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Prospects of development of techniques and technologies in the XXI-st century

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Pachurin V.G., Phillipov A. A.; Pachurin G. V.

RESOURCE-SAVING TECHNOLOGY OF PREPARATION OF HIRE OF A STEEL 38XA UNDER COLD DISEMBARKATION OF RESPONSIBLE FIXING PRODUCTS

Nizhegorodsky State Technical University of R.E. Alekseev

ABSTRACT

In work is offered economical and ecologically purer manufacturing techniques of the calibrated hire from steel 38XA by diameter 9,65 mm for cold volumetric punching high-strength fixing products for motor group of the cars, excluding expensive operation of mechanical turning.

Keywords: *rolling, pressing, sizing, bolts, mechanical turning*

1. INTRODUCTION

Wide assortment and big a variety of demanded properties of fixing products are caused by specificity of their use in various areas of mechanical engineering. Characteristics of fasteners and their operating rates are determined at all stages of metallurgical, from the selection of charge materials for melting metal and finishing technology training drawn steel and manufactures landing [1]. On the technological processing of drawn steel and, ultimately, to the operating performance of the finished fastener obtained by the method of cold heading, strongly influenced by the properties of steel - the chemical composition, mechanical properties, macro-and microstructure, the presence of nonmetallic inclusions, etc.

In the production of fasteners to the cold upsetting hot rolled often subjected to plastic deformation compression and removal of harmful surface defects by turning an expensive operation.

Most fully the ability of steel to plastic deformation in the cold state is accepted to estimate the ratio of proof stress to ultimate strength $\sigma_{0,2}/\sigma_в$. Steel is suitable for cold forming, if $\sigma_{0,2}/\sigma_в < 0,6$. When ratios $\sigma_{0,2}/\sigma_в > 0,8$ observed high its resistance to cold plastic deformation, which leads to overload chill-forging equipment and reduce tool life. Unacceptably high values of proof strength and tensile strength, and, consequently, the relations $\sigma_{0,2}/\sigma_{\varepsilon}$, determined by a high degree of work hardening in the process of turning and calibration. This leads to the formation of metal poor microstructure and is unacceptable for cold upsetting heavy-bolts of the motor of the vehicle. In addition, the turning of the surface of drawn steel arise and other unwanted surface defects. Since in this type of technological operation using a tool with a curved cutting edge, then in a thin surface layer of metal appear high temperatures. Depth of hardened layer is in the range 0,15-0,3 mm. On the surface of rolled formed coarse screw reza and cracks. Because of the complexity of alignment quality rod is uneven removal of metal from the surface to a circle and obezuglerozhenny layer on the surface is unacceptable values (more than 0,1 mm).

Moreover, in the course of realization of the given technology of processing of ~5,5 % of metal sends in a shaving.

At the enterprises which are engaged in manufacturing of responsible fixture, the steel 38XA is widely applied.

Existing technology training under cold upsetting (for example, hot-rolled Source - 12,0 mm, the size of the finished drawn steel - 9.65 mm) of steel fasteners 38XA includes: - Sferoidiziruyuschy annealing of hot-rolled in the chamber Bogie hearth furnace at temperatures 750°C (total annealing time - 24 hours); -Metal etching to complete removal of scale; -Calibration rolled diameter 12,0 mm 10,55 mm (degree of compression - 19,1%); -Turning drawn steel with a diameter of 10.55 mm in diameter 9.97 mm; -Calibration rolled diameter 9,97 mm 9,65 mm (degree of compression - 6,0%).

In order to remove surface defects and eliminate decarbonizes layer is turning drawn steel. Cold drawn steel front landing fixture should meet the requirements of GOST 10702-78 ($\sigma_в$ = 600 МПа, hardness HB < 207; value decarbonized layer < 0,05 mm, the surface quality must comply with Group E, GOST 14955-77, it is permitted individual risks depth not more than half the limiting deviations in diameter).

Found that calibrated rolled steel grade 38XA made on existing technology, in most cases has $\sigma_в$ above 700 МПа (mean $\sigma_в$ = 780 МПа) and invalid values $\sigma_{0,2}$> 640 МПа (mean $\sigma_{0,2}$ = 680 МПа) , the difference in $\sigma_{0,2}$ and $\sigma_в$ checking reaches 100-120 МПа, with half checked steel has a hardness higher than the permissible value according to GOST 10702-78 - HB> 207, in most cases, Ψ <60%, ie below the permissible; ≈ 20 % carbon-free layer of metal is larger than 0.05 mm, which exceeds the allowable rate and more than 50% of drawn steel on the surface quality does not meet the requirements of GOST 14955-77, due to the uneven heating of the metal cages in the working space of the heating furnace is only half of the metal after annealing the requirements for NTD microstructure.

2. METHODS

In order to eliminate these disadvantages is proposed technological process of manufacturing a cold drawn steel landing of this size were 9.65 mm from the source of hot-rolled diameter of 14.0 mm without the operation of mechanical peeling.

It includes:

- Annealing of hot-rolled method HDTV (high-frequency currents) at a temperature of 760-780° C; metal etching to complete removal of slag; calibration rolling with a diameter of 14.0 mm to 12,5 mm diameter (degree of compression 20%); annealing method HDTV (currents of high frequency) at a temperature of 760-780° C; metal etching to complete removal of slag; calibration rolling with a diameter of 12,5 mm to 11.0 mm diameter (degree of compression 22%); annealing method HDTV (high-frequency currents) at temperature of 760-780° C; metal etching to complete removal of slag; calibration rolling with a diameter of 11.0 mm to a diameter of 9,65 mm (degree of compression 23%); annealing method HDTV (high-frequency currents) at a temperature of 760-780° C; metal etching to complete removal of scale; calibration through spinnerets diameter 9,65 mm (within the elastic deformation).

In this case, the total compression is 65%. For etching of samples salting the acid was used at temperature 63-67°C. Revealed that after annealing method on the surface of HD rentals, there is very little layer of oxidative attack, is deleted in hydrochloric acid for a few seconds.

Mechanical properties of the metal in the original hot-rolled condition and at all stages of technological repartition were defined at test for a stretching by explosive car TSDM-100. Tests were spent on 4 samples in length of 300 mm, the received results were averaged. Rupture of bolts, with definition of explosive loading, made by car MUP-50. The kind of breaks of bolts after destruction was studied.

Microstructure was studied on transverse microsections on an optical microscope with increasing x 600. Firmness was analyzed Rockwell scale C, in parallel polished Lysko. Tests were performed on 4 samples, the data were averaged. Microstructure and hardness were investigated in hot rolled condition and production stages.

3. RESULTS

Revealed that in the state of delivery hot rolled steel 38XA is uneven mechanical properties, the risks to the surface and partial decarbonization.

As the number of annealing at 760-780°C after a cold way HDTV calibration of plastic deformation observed a significant change in microstructure state. So perlite as sorbit becomes less dispersed, and after annealing method HDTV at an intermediate rate Ø 11,0 mm appears in the microstructure of fine-grained pearlite. At the final size of Ø 9,65 mm after the fourth annealing method HDTV formation is achieved be-fore a uniform microstructure of fine pearlite and a point with a uniformly distributed ferrite. Hardness drawn steel with a microstructure not exceeds 194 HB. There is a change in the mechanical properties of drawn steel: strength characteristic - have declined and plastic - increase. 3-time calibration and the lack of scale after annealing method HDTV leads to greatly increase the surface quality of drawn steel. Not equally for bulgarians and the fact that this metal is absent on the final size of the ellipse.

Unlike operating technology the calibrated hire of a steel 38XA, prepared on the offered technology, has considerably smaller resistance of plastic deformation, higher plasticity and lower hardness. The layer without the carbon maintenance on the given metal rolling is absent. Thus ability of the calibrated hire to deformation ($\sigma_{0,2}/\sigma_в$) makes 0,6.

Hence, such calibrated hire is considered suitable for cold volume punching.

By working out of modern power saving up technologies of reception of fixing products of a class of durability 8.8 also it is more it is necessary to use additional reserves of improvement of quality at all stages repartitions. The material applied to cold punching should possess sufficient plasticity, have uniform mechanical properties and a chemical compound and not to have superficial and internal defects.

The possible degree of compression rentals (g) depends on the plastic properties of steel and is largely determined by the microstructure [2]. The best combination of properties is achieved with melkoglobulyarnoy homogeneous microstructure with a uniform distribution of cementite in ferrite. To do this, you must correctly set the mode of heat treatment. As an intermediate heat treatment, usually applied annealing, after which the microstructure must not be detected large emissions-free ferrite. Otherwise rent due to rapid work hardening of ferrite parts will not be able to withstand high degrees of compression.

To identify the optimum degree of compression rolled, providing the required mechanical properties of drawn steel and finished products, while eliminating the quenching and tempering operations, consider three variants of the technological production of bolts of hot-rolled steel 38XA (diameter 13.0 mm) for cold heading [2] - Action (1 variant) and two proposed (2nd and 3rd options). The chemical composition corresponded to GOST 10702-78 "Steel structural quality carbon and alloy for cold extrusion and upset. Mechanical properties of hot-rolled meet the requirements of GOST 10702-78 without heat treatment. After calibration rolled by cold heading and check the microstructure and mechanical properties - $\sigma_в$, $\sigma_{0,2}$, δ, Ψ.

1st variant

This technology is the preparation of drawn steel and hardening of fasteners often used in factories, are fabricated a hardware product.

Annealing of hot-rolled (a gas chamber furnace with a retractable hearth) → graded with the degree of compression 20-26,5% → landing bolts → manufactures heat treatment (hardening + from-start).

a) Annealing of hot-rolled products was carried out by the regime: heating temperature 730ºC, holding in the furnace within 3 hours, cooling the furnace to a temperature of 650ºC, holding for 3 hours, cooling the furnace.

Application of this type of heat treatment before cold deformation is aimed at creating a certain structure to perceive large plastic signs. In this case, the microstructure of the metal reached the proportion of granular pearlite at least 80%.

b) Final calibration of the diameter of 11,0 mm on the diameter of 9.45 mm (g = 26,5%). Note that during deformation, especially with a reduction of over 22%, there is a significant mechanical hardening (increase in hardness, tensile strength and yield strength, lower elongation and contraction).

c) The landing bolts - diameter of 9.45 mm - 200 bolts.

Temperature quenching bolts consistent temperature of 860°C, a temperature of leaves - 540°C. Quenching medium - industrial oil IS-20.

However, as a result of quenching metalware products may have undesirable deformation and cracks that reduce the quality of products and increase their rogue. In addition, thermal treatment of finished metal products in the form of hardening and tempering is a cost of more than 8% of their cost.

In order to eliminate the above-mentioned negative phenomena offered two options for making drawn steel for the manufacture of fasteners by cold heading, precluding the operation of their subsequent quenching.

2nd variant

Annealing of hot-rolled (a gas chamber furnace with a retractable hearth) → preliminary ing graded with the degree of compression 15-22% → heat treatment of drawn steel → final graded with the degree of compression 5% → landing bolts.

a) Annealing of hot-rolled on the regime: temperature of 780º C, holding in the oven during 3 hours, cooling the furnace to the temperature 700º C, holding for 3 hours, cooling the furnace.

b) Preliminary calibration of intermediate sizes - with a diameter of 11.0 mm diameter 9,7 mm (g = 22%).

c) Heat treatment of the calibrated hire on a mode: temperature of salt bath at 880ºC, cooling in nitrate at a temperature of 400ºC with the support of you, within 5 minutes, air cooling 2 minutes, the final cooling in water.

For a possibility of achievement of high degrees of deformation at last transitions калибрования a steel subject to the "patenting", concluding in its heating to c to the austenitic state conditions and to cooling in the fused salt.

d) Gauging the final size with the degree of compression 5% - with a diameter of 9,7 mm diameter 9,45 mm (g = 5%).

e) Disembarkation of bolts (on 200 pieces) - diameter of 9,45 mm.

