aggressive gases causing corrosion to metal product surface, but on the other hand, it should absorb moisture which is inside after packing of product and condensed in case of temperature differences. Moreover, it should possess the necessary strength properties guaranteeing its safety and preventing of packed hardware from mechanical damages. Package should provide counteraction to different loadings in case of

logistic operations.

The packing combined materials containing volatile corrosion inhibitors (VCI), which successfully compete with traditional means of anticorrosive protection (oils, lubrications, varnishes, enamels, etc.), correspond to the criteria stated above. Crepe base paper is carrier of corrosion inhibitor and absorber of condensation moisture. The polymeric covering is a barrier from atmospheric contaminants and moisture. For increase of strengthening properties of packing material, the paper web is reinforced by grid from polypropylene threads.

The purpose of researches consists in study of physical and mechanical and protective properties of packing materials under the conditions of atmospheric corrosion.

For achievement of purpose, the following problems were solved:

- to study physical and mechanical properties of combined packing materials;
- to analyze barrier properties of packing materials;
- to evaluate corrosion-preventing properties of packing papers under the conditions of atmospheric corrosion.

Materials and methods of research

The package papers Fislage (Germany) laminated by polyethylene, reinforced by polypropylene grid and containing volatile corrosion inhibitors were the objects of research (Table 1). Package paper Fislage with N inhibitor is intended for packing of cold-rolled steel, with Z inhibitor is intended for packing of galvanized steel. The composition of volatile corrosion inhibitors (VCI) is confidential.

Table 1. Objects of research

Paper name	Inhibitor	Inhibitor mass, g/m^2	Paper mass, g/m^2
Fislage	Volatile «N»	9,5	159,0
Fislage	Volatile «Z»	12,7	170,0

Deformation and strength properties of the studied materials were determined by the universal electromechanical test machine Walter+baiag with digital control system EDC-120 according to GOST 30436-96 (ISO 1924-2-85).

Materials strength in case of stretching or breaking stress is characterized by strength limit, that is maximum stress σ which is withstood by material without destruction (gap). The breaking strength in case of σ_T (Pa) is determined by formula (1):

$$\sigma_T = \frac{F_{\max}}{S}, \qquad (1)$$

where $F_{\max}$ – maximum tensile strength, N;

S – cross-sectional area, m^2.

The relative lengthening of material in case of stretching (%) is determined as ratio of absolute deformation Δl (m) to the initial length of sample of l (m) (2):

$$\varepsilon = \frac{\Delta l}{l} \cdot 100, \qquad (2)$$

Vapor transmission rate of combined materials in the range of temperatures from 20 to 60 ˚C was determined in accordance with GOST by 9.507-88. Vapor transmission rate of q is expressed in grams of water vapors which passed through the unit of surface of combined material within 24 hours at the specified temperature and relative humidity (95±5) % and is calculated in g/m^2 for 24 h by formula (3):

$$q = \frac{9{,}6 \cdot 10^7 \cdot \Delta m}{\pi \cdot d_{in}^2 \cdot \tau}, \qquad (3)$$

where Δm - mass change, g;

d_{in} – inside diameter of sample, mm;

τ – test time, h.

For evaluation of absorption capacity, samples of package papers were exposed under conditions of various relative humidity, then changes of samples mass were determined gravimetrically.

Under the conditions of various relative humidity, evaluation of protective effect of package papers from atmospheric corrosion of cold-rolled and zinc galvanized steel according to GOST 9.054-75 was carried out.

The metal plates packed into the studied papers were exposed under conditions of various relative humidity within 30 days. Tests with periodic moisture condensation in samples were carried out cyclically. Each cycle consists of two parts. In the first part of cycle samples are affected by air medium with temperature (40±2) ˚C and relative humidity (95±3) % within seven hours. In the second part of cycle, moisture condensation conditions within 17 hours are formed. Corrosion index K (g/m^2) was calculated according to test results by formula (4) [7]:

$$K = \frac{m_1 - m_2}{S \cdot \tau}, \qquad (4)$$

where m_1 – initial mass of sample, g;

m_2 - sample mass after tests, g;

S - sample surface area, m^2.

Speed of uniform (general) corrosion (g/m^2 · w) is determined by formula (5):

$$V = \frac{m_1 - m_2}{S \cdot \tau}, \quad (5)$$

Protective effect of corrosion inhibitors Z (%) on loss of control samples mass was determined by formula (6):

$$Z = \frac{V_0 - V}{V_0} \cdot 100, \quad (6)$$

where V_0 – speed of sample corrosion in case of absence of inhibitor, g/m^2 · h;

V – speed of sample corrosion with inhibitor, g/m2 · h.

Results of research and their analyze

The typical deformation curve of package paper Fislage is provided in Figure 1.

The maximum in curve corresponds to rupture of thin polyethylene covering. Further deformation is of stage character due to stretching and break of crepe paper and polypropylene threads.

The relative lengthening of sample of paper Fislage "Z" is insufficient at the destruction point (Table 2), therefore, problems in case of the mechanized package of steel rolls, namely, paper break and discontinuance of package, can appear.

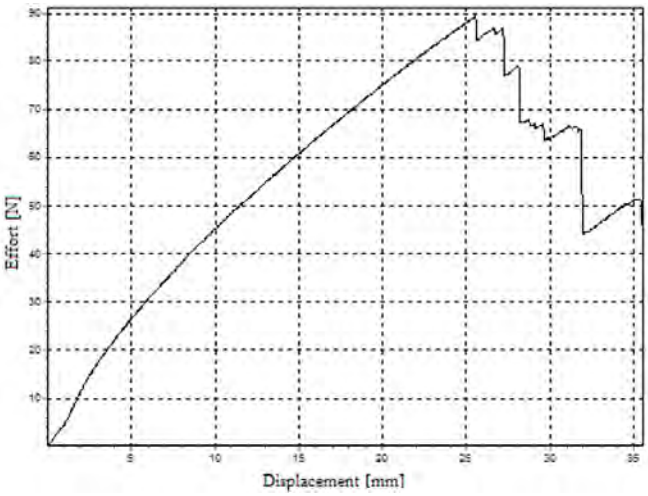

Figure 1. Deformation curve of package paper Fislage

Table 2. Deformation and strength properties

Indices	Type of paper	
	Fislage «N»	Fislage «Z»
Maximum load, N	82,0	82,0
Breaking strength, kN/m	5,4	5,4
The relative lengthening at the destruction point, %	29,0	16,0

The important factor determining the speed of atmospheric corrosion is humidity. The amount of water, which is condensed when cooling on metal surface, depends on the relative humidity. Thus, thickness of the water film, which is formed on iron surface in case of relative air humidity of 55%, is 15 molecular layers, and in case of the relative humidity of 100% is 90-100 layers [2]. The crepe base paper of package material should absorb condensation moisture and therefore prevent development of corrosion process.

Barrier properties of packing materials in relation to water vapors can be evaluated through vapor transmission rate, that is transfer of water vapor through packing material. Driving force of this process is differential of pressures or concentration. Two mechanisms of process of vapor transmission rate are implemented in combined packing material. In polymeric material, transmission is caused by diffusion processes, which are described by the first Fick's law. Molecular diffusion always proceeds in the direction of concentration reduction and depends on properties of diffusing substance, properties of packing material, temperature and pressure [2]. Passing of water molecules through the base paper is of more complex nature that includes the diffusion mechanism of vapors transfer and mechanism of streamline flow submitting to the Poiseuille's law [8].

Temperature dependence of vapor transmission rate of the studied packing papers is provided in Figure 2. In case of temperature increase, growth of vapor transmission rate is caused by the following processes: water molecules form hydrogen bindings with cellulose hydroxyl group that conduces cellulose swelling. In case of further temperature increase, breaking of hydrogen bindings takes place that is followed by growth of kinetic mobility of macromolecules of cellulose, their binding and compacting; consequently, vapor transmission rate is reduced [8].

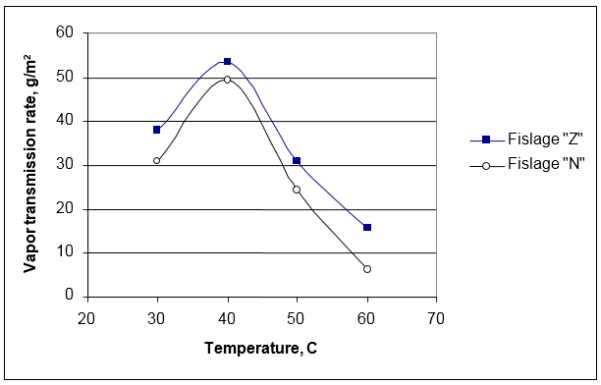

Figure 2. Temperature dependence of vapor transmission rate

Thus, the most unfavorable temperature range from the standpoint of operation is the interval of 30-40 °C when growth of vapor transmission rate is observed and access of water vapors to metal surface increases.

The main benefit of packing materials on paper basis is ability of paper to absorb the moisture which is condensed in package in case of temperature differences. Dependence of mass of packing papers on relative air humidity is presented in Figure 3.

In case of low values of relative humidity, water vapors are occluded forming hydrogen bindings with cellulose hydroxyl group. In case of the relative humidity of 75-85%, certain level of saturation is reached that is followed by devitrification and restoration of structure of cellulose fibers with thin system of pores and capillaries. In these pores and capillaries, condensation of water vapors takes place. The main increase in water absorption is observed in the field of relative humidity higher than 90% in course of process of capillary condensation [8, 9].

The evaluation of protective action of package papers from atmospheric corrosion of cold-rolled and zinc galvanized steel was carried out under the conditions of various relative humidity. Results of corrosion-preventing tests and calculations are presented in Table 3.

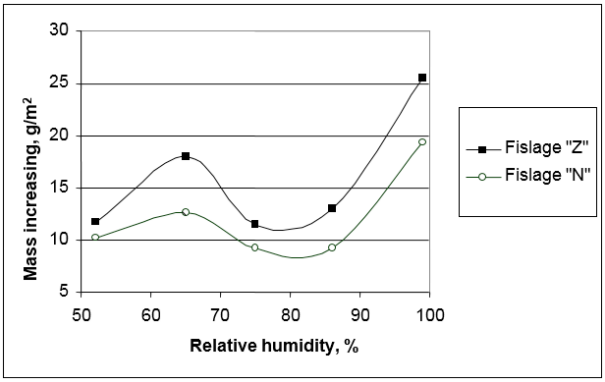

Figure 3. Dependence of papers mass on the relative humidity

Table 3. Results of corrosion-preventing tests under the conditions of various relative humidity

Paper sample	Relative moisture, %	Corrosion products mass, g	Corrosive index K, g/m²	Corrosion rate V, g/m² ·h	Protective effect of corrosion inhibitors Z, %
Paper without inhibitor	52	0,053	11,8	0,016	-
	65	0,044	8,7	0,012	-
	75	0,178	34,0	0,047	-
	86	0,132	25,1	0,035	-
	99	0,093	17,9	0,025	-
Fislage “N”	52	0,016	3,9	0,005	69
	65	0,017	2,2	0,003	75
	75	0,019	2,8	0,004	91
	86	0,015	3,2	0,004	89
	99	0,017	4,2	0,006	76
Fislage “Z”	52	0,006	1,3	0,002	87
	65	0,013	2,9	0,004	67
	75	0,009	1,9	0,003	94
	86	0,014	3,1	0,004	89
	99	0,008	2,3	0,003	88

According to [10], products of atmospheric corrosion on cold-rolled steel are $FeOOH$, Fe_2O_3 and Fe_3O_4, on zinc galvanized steel they are $2ZnCO_3 \cdot 3Zn(OH)_2$ and $ZnCO_3 \cdot 3Zn(OH)_2$. After exposure under the con-

ditions of the increased relative humidity, the mass of plates made of cold-rolled steel increased. Weight increasing of metal corresponds to the mass of corrosion products, which have good adhesion to metal. The mass of plates made of galvanized steel is generally reduced that demonstrates loss of corrosion products due to their bad coupling with the surface of metal and partial dilution.

Dependence of index of corrosion on the relative humidity for the plates packed into papers Fislage is approximately at the same level - less than 5 g/m^2 (Figure 4) that is caused by protective effect of volatile corrosion inhibitor [2, 3].

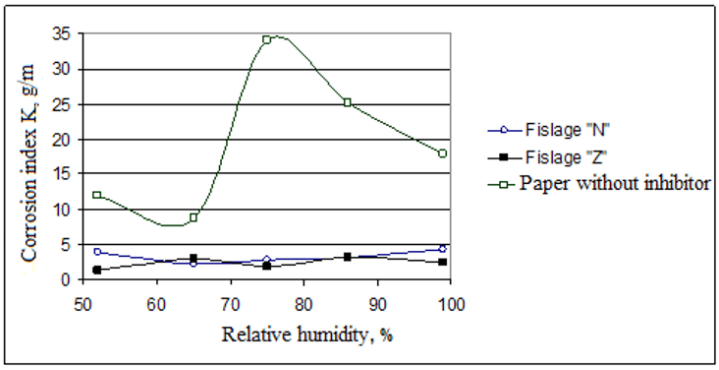

Figure 4. Dependence of index of corrosion on the relative humidity

Corrosion index values for the plates packed into paper without volatile inhibitor of corrosion is much higher. The maximum corrosion corresponds to the relative humidity of 75-80%.

Conclusions

Thus, in course of evaluation of deformation and strength properties, it has been revealed that the relative lengthening of sample of paper Fislage "Z" is insufficient at the destruction point (Table 2), therefore, problems in case of the mechanized package of metal products can appear.

Thus, it has been established that the most unfavorable temperature range from the standpoint of operation is the interval of 30-40 °C when growth of vapor transmission rate is observed and access of water vapors to metal surface increases.

The low absorbing ability of papers in the field of relative humidity of 75-85% conduces formation of thin film of water on the surface of metal plate that leads to emergence and development of corrosion process.

The packing papers containing vapor-phase inhibitors of corrosion have protective effect under the conditions of the increased relative humidity: the index of corrosion does not exceed 5.0 g/m^2.

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Reliability process of long-term operated gas pipelines in difficult mining and geological conditions

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Abstract
The analysis of emergency risk starts with expert assessment of conditions and mechanisms of accidents on concrete components of gas transmission and formation of general idea about priority of certain actions concerning reliability increase. At the same time experts should be informed about accidents, taking place both on the object, and on the similar objects. Information on all service conditions of the considered object is also important.
Key words: FATIGUE, FLOOD, STRESS RAISER, WELDED JOINT, WELDED SEAM, GAS PIPELINE, STATIC LOAD, LOW-FREQUENCY LOAD

The problem of ensuring of high operational reliability of main pipelines (MP) is important for national economy of Ukraine as their considerable part is operated for a long time and has already depleted the standard resource. Stable work of MT and its high economical efficiency, first of all, depends on its technical condition. When estimating technical condition of the pipeline, the prominent place is held by reliable determination of strain-stress state (SSS) of its linear part as one of major factors on which depends the level of operational reliability of construction [1, 2].

During emergency (unsealing) of gas pipelines explosive gas comes to the surface under high pressure into atmosphere. At pressure decrease in the gas

pipeline automatic devices for cranes closing are activated that turns over emergency division. Volume of gas reached the environment depends on the length and is blocked by automatic mechanisms of division and reaction time of block valves. Propagation distance of a cloud of explosive mix in the direction of wind is determined by empirical formula:

$$l = 25 \cdot \sqrt{\frac{M}{w}} \text{ , m} \qquad (1)$$

where M – mass velocity of gas from damaged area of gas pipeline, kg/s; w– wind speed, m/s.

USA scientists faced more serious problem. Formula for determination of radius of potential impact (PIR - potential impact radius) is unusable in Willa Houston view. In particular, in regulating documents of the USA the formula for determination of potential impact radius looks as follows:

$$r = 0.69 \cdot D \cdot \sqrt{p} \text{ ,} \qquad (2)$$

where r – radius of potential effect, foot (1 foot = = 0.3048 m);

p – maximum working (operating) pressure, pounds per square inch (1 pound per square inch = = 6834.76 Pa);

D – outer diameter of gas pipeline, inches (1 inch= = 0.0254 m).