The given manufacturing techniques of the calibrated hire under cold disembarkation exclude training of ready fixing products under a class of durability 10.9.

3rd variant

Heat treatment of hot-rolled → graded with the degree of compression 20-26,5% → landing bolts.

a) Heat treatment of hot-rolled on the regime: temperature of salt bath at 880º C, cooling nitrate at a temperature of 400ºC with you-ing the course of 3 minutes, the final cooling in water.

b) Definitive calibration for the sizes - since diameter of 11,0 mm for the diameter of 9,45 mm (g = 26,5 %).

c) Disembarkation of bolts (on 200 pieces) - diameter of 9,45 mm. The given manufacturing techniques of the calibrated hire under cold disembarkation also exclude training of ready fixing products under a class of durability 10,9.

4. DISCUSSION

It is revealed that a hire microstructure in Hot a hire condition a–pearlite as sorbite and thin plates + ferrite in the form of the broken off grid on borders grains pearlite. Hardness makes 90-96 HRB.

At the calibrated hire prepared by a variant 2, value of time resistance to rupture a little above, than at the calibrated hire prepared by a variant 1 (on 120 МПа). Sizes of relative lengthening and relative narrowing are almost identical. Hence, the calibrated hire prepared by a technological variant 2, can be used for disembarkation of bolts by cold way.

At the calibrated hire made by a variant 3 time resistance to rupture higher, than at the calibrated hire made by a variant 1 (on 290 МПа), therefore it cannot be recommended to use for disembarkation of bolts by cold way as with increase of durability and hardness of a stamped material loadings on the tool increase and decreases its firmness.

Firmness of the tool, the major factor influencing stability of technological process and quality of landed bolts, at use of the calibrated hire prepared by a variant 3, for fixture manufacturing decreases on 5,25 %.

5. CONCLUSIONS

1. The calibrated hire of a steel 38ХА, made the technology excluding expensive operation of turning, possesses higher ability to cold plastic deformation and surpasses the calibrated hire made on operating technology in all indicators.

2. The offered technology is Savings of materials and energy, ecologically purer in relation to operating technology:

- There are no harmful emissions from chamber furnaces where occurs Thermal processing hire;

- Etching solutions are less often freshened, as after Thermal processing hire by way ТВЧ on it is not formed dense scale.

3. The calibrated hire of a steel 38ХА, prepared by a variant 1, meets the requirements of GOST 10702-78 and 10-12 mm can be used for manufacturing of fixture by a method of cold disembarkation with diameter of a carving.

However in this case, to correspond to a class of durability 10.9 according to GOST 1759.4-87, products of hardware should be subject to training and holiday.

4. The hire prepared under the technological scheme 3, possesses higher resistance of plastic deformation concerning technological variants 1 and 2.

Disembarkation of bolts with the given mechanical properties worsens power indicators and reduces firmness of the tool at the expense of high specific loadings on 5,25 %.

5. The calibrated hire prepared by a variant 2, meets the requirements of GOST 10702-78 and 10-12 mm can be used for manufacturing of fixture by a method of cold disembarkation with diameter of a carving.

Thus products from a steel 38XA correspond to a class of durability 10.9 according to GOST 1759.4-87 without their subsequent training and holiday that allows to lower power consumption of technological process and the cost price of reception of qualitative high-strength fixture a method of cold disembarkation.

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Ovcharuk V.N.

WAYS TO IMPROVE ACOUSTIC EMISSION NDT METHOD

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Abstract — *Acoustic emission method is used as a means of analysis of materials, constructions, productions control and diagnosis during operating time.*

It's important advantages over other control methods are that it only reacts upon upcoming really dangerous defects and its ability to scan large areas or the whole of product without scanning it by a transducer.

Index Terms — *Acoustic emission, spectral analysis, hardware-software complex.*

Introduction

Material acoustic emission is the process of producing elastic waves, provoked by local dynamic reconstruction of its structure [1]. Acoustic emission method allows detecting and registering of only developing defects, prompting to classify them not by the size but by the danger level. Besides, it is the most sensible method of NDT. All above mentioned gives acoustic emission method undeniable advantage which unfortunately is hard to always realize.

In early 60s, when the opposition of two great powers inspired the studies of acoustic emission phenomenon, there was no special equipment for that. The peculiarities of acoustic emission signals forming and propagation (complex spectrum, low energy level, wide frequency and dynamic range, etc.) raise the demands to measuring equipment [2]. Acoustic emission equipment should have high sensibility, high amplification coefficient, minimal noise level and introduce minimal distortions. Ionizing emission detecting equipment met all these requirements that time. Besides, the majority of new phenomenon researchers were nuclear physicists. It is reasonable that receiving and measuring devices designed to amplify and measure electrical signals at ionizing signals detector output were used to detect weak elastic vibrations of acoustic emission signals by simple replacement of detector by piezoelectric converter. Geiger-Muller-based devices with their scale marked in impulses per time unit were widely used to measure ionizing emissions. These devices were called intensimeters and the value measured using them – intensity. This was very convenient for detecting the particles with foregone energy characteristics. At that it was meant that to get the actual values of ionizing emissions intensity it is necessary to multiply the result by the correction factor depending on the converter type, as well as registered ionizing emission type and energy. In the process of using this type of electronic equipment to detect acoustic emission such sharpness was lost. As a result, the most common acoustic emission signals parameter is the intensity or the counting rate became deficient of physical content. Contrary to ionizing emissions the number of impulses per time unit here is by no means connected to the intensity of ultrasonic wave propagated on the deformable body.

1. Status and prospects of development

It cannot be stated that nobody was aware of the situation. As early as in 80s NPO “Dalstandart” in Khabarovsk carried out experiments which have demonstrated that applying acoustic emission parameters based on impulses reading (total acoustic emission, number of AE impulses, AE count rate, and AE activity) for quantitative acoustic emission description principles invariably results in low researches results precision. Such situation in measurements may occur in the presence of not excluded systematic inaccuracies and bear the evidence of incorrectness of such measurements due to improper choice of physical units characterizing acoustic emission properties. If to compare main acoustic emission measurement units with the International System of units [3], it can be seen that generally accepted acoustic units are almost never used for acoustic emission description. The same situation was observed before 70s in the sphere of ionizing radiation measurement just due to wide use of measurement units based on impulses counting. Upon switching to International System of units there was some regulation in values and units usage characterizing ionizing radiation and its field, and that increased measurement results reliability. Unfortunately, that did not happen in the sphere of acoustic emission. All existing normative documents starting from GOST 2763-83 and ending with rather up-to-date RD 03-131-97 and RD 03-299-99 recommend using parameters based on impulses counting.

Experimental studies results inconsistence and huge measuring inaccuracies apply not only to parameters based on impulses counting. Such parameters as AE signal maximum value (amplitude), AE signal average power, AE signal energy, the physical sense of which is beyond exception, are measured by modern acoustic emission systems with abnormally large error. Just receiving converter calibration error is 30%, adding thereto converter unit error and physical quantity measuring error. In the process of metering parameters registration these errors at least double. But this is still not the determining factor. The main error and variability source is the unwillingness of the researches to work in broad band. And we can understand them – in the process of receiving converter pass band spread its sensibility decreases. Up to this day they failed to create broad pass band converter with suitable characteristics. This forces the users to work in narrow band, having measuring error in the above mentioned parameters exceed 100%, thus loosing the meaning of the measurements. Researchers try to solve this problem demonstrating miracles of ingenuity. This results in the variety of parameters, the physical sense of which can be hardly explained.

The author as early as in 1982 during the X International Conference on nondestructive testing in Moscow, based on spectral analysis of the research studies of acoustic emission features of different materials demonstrated the inconsistency of using traditional parameters when analyzing narrow band acoustic emission signals [4], and several times proved that in his further research works. The situation is paradoxical. It turns out that it is simply impossible to measure the majority of acoustic emission parameters. We talk only about detecting an event, the validity of which should be first proved. All that is not beneficial to the method and thwarts its wide application. The situation makes the usual NDT specialist at best having passed the course in the process of qualification, become the experimentalist. Such transformation is hard for some people, and that is the main reason of the non-usage of acoustic emission method. It still used by small number of people and wide sphere for scientific researches. The existent expert NDT reference aids recommend to use twenty six parameters, eighteen of which are primary. The number of secondary parameters used by researchers in their work is kiting with each new thesis and has long ago exceeded reasonable limit.

Another difficulty of AE method realization is associated with the fact that technically we are not able to record every AE act separately. We are bound to analyze only the part of a collective process which appears to be above the equipment sensitivity threshold. This fact gives rise to multiple speculations and scientific fantasies. Mostly we can only see the tip of an iceberg and the rest data is left behind-the-scenes, under sensitivity threshold. As a result, even genuine values of such AE signal physical quantities as pulse height and energy are frequently do not allow to establish any correlations. We need comprehensive knowledge of process physics to evaluate the whole process by available data. It is important to realize that forming of the "tip" is indissolubly related to sensibility and frequency characteristic of a converter, method and accuracy of converter positioning, AE properties of a material and wave characteristics of a survey item, as well as to loading dynamics and structural in homogeneity of the material. We also have to take into consideration that AE formation process is comprised by several simultaneous processes part of which are auxiliary and depend on environmental conditions. I have recited just part of the factors to be considered in AE signal analysis. It is notable that in 70-80s AE was nicknamed as "black magic" in scientific back rooms.

AE research worker challenge can be substantially simplified by excluding doubtful physical parameters. Only unquestionable parameters should be taken. Let's try to prove the necessity of AE signal analysis in broad band. It is well-known that material AE is the process of producing elastic waves, provoked by local dynamic reconstruction of its structure. It is important to give much attention to cracks formation and development as emergency situations and breakdowns at industrial facilities are commonly stipulated by formation and further development of cracks in material of the survey item.

Solid body is a random set of structural formations. Viewing it in one scale level it can be considered as a set of grains on the surface of failure. The grains can be of a random shape. Crack development process is easy to consider as a process of successive destruction of its separate structural formations (grains). Every coherent destruction of each grain will have its emission of corresponding AE impulse. Each impulse will have individual properties reflecting grain's individual shape and size. The sequence of mentioned impulses will thus compose AE process.

From what has been said we can conclude that the energy of AE signal of the developing crack will be irregularly distributed along the frequency band. The irregularity will be of a random nature as every AE signal with its spectrum will be unique composition due to its formation and development features. These facts were many times established and this is the reason why energy and amplitude properties of the signal should be measured in broad band, taking into account all frequency components. Besides, while material destruction acoustic waves (AE signals) undergo serious changes when they spread along the survey item. AE signal in receiver point is a sum of signals from different paths. As a result the wave shape becomes distorted and impulse signals duration increases by hundreds and thousand times.

As is well-known, spectrum of signals sum equals sum of spectra, hence effective width of summarized signal spectrum should not increase. However, its distortion is considerable. Transfer properties of the acoustic tract are described by frequency response function (FRF). Classical method of frequency distortion influence exclusion consists of FRF calculation with subsequent adjustment of received signals spectral characteristics. Plane shape objects FRF can be calculated theoretically. Let us do FRF calculations for a long road.

2. Theoretical analysis of the properties of FRF samples of materials and objects of control

Metal or ceramic survey item, as well as other items made of high elasticity material can be calculated with high accuracy by linear systems. In a general way spectral characteristic module of the signal taken from converter output is defined by the following formula:

$$S_{np}(\omega) = S_u(\omega) \cdot K_{mp}(\omega) \cdot K_{np}(\omega) \quad , \qquad (1)$$

Meanings of the symbols: $S_{\ddot{\imath}\eth}(\omega)$ and $S_{\grave{e}}(\omega)$ are spectral characteristic module of the converter output signal and AE source respectively; $K_{mp}(\omega)$ and $K_{np}(\omega)$ stand for FRF of acoustic tract (survey unit) and converter respectively.

With the help of distributed parameters system mathematical apparatus it is possible to find complex transfer rating coefficient for the separate type of the wave for survey unit (long rod) FRF structure effect qualitative and quantitative assessment:

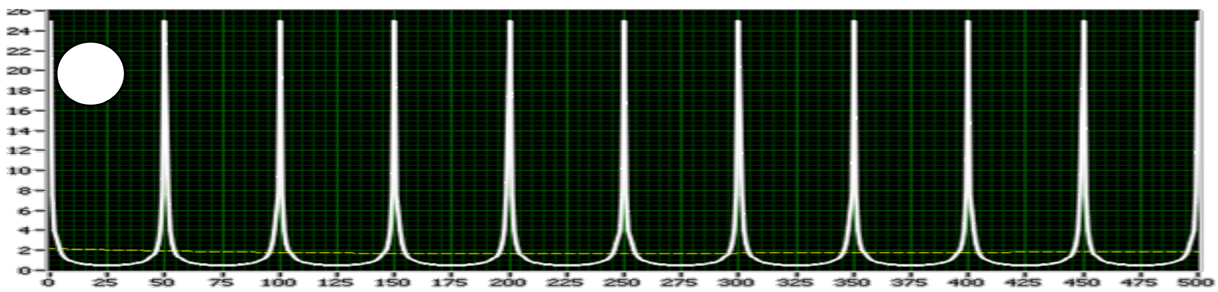
$$K_{CT}(j\omega) = \frac{ch[\gamma(j\omega)\cdot(l-x)]}{sh[\gamma(j\omega)\cdot l]}, \qquad (2)$$

Meanings of the symbols: $\gamma(j\omega) = \alpha(\omega) + j\beta(\omega)$; $\alpha(\omega)$ - acoustic signal fading coefficient; $\beta(\omega) = 2\pi/\lambda = \omega/v$ - phase coefficient; v - acoustic wave propagation velocity; λ - length of the wave; x - signal source coordinate; l - rod length.

If we place the receiver on the end surface of the rod (x = 0), FRF of the rod will be defined as follows:

$$K_{CT}(\omega) = |\ K_{CT}(j\omega)\ | \qquad (3)$$

Fig.1 represents diagrams of rod FRF relation to geometric center source coordinate. Frequencies beat results in suppression of some frequency components. Owing to above said, Ω_1 frequency halves (Fig. 1, a). Ω_2-type frequencies reveal themselves while source coordinate slight deflection (Fig. 1; b, c) with FRF curve deeply notched (Fig. 1, d). All represented relations are correct if α, l, v values are permanent.



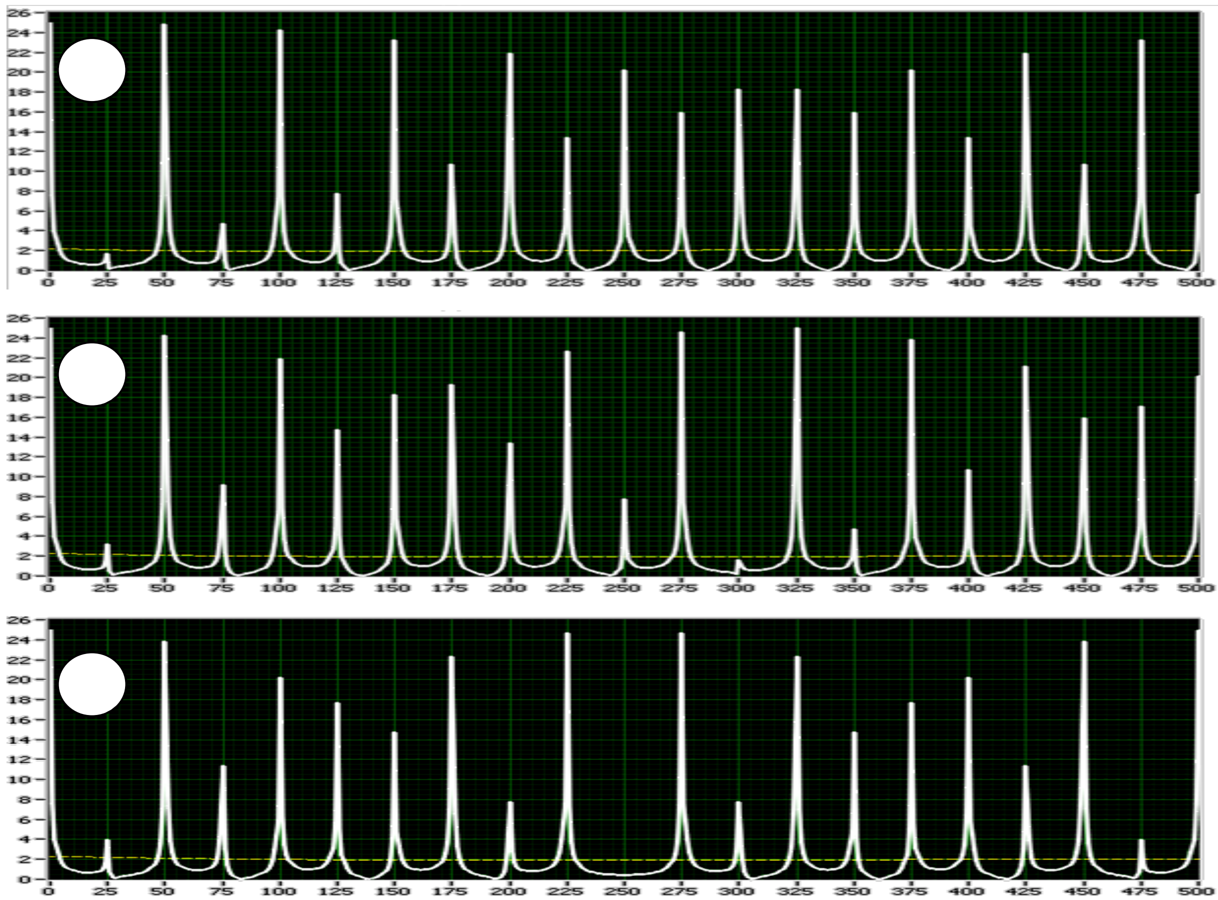


Fig.1. FRF of the rod within 0-500 kHz frequency band with following parameter values:

α=0.4 Np/m, v=5000 mps, l=0.1 m for signal source coordinate:

a) x=50mm; b) x=52mm; c) x=54mm; d) x=55mm.

Unfortunately the statement that alterations of $K_{\tilde{N}\grave{O}}(\omega)$ with frequency change has periodic nature with the following periods $\Omega_1 = \pi \cdot v/l$ and $\Omega_2 = \pi \cdot v/(l - x)$ cannot be called ultimate. Influence of the α, l, v, x parameters on FRF curve distortion is much stronger and complex. Apart from that, we can emphasize Ω_2-type frequencies, which characterize slow FRF altering. These frequencies take place as a result of frequencies beat, leading to the formation of frequency components when α, l, v, x parameters are aliquant. At the same time, these parameters can alter simultaneously resulting in ideal model disintegration (Fig. 2).

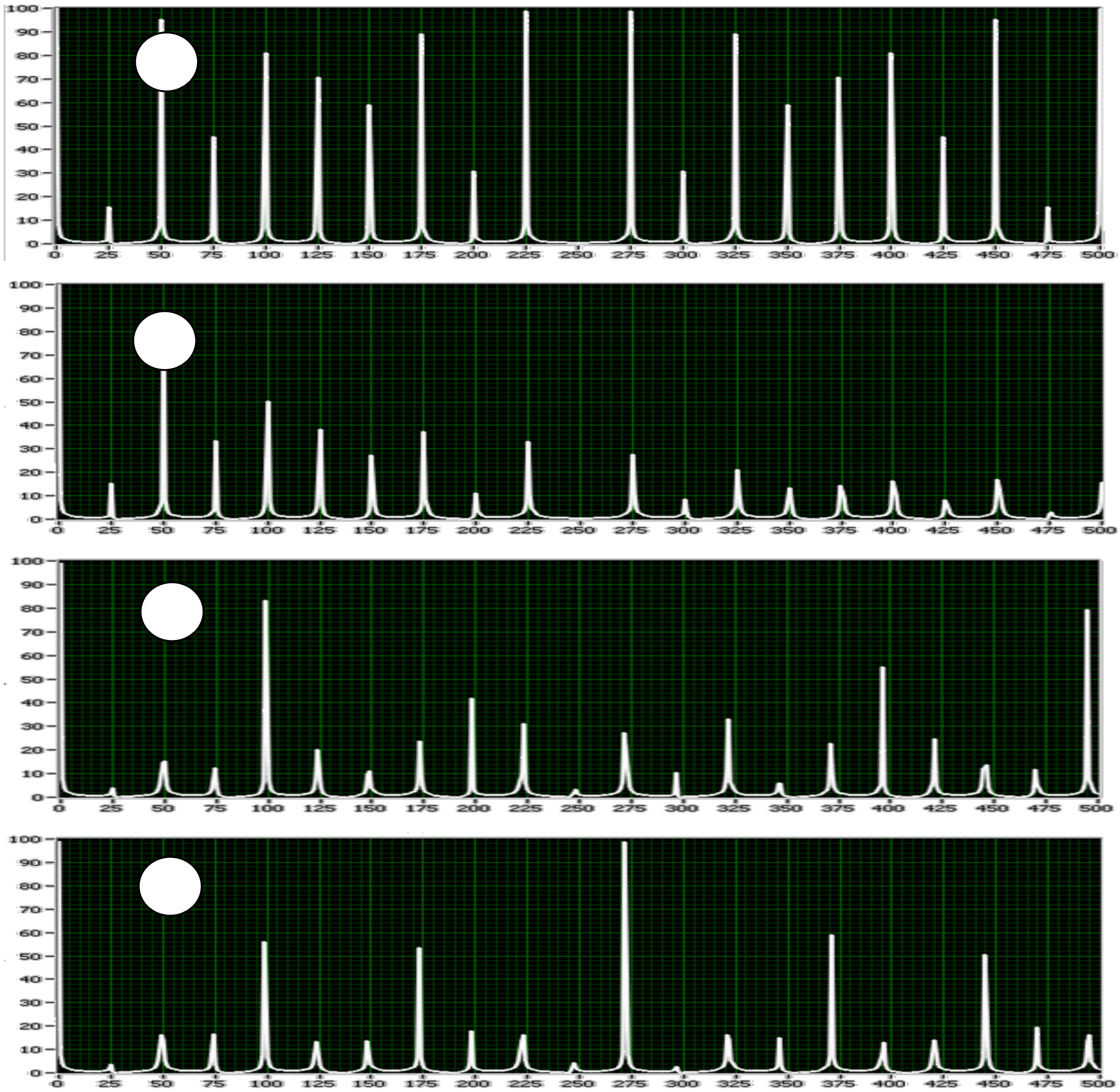


Fig.2. FRF of the rod within 0-500 kHz frequency band with fading parameter α=0.1 Np/m *and parameters: a) v=5000 mps, l=0.1 m; b) v=5005 mps, l=0.1 m; c) v=5000 mps, l=0.101 m; d) v=4995 mps, l=0.101 m. Signal source coordinate x=55mm*

Let’s take a look at the process in the most preferable 150-350 kHz frequency band. It is usually used in material and product AE properties analyses as scientists reasonably consider this band to be less influenced by noise and high frequency AE signal components fading is inconsiderable.