Edison Township, New Jersey, 4/23/94 TETCO – explosion of gas pipeline (36» pipe diameter, working pressure 975 pounds per square inch). Forecasted PIR is 775 feet (236.4 m). However, visually the radius of action is 1000 feet (304.8 m) (fig.1). 70 people were injured, 1500 people were evacuated, 9 placements were destroyed.

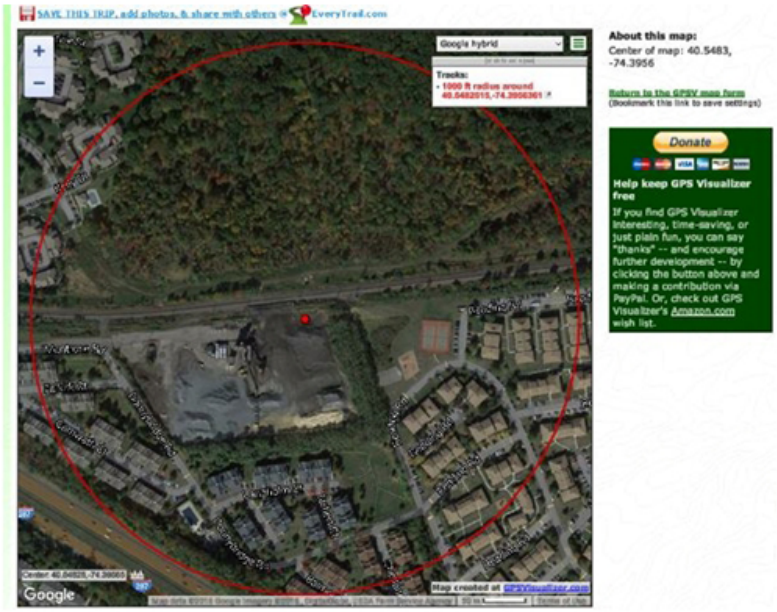

Figure 1. Accident on the gas pipeline Edison, the State of New Jersey, USA, 1994

In work [4] there suggested formula for evaluation of effective zone during failure of main gas pipeline along full cross-section:

$$r = 99 \cdot D \cdot \sqrt{p} \text{ ,} \qquad (3)$$

where: r – potential effect radius, m;

p – maximum working pressure, MPa;

D – outer diameter of gas pipeline, m.

Having applied formula 3 for calculation, according to the mentioned above data we obtained 234.7 m (770 feet). As one may see there is small inaccuracy.

On May 12, 2014 there occurred unsealing of aerial crossing of MG «Urengoy - Pomary - Uzhhorod» (4268.4 km.) through the river of Limnitsya. During investigation of pipe body there was revealed a handling mark of oval form with dimensions of 300*285 mm, depth 49 mm, in the center of handling mark there is a through crack with the length of 70 mm, crack extension – up to 4.0 mm at a distance of 2870 mm from 12 hours in the place of circular weld between the 2nd and 3rd segmented bends (along the gas flow) at the entrance of aerial crossing of MP "Urengoy-Pomary- Uzhgorod" through the river of Limnitsya. In the place of refusal there are no corrosion or other defects that is confirmed by data of in-line and visual inspections. The committee considers that the reason of failure is mechanical damage of pipeline from outside by strangers as a result of operation of explosive device of unknown design that led to formation of oval handling mark with through crack.

Figure 2. Aerial crossing of MP "Urengoy-Pomary- Uzhgorod" through the river of Limnitsa

Figure 3. Pipelines passing in one technological corridor and cross natural obstacles

Statistics shows that about 80% of accidents are followed by heavy fires and explosions. There appear sparks as a result of interaction of gas particles with metal and firm particles of the soil. As is seen from the figure 3, in the mountain area, in particular Ivano-Frankivsk and Transcarpathian Region, pipelines pass in one technological pipeline, cross natural and artificial obstacles.

For safe operation and reduction of losses during accidents, it is necessary to clearly establish and define the area of explosive influence. Let us analyze and calculate a zone of potential influence for gas pipelines, passing in parallel, in particular «Urengoy-Pomary- Uzhgorod» and «Progres».

Change of knocking zone value is represented in figures 4-6.

Simple burning can turn into explosion due to the speed of distribution of flame at its propagation across the relief and in forests.

Besides, at guillotine rupture of gas pipeline of high pressure there is distribution of metal pieces and fragments of pipes as during destruction of the pipeline energy of expansion of gas is spent for pipe deformation, its destruction, formation of primary and secondary splinters.

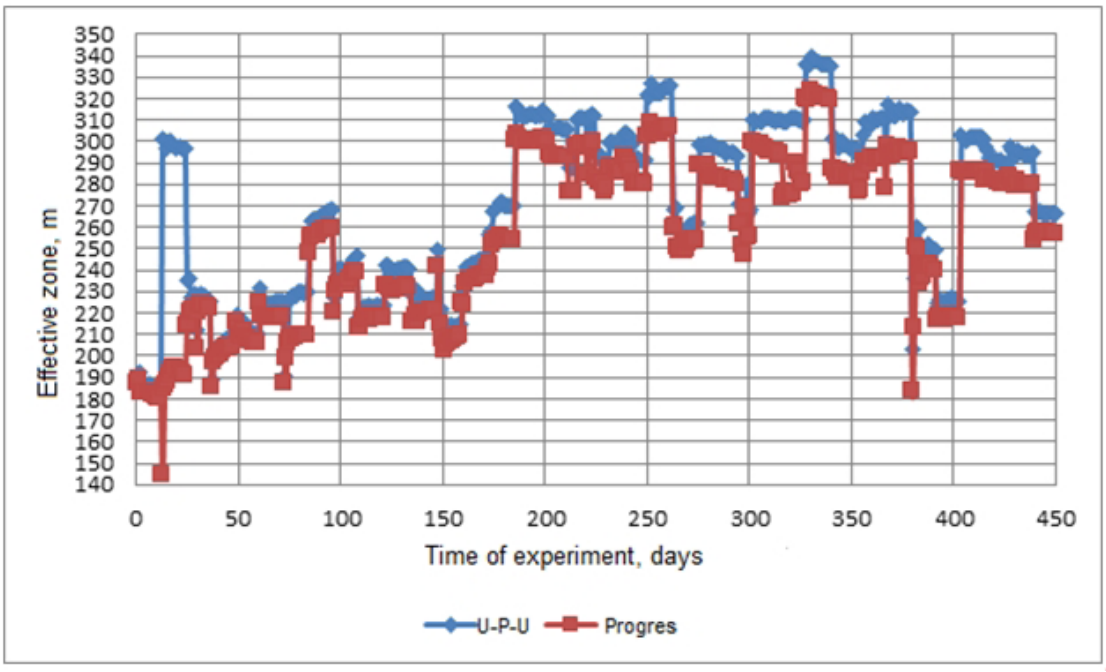

Figure 4. Radius of potential effect, in meters, that occurs in result of change of gas transportation mode (according to formula 1)

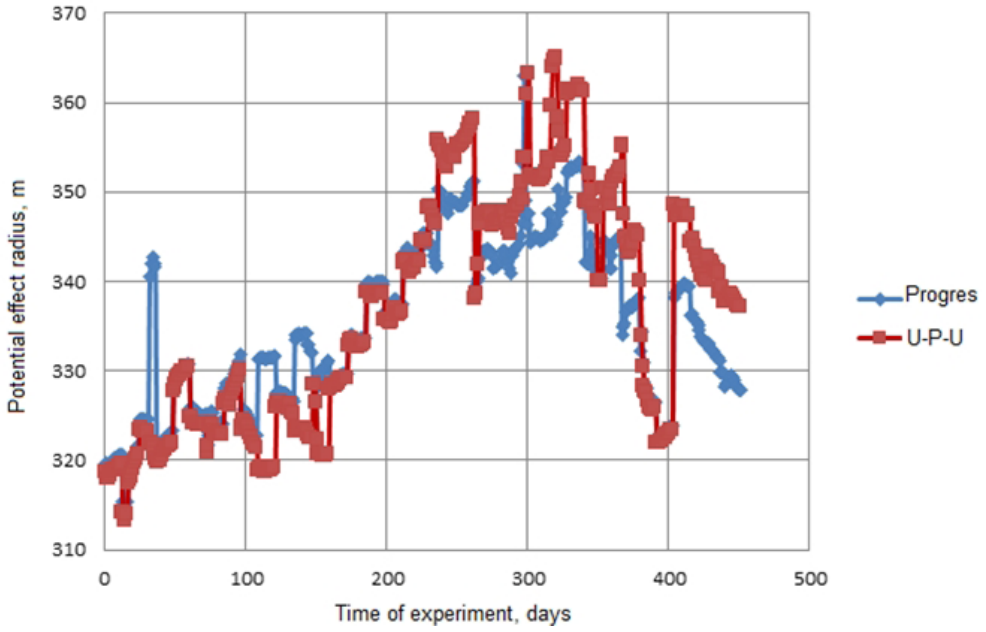

Figure 5. Radius of potential effect, in meters, that occurs in result of change of gas transportation mode (according to formula 2)

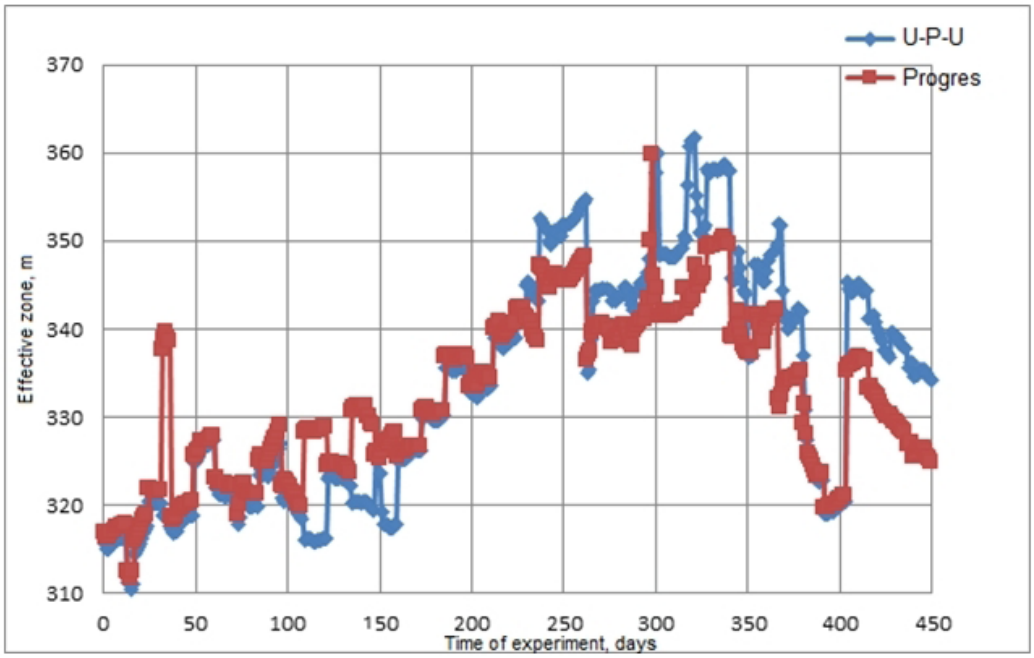

Figure 6. Radius of potential effect, in meters, that occurs in result of change of gas transportation mode (according to formula 3)

Conclusions

During researches the maximum value of knocking zone is 340 m, and minimum - 140 m. Effort variation factor is 162% that testifies to considerable nonuniformity of selection and consequently the modes of operation of gas pipeline. Change of knocking zone causes change of influence of operation of main pipelines on environment and therefore requires additional checking. Mass flow, which describes processes of origin of sharp amplitude oscillations of pipeline effective zones, dominates.

To increase the safety of operation of the main gas pipelines, it is necessary to analyze creation of security and safe zone towards the axis of pipeline construction. Taking into account the above-mentioned facts, it is possible to tell that correctly calculated and well balanced security zone as well as timely and good-quality engineering service of pipelines will con-

siderably reduce losses and scales of accidents.

With respect to the available data, including explosions in the USA, for the pipelines passing in one technological corridor, private data on the value of radius of potential influence should be available.

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Project-oriented approach to metallurgical enterprises sustainable development management

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Abstract
The management of sustainable development of metallurgical enterprises through a portfolio of projects is examined. There are presented a conceptual framework for managing projects portfolios in organization and formalization of methodological bases of creation of value-oriented development portfolio for metallurgical enterprises.
Keywords: SUSTAINABLE DEVELOPMENT OF METALLURGICAL ENTERPRISES, FORMATION OF A PROJECTS PORTFOLIO, MANAGEMENT BY VALUES

Introduction

In June 1992 at the UN Conference on environment and development representatives of 178 countries signed a Declaration on sustainable human development, as a biosocial system in conditions of growth speed of environmental changes [1]. This event is directly related to the approach, which was introduced into science under the name of "sustainable develop-

ment", which allowed doing in the professional literature a large number of generalizations regarding the proposed concept [2-4]. Since metallurgy is one of the main branches of economy of Ukraine, therefore the effective modernization of this sector has a key importance in the context of sustainable development. Proposed for consideration in Johannesburg summit plan of action for the sustainable development strategy consisted of ten items, among which the particular importance for Ukraine have, in our opinion, the following three: to guide the process of globalization towards promoting sustainable development; to modify the national model of production from raw material processing to innovative service [4]; to strengthen international governance of sustainable development. Ukraine is planning a gradual transition to sustainable development strategies too. In 2003, there was created the national Commission of sustainable development of Ukraine and approved the "Integrated program of national implementation of decisions taken at the world summit on sustainable development, for 2003-2015". However, there is a lack of financial resources for the system concrete actions [5, 6]. At the moment in Ukraine there are very few companies that would not implement innovative projects, but not all of them use the same corporate methodology of project portfolio management that is detrimental to efficiency and results.

A common mistake is that there is no clear correspondence between the strategy of sustainable enterprise development and implementation of portfolio management. The mastery of Ukrainian managers of portfolio management methodology would allow enterprises to better realize their strategic priorities and commitments. The mastery of Ukrainian managers of project management basic methodology would allow the country's leadership to implement their strategic priorities and commitments.

The analysis of literature and problem statement

During the last years the numerous scientific discussions about the search for a conceptual model of sustainable development that are relevant to many global challenges were conducted. The most reputable scientists recognized that the systemic imperative of life and activity of society is the concept of sustainable development, which declared equal and harmonious combination of three elements of social system – economic, social and environmental aspects [7].

International UN forum on sustainable development held in June 2012, confirmed the conformity of the named concept, and most of the forum partici pants mentioned among the priority ideas, that will have the greatest impact on humanity in the period up to 2050, the idea of sustainable business [8].

However, theoretical development and implementation of competitive strategies for sustainable development directly depends on the decision of problems of methodology and formation of "modern paradigm of development" [9], which can be a powerful stimulus to socio-economic transformation.

Taking into account the availability of developed tools to support processes of sustainable development in the theory of organizational development [10, 11], it should be noted that the project management methodology of sustainable development with some exceptions [12, 13] does not exist. However, today project management has become a universally recognized tool of the evolutionary development of organizations through the integration of elements of strategic and tactical management. The following study is one of the first attempts of application of the sustainable development general provisions to the modernization of metallurgic enterprises through portfolios of projects.

Purpose and objectives of the study

The conducted research was aimed to determine the features of project management for sustainable development of metallurgical industry of Ukraine. In the world there are a large number of technological and structural solutions for reduction of energy consumption and emissions of the steel industry [14]. The aim of this work is an overview of the methodology and tools for portfolio management of development organizations in the context of achieving sustainable development of native steel industry.

Methodical materials of the study

Today the metallurgical industry of Ukraine meets very serious challenges. The paradigm of sustainable development requires from the steel industry reduction of energy consumption and environmental pollution while maintaining production volumes and this in turn requires considerable investment. In 2009, Boston consulting group [15] identified three main challenges facing the metallurgical enterprises, which can be defined as follows:

– despite continuous growth of energy costs it should remain competitive;

– it is necessary to improve production performance while reducing environmental pollution;

– it is necessary to use new resources in time that arise with the development of technology.