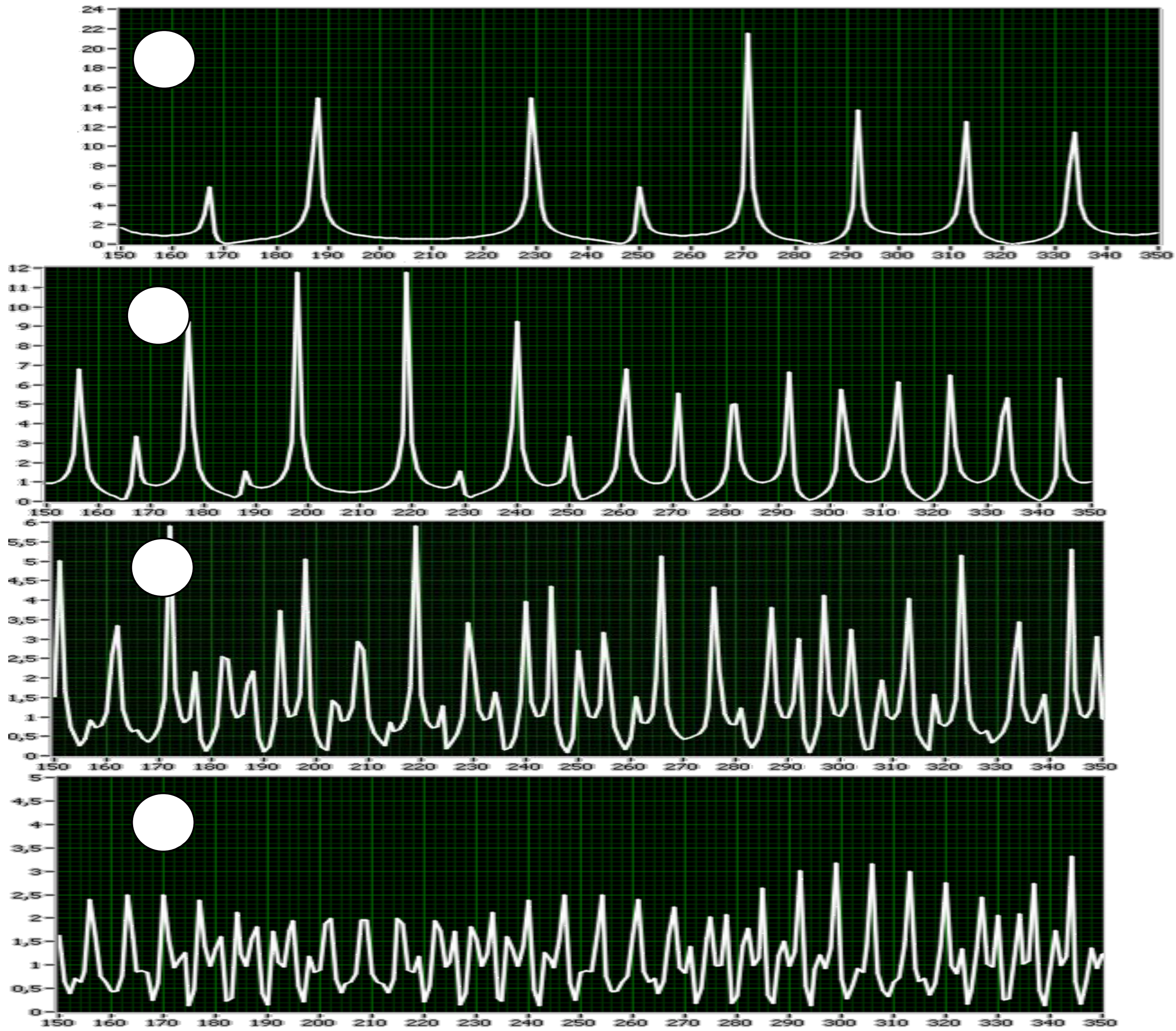


Fig.3. FRF of the rod within 150-350 kHz frequency band with fading parameter α=0.34 Np/m, v=5000 mps, x≈l /2mm and length of the rod: a) l=0.12 m; b) l=0.24 m; c) l=0.48 m; d) l=0.72 m.

Fig.3 pictures FRF of the rods. Rods length parameters are as follows: l=0.12 m; l=0.24 m; l=0.48 m и l=0.72 m, source coordinate x equals half of rod length. It is clear, that Ω_1 and Ω_2 frequencies are strongly pronounced only with low l value and constant position of source coordinate ($x=0$, $x=l/2$).

3. Experimental studies of FRF samples of ceramic materials

Slight deflections of the x coordinate from critical points leads to Ω_1 and Ω_2 frequencies beat and frequency component emerging.

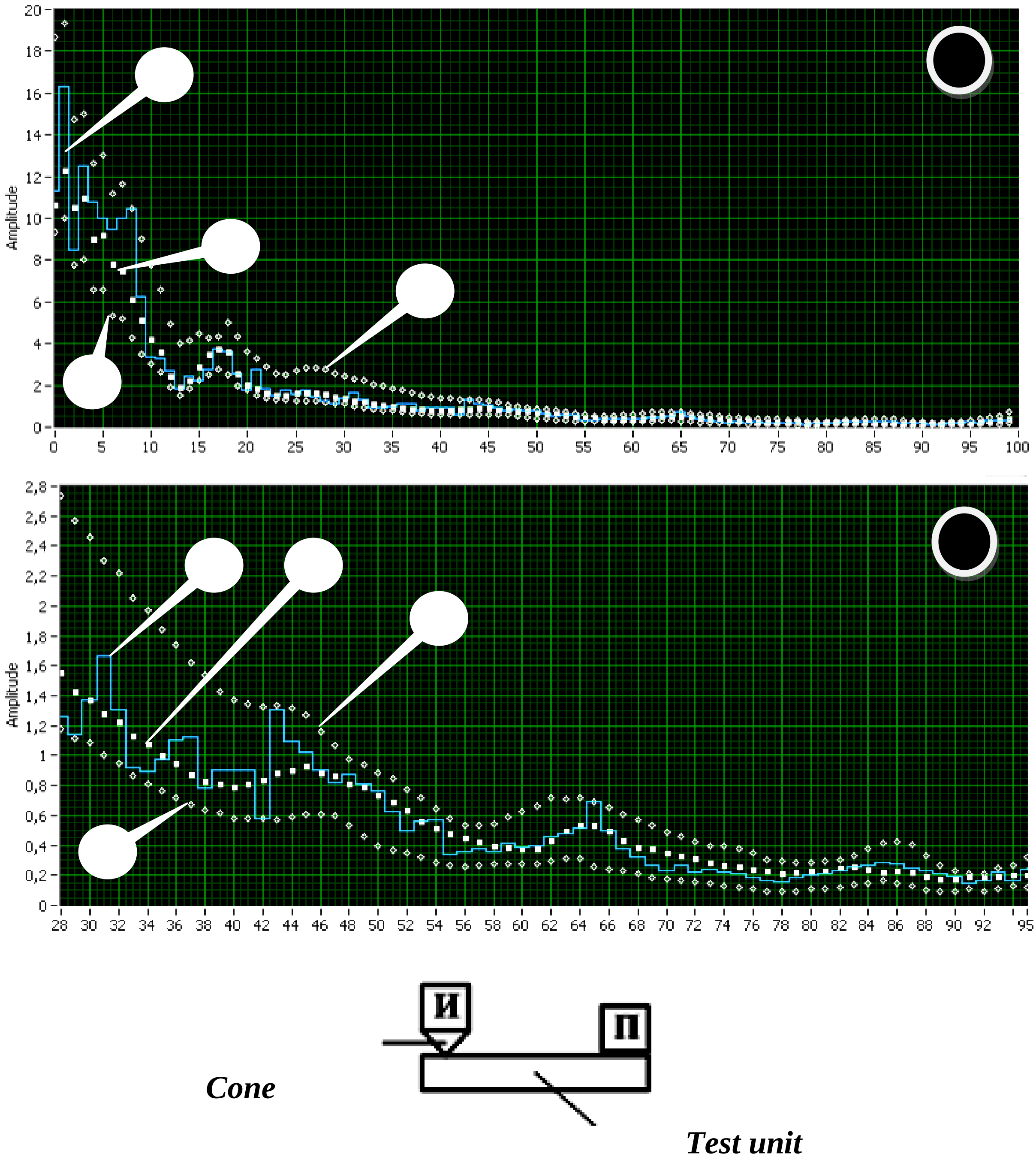


Fig. 4. FRF of the test unit within 20-2000 kHz (a) and 560-1880 kHz(b) frequency bands. Frequency-response curves are smoothed with $\Delta f \cong 10$ kHz (curve 1)

and $\Delta f \cong 100$ kHz (curve 2) in acceptable value range (curve 3, 4)

Fig.4 displays experimentally acquired FRF of 0,12m-long square ceramic rods. Acquired curves are definitely of exponential nature, which gives evidence to the fact that the model (2) is not perfect. This model along with other factors makes no allowance for fading frequency dependence. For more precise estimation of fading dependence on frequency the positive verification range is limited to 560-1880 kHz range. This allows evaluating FRF of the test unit with the 30% max error.

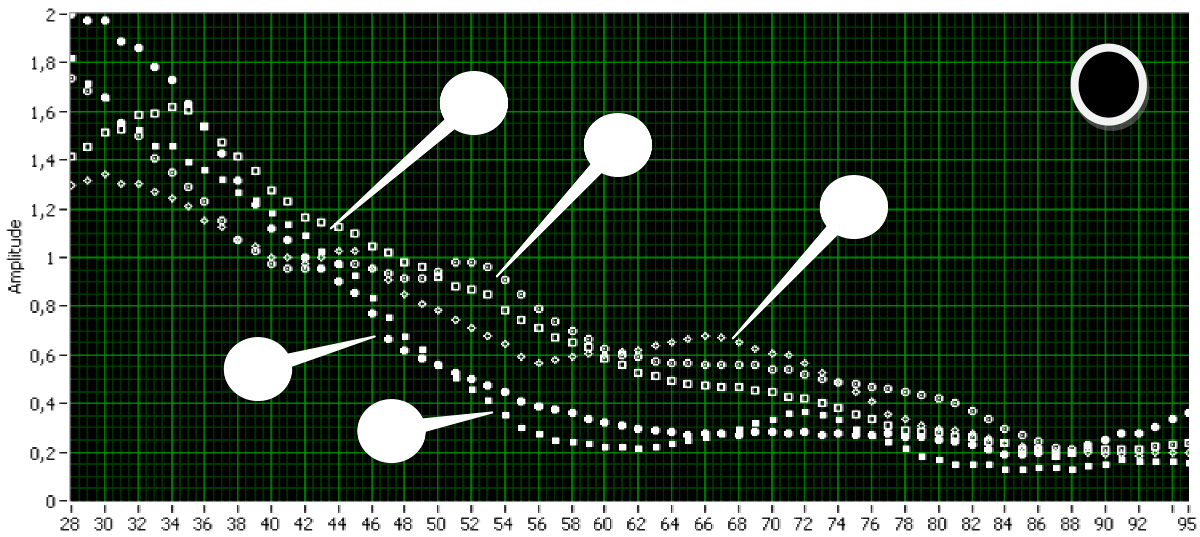


*Fig.5. FRF of S-C-T-R (*signal source-*cone-test unit-receiver) system within 20-2000 kHz (a) range and adjusted FRF of the test unit within 560-1880 kHz range (b).*

Smoothed-out spectrogram represented on Fig. 5 characterize test unit FRF altering in relation to receiving converter positioning. When the receiving converter is positioned on the end surface (curves 1, 2, 3) the FRF has broader band (high frequency components increase) as compared to when receiving converter is positioned on the surface lateral side (curves 4, 5) irrespective of signal source orientation. In the positive verification range (560-1880 kHz) curves can be easily approximated by means of exponent function.