Below is the analysis of possibilities of solutions to these three problems for Ukrainian metallurgical enterprises by the implementation of a portfolio of

sustainable development projects.

The results of the study

Ukrainian metallurgical companies are moving to the concept of value-oriented business management (Value Based Management). But in order value-oriented business management to become possible, it is necessary to have effective methods of assessing and increasing the value of the business. The value of business has been and remains a figure that has several meanings, depending on the purpose and stakeholders. There is only a certain reference value towards which the rating tends. When analyzing the values of one company, you should first focus on the values of sustainable business as a going concern, bringing revenue. There is only a certain reference value sought by the estimates. When analyzing the values of one enterprise should first focus on the value of sustainable business as an operating enterprise bringing revenue.

The category of "sustainable enterprise development" should be considered as a system combination of two components – resistance of achieved state and stability of motion, determined by system development. The first value is scalar and is characterized by the sustainability of number of indicators, such as profits and costs. With a long-term perspective, the stability of the system state implies keeping it within a certain time period. The second component of sustainability is directly linked to the trend of movement to a specific purpose, and therefore determines the stability of the direction of development and its speed.

In mature systems, project management at the highest level is used as a projects portfolios management. Current research of portfolio management is enhanced by intensive growth of the number of problems the solution of which requires changes in the scientific approach. The implementation of portfolio development can be considered primarily as an approximation to the ideal condition, "portrait" of which at a certain development stage "drew" organizationally-technical system. As is known, the system may not be successful in its development, if it successfully implements the "wrong" projects. Thus, all components of the development portfolio should correspond with the main vector of development of organizational-technical system.

The introduction of professional project management in the enterprise management should be started with individual projects. It is believed that in order to efficiently manage the projects portfolio, companies must first master the management of individual projects and programs. Portfolio represents a set of portfolios, programs, projects and individual works, which are united in a point in time [15]. Management of the portfolio requires from managers holistic thinking embracing the complexity of problems and the sources of their occurrence, to properly understand the relationships and interaction between phenomena and processes which are related to different levels of project management [16].

The first step in the process of value-oriented system development based on the standard P2M [17] is a description of mission that defines the vision of the dominant organizational values, on the base of which corresponding strategy is developed. Next, the strategy must be translated into the main objective of the program/portfolio, which is broken down into subgoals corresponding to the priority directions of development of the organization. In the practice of value management there considered the following three functions: identify value, create value, assess the value [17]. To identify the value of the project product or its results often means just copy the values. Imitation and copying of the product value is the path that passed many well-known companies. According to the evolutionary theory of the development of human values of K. Graves [18] the company makes development strategy, relying on the dominant system of values, because values govern the behavior of managers. When building a strategic development focus of the campaign the predominant level of values of the campaign should be considered, as that is the only way to realize the unique properties of the organization to create competitive advantages.

The main features of the transformation in project management are organizational, technical and social systems at any level. The basic Foundation of project oriented management system development is the concept of 5P (Portfolio – Program – Project – Process – Product), which is focused on the continued reproduction of the products of the projects portfolio [15].

Today, the concept of project oriented management in world standards and models is treated from different points of view, that effect on the requirements for procedures and means of projects, programs and portfolios management. In practice, many Ukrainian companies already using the terms and definitions given in the system of knowledge PMI [16] and P2M [17]. A comparative review of various aspects of project, program and portfolio management is considered in table 1, which summarizes the major provisions of the organizational platform of project management [16].

In the system of knowledge of PMI [15] portfolio management is represented by two process groups:

aligning process group and monitoring and control process group. Aligning Process Group determines how components of portfolio will be categorized, evaluated and selected for inclusion, and managed in the portfolio. Monitoring and control process group based on key performance indicators, which are periodically reviewed for alignment with strategic objectives.

Models of portfolio formation can be divided into two broad classes: one-criteria and multi-criteria [10]. Formation of portfolio of sustainable development is definitely applied to multicriteria problems. To solve this problem, you need to submit the value of the proposed alternative projects in the numeric criteria. The system of criteria in the general case may include both a quantitative and qualitative criteria. And the values of characteristics of alternative projects can be specified both by continuous and discrete values.

Most often in practice there applied methods for the formation of the portfolio, which are focused on the evaluation of the project from the point of view of its financial indicators (ROI, NPV, DPP, PI) [10, 11]. However, the portfolio of sustainable development companies should include only the projects that bring the greatest value to sustainable development, and meet resource and time limitations. In this regard, there is a problem of estimating the value of the project, how closely it matches the sustainable development strategy of an enterprise at the given conditions. So the list of projects candidates into the portfolio in addition to financial performance should contain quantitative indicators of certain aspects of sustainable development of the enterprise.

Table 1. Comparative overview of Project, Program, and Portfolio Management

Aspect	Projects	Programs	Portfolio
Scope	Projects have defined objectives. Scope is progressively elaborated throughout the project life cycle.	Programs have a larger scope and provide more significant benefits	Portfolios have an organizational scope that changes with the strategic objectives of the organization.
Changes	Project managers expect changes and implement processes to keep change managed and controlled	Program managers expect changes from both inside and outside the program and are prepared to manage it.	Portfolio managers continuously monitor changes in the broader internal and external environment.
Planning	Project managers progressively elaborate high-level information into detailed plans throughout the project life cycle.	Program managers develop the overall program plan and create high-level plans to guide detailed planning at the component level.	Portfolio managers create and maintain necessary processes and communication relative to the aggregate portfolio.
Management	Project managers manage project team to meet the project objectives.	Program managers manage the program staff and the project managers; they provide vision and overall leadership.	Portfolio managers may manage or coordinate portfolio management staff, or program staff and the project management staff that may have reporting responsibilities into the aggregate portfolio.
Success	Success is measured by product and project quality, timeliness, budget compliance, and degree of customer satisfaction.	Success is measured by the degree to which the program satisfies the needs and benefits for which it was undertaken.	Success is measured in terms of the aggregate investment performance and benefit realization of the portfolio.

Monitoring	Project managers monitor and control the work of producing the products, services, or results that the project was undertaken to produce	Program managers monitor the progress of program components to ensure the overall goals, schedules, budget and benefits of the program will be met	Portfolio managers monitor the strategic changes and aggregate resource allocation, performance results, and risk of the portfolio.

In general, during portfolio formation one should select projects with fairly large set of parameters that solve the problem of multi decision and deal with many alternatives, with a set of criteria and with plural scales of criteria evaluation. To simplify this task there used methods of rolling of values by weighted criteria method, which was proposed by T. Saaty in the last century. [19]

The main principles of the method are based on the fact that for practical purposes the system is often seen in the form of hierarchical structure that reflects the relationship of its components and their importance for the functioning of the whole system. If we consider the elements in each group independent, the assessment of options for making decision by analysis of the hierarchy is as follows:

1. The system is represented as hierarchical tree showing the relationships of related items.

2. For calculations there used matrix comparisons priority elements of the lower level of the hierarchy in terms of top-level elements, determined by experts.

3. The vector, which is calculated on these matrices relative priorities, is own normal judgments matrix vector.

But the main difficulty in applying this method of writing arises in a particular subject area, in this case the required information on the properties, relationships, constraints, axioms and assertions for a particular steel plant. The source of information for such modeling are the experts and documents from various divisions, which reflects the financial, technological, human and other aspects of the company.

Currently, there is no any common design methodologies and verification model for these purposes. Among the general issues concerning modeling, there distinguished some fundamental rules and generally offered one of the possible ways to develop the domain [20]. Suggested in [20] iterative approach begins with the first superficial description of the subject area, which then is reviewed and refined at the next steps. But such information is not enough for determination of portfolio of sustainable enterprise development. It is necessary to consider the current quarter relative to the dynamic environment, the complexity is constantly increasing. The continuous growth of algorithmic complexity of the environment makes the need for development of tools based on the creative transformation capabilities and resources to build the projected future.

Thus, the task of selecting project portfolio to sustainable development comes down to the task of maximizing the integral target criteria $F(\cdot)$.

Formally, this problem can be represented as follows:

$$F(s) \rightarrow \max,\ s \in S \qquad (1)$$

where S – vector of possible strategies.

At the stage of pre-selection of projects it was deliberately eliminated inefficient projects. At this stage, instead of the criterion of maximum objective function, it is more appropriate to use a certain threshold value criterion of efficiency:

$$F(s) \geq D,\quad s \in S_D \qquad (2)$$

where D – some real number; S_D – subset of set S .

The next step is an analysis of the most competitive projects. Analysis estimates and searches the optimal solution, which is determined by the type of the problem. For structured problems described by objective models, it uses techniques of additive or multiplicative convolution, selection of main criteria and displaying the others criteria as other restrictions. There are a fairly large number of methods for expert evaluation of the effectiveness of projects based essentially on a single methodological basis, differing mainly by the terms and subject of applicability industry. At the level of programs/portfolios to quantify the effectiveness discounted cash flow method and expert assessments are commonly used. The most adequate to the requirements of [20] is a method of expert review of important parameters and their assessment in points. In this method each expert evaluates the options according to a point system. The different factors weighted by experts provide a transition from the parameter estimates in points to coefficients weight.

Based on this information, you can create a portfolio of projects that will provide maximum value to the organization. Unfortunately in professional litera

ture, there are few works, in which the object of study would be large portfolio of projects as a means of synergetic development of complex systems. By the effect of synergies of portfolio is meant a situation where the utility derived from the portfolio exceeds the sum of each project values separately. Most of literature sources propose to describe the synergistic effects as depending from three variables: increase profits, reduce costs, decrease investment and track the dynamics of these variables. Thus, the overall synergy effect could be expressed by the growth of the cash flow scale or return on investment capital.

In our case, the task of obtaining a synergistic effect is required to determine the structure of the portfolio by joint projects maximizing the synergistic effect. The task is extremely complex and there are no effective methods of its solution. In some cases, the problem is solved sequentially. First, the problem of selecting a certain number of projects united by a common purpose is solved. For example, it has been selected N projects that can be attached to the portfolio. The cost of each project is estimated as:

$$C_i = K_i(1+S_i) \tag{3}$$

where K_i – assets of each project after its completion S_i – return on investment. The cost of the combined portfolio will be considered as:

$$C = K(1+S) \tag{4}$$

where K_i – sum of all portfolio assets; S – return on investment.

The Company Investment Yield from the sale of the portfolio will be presented in the next form:

$$S = \sum_{i=1} \beta_i S_i \tag{5}$$

where β_i – weighted coefficient of each component of the company's portfolio; S_i – return on investment of each component of company's portfolio.

There is introduced variable x for each potential component of the portfolio to solve the problem of portfolio formation: $x_i = 1$ if the project went into a plurality of portfolio components, otherwise $x_i = 0$. Then the problem becomes: $x_i = \{0;1\}$ $i = 1, n$, maximizing

$$S(x) = \beta_0 S_0 + \sum_{i=1}^{N} \beta_i S_i x_i \tag{6}$$

where β_0 – efficiency ratio of investment before the beginning of the portfolio; S_0 – coefficient of return on investment before the implementation of the portfolio. At the limit:

$$\sum_i C_i x_i \le R \tag{7}$$

where C_i – cost of each portfolio components; x_i – variable for each portfolio components; R – the total budget of the company for a specified period of the portfolio.

In our case, the effect of portfolio synergies refers to a situation where the utility of implementing project portfolio exceeds the benefits of each implementing project separately in a specified period of time. But as we know the success of final product of any system is dependent on environmental factors. Each external factor has a share in the total process of the company development and shows the synergism phenomena at the system level – in the system genesis. The genesis of system in the case of complex systems is based on the adaptation of key organizational values to changes in the environment, considering the typical cases of system behavior in terms of external and internal changes [21].

Conclusions

For decades there was a contradiction between the recommendations for implementation of new projects, which managers received from textbooks on management, leadership and guidance of the company, and too much dependent from the adopted organization corporate culture.

An important advantage of value-oriented management is the ability to use and align the interests of company owners and the interests of projects on the base of evaluation of company performance values.

The article formalizes the conceptual foundations of enterprise sustainable development through the implementation of project portfolio where portfolio management processes are considered as means of implementation of strategic decisions. This enables to obtain efficient combination of organizational change and sustainability management based on existing standards of project management.

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Significance of teaching organization of humanitarian disciplines in technical higher education institution in the context of individual strategies formation of the students' independent-cognitive activity

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Abstract
The article analyzes the specifics of teaching organization of humanitarian disciplines from the viewpoint of certain scientists, and emphasizes the formation of individual strategies of the students' independent-cognitive activity in technical higher education institution. The requirements are defined and didactic function of the humanitarian disciplines are detalized. The significance of the humanities teaching in the context of individual strategies of the students' independent-cognitive activity consists of forming the students' scientific knowledge about human, his/her place in society, the ability to develop independently and furthermore it affects the formation of key competencies of future professionals. A significant increase of the role of the human factor in the production process due to the humanization of production requires considerable mental preparation of engineer. The important aspects that affect quality of teaching of these subjects are determined.
Keywords: HUMANITARIAN DISCIPLINES, INDIVIDUAL STRATEGIES, DIDACTIC POTENTIAL, DIDACTIC FUNCTION, INDEPENDENT-COGNITIVE ACTIVITY, SPECIAL EDUCATIONAL FORMULA

In the education service of the technical universities the role of humanitarian approach that requires greater attention to training of humanitarian disciplines increases. Development of the humanities is possible during the formation process of personal research paths based, unlike the natural science approach, on knowledge of the actions of the individual, social environment and communication.

Various aspects of humanitarian disciplines are reflected in many psychological and pedagogical researches. One of the important components is specificity of the problem of teaching of humanities in technical universities in the context of individual strategies of the students' independent-cognitive activity. Analysis of research of teaching organization of the humanitarians showed that one of the major flaws in the system of learning and formation of professional skills at the technical universities is the inability to acquire knowledge independently, prevalence of educational measures, including organization, management, regulation that harm self-organization, self-education and self-regulation [2].

The humanitarian cycle disciplines have the potential, which allows to manage training activities of students considering individual psychological characteristics of personality. Teachers should help students to formulate the individual strategies that effectively help to achieve goals in the training of future professionals. The humanitarian disciplines organization is inextricably connected with the formation of a holistic vision of the individual and general ideas about himself, the world around, phenomena and laws. A significant increase of the role of human factor in the educational process due to the humanization of production requires considerable mental preparation of engineer [3]. The specificity of humanitarian disciplines is that cognitive activity acts as a result of personal mental processes of individual, when educational material is not just transmitted as the experience of the teacher, but moves to deeper levels of perception and, therefore, the student acquires the scientific worldview that allows him to understand the laws of life. If educational material remains on the surface level of perception and does not hit the system of own views, in this case there is no critical reflection. This is especially noticeable in the social sciences, particularly in the humanitarian disciplines, when the new life situation requires from the student deep understanding of the nature of events and personal conviction for their explanation. Educational process should be structured in such a manner to provide understanding for student of educational material at its maximum self-cognitive activity in the context of individual strategies. This will help students to form their own views, develop the ability to think critically and acquire knowledge independently. If students' independent-cognitive activity occurs in positive passion, students and teachers interact more effectively. In addition, the teacher in the process of cooperation does not just teach the educational material, but also organizes and coordinates training activities, provides friendly psychological climate among students, indicates errors and corrects them.

Today technical devices are the tool, which exerts a powerful impact on all spheres of person being in his natural environment, social life, inner world. Moreover, this tool comes into the hands of engineers and technicians almost immediately after they have received the diploma of higher education. That is why in the preparation of such specialists not only the completeness and the fundamental nature of their natural scientific and professional education are important, but also education of corresponding to their abilities sense of duty and responsibility. Taking this into account the value of the humanitarian component of the engineering and technical education in modern conditions should be evaluated.

Modern Ukrainian scientist D. Schepova has formulated requirements for the humanitarian disciplines lessons in her work: learning environment, necessary condition of which is constant activity of students; motivational component and the use of reserve capacity of students; personality oriented approach aimed at the improving of individual and professional abilities of students; positive attitude that makes learning activities the exciting game; joint work of the teacher and students, in which the teacher directs learning activities at the required channel; increase of hours of independent work, providing a reflection in the academic and professional field [6]. We share the view that it is necessary to use forms that relate to future profession, including professional tasks and model situations that require creativity. Humanitarian disciplines affect the development of aesthetic and patriotic education of students by involving them in national traditions. Because of independent development, education and improvement of individual "I" - Concept and moral values of the future specialist are formed. In the process of the humanities studying a connection between social life and future career is established, which allows the student to feel like the subject of his own life and career, and to be useful to society and to develop active and positive attitude to himself and to others.

In fact, only the humanitarian disciplines in the education service today contribute to the development

of the human person beginning: morality, responsibility, conscience, tolerance, etc. The study of the humanities at all levels of education, from primary to higher education, has always been a factor in the formation of the complete person, the ability to understand the ultimate meaning of his public professional activity and distinguish it from the immediate short-term interests and goals. At the same time progress towards the understanding of new criteria of the personality requires the overcoming of the traditional dissociation of the components of society culture: natural-scientific, technical and humanitarian [5].

Using their own individual strategies of self-cognitive activity of students will help, to some extent, to prepare future professionals to the modern market conditions, create professional-orientation of values, that generally corresponds to tasks of humanization of the educational process in higher education. Motivational sphere of the student should be adjusted according to the social demands of society for the future specialist.

The priority of training in technical higher educational institution besides professional knowledge and skills is something that directs thinking of the future specialist, its potential in professional and practical field. The principle of humanization of education is based on requirement to all subjects to have humanitarian focus, which forms critical minds. The specificity of humanitarian education in technical university is that during the process of study the competence, knowledge and skills, and general knowledge of the methodology, philosophy and cultural studies are being formed by students. It is important to note that mastering subjects of the technical and natural science cycle is based on the humanities. The main objective of the process of the education humanization is to improve the use of methods and techniques of the humanities. Due to the content, while studying humanities, the values are being formed. Humanitarian disciplines are filled with special content that contributes to the spiritual values and motivation formation to benefit society. By means of their methods humanities help to develop personality and cognitive abilities and play an important role in emotional terms. These factors improve the quality of training.

An important task of humanistic orientation training content is not the provision of humanitarian subjects of human and social content. Each training course should reflect the ideological, humanitarian and special training. A. Myshak in his study gave an educational formula, which expresses the unity of the scientific content of the dialectical method and humanistic purpose [4]. However, in higher education much attention is paid to subjects of professional direction, but there is no time remained for public position and cultural development of the individual, which can not affect the overall result of special training. Ukrainian scientist L. Belousova in her article reveals the essence of didactic potential through systematization of didactic functions which, according to the researcher, can be divided into four groups: the function of positive attitude formation of the student to learning process and results, the functions of learning content promoting, the functions of learning process optimization, functions focused on formation of successful further education of the student [1].

Summarizing the analysis of psychological and pedagogical experience of the individual strategies forming of students' independent-cognitive activity and systematizing of educational functions of humanities, we propose to consider the important aspects that affect the quality of teaching of these subjects: formation of integral worldview of the individual; own mental processes activation; the use of general principles; slow achieving of the effect; the difference between students' thinking, which study technical specialties and humanities; special educational formula that expresses the unity of the scientific content of the dialectical method and humanistic purpose; consideration of the optimization ways and didactic potential. Thus, significance of humanities teaching in the context of individual strategies of the students' independent-cognitive activity consists in forming the students' scientific knowledge about human, his/her place in society, the ability to develop independently and also affects the formation of key competencies of future professionals.

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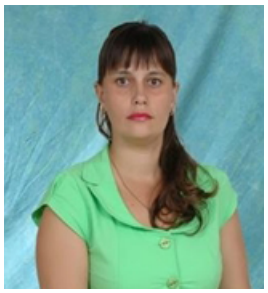
Formation of ecological competence of future engineers of mining profile on the basis of geoinformation technologies



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Abstract
The purpose of National strategy of development of education in Ukraine for the period till 2021 is renovation of content, forms, methods and means of education by widespread introduction of modern ICT and web content into educational-bringing-up process. And priority of education development is implementation of the modern ICT providing improvement of educational-bringing-up process, availability and efficiency of education, training of younger generation for activity in information society.
Therefore, modern technologies of education at the higher engineering school should be directed to training of the specialist with high level of professional competence, professional mobility and capability to lifelong training.
The solution of task of formation of ecological competence of mining profile engineer requires the reasonable selection of the means of ICT conducing formation of ecological competence. Today the use of ICT is particularly relevant when studying professionally directed disciplines by students of engineering specialties. Pressing task is constructive and research approach to preparation of future engineers to performance of professional duties in order to make them capable to develop engineering projects independently and exercise control competently.
Key words: MINING PROFILE ENGINEERS, ECOLOGICAL GEOINFORMATION TECHNOLOGIES, ECOLOGICAL COMPETENCE, PROFESSIONALLY DIRECTED DISCIPLINES, EDUCATIONAL-BRINGING-UP PROCESS

In Ukraine, mining profile engineers engaged at the enterprises of production of iron ore, ore of non-ferrous and rare metals, manganese and uranium ore, coal and other nonmetallic minerals are subjects of the Law of Ukraine "On increase in prestige value of miners' labor", according to which the state "conduces development of coal and mining industry and provides conditions for high-productive and safe work on the basis of mechanization and implementation of the advanced technology into production processes" [1]. Legal and organizational basis of mining profile engineers activity is determined by the Mining law of Ukraine [2], according to which state policy in the mining industry is based on the principles of increase in ecological safety of mining enterprises and providing personnel training of high qualification for mining industries.

The purpose of National strategy of development of education in Ukraine for the period till 2021 is renovation of content, forms, methods and means of education by widespread introduction of modern ICT and web content into educational-bringing-up process. And priority of education development is implementation of the modern ICT providing improvement of educational-bringing-up process, availability and efficiency of education, training of younger generation for activity in information society [3].

Therefore, modern technologies of education at the higher engineering school should be directed to training of the specialist with high level of professional competence, professional mobility and capability to lifelong training [6].

Various aspects of professional training of mining profile engineers are investigated by: N. M. Bidiuk, T. P. Medvedovska (comparative analysis of professional training), S. Ye. Blokhin, O. V. Derevianko (formation of professional competence), L. I. Zotova, O. F. Ivanov, O. O. Rusanova, L. M. Sadriieva, L. B. Shu-melchyk (training in the use of means of ICT), Yu. V. Baikovskyi, O. L. Herasymchuk, S. O. Zelinska, (pedagogical system of insurance of human safety, formation of ecological culture and competence).

Today the use of ICT is particularly relevant when studying professionally directed disciplines by students of engineering specialties. Pressing task is constructive and research approach to preparation of future engineers to performance of professional duties in order to make them capable to develop engineering projects independently and exercise control competently. It gives the opportunity to determine the following approaches to training of students of engineering specialties:

- formation of motivation and activation of cognitive activity in educational process;
- professional orientation of educational process;
- creative approach of teacher to management of educational process and formation of creative approach of students to training in subject-oriented computer environment;
- complex application of interactive methods and means in educational process;
- system control and evaluation of quality of training of future engineer during entire period of training.

The solution of task of formation of ecological competence of mining profile engineer requires the reasonable selection of the means of ICT conducing formation of ecological competence. Scale of works on evaluation of impact of mining on the environment considering specifics of natural climatic conditions has determined the choice of geoinformation technologies, namely, sets of "methods, means and technics used for collection, systematization, storage, processing, transfer, presentation of various messages and data" [4].

Use of means of geoinformation technologies in professional activity of mining profile engineer provides meeting of the main ecological requirements in the sphere of mining operations by means of geomodelling of arrangements of production divisions of mining enterprises, remote monitoring of use of ecologically safe mining technologies on the Earth surface, system analysis of multi-level and heterogeneous geoinformation in the course of implementation of advanced technologies of open mining operations, aerospace sensing of use of mineral waste for recycling, geoinformation mapping and so forth.

Use of ecological geoinformation technologies in forming of ecological competence of future mining engineers is a basis of optimum control of mining enterprises, and also the forecast and control of environment conditions. It also leads to rational economically and ecologically well balanced research of natural resources in mining districts. In this regard, the social importance of geoinformation technologies training of future mining profile engineers reflects the sustained ecological development, which is the component of concept of sustained development.

Therefore, it appears the necessity of solution of contradiction between:

- requirements to reorganization of training standards of specialists with higher education on the basis of competence-based approach and non-developed system of competence of future engineer of mining profile;
- public contract on training of competent specialists capable to provide sustained ecological development

of mining industry and non-developed complete system of formation of ecological competence of future engineer of mining profile;

- potential of geoinformation technologies in training of future engineers and non-developed technique of their use for formation of ecological competence of future engineer of mining profile.

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Effective bench for scientific researches of the brake systems of a railway freight rolling stock

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Abstract
Purpose - Information to the all interested persons and organizations about authors' possibilities in regard to precise researches of brakes of freight rolling stock of railway gauge 1520 mm (CIS and Baltic countries).
Methodology - Natural tests by means of the special stands in a research laboratory.
Findings - Data of increase/decrease of pressure of the compressed air at inlet/outlet of brake devices chambers with exact time dependence, measured to high precision.
Originality - Laboratory researches about work of brakes devices or brake system on any required program of tests with high-precision measurements.
Practical Values:
a) to obtain scientifically-reasonable data about functioning of the brake system and brakes devices;
b) to determine veritable reasons of failure of the brake devices dismantled from a railway rolling stock after accidents or incidents;
c) to create adequate mathematical models of work of brake devices and brake system for the aims of computer simulations;
d) to teach students of professional and high degrees on two specialities "Locomotives" and "Wagons" to operate brakes of railway freight rolling stock of CIS and Baltic countries.
Key words: RAILWAY FREIGHT ROLLING STOCK, BRAKE SYSTEM OF RAILWAY TRAIN, PNEUMATIC BRAKES, INTERNAL GAS-DYNAMIC, SCIENTIFIC RESEARCH BENCH, PROVING STAND, TEST BED

Formulation of general problem

Two methods, theoretical and experimental, gained widespread worldwide for scientific researches of technical objects, including brake devices and systems of rolling stock of railway transport.

Recently, with increasing frequency, experiments are conducted in a digital form by means of computers that on determination are closer to theoretical researches, rather than to the natural experiments. The problem of adequacy of mathematical models appears in case of application of computer simulation. Certainly, the most reliable method of researches is experimental. Realization of experiments during normal operation with the brakes of railway rolling stock on plants of metallurgical and mining industry is difficult, risky and expense experience.

Achievements of predecessors and unsolved part of problem

The leader of production of brake devices for the rolling stock of CIS railways is OAO MTZ TRANSMASH (Moscow, Russian Federations). This enterprise offers automated stand for the tests of air distributor of freight type to the customers [1].

Similar proprietary stand is made and realized by ZAO NPP TORMO (Ekaterinburg, Russian Federations) [2].

Both mentioned stands are intended for automation of productive process on repair of air distributor, i.e. verification of operation in accordance with normatively-technical documentation on brake devices. These stands considerably promote the productivity at repair, allow minimizing human factor, but for scientific researches these stands are not suitable, because they execute one and the same program of tests.

Contribution of authors in the solution of problem

Conserning research of railway brakes of rolling stock on the enterprises of metallurgical and mining industry it is more acceptable to conduct basic experiments in laboratory on benches (otherwise proving stand or test bed), that are made from typical brake devices and systems; certain positions may be checked during normal operations if necessary. Compressor station and complete set of stands-trainers that have all elements of freight and passenger typical units of railway rolling stock were created by authors. Mentioned above stands are made and placed in operation in the laboratory of brakes of railway rolling stock at the State economic and technological university of transport (Ukraine) [3]. All stands have own posts of control and are connected with general main pipe and brake pipe of laboratory. If necessary, it allows to form a sort of train and control this general brake system from the post of control of any stand. Compressor station has the productivity of 2.0 cubic meters of air per minute, max pressure of 0.8 MPa (or 116 psig) and main reservoir with capacity of 1.6 cubic meters.

The authors' work on creation of precise instrument (bench) for laboratory researches of internal gas-dynamic processes in the brake system of railway air-brakes by natural experiments has signs of scientific novelty. Methods and facilities of research of working processes of pneumatic brake systems and its component parts gained further development. It is expressed, firstly, that now there is a possibility to realize practically any program of tests, and, secondly, changes of pressure of the compressed air are possible to register by means of the specially created measuring complex with high exactness.

Aim of the article:

Inform interested persons and organizations about authors' possibilities in scientific researches of brakes of railway freight rolling stock for track width 1520 mm (CIS and Baltic countries).

Review of authorial bench

In figure 1 the pneumatic diagram of authorial bench is shown (there stated in denominator: types of brake devices; for reservoirs – capacity in liters; and for air-flow constrictor – diameter hole in millimeters). This stand recreates at the same time both typical pneumatic brake system of wagon and locomotive of freight sort of service for CIS and Baltic countries railways.

The diagram reflects such brake devices as: A1 – main brake controller; A2 - pneumatic reduction gear; A3 – assist brake controller; A4 – air distributor (or governor); A5 - automatic regulator of the braking modes depending on loading of wagon; A6 – brake cylinder. Movement of piston rod of brake cylinder is limited by the special screw mechanism, that allows to set this size within 235 mm with accuracy of 1 mm. Level of wagon loading on a bench is specified by means of next special screw by the change of gap between support of regulator and framework of bench. In position A4 of the chamber of 295M type depending on the program of tests any both main and main line parts of air distributor can be set, including break of brake pipe sensor of 418 type. Air-flow constrictor C1 (see fig. 1) is intended for retarding of charging of main reservoir R2. Others air-flow constrictors (C2-C9, see fig. 1) are appointed for discharges of compressed air from chambers and pipelines of stand. Diameters of expense openings of all the air-flow constrictors, depending on the aims of research, can be set within 0.3...8.0 millimeters.