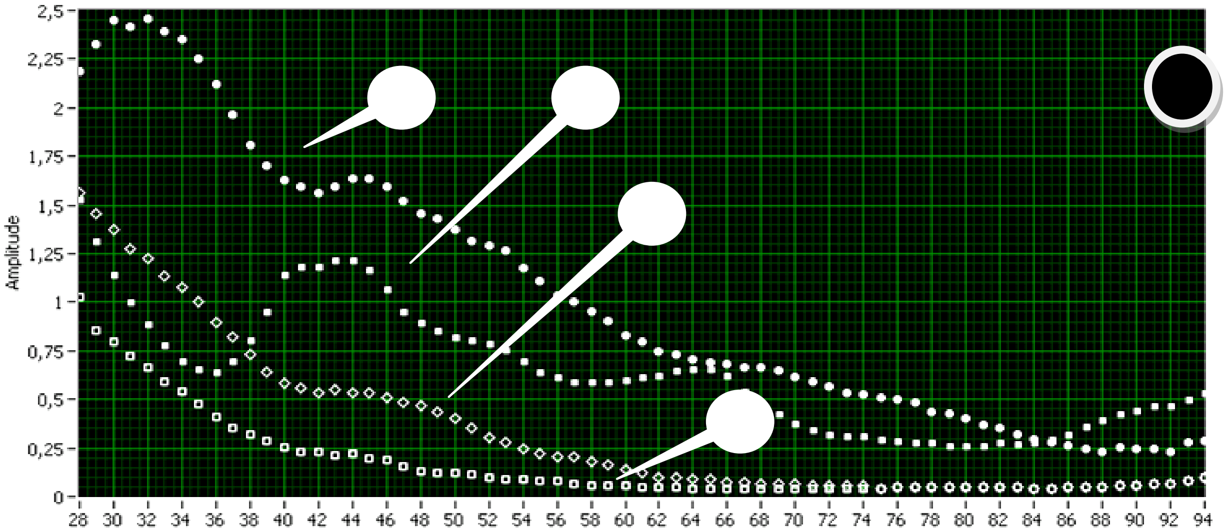


Fig. 6. FRF of the test unit within 560-1880 kHz range

1- electrical insulator porcelain; 2- silicium nitride; 3- alumina refractory; 4- alumina-boron nitride

Fading frequency qualities depend not only on geometry of the sample and converter positioning but also on material properties of the sample. Fig.6 represents adjusted frequency characteristics of the signals passed through different samples made of various materials: curve 1 - electrical insulator porcelain, 2 - alumina-boron nitride, 3 - alumina refractory, 4 - silicium nitride. Frequency characteristics of mentioned materials differ significantly.

To evaluate analyzed materials emission ability 4-point bend tests were conducted. AE signals taken were processed by the spectrum analysis device. Spectrum functions were standardized by assigned criterion and adjusted due to FRF. Fig.7 represents $S_{cp}(f_i)$ average number diagrams and ranges of limiting acceptable values of AE signals spectrum functions taken directly before destruction. The obtained results confirm high rate of AE signals emission irregularity and large fluctuations of spectrum components. This conclusion is valid for all ceramic materials under test.

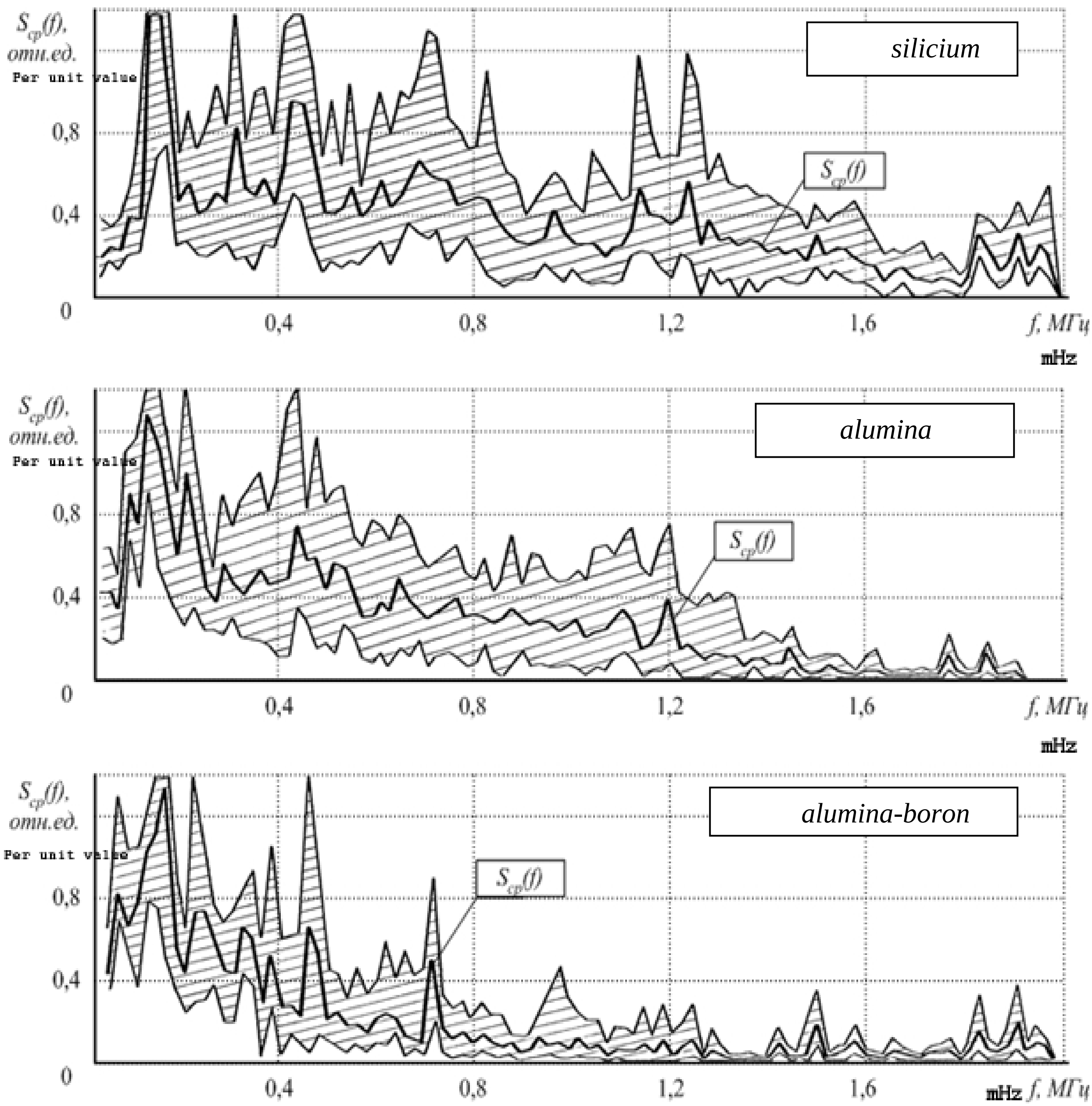


Fig.7. Averaged spectral functions $S_{cp}(f_i)$ *within 20-2000 kHz range*

Conclusions

Conclusions made are fortified by performed theoretical and experimental analysis of AE signal spectrum properties and FRF samples. Taking into consideration all above mentioned I think that:

1. It is necessary to separate the detectors which are the majority of modern means of acoustic emission control from the measuring equipment and in new researches make special reference to measuring the limited amount of parameters having physical sense.

2. It is required to bring into sync the acoustic emission measurement units and International systems of units, abandon the parameters based on impulses counting, or use correction factor when detecting each separate impulse.

3. When registering signal amplitude it is required to consider its frequency distribution connecting each amplitude rate with the corresponding vibration rate.

4. It is strictly contraindicated to measure signal energy in narrow band, naming such measures as “energetic parameters”. Energetic parameters as the acoustic emission energy itself may be obtained only based on the whole spectrum analysis.

5. With the purpose to reduce the measurement error it is required to perform receiving piezoelectric converters calibration right on the tested unit and in the process of test analysis consider “unit-converter” transfer characteristic.

6. It is required to create the commission with the purpose to draw out general provisions of the normative document that would determine the rules of acoustic emission control organization and performance rules as well as specify main requirements to acoustic emission equipment.

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MATHEMATICAL MODEL FOR COMPRESSION OF CARBON COMPOSITES FROM GAS PHASE

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The compression of porous structure of carbonized coal-plastics from a gas phase is one of important redistributions in technology of production for carbon composites. The declines of porosity for these materials secures by realization the process of filling for their structure by pyrocarbon with the use of gas-phase compression methods, to the number of which is belong an isothermal method and method of thermogradient.

Isothermal methods are successfully used for the compression of the thin-walled products from composites at two-sided admission to them reactionary gas. For the thick-walled products of these materials more preferable is a method of thermogradient compression, which is characterized by variable field of temperatures on the thickness of product, the conditioned change of coefficients heat conductivity for porous composites and pyrocarbon.

The global analysis of methods for gas-phase compression of porous composites is realized in work [1], the mechanism of thermogradient compression of these materials is considered in work [2]. The question of change for density of carbon composite on the thickness of his wall at the conditions of compression by pyrocarbon from a gas phase is actual.

The elaboration of mathematical model of compression for carbon composites by pyrocarbon from a gas phase for the conditions of isothermal method and method of thermogradient is the purpose of work.

1. Compression of carbon composites by an isothermal method

At the isothermal compression of carbon composites in the volume of reactor of running type is carried out decomposition of methane with formation of radicals (

CH_3^*, C_2H^*), hydrocarbons [$\tilde{N}_2H_2$ and $\sum C_nH_m$ (C_2H_4, C_2H_6, C_3H_8, C_4H_{10}], and also soot carbon C_{so}.

The presence of the defined chart of percolation of homogeneous reactions is accompanied by complication of diffusion for initial matters and products of reactions to the heated surfaces of carbonized coal-plastic and in his porous structure. The heterogeneous reactions with besieging of hard phase – pyrocarbon – are realized on all of the heated surfaces carbonized coal-plastic [3-5].

Permanent pressure and stationary temperature of walls is supported in a reactor. A carbonized coal-plastic and walls of reactor have practically equal temperatures. Heat transfer a radiation will be realized at the temperatures of thermal decomposition of natural gas.

At the modeling of mass transfer for reactive components of reactionary gases mixture for the conditions of thermochemical transformation the followings assumptions are accepted:

– there are examined the stationary regime of operations for circular oxisymmetric reactor, where functions, describing the structure of gas streams, do not depend from a circuitous co-ordinate;

– motion of gas streams is carried out along the ax of reactor;

– speed of diffusion for gases along the ax of reactor scorned small in relation to the speed of gases motion;

– speeds of all of homogeneous and heterogeneous reactions for every reactive component of reactionary gases mixture in a reactor set the first order on the concentrations of initial matters and products of homogeneous decomposition;

- the decision of task was carried out with the use of method of equally accessible surfaces [6], specified the twostream approaching for porous surfaces.

At this case the system of equalizations for mass transfer of i reactive component in mixture of reactionary gases will look like [6]:

$$\frac{d\left(U \cdot C_i\right)}{dz} + \Omega_i = W_i^x, \qquad (1)$$

where U is speed of gas stream on the ax of reactor; C_i is a concentration of reactive component in the volume of reactor; z is a co-ordinate on the ax of reactor; W_i^x it is speed of chemical transformation for *i* reactive component; $i = 1 \ldots 6$ is a quantity of reactive component; β is a constant of diffusion speed; k_i^s are a constant

$$\Omega_i = \frac{2\beta \cdot k_i^s \cdot C_i^s}{R \cdot \left[\beta + \left(1 - \omega_i\right) \cdot k_i^s - \pi \cdot \omega_i \cdot \frac{2k_i^s \cdot r}{D_i} \right]};$$

of speed for heterogeneous reaction i reactive component on the surface S of the compact carbon composite; C_i^s is a concentration of i component on the surface S of carbon composite; R is a radius of reactor; ω_n is relative porosity for surface of carbon composite; D_i is a coefficient of diffusion for i reactive component; r is a radius of pore.