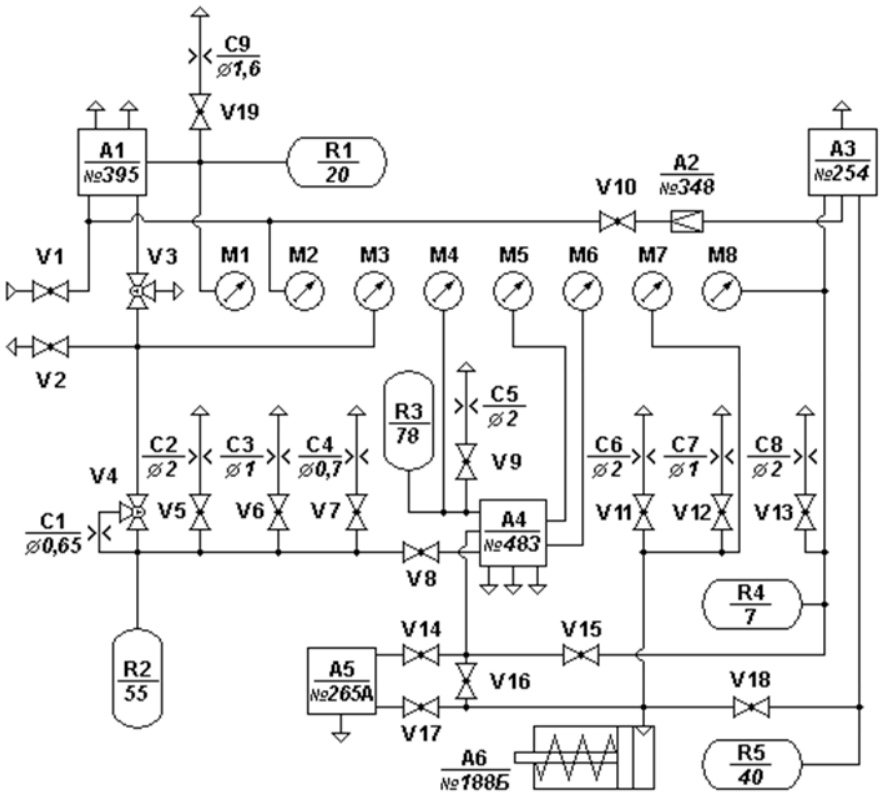

Figure 1. Authorial pneumatic diagram of a bench

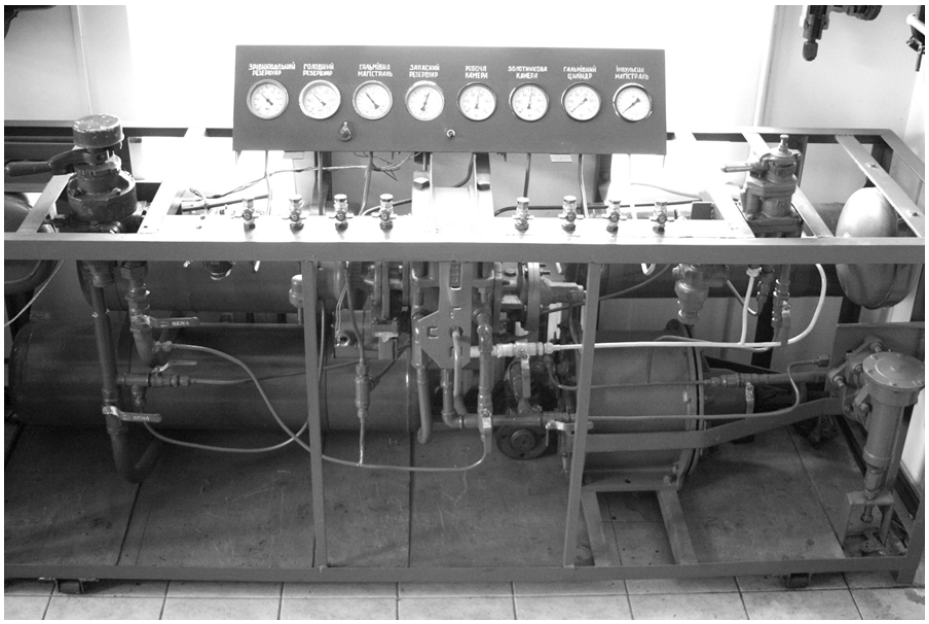

Figure 2. Photo of authorial bench

A bench in the interior of laboratory is shown in figure 2 in the state of work (‘under pressure’).

The patent of Ukraine on an utility model for this bench as device is got [4]. Dmitriy Dmitriyev suggested the idea of creation of bench and its primary pneumatic diagram. Mykola Valigura made practical embodiment of bench with certain improvement of primary pneumatic diagram and financed the work. Mikhael Kelrikh carried out common scientific and administrative guidance of the project. A feature of this bench is the possibility to register and document pressure changes of compressed air in all its reservoirs and chambers in the form of oscillograms. The record of oscillogram pressure is realized by means of

portable measure-computing complex that was worked out and made by Dmitriy Dmitriyev individually. This eight-channels authorial apparatus on the base of notebook passed metrology attestation and allows to measure and keep in energy independent memory of oscillograms fluctuating of air pressure with time resolution from one millisecond (for fast processes) to one second (for slow processes). Authorial electro-manometers are intended for exploitation on spring parts (frames, bodies) of railway rolling stock. They have a differential electric circuit of connecting; the measuring range of air pressure up to 1 MPa (145 psig); class of exactness not worse than 0.4; degree of protection is IP67 (possible immersion under water on the depth of to 0.5 m); mechanical implementation is M25 (possible external vibration is in the range of frequencies 0.5...100 Hz with amplitude up to 1.0 g) and category temperature range varies from -45 to +60°C. Connecting thread on body of electro-manometers is conical pipe screw-thread with diameter 1/2 inches. In laboratory terms (at the temperature of surrounding air +20...+25°C) class of exactness of these electro-manometers is not worse than 0.25. These electro-manometers are connected in parallel to pointer manometers shown in figures 1 and 2. Appearance of electro-manometers with body from stainless steel is shown in figure 3.

Figure 3. Photo of authorial electro-manometers

Conclusions

The authors of the article designed and made bench for laboratory scientific researches of brake system of railway freight rolling stock of the CIS and Baltic countries. The announced bench can be effectively applied for solution of many practical and scientific tasks. For example, for investigation of reasons of emergency failures of brakes by research of brake devices on the bench, that are taken off from a unit of rolling stock after accident. Otherwise as a source of basic data for building of adequate mathematical models of brake devices and brake system. Authorial bench can be used in educational process as a training simulator in relation to work of brakes of unit of railway rolling stock of freight type of track width 1520 mm. Bench, which was briefly considered in the article, is expedient to apply in laboratory researches of brake devices of railway rolling stock first of all in relation to enterprises with the heavy and dangerous terms of labor, where possibilities of realization of natural experiments are limited and their cost is considerable, first of all in metallurgical and mining industry.

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The force analysis of interaction of furnace charge layer with working body of vibration feeder for sintering machine charging

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Abstract
For change of drum feeders for laying of furnace charge to the sintering belt by vibrational ones providing laying of layer with the specified thickness and profile, regularities of layer motion relating to the bottom of charging device are considered and expressions for calculation of forces affecting in the contact of layer with its bound elements of vibrating feeder are developed. On this basis, the conclusion on possibility of electric power costs reduction in case of layer blowing and improvement of agglomerate quality is drawn.
Power analysis opens the potential of further improvement of charge unit of agglomerative machines providing formation of layer with specified geometry and profile.
Key words: CHARGING DEVICE AGGLOMERATIVE MACHINES, VIBRATIONAL FEEDER, SINTER BURDEN LAYER, INTERACTION OF LAYER WITH THE BOTTOM, FORCES IN A LAYER, LAYING OF FURNACE CHARGE, ELECTRIC POWER COSTS, QUALITY OF AGGLOMERATE

One of methods of improvement of agglomerative factories is change of drum feeders for laying of furnace charge to the sintering belt by vibrational feeders allowing formation of efficient profile of layer in sintering belt providing decrease in gas-dynamic impedance during furnace charge layer blowing in the course of its agglomeration.

Formation of layer in the charging device takes place due to forces affecting in the layer and its contact with the bottom and walls of vibrating feeder.

The charging device (vibrating feeder of special design) is installed under the tap hole of charge hopper blocking its section completely; this provides smooth charging of sintering belt with the specified layer profile without arch formation and hanging.

Such charging devices can form any profile of layer surface in sintering belt and efficient distribution of particles size in the layer thickness providing saving of the electric power layer blowing and improvement of agglomerate quality due to reduction of content of class (-5) mm in shattered agglomerate.

The bucket of the charging device can execute the following types of vibrations depending on their trajectories:

- rectilinear vibrations, at an angle to the load-carrying plane, uniform (identical to all points of bucket along its length);
- circular uniform vibrations, each point of bucket race out circular trajectory (in the specific case - elliptic);
- elliptic non-uniform vibrations, each point of bucket executes vibrations along its length with the trajectory (linear or elliptic) with parameters (big axis of ellipse and angles of its slope) changing along the bucket length.

Let us consider forces affecting the layer of material moving in the bottom of charging device tilted at an angle α to the horizon. Let us consider a case when the bucket executes rectilinear vibrations which direction makes an angle β with its bottom.

The equations of movement of material layer relating to the bottom of charging device are of the following form:

$$\begin{aligned} m\ddot{X} &= P\sin\alpha + I_h + F_B + F_{s.h.} \\ m\ddot{Y} &= P\cos\alpha + I_v + N + F_{s.v.} \end{aligned}, \qquad (1)$$

where m – the specified mass of layer [1]; I_h, I_v - projections of forces of inertia to the axes OX and OY, P — gravity force; N — normal reaction of bucket or underlying layer to overlying layer of material; F_B - friction force of material on the bottom of bucket or underlying layer of material; $F_{s.h.}$, $F_{s.v.}$ - material friction force projections on side surfaces (walls) of bucket to the axes OX and OY.

Normal reaction N and friction force F_B are determined for the bucket bottom plane (or planes parallel to the bottom), gravity and inertia are determined for the whole volume of material, and friction force on walls is determined by height of all layer. Relative accelerations $\ddot{X}$ and $\ddot{Y}$ are determined as average accelerations of layer.

In case of solution of the similar task for unit load, normal reaction and friction force on the bottom of bucket are determined from condition that unit load moves together with bucket for some time, i.e. $Y=0$ and $X=0$. The movement equations turn into balance equations, in which the left parts are set to zero and expressions for determination of N and F_B are found. At that, forces of side friction are absent.

Such assumption would be incorrect for material layer; even without frictional sliding of material on the bottom, the upper layers of material move according to the law different from the law of bucket vibration.

According to [1, 2], let us accept the assumption on consideration of all the internal interactions in a layer by coefficients of vibrations damping throughout its height. Under condition of absence of material frictional sliding on the bottom or material separation from vibrating plane, the vertical component of absolute acceleration of material in the point at height h will be equal to $A\omega^2 \cdot e^{-\gamma_v h} \cdot \sin\beta_T \cdot \sin\omega t$, and horizontal component will be equal to $A\omega^2 \cdot e^{-\gamma_h h} \cdot \cos\beta_T \cdot \cos\omega t$, where A – amplitude, ω – vibration frequency of bucket, β_T – slope angle of rectilinear trajectory of point to the bucket plane, γ_v, γ_h – coefficients of damping of plane stress waves of compression and shift throughout the layer height.

Relative specific (on height unit) acceleration of layer with height of N in periods when there is no sliding and separation:

$$\ddot{X} = \frac{1}{H-h} \cdot A\omega^2 \cdot \cos\beta_T \cdot \cos\omega t \int_h^{II} \left(e^{-\gamma_h h} - 1\right) dh$$
$$\ddot{Y} = \frac{1}{H-h} \cdot A\omega^2 \cdot \sin\beta_T \cdot \sin\omega t \int_h^{H} \left(e^{-\gamma_v h} - 1\right) dh \quad (2)$$

Inertia force for material will be determined by acceleration of translation:

$$I_v = mA\omega^2 \sin\beta_T \sin\omega t;$$
$$I_h = mA\omega^2 \cos\beta_T \sin\omega t; \quad (3)$$

Having substituted expressions (2) and (3) into the equations of movement (1), we obtain the equations for determination of normal reaction and friction force on bottom:

$$N + F_{s.v.} = mg\cos\alpha - \frac{mA\omega^2}{(H-h)\beta_V} \sin\beta_T \cdot \sin\omega t (e^{-\gamma_h h} - e^{-\gamma_h H}) + F_B + F_{s.v.}, \quad (4)$$

Normal reaction of the bottom or layer of material to overlying layer is function of gravity force of material, its mechanical properties, amplitudes, vibration frequencies, angle of vibrations and coefficient of vertical vibrations damping.

Friction forces on walls of bucket and normal reaction to the bottom depend on bucket width. At that, the direction of friction forces on walls depends on the bucket wall, weather it moves together with the bottom or is motionless. If the walls of bucket are motionless, specific friction force on walls at layer height h is equal to:

$$F_{s.sp.} = 2f_1 n \frac{N(h)}{B}, \quad (5)$$

where $N(h)$ - normal reaction of plane parallel to the bucket bottom at height h, f_1 - coefficient of layer friction on bucket walls, B – the layer width equal to bucket width.

The coefficient of side pressure n is determined by a formula: [2]

$$n = \frac{1}{1 + 2f^2 + 2\sqrt{(1+f^2)(f^2 - f_1^2)}}, \quad (6)$$

where f - coefficient of internal friction of material.

The angle β_T made by friction force on bucket walls is changed with the layer height as horizontal and vertical components of this force are reduced unequally for longitudinal and cross waves of compression and shift due to inequality of coefficients of these waves damping.

$$tg\beta_T = \frac{\sin\beta \cdot e^{-\gamma_v h}}{\cos\beta \cdot e^{-\gamma_h h}}, \quad (7)$$

The complete frictional force on walls emerging in unit of bucket length and walls is determined as integral variable value along the layer height of specific frictional force:

$$F_{s.v.} = 2N \int_h^H f_1 \frac{n}{B} dh, \quad (8)$$

Material gravity force in bucket length unit is:

$$mg = (H-h)B\gamma, \quad (9)$$

where γ – bulk density of furnace charge.

The directions of bucket acceleration are determined by expression $\sin\omega t$, i.e. for values $\omega t = 0 \div \pi$ acceleration is positive, and for values $\omega t = \pi \div 2\pi$, it is negative. Friction force on walls changes a sign at other moments of vibration cycle. For example, in case of forward-upward movement of working body, i.e. at

$$\omega t = -\frac{\pi}{2} \div \frac{\pi}{2},$$

the force F_s is negative, and at

$$\omega t = \frac{\pi}{2} \div \frac{3}{2}\pi,$$

it is positive.

Normal reaction for interval $\omega t = -\frac{\pi}{2} \div \frac{\pi}{2}$ is determined by expression:

$$N = \frac{B\gamma\cos\alpha}{a}\cdot(e^{a(H-h)}-1)+\frac{B\gamma A\omega^2\sin\beta_T\sin\omega t}{g(a-\beta_v)}\left[e^{-\gamma_v h}-e^{-a(H-h)-\gamma_v H}\right], \quad (10)$$

where $a = \frac{2fn\cdot\sin\beta_T}{B}$.

We obtain vertical projection of friction force of material on bucket walls with the use of expression (8).

For an interval $\omega t = -\frac{\pi}{2}\div\frac{\pi}{2}$:

$$F_{s.v.} = \frac{B\gamma\cos\alpha}{a}\left[e^{a(H-h)}-1-a(H-h)\right]+\frac{B\gamma A\omega^2\sin\beta_T\cdot\sin\omega t}{g(a-\beta_v)}\left[\frac{a}{\beta_v}e^{-\gamma_v h}-\frac{a-\beta_v}{\beta_v}e^{\gamma_v H}-\right.$$
$$\left.-e^{a(H-h)-\gamma_h H}\right], \quad (11)$$

For an interval $\omega t = \frac{\pi}{2}\div\frac{3}{2}\pi$ we obtain:

$$N = -\frac{B\gamma\cos\alpha}{a}(e^{-a(H-h)}-1)-\frac{B\gamma A\omega^2\sin\beta_T\sin\omega t}{g(a-\beta_v)}(e^{-\beta_v h}-e^{-a(H-h)-\beta_v H}), \quad (12)$$

$$F_{s.v.} = \frac{B\gamma\cos\alpha}{a}\left[e^{-a(H-h)}-1+a(H-h)\right]+\frac{B\gamma A\omega^2\sin\beta_T\cdot\sin\omega t}{g(a+\beta_v)}\left[-\frac{a}{\beta_B}e^{-\beta_v h}+\frac{a+\beta_B}{\beta_a}e^{-\beta_v H}-\right.$$
$$\left.-e^{-a(H-h)-\beta_v H}\right] \quad (13)$$

In expressions (10-13), $\sin\beta_T$ the average value of angle of vibration along layer thickness is

$$\sin\beta_{T.av} = \frac{1}{H-h}\int_h^H \sin\left[arctg(tg\beta_T\cdot e^{h(\beta_z-\beta_B)})\right]dh = \frac{1}{(H-h)(\beta_z-\beta_B)}\times$$
$$\times\ln tg\left(\frac{\pi}{4}-\frac{arctg(tg\beta_T\cdot e^{H(\beta_z-\beta_B)})}{2}\right)-\ln tg\left(\frac{\pi}{4}+\frac{arctg(tg\beta_T\cdot e^{h(\beta_z-\beta_B)})}{2}\right), \quad (14)$$

Friction force of material on the bottom of bucket or on the surface parallel to the bottom is

$$F_B = -\gamma B(H-h)\sin\alpha-\frac{\gamma B}{g\beta}A\omega^2\cos\beta_T\cdot\sin\omega t(e^{-\beta_h h}-e^{-\beta_h H})\pm\frac{F_{s.v}(\beta_h-\beta_v)(H-h)}{tg\beta_T\left[e^{(\beta_h-\beta_v)H}-e^{(\beta_h-\beta_v)h}\right]}, \quad (15)$$

The upper signs correspond to the intervals $\omega t = -\frac{\pi}{2}\div\frac{\pi}{2}$, lower ones correspond to intervals $\omega t = \frac{\pi}{2}\div\frac{3}{2}\pi$.

Conclusions

The expressions determining affecting forces in bulk layer (agglomerative furnace charge) in the course of its charging in sintering belt are obtained. Application of the obtained expressions for forces affecting in the layer and its contact with bottom and walls of charging bucket allows setting of kinematic and geometrical parameters of bucket providing laying of furnace charge layer of specified height and profile of section. Therefore, electric power costs in case of layer blowing at its agglomeration are reduced and the quality of agglomerate is increased due to reduction content of fraction (-5 mm).

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Estimation of soils pollution and model of catastrophic chemicalization

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Abstract
The scheme of environment ecosystems catastrophic destruction is suggested during natural leaching of metals and salts. The special attention is given to a problem of threat estimation of soils and plants chemicalization. The universal model for the description of catastrophic danger of technogenic chemicalization of biosphere is suggested.
Keywords: MINERAL DEPOSITS, DEVELOPMENT CONCEPT, MOUNTAIN MANUFACTURE, ENVIRONMENT, CHEMICALIZATION

The growth of scientific and technological progress and increase of population of the Earth demand ever-increasing consumption of mineral resources. About 80-85% of the total oil volume, about half of the coal and iron ore extracted in the human history have been consumed only for the last 30-40 years. The consumption of various metals, fertilizers and other minerals increased 3-5 times.

As modern technology of development and processing of mineral deposits is not perfect and rejectous million tons of gas- and vaporous, liquid and solid wastes, causing total pollution are released into environment. Location layout of mining and processing enterprises, as well as their impact on environmental pollution, air, water and arable land [1-4].

Taking into account the fact, that the dumping sites and tailings have a negative impact on the environment, emerged an urgent need to carry out environmental-economic assessment. This assessment allows to define the environment protection with combined account of natural and anthropogenic influence mechanisms, as well as the quantitative use

of mineral resources deposits, thereby to assess the avoided ecological damage to the environment.

Soils pollution assessment must be performed not only in technogenic field but mainly by its response to impact using value of its ecological potential [5-9].

There were selected three sites (zones) in vicinity of mining enterprise for quality determination of soils degraded by dust emissions. Base site 3 is located at distance of 20 km, and others – closely to open-cast at distances 10 km (site 2) and 5 km (site 1). In each site 10 samples of trees and bushes leafs were collected [10]. Leafs investigation were performed during summer season in one-month interval. Averaging data allows to estimate variation of metals concentration with distance from the source (Table 1).

It is determined that iron and copper concentration in vegetation is changing with distance from source in parabolic dependence (Fig. 1).

Table 1. Content of minerals in vegetation, mg/kg anhydrous substance

Site	Metals	
	iron oxide	copper oxide
	bushes	
1	280	30
2	120	15
3	20	10
	trees	
1	410	39
2	190	19
3	70	9

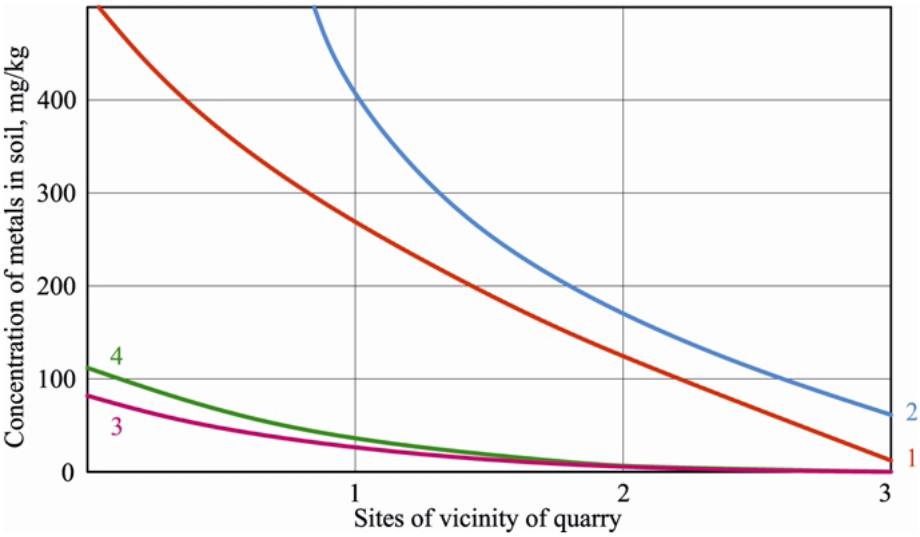

Figure 1. Variation of metal concentration in vegetation with distance of dust source: 1 – iron in bushes; 2 – iron in trees; 3- copper in bushes; 4 – copper in trees

Metals are greatly accumulated on the leaves of trees and bushes. Both vegetation groups choose iron over copper, which is explained by higher copper mobility in propagation of metals in solutions of natural leaching [11, 12]. Average content of metals in vegetation changes less considerable: 162-450 mg/kg for iron, 4,5-6,7 for copper, 12-32 for zinc, 53-80 for manganese, 1,8-3,0 for nickel.

Soil dilution by toxic substances causes significant reduction in crop yields. At 20% of dilution soil productivity is less than 30% from basic value, and only 10% at 50% dilution.

Content of iron in human organism variates from 4 to 7g. Daily maintenance of human in iron is 11-30 mg [13].

Metals influence on biota structures is universal and characterized by regular reduction in yields and vital activity.

Metals getting in soils with fine dust particles are accumulated in upper, accumulational horizon and crop yelds reduction is observed.

Total soils pollution is dangerous not only by technogenic effect but also response to impact in consequence of synergetic effects phenomena of combined influence of their components.

Anthropogenic effect of metallic toxicants on biota is divided in insignificant, moderate and ultimate.

Mechanics of metals accumulation, assimilation and transformation in borders of system "enterprise – medium – biota" is described by model:

$$M_b = M_{b.base}\left(1 - \frac{Q_t k_f k_{am} k_a k_c}{k_{sd}}\right), \quad (1)$$

where M_b – is the mass of living material on the territory, weight units; $M_{b.base}$ – is the mass of living

material before technogenic effect, weight units; Q_t – is the amount of generated toxicants, weight units; k_f – is the soil filtration coefficient; k_{am} – is the coefficient of toxicants transmission in aqueous medium; k_a - is the coefficient of toxicants assimilation; k_c - is the coefficient of collective toxicants influence; k_{sd} - is the coefficient of soil depth or invaded zone influence.

The proposed model describes the state of not only plants, but also representatives of living matter, including humans, considering the individual characteristics [14-15].

Thus, the influence reduction of processes of extraction and processing of ores on the ecosystem of the natural environment is possible after:

- conversion from ecologically and socially dangerous methods of open pit and underground mining to the physical, technical and physical-chemical geotechnologies (borehole hydraulic mining, underground leaching, underground coal gasification, underground melting of sulfur, the use of coal-bed methane, coal-water fuels, etc.);
- development of high-performance complex processing technologies and opening of the mineral grains of middle quality and hardly separated ores, as well as technogenic materials;
- development of complex waste-free closed systems of final products separation obtaining;
- development of fundamentally new technologies of mineral raw materials processing - in the first place using biological organisms, plasma-chemical reactions, etc.;
- development of new deep mineral deposits and the bottom of World ocean;
- involvement in the industrial use of unconventional energy resources (solar, wind, tides, etc.).

Conclusions

Implementation of the latest technologies can radically change our understanding of the quantitative and qualitative characteristics of the mineral resources of the planet and fully confirm the thesis of Academician A.E. Fersman that the future of geology is in technology.

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Cartridged and granulated explosive substances of grade Ukrainit for underground mines

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Abstract
The paper presents a part of set of operations on change of underground mines for trotyl-free explosive substances (ES). The purpose is development and introduction granulated and cartridged trotyl-free explosive substances with high detonation and technological parameters in the underground mines of Ukraine. The unique structure of fuel phase and unparalleled technology of obtaining of highly-stable granulated ES Ukrainit-ANFO on the basis of agrarian ammonium nitrate is created. Ukrainit-ANFO is intended for pneumocharging of holes and wells of small diameter, possess high level working capacity and safety, minimum toxicity of explosion products, long guarantee period (3 months). Scientifically based approach to creation of formulas and technology of obtaining cartridged emulsion ES Ukrainit-P is implemented. According to functional purpose, cartridges Ukrainit-P are universal and intended for formation blast-hole charges, for initiation (as intermediate detonator) of charges of emulsion and granulated ES in wells and holes of any diameter, and also for crushing of oversize material. High parameters of working capacity and small critical diameter allow production of cartridges of any diameter (from 32 mm). The range and technology of developed of granulated and cartridged ES of grade Ukrainit in combination with filling emulsion ES Ukrainit provide complex solution of problem of underground mines Ukraine change for trotyl-free ES.
Key words: GRANULATED EXPLOSIVE SUBSTANCES, AMMONIUM NITRATE, MODIFICATION, EMULSION, CARTRIDGED EMULSION EXPLOSIVE SUBSTANCES

Relevance

One of tasks of complex conversion of underground mines of Ukraine to the safe trotyl-free explosive substances (ES) is refusal of application of standard trotyl-containing materials, namely, the granulated Grammonite 79/21 and cartridged Ammonite No 6ZhV. Trotyl is highly toxic substance which causes more than 30 occupational diseases of staff and is dangerous in use and generates a large amount of harmful gases in case of explosion. Safe alternative to cartridges Ammonite No 6ZhV and Grammonite 79/21 are cartridged emulsion ES and granulated ES for pneumocharging.

In underground conditions, cartridged ES are used: 1) for blast-hole charges formation; 2) for crushing of oversize material of rocks in the form of pressure charges; 3) intermediate detonator of borehole charges. These application areas cause distinction of requirements to detonation parameters of cartridged emulsion ES that complicates introduction of similar ES in underground mines of Ukraine.

Application of mixed trotyl-free explosive substances on the basis of the granulated ammonium nitrate in underground mines is economically sound. Experience of the USA and Canada shows that use of such ES on the basis of system "ammonium nitrate / liquid combustible component" (AS-DT, Igdanit, ANFO, granulites) allows reduction of the cost of explosive operation by 40 – 50% of [1]. However, the majority of the granulated ES for pneumocharging are characterized by small physical stability in time, separation when pneumotransporting, insufficient detonation parameters, namely, low speed of detonation and big critical diameter. It does not allow such ES to be used effectively for pneumatic charging of holes and wells of small diameter (32 – 80 mm). Moreover, majority of known trotyl-free granulated systems [2] contain oil products as liquid fuels which form toxic aerosols in case of pneumocharging.

Purpose and research problems

The paper objective is development and introduction to the underground mines of Ukraine of granulated and cartridged trotyl-free explosive substances with high detonation and technological parameters. Implementation of objective means solution of the following tasks:

- development of composition of fuel phase and technology of obtaining of highly effective granulated ES with guaranty period of storage at least 1 month;

- development of structures and technology of cartridged emulsion ES used for forming of blast-hole charges, pressure charges for crushing of oversize material and as intermediate detonators.

Technology of highly stable granulated ES for pneumocharging of Ukrainit of ANFO.

Based on the generalized experience of application of various granulated ES in mines, which are not dangerous on gas and dust, the main requirements to ANFO can be formulated: 1) physical stability within at least 30 days; 2) maintenance of balance oxidizer-fuel in each part of charge (perfectly – in each granule); 3) strength of granules, the nitrate should maintain pneumatic transportation and charging; 4) absence of oil products in composition; 5) detonation parameters should provide effective application in holes and wells of small diameter (32 – 80 mm).

The detonation mechanism, at which chemical reaction of explosive transformation takes place between oxidizer and reducer, which are not in molecular contact [3], is inherent in mixed power condensed systems on the basis of mixed ammonium nitrate. In this case, increase in temperature in a zone of chemical reaction, which width determines the critical diameter of detonation [3] can provide high detonation ability. In turn, width of chemical reaction zone is determined by the thermal emission speed, which directly depends on the speed of oxidation of combustible phase and nature of sensitizer.

For development of composition of liquid fuel phase of granulated ES, it has been systematically investigated influences of nature of combustible component on the nature of thermo-decompounding and time of induction of autogenous ignition [2] of systems "ammonium nitrate / liquid combustible component" of sensitizing agent.

Nature of thermo-decompounding was evaluated by efficiency of oxidation of fuel ammonium nitrate (Ammonium nitrate) and products of its desintegration (Termoskan-2 device, SPA Analitpribor, S.-Peterburg). Parameters: temperature of the beginning of intensive exothermic decomposition (t_b); growth rate of the differential temperature (v^t); characteristic to temperature of exothermic peak (t_{peak}) and its intensity (h_{peak}); relative coefficient of thermal emission of system (K), which is calculated as the ratio of the area of exothermic peak of system to the area of peak nitrate ammonium. Results of thermal researches are given in Table 1.

Table 1. Nature of thermo-decompounding of the stoichiometric mixtures "ammonium nitrate — combustible component"

System	T_b, ^{0}C	v_t, grad/(min)	T_{peak}, ^{0}C	H_{peak}, ^{0}C	K
Ammonium nitrate (AN)	230	1,47	276	2,13	1
AH— diesel gas oil	223	2,8	282	3,05	2,44
AH–industrial oil I-20	250	7,9	290	13,09	3,67
AH– black oil fuel	216	8,95	262	11,79	9,04
AH– paraffin	250	6,6	282	4,19	1,91
AH– ceresine	253	4,2	283	5,66	2,23
AH– wax paraffin oil	255	5,86	290	5,62	2,22
AH– sunflower oil	230	16,7	255	17,7	10,91
AH– linseed oil	216	21,3	248	20,6	11,89
AH– esters of plant oils	204	8,71	257	9,24	8,01
AH- natural boiled oil	216	21,5	245	11,8	14,15

It is established that while transition from oil products to plant oils, level of their influence on thermo-decompounding of the power condensed system increases. At the same time, with increase in degree of unsaturation of the fatty acids which are a part of oils composition, the speed of their oxidation grows. Among the oils containing olein (CI18), linoleic (CII18) and linolenic (CIII18) acid (contain one, two and three unsaturated bonds, respectively), the ratio of speed of oxidation is 1:27:77 [4].

Apparently from Table 1, the relative coefficient of thermal emission (K) of the systems containing plant oils (sunflower and linseed) exceeds a thermal emission of systems with industrial oil and waxes by 3-5 times, and the growth rate of differential temperature – by 2-2,5 times. The maximum intensity of thermal emission is observed in case of natural boiling oil. It can be explained by desiccants (salts of cobalt,

manganese and lead with resin acids) in drying oil; they are catalysts of the radical mechanism of oxidation of unsaturated hydrocarbons [5].

As it follows from the provided data, it is necessary to use linseed oil and natural drying oil as a fuel phase for obtaining of the elementary ammonium nitrate ES. However, because of high viscosity of these products (20-30 mm^2/s),exceeding much viscosity of diesel fuel, the attempt of achievement of uniform distribution of combustible component on the whole surface of granules of ammonium nitrate (AN) and throughout the volume of ES was not successful.

The problem was solved due to use of mix of esters of vegetable oils, vegetable oils and desiccants (naphthenates and oleates of transition metals) as a fuel component of granulated by ES. The similar fuel phase possesses the high speed of oxidation and provides sufficient intensity of thermo-decompounding of system that improves its detonation characteristics. It was confirmed also by experimental measurements of delay of autogenous ignition; presence of up to 1% of desiccants in composition of combustible phase provided decrease in specified effective energy of activation of thermo-decompounding of system by 2-2,5 times.

The explosive substance obtained on the basis of the granulated ammonium nitrate and developed fuel phase has obtained the name Ukrainit-ANFO (Pat. UA 79813, UA 85959).