Writing down the system of equalizations (1) for methane and basic products of his homogeneous decomposition in a reactor, get the mathematical model of convection-diffusion mass transfer of reactionary gases, chemically reactive in the volume of running reactor of isothermal type and on the porous heated surfaces of a compact carbon composite with besieging of pyrocarbon:

$$\frac{d\left(U \cdot S \cdot \phi\right)}{dz} + \Omega_6 \cdot \phi = S \cdot \left(k_1 + k_2\right) \cdot \varphi \ ;$$

$$\frac{d\left(U \cdot S \cdot \varphi\right)}{dz} + \Omega_3 \cdot \phi = S \cdot k_3 \cdot \varphi - \left(k_2 + k_4 + k_6\right) \cdot \phi \ ;$$

$$\frac{d\left(U \cdot S \cdot b\right)}{dz} + \Omega_1 \cdot b = S \cdot k_1 \cdot \varphi \ ; \qquad (2)$$

$$\frac{d\left(U \cdot S \cdot e\right)}{dz} + \Omega_2 \cdot e = S \cdot k_2 \cdot \varphi \ ;$$

$$\frac{d\left(U \cdot S \cdot f\right)}{dz} + \Omega_5 \cdot f = S \cdot k_5 \cdot \varphi \ ;$$

$$\frac{d\left(U \cdot S \cdot d\right)}{dz} + \Omega_4 \cdot d = S \cdot k_4 \cdot \varphi \ ,$$

where $\phi = 1 - x - b$; $\varphi = x - e - d - f$; x, b, e, f, d are relative parts of decomposition for methane to the products of homogeneous reactions of $C_2H_2 \ldots$ C_nH_m, $C_{\grave{o}\hat{a}}$ accordingly.

Constants of speeds of $k_1 \ldots k_6$ chemical homogeneous-heterogeneous reactions in the system (1) determine with the use of correlations:

$$k_1 = -\frac{b}{(x+b)\cdot\tau}\cdot \ln\frac{\tilde{n} - x - b}{\tilde{n}} \ ;$$

$$k_2 = \frac{e}{(d+e+f)\cdot\tau}\cdot \ln\frac{\varphi}{k_3 \cdot \tilde{n}\cdot t} \ ;$$

$$k_3 = -\frac{x}{(x+b)\cdot\tau}\cdot \ln\frac{\tilde{n} - x - b}{\tilde{n}} \ ; \qquad (3)$$

$$k_4 = \frac{d}{(d+e+f)\cdot\tau}\cdot \ln\frac{\varphi}{k_3 \cdot \tilde{n}\cdot t} \ ;$$

$$k_5 = \frac{f}{(d+e+f)\cdot\tau}\cdot \ln\frac{\varphi}{k_3 \cdot \tilde{n}\cdot t} \ ,$$

where c is an initial concentration of methane; τ is duration of process.

There are supposed that the processes of compression would be realized at execution of the followings conditions:

- speed of besieging for pyrocarbon in the porous structure of a compact carbon compositea is small;

- porosity of compact carbon composite is the slowly changing function of time.

At this case task for mass transfer in a single cylindrical pore carbonized coal-plastic is possible to formulate like that:

$$\frac{d^2C_i}{d\ell^2} = \frac{2k_i^s \cdot C_i}{\bar{r}\cdot D_i} \ ; \qquad (4)$$

$$\vartheta \cdot \frac{d\rho}{d\ell} = \sum_{i=1}^{N} S_i \cdot k_i^s \cdot C_i \ ; \qquad (5)$$

$$C_i\big|_{\ell=0} = C_i^0 \ ; \qquad (6)$$

$$\left.\frac{dC_i}{d\ell}\right|_{\ell=h} = 0 \;; \qquad (7)$$

$$\left.\rho\right|_{\ell=0} = \rho_0 \;, \qquad (8)$$

where ℓ, $\overline{r}$ are a middle radius and depth of pore accordingly; $2h$ is a thickness of product; S_i is a specific reactionary surface of carbon composite; ρ_0 is an initial density for material of composite; ϑ is speed of growth for pyrocarbon; N is an quantity of reactive components in the volume of reactor.

Decision of equalization (4) taking into account conditions (6)…(8) is possible to present as expressions:

$$C_i = \frac{C_i^0 \cdot \left\{ \exp\left[\left(\frac{2k_i^s}{\overline{r} \cdot D_i} \right)^{0,5} \cdot (\ell - 2h) \right] + \exp\left[-\ell \cdot \left(\frac{2k_i^s}{\overline{r} \cdot D_i} \right)^{0,5} \right] \right\}}{1 + \exp\left[2\ell \cdot \left(\frac{2k_i^s}{\overline{r} \cdot D_i} \right)^{0,5} \right]}, \qquad (9)$$

where C_i^0 is an initial concentration of i reactive component.

At connection with that size of specific reactionary surface carbonized coal-plastic S_i conforms the specific surface of pores it is possible to define with using of a formula:

$$S_i = \frac{2\left(\rho_{ccp} - \rho\right)}{\overline{r} \cdot \rho_{ccp} \cdot \rho} \;, \qquad (10)$$

where ρ_{ccp} is a veritable density of material for carbonized coal-plastic.

After the substitution of expression (10) in differential equalization (5) and bear in mind, that $\vartheta = \frac{1}{\rho_0} \cdot \sum_{i=1}^{N} k_i^s \cdot C_i$ can be written down:

$$\frac{d\rho}{d\ell} = \frac{2\left(\rho_{\ddot{\imath}} - \rho\right)}{\overline{r} \cdot \rho_{\ddot{\imath}} \cdot \rho} \cdot \sum_{i=1}^{N} h_i \cdot C_i \cdot \frac{\rho_0}{\sum_{i=1}^{N} k_i^s} \;. \qquad (11)$$

Subsequent integration of expression (11) on ρ (at limits from ρ_0 to ρ) and on ℓ (at limits from 0 to ℓ) allows to get transcendent equalization in relatively to a parameter, characterizing a change the apparent density of carbon composite on the thickness of product wall:

$$\rho_{ï} \cdot \ln\left(\frac{\rho_{ï} - \rho}{\rho_{ï} - \rho_0}\right) = \frac{2\rho_0}{\bar{r} \cdot \left(\frac{2k_i}{\bar{r} \cdot D_i}\right)^{0,5} \cdot \rho_{ï} \cdot \sum_{i=1}^{N} k_i^s} \cdot \sum_{i=1}^{N} k_i^s \cdot C_i^0 \cdot$$

$$\cdot \frac{\left\{1 + \exp\left[\left(\ell - 2h\right)\cdot\left(\frac{2k_i^s}{\bar{r} \cdot D_i}\right)^{0,5}\right] - \exp\left[-\ell \cdot \left(\frac{2k_i^s}{\bar{r} \cdot D_i}\right)^{0,5}\right] - \exp\left[-2h \cdot \left(\frac{2k_i^s}{\bar{r} \cdot D_i}\right)\right]\right.}{1 - \exp\left[-2h \cdot \left(\frac{2k_i^s}{\bar{r} \cdot D_i}\right)^{0,5}\right]}, \quad (12)$$

It is developed the computer program at «TURBO-PASKAL» algorithmic language for realization of calculable experiment with the use of the offered mathematical model.

Basic facts for a calculation are composition and discharge of natural gas; geometrical parameters of reactor; initial porosity carbonized coal-plastic; middle radius of pores; thickness of product wall; a temperature and remaining pressure in a reactor; duration of besieging process for pyrocarbon; energy of activating for decomposition of individual hydrocarbons.

Idem out parameters are served distributing of concentration for individual hydrocarbons (radicals) in the volume of reactor and porous structure of a compact carbon composite; speed of besieging for pyrocarbon; distributing of density carbonized coal-plastics at the thickness of product wall on his different areas.

As an example it is executed the calculation of pyrolytic compression for composite material on the basis of graphitized carbon fabrics and phenol-formaldehyde connective novolak type in the environment of natural gas (95,30 % $\tilde{N}H_4$; 2,4 H_2; 0,90 % N_2; 0,85 % C_3H_8; 0,50 % C_2H_6; 0,05 % C_4H_{10}) at a temperature 1300…1340 K and remaining pressure of 1,0 кПа (discharge of gas – 1 ·10^{-3} m^3/s, opened porosity of a compact composite – 28 %, middle radius of pores – 9,0 мкм).

Table 1.

Distributing of density at the thickness of composite after his compression at the isothermal regime

Distance from surfaces, mm	Density, g/sm^3		
	initial	calculation	actual
0	1,070	1,293	1,291
2	1,070	1,285	1,282
4	1,070	1,274	1,267
6	1,070	1,257	1,263
8	1,070	1,251	1,252

The comparison of calculation values of density carbonized coal-plastics with fact results, got during carried out of methano-optical researches is realized with the purpose of authentication of mathematical model (12) (table 1). Divergence of theoretical and experimental values of density did not exceed 0,6 %, that confirms authenticity of the offered model and it applicability for the quantitative estimation of distributing for density of material at the thickness of product wall at his isothermal compression from a gas phase.

2. Compression of carbon composites by the method of thermogradient

It is examined a model carbonized coal-plastics as a plate with thickness δ, which has cylindrical pores, perpendiculared to the surface, with the effective radius of $r_{\mathring{a}f}$ and porosity Π, the surface of pores is smooth and it is power homogeneous. Surface of plate with a coordinate $\ell = 0$ is heated to the temperature T_{int}, and surface with a coordinate $\ell = \delta$, which charactered by temperature T_{ext}, is washed reactionary gas with the temperature $\grave{O}_{gas}$.

Distributing of temperature on the thickness of model plate is described differential equalization of heat conductivity [7]

$$c \cdot \rho \frac{\partial T}{\partial \tau} = \frac{\partial}{\partial \ell}\left(\lambda \frac{\partial T}{\partial \ell} \right) , \qquad (13)$$

where $\tilde{n}$, ρ is a heat capacity and moving mass density of composite accordingly; λ is a coefficient of heat conductivity for composite; T is a temperature; ℓ, τ – moving linear and time coordinate accordingly.

For equalization (13) the regional conditions are executed:

$$T(\ell,\tau)\Big|_{\ell=0} = T_{int} \; ; \qquad (14)$$

$$\grave{O}(0,\tau) = \grave{O}_0 \; ; \qquad (15)$$

$$\lambda \frac{\partial T}{\partial x}\Bigg|_{\ell=\delta} = \alpha \cdot \left(T_{ext} - T_{gas} \right) , \qquad (16)$$

where α is a coefficient of heat emission by a convection; T_{ext}, T_0 is a temperature of outward surface and initial temperature of composite accordingly.

The heat sink conditioned passing of exothermic reactions of decomposition for reactionary gases, is not taken into account in equalization (13).

Coefficient of heat conductivity of composite the value of which depends on a change his porosity, taking into account results of work [8] is written down in a kind

$$\lambda = \lambda_{pcc} \cdot \frac{\rho_0}{\rho} + \lambda_{pc} \cdot \left(1 - \frac{\rho_0}{\rho} \right) , \qquad (17)$$

where $\lambda_{pcc}, \lambda_{pc}$ is a coefficient of heat conductivity of porous carbon composite and pyrocarbon accordingly; ρ_0 is an initial mass density of composite.

Equalization (13) with taking into account correlation (17) be of the form

$$\tilde{n} \frac{\partial \grave{O}}{\partial \tau} = \frac{\rho_0}{\rho} \cdot \left[\left(\frac{\lambda_{pc} - \lambda_{pcc}}{\rho} \right) \cdot \frac{\partial \rho}{\partial \ell} \cdot \frac{\partial \grave{O}}{\partial \ell} + \lambda_\rho \frac{\partial^2 \grave{O}}{\partial \ell^2} \right], \qquad (18)$$

where $\lambda_\rho = \lambda_{pcc} - \lambda_{pc} \cdot \left(1 - \frac{\rho}{\rho_0} \right)$.

During realization of thermogradient method the temperature of reactionary gas in the volume of reactor considerably below than threshold value, which characterizes beginning of passage for homogeneous processes [6]. The volume of natural gas, diffusing in the porous structure of composite, is small and it is possible homogeneous processes to neglect in a separate pore.