The technology of obtaining the highly stable granulated ES assumes increase in absorbing ability of granules of ammonium nitrate in relation to liquid fuel from 2,0-2,5% up to 7,5-9,0% of mass. The created technology excluded use of porous ammonium nitrate which is not produced in Ukraine. Moreover, the majority of low-density ammonium nitrate produced abroad along with the high absorbing ability possesses low mechanic-strength characteristics that leads to blocking of charging hoses when pneumotransporting and charging of ES.

On the basis of systematic experimental work on modifying of AN granules, the unique technology of porization of agrarian granulated ammonium nitrate (grade B) in case of maintenance of sufficient strength of granules has been developed.

The technology assumes processing of AN by pore-forming solutions of salts of ortho-phosphoric acid and subsequent heating in special vacuum mixers at a temperature of 60-65^{0}C and negative pressure of 0,7 ÷ 0,9 atm. The hot modified nitrate is mixed with the esters of fatty acids of plant oils and/or vegetable oil containing oxidizer catalysts, namely, fat-soluble salts of transitional metals (Pat UA 106118).

Solutions of salts of ortho-phosphoric acid not only wash away free flowing agents(decomposition phlegmatizers) from a surface of AN granules and conduce pore formation, but also increase granules strength. Mechanic-strength characteristics of granules are improved due to formation of reinforce frame from compounds slightly soluble in water. These compounds are phosphates of alkaline-earth metals which are a part of the conditioning additives of granulated AN. The granules obtained as a result of modification of AN possess highly-developed surface, which allows holding up to 7,5–9,0% of mass of liquid fuel, also possess sufficient strength. This technology was successfully implemented in granulated ammonium nitrate of all the Ukrainian producers, and also KazAzot LLP (Kazakhstan), JSC Maxam-chirchiq and JSC Farg'onaazot (Uzbekistan), JSC Minudobrenie (Rossosh, Russian Federation), AZ "Pulawy" (Poland).

The technology and composition of the granulated trotyl-free explosive substances of factory production of Ukrainit-ANFO have no analogs among the known systems of this kind. Ukrainit-ANFO is well-balanced on fuel almost in each granule of ES, does not possess the obvious smell of oil products, has guarantee period at least 3 months, removal of combustible component from surface of granules is not observed in case of pneumocharging. Detonation characteristics of Ukrainit-ANFO allow effective use of it for pneumatic charging of hole and wells of small diameter. Industrial production of Ukrainit-ANFO is implemented in the production site PJSC "Promvzryv" (Zaporizhzhia). Developed ES is successfully used for pneumocharging of holes and wells in mines PJSC "Zaporizhzhia iron ore plant" and PJSC "Evraz Sukha Balka" in amount up to 250 tons a month.

Table 2. Physical and chemical characteristics of ES Ukrainit-ANFO

Index	Norm
Oxigen balance, %	- 0,1 ÷ -1,7
Heat of explosion, kJ/kg	3760 – 3820
Gases volume, l/kg	980 – 990
Speed of a detonation, km/s: – in a steel pipe	 3,2 – 3,8

Critical diameter of detonation of an open charge, mm	35-40
Sensitivity to blow in shock machine K-44-II: – the lower bound at P = 10 kg, mm – frequency of explosions at P = 10 kg, N = 250 mm, %	 500 0
Sensitivity to friction (lower bound) in shock machine K 44-III, MPa (kgf/cm^2)	≥ 702 (≥ 7020)
Transition from deflagration to detonation in open volume	Impossible
Amount of harmful gases of explosion in conversion to relative CO, l/kg	28 – 40

Technology of cartridged of emulsion ES Ukrainit-P.

The cartridged emulsion explosive substances (ES) should not be exceeded in working capacity and universality, and should exceed considerably standard cartridged ES Ammonite No 6ZhV in safety of application. Moreover, cartridged emulsion ES should possess steadiness (for manual charging of holes) and long (not less than 6 months) holding of physical stability and high detonation parameters for use in underground mines of Ukraine.

As it is known [6-7], the inverted emulsions of the high-concentrated oxidizer solution (91-93% of mass) in the hydrocarbonic medium (7,0-9,0% of mass) are the basis of EES. It is established that the majority of EES properties are determined by dispersion of emulsion, with which growth the interphase surface "oxidizer / fuel" is increased that provides high sensitivity and detonation characteristics of system [5]. However, with growth of dispersion the thermodynamic probability of destruction of emulsion also increases.

Obtaining of stable cartridged ES with high detonation parameters can be provided only by scientific-based approach to the solution of complex of research tasks: definition of the nature and concentration of an oxidizer phase, fuel phase and emulsifier, technology of emulsification, and sensitization.

Unlike filling emulsion ES where the content of water is 14–18% of mass, in cartridged emulsions this value should not exceed 7–10% of mass. It is caused by effect of water as phlegmatizer due to selection of heat for evaporation from a zone of chemical reaction of explosive transformation (increase of water content in emulsion by 1% of mass leads to decrease in operability of explosive system by 1,7% [8]). However, at the low content of water, the probability of crystallization of nitrate and loss of detonation ability of EES increases in disperse phase of emulsion.

When studying of solubility of ammonium nitrate and its combinations with sodium and calcium nitrate, it has been established that use of AN monosolution requires holding of high technological temperatures of production of EES. During transition to binary systems solution, crystallization temperature decreases significantly. However, use of system ammoniac/sodium nitrate when creation cartridged emulsion substances, it is limited to low solubility of sodium nitrate (176 g in 100 g of water at 100 ^{0}C).

For EES with various composition of oxidizer, calculations of detonation characteristics of EES (perfect speed of detonation, critical diameter of detonation, relative working capacity) have been carried out according to the approximating model [9]. According to the obtained results of system on the basis of binary solution, ammonium/sodium nitrate possesses considerably lower speed of detonation and bigger critical diameter of detonation, than emulsion on the basis of ammoniac/calcic nitrate. The obtained data are confirmed by the results given in paper [10], replacement of a part of ammonium nitrate by sodium nitrate led to decrease in operability of ES by 7,5%.

As a result of researches optimum for cartridged emulsion substances, the following composition of oxidizer has been determined: % of mass, H_2O 7,0-10,0; $Ca(NO_3)_2$ 27,5-31,5; NH_4NO_3 58,5-65,5.

The composition of fuel phase of cartridged ES developed by results of thermal researches and model experiments is based on application of composition of dimeric surface-active reagents on the basis of seed fats in mixture of industrial oil and products of conversion of plant raw materials, and ceresin or oil wax are used as structure additive.

The task of ensuring high dispersion of emulsion and stability of cartridged emulsion ES with the content of water up to 10% of mass has been solved by means of the device of static emulsification of original design (Pat. UA 69553). The device is distinctive in that in one case it combines several operated emulsification stages, and allows obtaining emulsions of the necessary viscosity (more than 103 Pa·s) and dispersions (1,3-3,0 microns).

It is known [6, 7] that emulsion systems are capable to detonate only when intake of hollow microspheres or gas-generating additives which reduce emulsion density. However, the chemical gas generation is successfully used for sensitization of bulk EES

and is almost not applicable for cartridged EES with long storage time. Proceeding from it, sensitization of cartridged emulsion was performed by input of hollow microspheres (polymeric or glass).

By results of comparative polygon testing of EES sensibilized by microspheres of various producers and various chemical nature, the following results were obtained. The systems with glass microspheres K1 of 3M grade possess best sensitivity and shattering effect (the true density is 0,12-0,14 g/cm^3, average diameter of particles is about 100 microns). Also, rather good results were obtained in glass microspheres Q-Cel 6014k of Potters Industries LLC (true density is 0,13-0,19 g/cm^3). However, higher density of these microspheres in comparison with K1 requires increase in their contents in an emulsion from 3,0% of mass up to 3,8-4,5% of mass that significantly reduces volume concentration of energy of ES. Mikrosfera Q-Cel 7019k (true density is 0,19-0,25 g/cm^3) and polymeric microspheres PSV-15 and PSV-25 are weakly applicable for sensitization of cartridged ES.

The obtained results provided the basis for cartridged emulsion ES of grade Ukrainit-P [11]. In case of blast-hole breaking, industrial tests of this ES have shown that Ukrainit-P is not exceeded in operating capacity, and exceeds Ammonite No 6ZhV in safety of explosive products. However, increased consumption of Ukrainita-P (for 30-40%) was noticed in comparison with Ammonite No 6ZhV when crushing of oversize material. It required additional researches on increase in operating capacity.

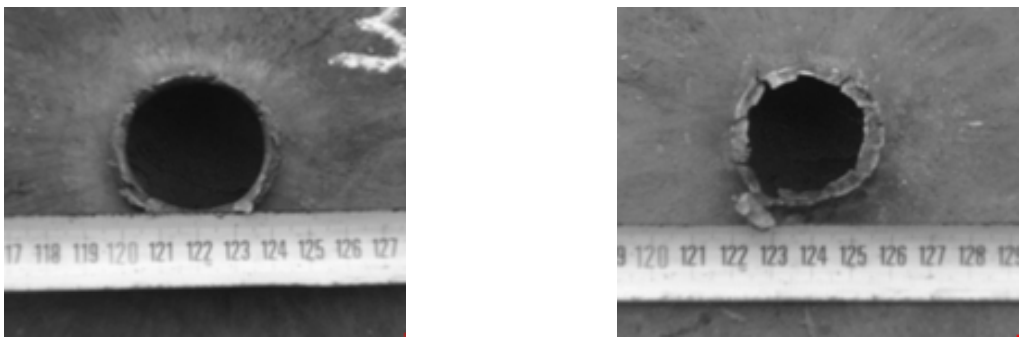
Ammonite No 6ZhV possess the increased working capacity due to combination of high level of heat of explosion Q = 4312 kJ/kg and speeds of detonation D ≤ 4,8 km/s. At the same time, the emulsion ES containing up to 10% of mass of waters cannot possess the explosion heat higher than 3400 kJ/kg at rather high speed of detonation D = 4,7-5,1 km/s.

For increase in heat of explosion of ES, energy additives are usually introduced into composition, for example aluminum powder. However, according to modern standpoints [3, 12], aluminum reacts not with ES components, but with explosion products by Chapman-Jouget plane, and energy of such interaction raises only high-explosive component of explosion without supporting the detonation front. It leads to reduction of speed of detonation and percussion action of explosion.

The task of increase in EES power parameters at maintenance of high speed of detonation has been solved due to joint introduction of powder of PA-4 aluminum with the high content of active aluminum and liquid chlorinated paraffin wax to the emulsion.

In literature [6], it is mentioned that chlorinated paraffin wax in small amounts (up to 1% of mass) can have the sensibilizing effect on emulsion systems. It has been confirmed with results of the differential and thermal analysis, introduction of 1% of mass of liquid chlorinated paraffin wax reduces the characteristic temperature of decomposition of emulsion by 12 degrees, at the same time, increasing intensity of system decomposition. It can be explained with decomposition of chlorinated paraffin wax at temperatures over 150^{0}C with formation of HCl [13] which has catalytic effect on thermo-decompounding of ammonium nitrate [14]. Chlorinated paraffin wax as a part of EES accelerates reactions of explosive transformation and provides increase in temperature in a zone of chemical reaction that leads to growth of speed of ES detonation and percussion action of explosion.

Cartridged ES with explosion heat of 3900-4300 kJ/kg and speed of detonation of 4,9-5,1 km/s were obtained by joint introduction of chlorinated paraffin wax and powder of highly active aluminum to the emulsion. Results of comparative tests of shattering effect of Ukrainita-P (with aluminum) and Ammonite No 6ZhV are given in Figure 1. Shattering effect was evaluated by penetration into steel plate with thickness of 12 mm.



1) 2)

Figure 1. Comparative tests of shattering effect: 1 - cartridged Ukrainit-P; 2 – trotyl-containing ES Ammonite No 6ZhV

According to results of conducted researches, composition and obtaining technology of cartridged emulsion ES Ukrainit of grades P-S, P-SA and P-P were developed. Ukrainit-P-P is intended for blast-hole charges formation, and Ukrainit-P-S and P-SA can be successfully used as an intermediate detonator for initiation of charges of the emulsion and granulated ES in wells and holes of any diameter, and also for crushing of oversize material. High parameters of operating capacity (heat of explosion is 3900-4300 kJ/kg, speed of detonation is 4900-5100 m/s and critical diameter is 20-23 mm) allow production of cartridges of any diameter (from 32 mm), and small amount of harmful gases of explosion (up to 25 l/kg in case of recalculation on AN) reduce toxic impact of personnel. Industrial output of cartridged ES Ukrainit-P is fulfilled at the production site PJSC "Promvzryv" (Zaporizhzhia, Ukraine). Cartridges Ukrainita-P are applied in shallow mines of Ukraine and can be used as industrial detonators of borehole charges at open works.

The range and technology of developed granulated cartridged ES Ukrainit in combination with filling emulsion ES Ukrainit provide the complex of solution of problem of conversion of underground mines of Ukraine to trotyl-free ES.

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Research of adequacy of mathematical model of heat-mass exchange in the furnace for fire resistance tests of bearing walls

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Abstract
The purpose of carrying out researches of this operation is the study of adequacy of mathematical models of fire furnaces for their further use in case of study of influence of constructive characteristics of fire furnaces on their metrological indices. For achievement of objective, fire resistance tests of bearing wall were carried out at test center and data on warming up of chamber of the furnace and of fragment under test are obtained.
Results. The mathematical model of the fire furnace, where the tests were carried out, was created in software environment of the computer system CFD FlowVision 2.5 by means of which computing experiment was conducted. Relying on results of computing experiment and fire tests, criteria of adequacy (Student criterion, Kokhren Q-criterion, F-ratio test) were calculated. On the basis of analysis, adequacy of the used mathematical models was investigated.
Scientific novelty. Application of computational experiments for design of new furnaces and enhancements of parameters of functional ones for tests according to fire resistance of bearing walls gained further development.
The **practical significance** consists in application of results of work for design and construction of new installations for test of bearing walls for the purpose of achievement of homogeneity of temperature field on the heated surfaces of constructions in the chamber of furnace, and as result, increase of efficiency of fire resistance tests as a basis for enhancement existing regulatory base and creation of new ones for tests of the specified constructions for fire resistance.
Key words: COMPUTER MODELLING, ADEQUACY OF MATHEMATICAL MODEL, BEARING WALL, FIRE RESISTANCE TESTS, COMPUTATIONAL FLUID DYNAMICS (CFD), FLOWVISION 2.5

Introduction

Enhancement of installations for fire resistance tests of building constructions is relevant problem, because in the existing laboratories, fire furnaces of such design differ significantly by geometrical configuration, type of fuel-injector system, layout diagram and design of measuring accessories. It can lead to the fact that different test facilities can give results which differ by 30% and more. In that case, it is impossible to guarantee correspondence of limits of fire resistance of constructions under test to valid standards. In this case, safety of people and material values in buildings and constructions can decrease significantly.

In order not to carry out expensive tests on study of the matter, there is an opportunity to perform such researches on the basis of results of computing experiments. The modern software on modelling of thermal processes by means of Computational Fluid Dynamics (CFD) allows considering all the necessary parameters of the researched processes and studying influence of geometrical and constructive characteristics of the furnace for tests of steel concrete constructions on quality of the obtained data.

The **purpose** of these researches is the study of adequacy of mathematical models of fire furnaces for their further use in case of study of influence of constructive characteristics of fire furnaces on their metrological indices.

Methods

For achievement of a goal, at test center of fire resistance the tests of bearing wall according to [1] were carried out and data on warming up of the chamber of furnace and fragment under test were obtained. The mathematical model of the fire furnace was created. In this model, tests in software environment of computer system CFD FlowVision 2.5, by means of which computing experiment was carried out, were conducted. Relying on results of computing experiment and fire tests, criteria of adequacy (Student criterion, Kokhren Q-criterion, F-ratio test) were calculated. On the basis of the carried-out analysis, adequacy of the used mathematical models is studied.

In papers [2, 3], advantages of application of methods of Computational Fluid Dynamics (CFD) for scientific researches in the sphere of modelling of fire resistance tests of building constructions were presented. Also in these papers, possibility of application of one of the program systems CFD FlowVision 2.5 of Tesis companies was described. Using the algorithm described in the specified papers, it was created geometrical and mathematical models of the vertical fire furnace on which tests were carried out.

The geometrical configuration of the fire furnace for fire resistance tests of bearing walls is presented in Figure 1

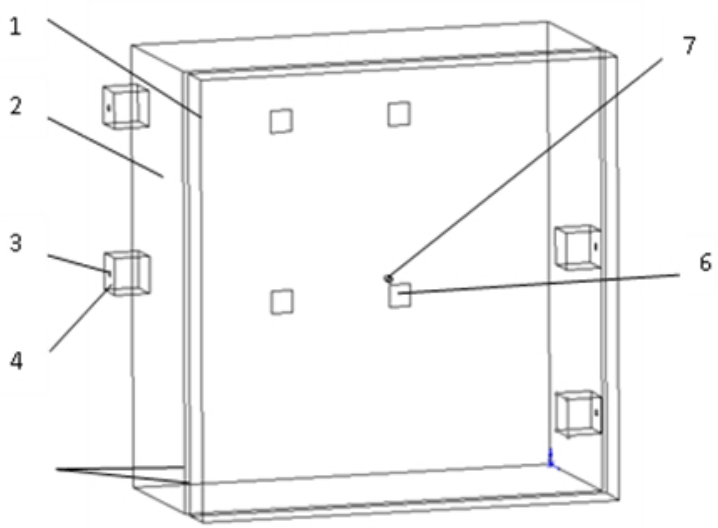
The created geometrical models import to the environment of program complex FlowVision for creation of analytical model. The basic principles of its creation are the following:

1) as the main instrument of model creation and carrying out computing experiment the program com-

plex “FlowVision 2.5” is used;

2) in the course of computing experiment, convective and radiation heat exchange of surface of constructions under test and space of chamber of the furnace is considered;

3) the thermocouple model in the form of the rod of 100 mm long and with diameter of 6 mm is provided in chambers considering convective and radiation heat exchange.



Dimensions of chamber of the fire furnace, mm			Source
Width	Height	Depth	
3000	3000	1500	[4]

Figure 1. Geometrical configuration of the furnace of installation for fire resistance tests of bearing walls: 1 – bearing wall; 2 - furnace skin; 3 - region of blow-in; 4 - region of injector; 5 - surfaces which interface; 6 - region of output of burning products, 7 – thermocouple model

After input of model parameters, the subarea of furnace chamber is interfaced to construction and thermocouple. Besides, general parameters such as gravitation axis, Courant-Friedrichs-Levy stability criterion [5], etc. are inserted.

The following stage consisted in creation of network model of the furnace. The method of control volumes applied in a program complex has certain features (Figure 2).

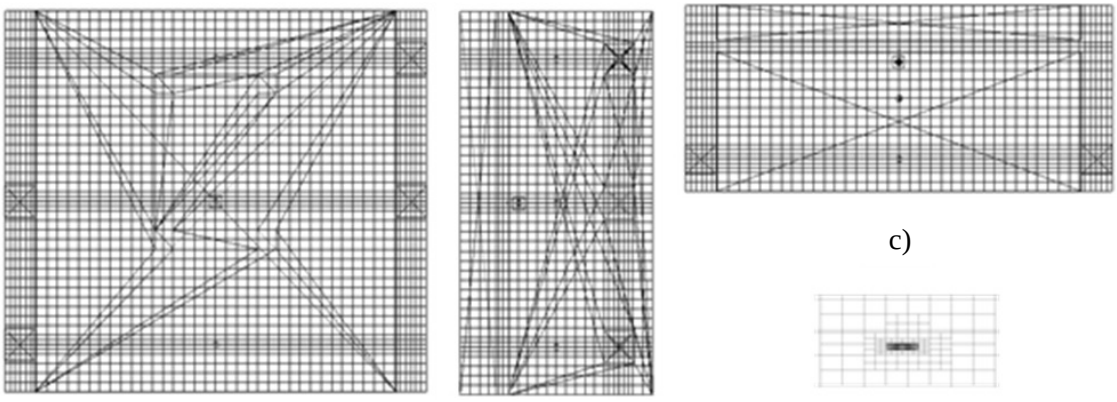


Figure 2. Grid model of area of the vertical furnace: a – view along the axis Y; b – view along the axis X; c – view along the axis Z; d – adaptive grid for the thermocouple (a view of lateral surface of the thermocouple)

Numerical integration of the equations on spatial coordinates is carried out with use of rectangular, adaptive and locally refined grid. On the one hand, this approach allows using of simple uniform non-adaptive grid in case of tasks execution on rather simple geometry. On the other hand, in the course of solution of tasks with complex geometry there is opportunity to carry out adaptation of grid to features of geometry close to boundary conditions, and in case of solution of tasks with noncontinuous flows, adaptation on values of analyzable functions, their gradients, etc. can be carried out.

Procedure of local refinement of grid in the field of adaptation assumes sequential distribution: from initial, each previous cell into 4 smaller-sized cells (in a three-dimensional case into 8) for fulfilment of condition of adaptation (for example, achievement of the specified accuracy of calculation of gradient of the considered function).

There is directly proportional dependence between the accuracy of calculation and quantity of computational cells, and inversely proportional dependence takes place between quantity of cells and time of calculation. Therefore, it is necessary to find balance between the necessary accuracy of calculation and time which will be spent for calculation.

For calculation of convective and radiation heat exchange of surface of the thermocouple and space of the furnace chamber, the adaptive grid for the thermocouple is considerably refined (Figure 2 d). Adaptation in the thermocouple is formed for this purpose.

For considering of feature which consists in availability of thermocouple models, two-stage adaptation is created at first of 1 level of space of the cylinder and 1 level of space of subarea thermocouple; it consists of the thermocouple with radius of 0.01 m and 0.12 m high.

Carrying out of computing experiment consists in initialization of burning process with temperature monitoring in thermocouple model in such a way that temperature condition of its heating precisely matches temperature standard curve of the fire [1]. For this purpose, control means of FlowVision system take off continuous data from the thermocouple in an interactive mode, and, in case of achievement of maximum temperature, for this step time parameters of burning process are changed. Then procedure of parameters change of burning process is repeated for the following time slot. At the same time, the data on temperature of surface, reinforcing layer and center of reinforced concrete products for this interval are recorded.

During experiment, temperature monitoring took place in such a way that temperature condition of thermocouple heating precisely matched temperature standard curve of the fire and did not exceed admissible limits of test [1]. For this purpose, control means of FlowVision 2.5 system took off continuous data from the thermocouple in an interactive mode, and, in case of achievement of maximum temperature, for this step time parameters of burning process were changed.

For carrying out computing experiment with use of the created mathematical models of fire furnaces, the sequences of calculation procedures described below are observed:

1) initialization of burning process with the minimum global step on time;

2) visualization value of temperature of the thermocouple and comparing control for time step of tests (the best selected value of 10 s);

3) establishment of coarser step after 0,05 s;

4) achievement of temperature corresponding to standard one of temperature condition of the fire for the current time slot, extinction of burning process by installation of the appropriate boundary conditions;

5) establishment of even more coarse step after burning-off of all particles of fuel (determined by flames temperature) to the following time slot;

6) repetition of estimated procedures for the following time slot;

7) temperature control in the construction and volume of the furnace when carrying out calculation is performed in the points of control (Figure 4 and Figure 5).

In Figure 3, the diagram of thermocouples arrangement for control of temperature condition in the furnace chamber is presented.

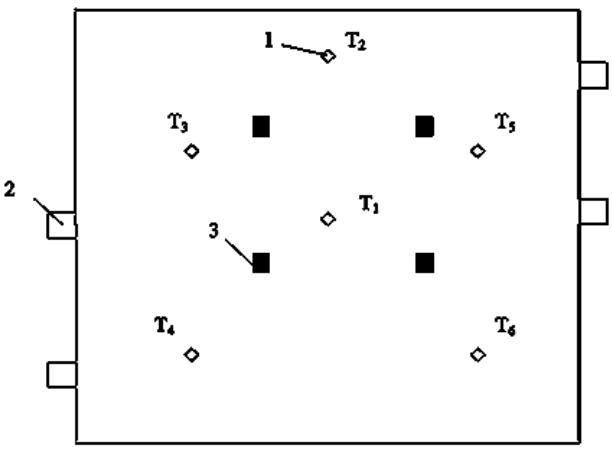


Figure 3. The diagram of thermocouples arrangement for control of temperature condition in the furnace chamber: $T_{1\text{-}6}$ – thermocouples; 1 –thermocouple; 2 – burner; 3 – hole for removal of burning products

In case of modelling of tests, the geometrical configuration of the furnace, which reproduces parameters of the chamber of real installation as accurately as possible, (Figure 1) was used. Temperature was controlled in 4 points of the furnace chamber, at distance of 100 mm from tested sample. Coordinates of temperature control area match coordinates of arrangement of thermocouples 1-6 (Figure 3) in the chamber of real installation. Temperature control is performed in such a way that the average temperature in the furnace chamber precisely matches a temperature of standard curve of the fire and did not exceed admissible limits of test [1]. In addition, the thermocouple model in the form of the rod with a diameter of 6 mm and length of 100 mm is provided in the chamber of the modeled installation for study of inertness of operation of the furnace thermocouples.

Results

Thermal process is combustion of the kerosene particles sprayed by nozzle in heating channels (Figure 1) and partially in the furnace chamber. Layout of channels causes circulation of hot air with combustion products in the chamber of the furnace and removal of the last via the smoke hole.

Indices of temperature were recorded every second for achievement of necessary accuracy during creation of diagrams.

In Figures 4 and 5, temperature curves of heating of chambers of the virtual and real furnaces are presented.

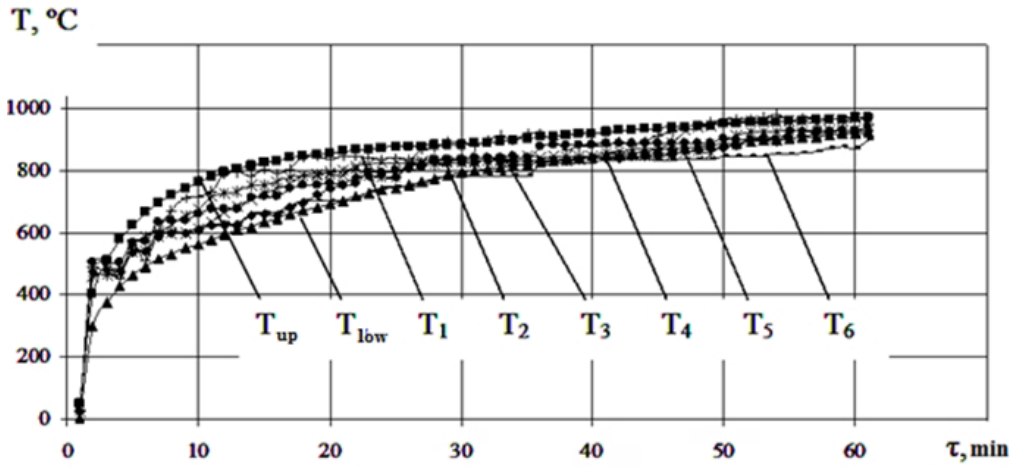


Figure 4. Temperature curves of heating of chamber area of the modeled furnace: T_{1-6} – temperatures in locations of thermocouples with appropriate numbers; T_{up}, T_{low} – limit curves of deviations of indices of thermocouples from standard temperature curve of the fire [1]

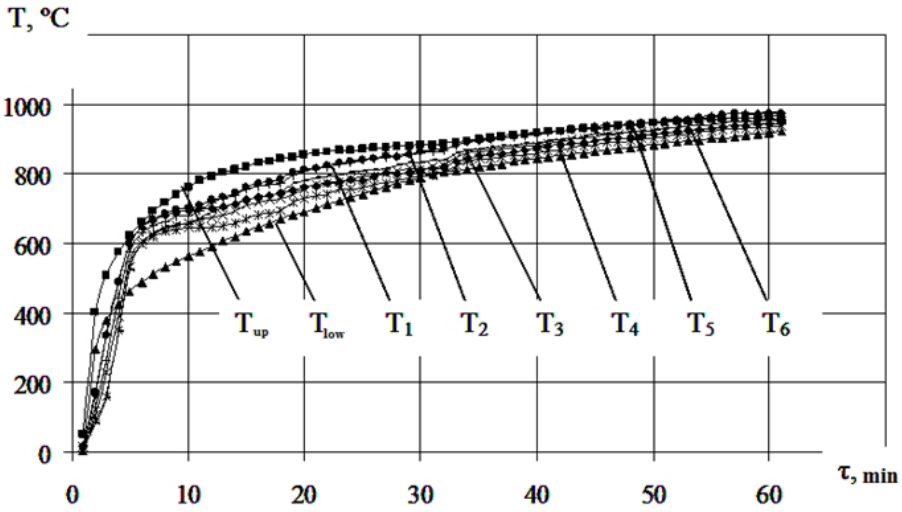


Figure 5. Temperature curves of heating of chamber area of the furnace according to the test protocol: 1-6 – temperatures of thermocouples with appropriate number; T_{up}, T_{low} – limit curves of deviations of indices of thermocouples from standard temperature curve of the fire [1]

A test of adequacy is carried out on the basis of the experimental information obtained as a result of fire tests of fragment of building construction; during this experiment, the interesting processes are observed [6].

For testing of adequacy of modelling results, such criteria of adequacy were used:

- F-ratio test. By means of Fischer's test, it is possible to check a hypothesis of equality of basic dispersions, dispersion of temperatures at every minute of tests.

Dispersion of adequacy was calculated as deviation between calculated and experimental data on each thermocouple of the experimental installation and corresponding place of temperature measurement in the model.

In the created model, 6 places of temperature control are equal as well as during experiment. Data of each thermocouple of calculation were compared with experiment thermocouples. Thus, 6 values of adequacy dispersion are obtained.

Dispersion of reproducibility was calculated as deviation of calculated temperature of area directly near the modeled thermocouple and indications of the modeled thermocouple considering experimental error [1].

Thus, we alternatively compare 6 values of adequacy dispersion, to reproducibility dispersion and calculate F-ratio test.

- Student criterion is applied to comparing of results of real and computing experiments.

6 values of criterion were obtained when calculating of reproducibility dispersion as deviation of calculated temperature of area directly near the modeled thermocouple and indications of the modeled thermocouple considering experimental error [1].

- Kokhren Q-criterion (determination of emissions and quasiemissions):

The Q-criterion is used when comparing three and more selections of identical volume. We have alternatively compared dispersions between experimental and computational data in location of each thermocouple to 2 dispersions between symmetric points in case of experiment (2 pairs of thermocouples in relation to longitudinal axis of symmetry). 6 values of criterion were obtained.

Results are summarized in the table.

Table. Parameters of dispersion of results of mathematical modelling of fire tests of bearing wall from the experimental data

Criterion		Maximum deviation, °C	Average deviation, °C	Rlative deviation, %	F-criterion	t-criterion	Q-criterion
Thermocouple zone	T_1	57,4	24,0	5,15	1,62	1,52	0,32
	T_2	64,3	22,4	4,81	3,84	1,77	0,35
	T_3	68,9	19,4	4,16	3,49	1,93	0,39
	T_4	108,1	25,0	5,37	3,77	1,82	0,32
	T_5	47,9	21,8	4,67	1,31	1,18	0,33
	T_6	42,8	21,7	4,66	4,03	1,45	0,32
Average value		64,9	22,4	4,81	3,01	1,61	0,34
Critical value		-	-	15 [1]	4,49 [6]	2,92 [6]	0,45 [6]

*author's development

Scientific novelty and practical significance. Application of computational experiments for design of new furnaces and enhancements of parameters of functional ones for tests according to fire resistance of bearing walls gained further development.

Conclusions

Relying on results of computing experiment in software environment of the computer system CFD FlowVision 2.5 and fire tests, criteria of adequacy (Student criterion, Kokhren Q-criterion, F-ratio test) were calculated. None of values of criteria exceed admissible values that shows efficiency of modelling of thermal processes for its further use in case of study of influence of constructive characteristics of fire furnaces on their metrological indices.

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