At these conditions equalization of diffusion for natural gas in a pore taking into account his decomposition on its surface for the examined method of compression it is possible to present as

$$\frac{1}{D}\cdot\frac{\partial C}{\partial \tau}=\frac{\partial^2 C}{\partial \ell^2}+\theta\cdot\frac{\partial C}{\partial \ell}-\frac{2k}{r_{åf}\cdot D}\cdot\exp\left[K\cdot\exp(\beta\cdot\ell)-\theta\cdot\ell\right]\cdot C=0\ , \qquad (19)$$

where D is a coefficient of diffusion for reactionary gas; $D=D_{ext}\cdot\left(\frac{T}{T_{ext}}\right)^{1,5}$; D_{ext} is a coefficient of diffusion for reactionary gas at the temperature of $Ò_{ext}$; C is a concentration of methane in the pore of carbon composite; $\theta=1{,}5\beta$; $\beta=\frac{1}{\delta}\cdot\ln\left(\frac{T_{int}}{T_{ext}}\right)$; $K=\frac{E}{R\cdot T_{ext}}$, E is energy of activating for formation of pyrocarbon; R – universal gas constant.

Regional conditions for equalization (19) it is possible to write down in a kind

$$C(\ell,0)=0\ ; \qquad (20)$$

$$C(\ell,0)=C^S\ ; \qquad (21)$$

$$-D\frac{\partial C}{\partial \ell}=\beta_m\cdot\left(C^S-C_0\right)\ , \qquad (22)$$

where C^S is a concentration of methane at the surface of composite; β_m is a coefficient of speed for mass transfer; C_0 is a concentration of methane in a reactor.

A change a density on the thickness of composite is described by equalization

$$-\vartheta\frac{d\rho}{d\ell}=\frac{2k\cdot\tilde{N}\cdot(\rho_{re}-\rho)}{r_{åf}\cdot\rho_{re}\cdot\rho} \qquad (23)$$

with a border condition

$$\rho\big|_{\ell=\delta}=\rho_0\ . \qquad (24)$$

System of equalizations (13), (19) and (23) with regional conditions (14)…(15), (20)…(22) and (24) describes the processes of distributing for temperature on the thickness of a compact composite taking into account diffusion of reactionary gas in the porous structure of material and besieging of pyrocarbon on the walls of pores, which stipulates the decline of porosity and increase of density of a compact material.

Decision of the offered system of differential equalizations is realized numerical methods. The algorithm of calculation is secured determination of distributing for temperature on the thickness of a compact composite, changes a concentration and speed of decomposition for reactionary gas at the thickness of wall for this material, and also changes his density.

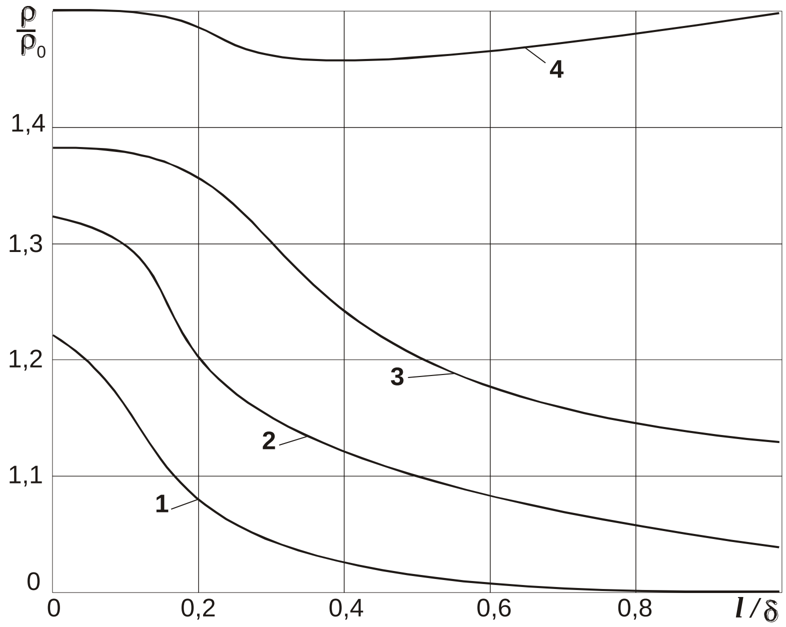

Figure 1 Distributing of density on a thickness of carbon composite at compression in the environment of natural gas:

1 - 0,1 τ_p; 2 - 0,3 τ_p; 3 - 0,5 τ_p; 4 - τ_p

Calculation researches realized for composite at his compression of pyrocarbon from natural gas of composition: 96,30 CH_4; 2,0 H_2; 0,80 N_2; 0,50 C_2H_6; 0,35 C_3H_8 i 0,05 C_4H_{10}. A temperature of internal wall of composite T_{int} – 1380 K, his initial density ρ_0 – 1,09 g/sm^3.

It is set the results of calculations (fig. 1), that density of a compact carbon composite in a center a plate on 3…4 % below, than in area of both surfaces, and calculation dependences for distributing of density on the thickness of this composite correspond the conclusions of work [2].

The got decision allows to set the technological parameters of compression for composition materials on the basis of carbon from a gas phase in the conditions of thermogfadient. The results of executed experimental researches of this process in the environment of natural gas confirmed sufficient exactness of the developed model, and also its applicability for the quantitative estimation of distributing of density of material on the thickness of wall plate (product at its compression in the conditions of thermogfadient.

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PARAMETERS OF DENDRITIC STRUCTURE OF COPPER ALLOYS

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Abstract

In this research it was examined the influence of conditions of crystallisation binary leaded bronze on parametres of a received microstructure. Change of crystallisation conditions was carried out by change of cooling melt speed, through preliminary heating of casting moulds. Quantitative regularities of influence of cooling rate of explored bronze on parametres dendritic cells, grain size are presented. The data about formation of lead inclusions between dendrites of a copper matrix are published as well. It is shown that high rates of cooling of an order 100-150°C/s lead to dendritic structures formation containing only axes of the first and second order. Decrease of cooling rate at the moment of crystallisation to the values less 15°C/s leads to appearance and growth of axes of 3rd order at dendrites matrix.

Introduction

Copper alloys, and bronze is the most frequent from them, are used in mechanical engineering for products manufacturing with high antifrictional and antiscoring characteristics, for example, sliding bearings. Quite often the details made of such materials, fail out not due to deterioration, but because of destruction. In many respects mechanical properties and possibility of such details outage will depend on the microstructure parametres – the size of a matrix grain, parametres of a dendritic cells etc. [1,2]. Such dependences are defined and revealed the quantitative laws reflecting the influence of microstructure parametres of antifrictional bronzes on their mechanical properties [3-5]. At the same time, the influence of crystallisation parametres on received structure of forming has been researched only qualitatively. The researches representing quantitative data about microstructure parametres formed under various conditions of crystallisation are practically missing.

In the course of the present work the researches showing the laws of influence of crystallisation parametres on dendritic structure formation in bronzes have been executed. The most detailed was examined the crystallisation parametre of cooling rate as its change is most often used in practice [6]

Experimental

Experimental samples for researches were made by liquid melt pouring of investigated bronze in graphite casting moulds and the subsequent crystallisation at various rates of cooling. Rates of cooling changed by preliminary heating of a casting mould to various temperatures (t_{mould}=20°C, V_{cool}=158°C/s; t_{mould}=200°C, V_{cool}=137°C/s; t_{mould}=400°C, V_{cool}=43°C/s; t_{mould}=600°C, V_{cool}=25°C/s; t_{mould}=800°C, V_{cool}=10°C/s; t_{mould}=1100°C; V_{cool}=0,15°C/s) [7]. The bronze was taken as an investigated material which chemical compound is listed in table 1. This bronze has diphasic structure – a copper matrix and small inclusions of lead [8]. In such bronze growth of the copper dendrites is not influenced by any other factors, except changeable rate of cooling.

In this case use of bronze of difficult structure leads to appearance of influence of other elements effecting on phase structure and on the form of the generated matrix dendrites. Such factors will influence depending on the rate of cooling as well and this will not allow to identify the results unambiguously. The choice of 10 % of the composition of a fusible phase is caused by affinity of this concentration to its maintenance in bronzes, used in the industry (C92900, C93700, C93800), and such inclusion of lead considerably improves machinability of the made experimental samples. Investigated bronzes were smelted in high-frequency induction crucible furnace from technically pure components in silicicated graphite crucible. Deoxidation was made with phosphorous copper before a lead laying in liquid melt. Pouring temperature was 1070°C and was controlled by high-speed optical pyrometer TPT-90 with laser pointing. Casts represented cylinders with a diameter 17 mm and height 70 mm. The microstructure of samples was studied on optical microscope ZEISS AXIO Observer.A1m with the built-in in camera and ZEISS Axiovert 40 MAT, section etchings had not been done. Quantitative characteristics of a microstructure (percent of structural components and their average size) defined by means of the developed computer program [9], and as with a help of specialized program complex Carl Ceisse delivered together with the above-mentioned microscope, by the techniques described in work [10].

Results and discussion

Carried out metallographic analysis shown the essential difference of mouldings structure at different rates of cooling.

On fig. 1 the mouldings macrostructure is shown at different temperatures of pouring. A typical view of casting, absence of contraction cavities near the free surface and presence of columnar crystals zone (fig. 1a), proves the directed cooling of casting from an external surface irrespective of temperature of form heating. This happens due to the small sizes of height and internal diameter of casting. The visual analysis shows that at high rates of cooling (fig. 1a, b) the casting macrostructure represents the classical macrostructure of a stationary ingot consisting of three easily distinguishable zones.

Tab 1 The chemical composition of the test material.

Chemical composition, % (mass)								
Cu	Pb	Mg	Al	Si	S	Ti	Fe	Sn
91,14	8,52	0,01	0,01	0,04	0,01	0,02	0,05	0,02

Zones of small crystals – crusts with the sizes 0,1-0,3 mm, completely from small homaxonic crystals, the sizes no more than 0,1 mm; zones of columnar crystals with a length about 0,5-1,1mm and the central zone of large homaxonic crystals, the sizes 0,7 - 1 mm. With reduction of cooling rate (increasing of heating temperature of a casting mould) happens a reduction of length and thickness of columnar crystals and at cooling rate 25°C/s (fig. 1c) and lower this zone disappears absolutely. At the same time, there is a growth of grains in the central and peripheral zones of casting so at cooling with a speed less 1°C/s the sizes of crystals in the casting centre reach 1,5 mm and more. It says about more uniform rate of cooling on section of casting during all period of crystallisation.

a) b) c)

Fig. 1 (a) macrostructure of castings obtained at a cooling rate 158°C/s; (b) – 50 °C/s; (c) – 10 °C/s.

At decrease of cooling rate takes place a considerable growth of dendrites [11]. As shown in the table 2 the change of cooling rate from 160°C/s to 80-100°C/s increases distance between axes of the dendrites of second order by small size of 17 % and 33 %.

Tab 2 Effect of cooling rate on the distance between the axes of second-order dendrites in the test material.

The cooling rate of casting, °C/s	The distance between the axes of second-order dendrites, μm
158	12
137	14
78	16
25	25
10	33
0,15	120

The further decreasing of cooling rate leads to more considerable growth of axes (fig. 2e, f). At cooling rate lower than 25°C/s dendrites get axes of the 3rd order.

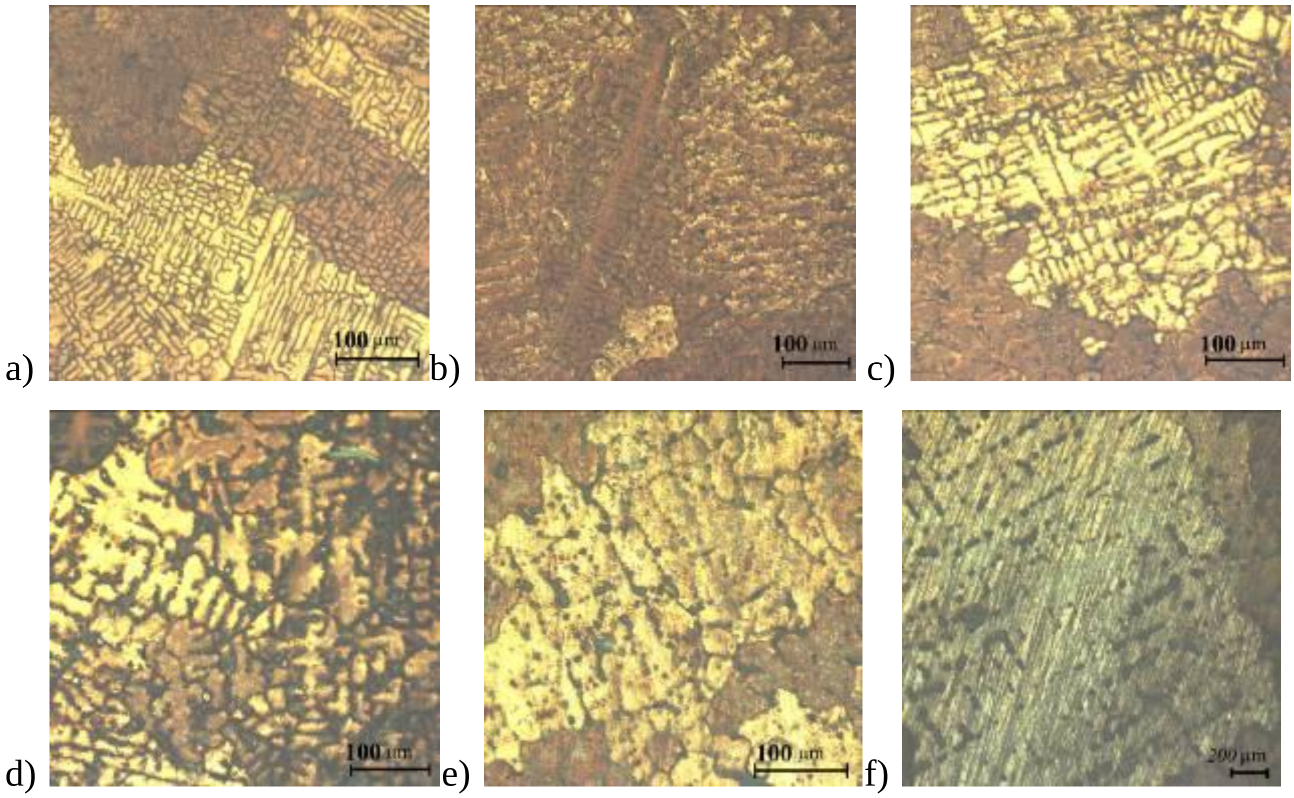

Fig. 2 (a) microstructure of castings received at a cooling rate 158°C/s; (b) – 137 °C/s; (c) – 78 °C/s; (d) – 25°C/s; (e) – 10 °C/s; (f) – 0,15 °C/s.

The increase of dendrites leads to grain growth, on fig. 2 it is shown that dendrites of one colour (or a shade) form uniform grain. Nature of dependence of grain growth from cooling rate repeats practically the nature of dependence of distance growth between axes of the second order from cooling rate. At high cooling rates the grain size changes gradually so at cooling rate of casting 158°C/s average diameter of grain is about 200 microns, and at 137°C/s – 250-300 microns. At lower cooling rates more active growth of grain begins. Cooling rate of casting 25°C/s gives average diameter of grain about 600 microns, and 10°C/s – ~ 1 mm and at cooling together with a form, heated to 1100°C (V_{cool}=0,15°C/s), grain can grow till the sizes of some millimetres. The sizes of grain are non-uniform on casting section, on a surface grain is smaller, and in the centre of the form is larger. The difference for high cooling rates is 2 and more times, with reduction of cooling rate this ratio decreases and, for example, at V_{cool}=10°C/s is 1,3-1,5 times.

On fig. 2a, b it is shown that for high cooling rates the lead in a form of very thin veins is distributed in interdendritic joints and on the borders of grains. At that the inclusions shape is the oblong and awkward. With reducing of cooling rate the roundish lead inclusions appear between axes of the second order of dendrites, between dendrites joints of one grain lead is not found practically, and settles on borders of grains mainly (fig. 2d, e).

Increase of cooling rate leads to substantial growth of matrix grains quantity and reduces time for processes of a liquid and copper crystallisation division. Lead inclusions have no time for coagulation. Besides they appear surrounded by crystallized matrix giving no possibility to unification of particles of a low-melting phase. As a result the lead inclusions, crystallising in last turn, occupy free space. The form of their surface repeats the form of surrounding copper dendrites. With cooling rate decreasing the quantity of matrix grains falls, their size grows and time of processes passing of stratification and crystallisation increases. Lead inclusions have a possibility to coagulate. The part of such particles settles itself between axes of the second and third order dendrites.

Acknowledgements

Falling of cooling rate of a copper matrix of investigated material leads naturally to dendrites growth and its grains. At that the obtained data say that at high cooling rate 120-160°C/s distances between axes of the dendrites of the second order will have size 10-15 microns. Thus the average diameter of a grain will be less than 200 microns. Axes of the third order of matrix dendrites will be absent at such speeds. Decrease of cooling rate of mouldings during crystallisation to 40-80°C/s leads to formation of undeveloped axes of 3rd order of dendrites and to grain growth to size ~500μm. Cooling during the process of crystallisation with very slow rates (less 1°C/s) received by cooling together with the furnace gives considerable dendrites growth and average diameter of a grain. At such rates the distance between axes of the second order reaches values 100 μm, developed axes of 3rd order appear. Diameter of some grains can reach values of several millimetres.

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INNOVATIVE GREEN MANURE TECHNOLOGIES ON THE ORGANIC FARMING IN LITHUANIA

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Abstract. *The paper presents effect of application of innovative green manure technologies on the productivity of ecologic cereals and effect on environment.*

Key words: *perennial grasses, green manure technologies, cereal productivity, indicators of soil ($N_{inorg.}$, $C_{org.}$, $N_{total.}$).*

Introduction

The achieved high level of advance in application of intensive crop cultivation technologies does not ensure safe application of manure and pesticides. Environmental problems of water and soil pollution, soil erosion, reduction of biological diversity as well as other problems still exist all over the country. One of strategic aims of Lithuanian agricultural farming is to ensure the long-term expansion of competitive agricultural and food economies, encouragement of various economic activities in rural localities, development of bio-energetics, farming, which protects and nurtures the environment. It is important to match good economic results with sparing application of resources and level of waste – by maintaining the biologic variety, saving ecosystems. Economics to be based on the newest knowledge and innovations, linked with regular management of biological resources as well as production and use, enabling the development of safe, ecologic and competitive agricultural food, forage and etc. products.

Application of EU and national support aids, interest of consumers in safe products, encourages the development of ecologic production farms in Lithuania. The number of such farms increased in 2002–2006; hence this process is dependent upon financial support, because production of ecologic products is often economically inefficient [2]. Moreover, single-type crop cultivation farms with low variety of crops, inappropriate crop rotation, dominate in Lithuania. It is difficult to deal with problems of crops' supply with nutrients, protection from harmful acts and other problems in such ecologic farms. The consequence is low productivity, sometimes insufficient quality of production, low efficiency of application of resources.

The base of organic farming should have multi-structural composition with legumes (*Leguminosae*), cattle and production, oriented towards the closed cycle of nutrient circulation [6]. Organic farming, unlike conventional farming, has complex relationships between different components of the agro-ecosystem and the quantity and quality of the final products depend on the functioning of the entire system [11]. Successful further development of ecologic agricultural farming shall depend on the fact how successful application of innovations – new products, technologies, processes – in ecologic production farms shall be. The aim of these researches is to assess the effect of application of innovative green manure technologies on the productivity of ecologic cereals, the quality of grains and effect on environment.

Materials and methods

Technological principles. This article deals with application of the green mass of perennial legumes for manure by applying the mulch technology. The aboveground mass of perennial grass is mulched in the soil surface 2–4 times during the period of vegetation: it is cut, chopped and spread in order to use the biologic nitrogen, bound by legumes more efficiently, and to save the environment from pollution [7]. Chopped mass of legumes is rich in nitrogen and has a property of rapid mineralization; therefore the free nitrogen is bound by intensively growing perennial grass or is incorporated to the content of organic matters of soil [8]. The mentioned above describes how organic compounds, rich in nitrogen, are formed in soil; they have feature of slow mineralization and provide cereals with nutrients for several years or may be incorporated to a more stable content of soil organic compounds.

Place and soil. Experiments were set up in 2007-2009 at the LIA's Joniškėlis Research Station on an *Endocalcari–Endohypogleyic Cambisol,* the texture of which is clay loam (clay particles < 0.002 mm in Ap horizon 0–30 cm is 27.0%), on silty clay with deeper lying sandy loam. Parental rock is limnoglacial clay, which transforms to morenic clay loam in the depth of 70–80 cm. Agrochemical characteristics of the ploughlayer: pH_{KCl} – 6.4, mobile P_2O_5 and K_2O – respectively 154 and 224 mg kg^{-1} of soil.

Experiment scheme and field management. Field experiments were carried out at Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry (LRCAF) in 2007–2010 on, chemical analysis – in Laboratory of Chemical Researches of Agriculture Institute (LRCAF). Research was conducted in the following sequence of the crop rotation: 2007 spring barley (*Hordeum vulgare* L.)+ undersown perennial grass – 2008 perennial grass – 2009 winter wheat (*Triticum aestivum* L. emend. Fiori et Paol.) – 2010 winter triticale (x *Triticosecale* Wittm.). Factor A: perennial grass: 1) festulolium (x *Festulolium*) (control, aboveground biomass removed from the field), 2) red clover (*Trifolium pratense* L.), 3) mixture of red clover and festulolium, 4) lucerne (*Medicago sativa* L.), 5) mixture of lucerne and festulolium. Factor B: management methods of aboveground biomass of perennial grass: 1) removed from the field, 2) mixed management, 3) mulching.

In the first experimental year (2007), spring barley (cv. 'Ula') was undersown with perennial grass in compliance with the experimental design: red clover (cv. 'Vyliai', at a seed rate of 7.5 million ha^{-1}), lucerne (cv. 'Birutė', at a seed rate of 7.5 million ha^{-1}), festulolium (cv. 'Punia', at a seed rate of 6.2 million ha^{-1}) and mixtures of both legume with festulolium (seed rate ratio of legume to grasses 2:1). In the first treatment (B1) of application of the aboveground biomass of perennial grass, the green mass was cut twice at the beginning of flowering: on 10 06 2008 and 25 08 2008 and removed from field. In the second treatment (B2), the aboveground biomass was used under mixed management: the first grass was cut at the beginning of flowering (10 06 2008) and removed from the field, the second and third cuts were taken during perennial grass inflorescence growth stage (17 07 2008, 12 08 2008) and mulched on the soil surface. In the third treatment (B3), the green mass was cut every 30–40 days four times (12 05 2008, 13 06 2008, 11 07 2008, 12 08 2008) and mulched on the soil surface. Aboveground biomass for green manure was cut by a self-propelled mower, equipped with a mulching device, then chopped and evenly spread on the plot. In the second half of August, the plots of all treatments were disked and 2 weeks later were ploughed at the 25 cm depth. Before sowing, the field was cultivated and harrowed at the same time. Winter wheat (cv. 'Tauras') was sown at a seed rate of 220 kg ha^{-1}. During the second experimental year, winter triticale (cv. 'Voltario') was sown with the seed norm of 240 kg ha^{-1}. Ecological winter cereal cultivation technology was applied.

Plants'and soil analysis. Aboveground mass of perennial grasses after every cutting was defined by the method of weighting. Samples of the aboveground biomass were taken for the determination of dry matter (dried to constant mass at 105^{o}C), nitrogen and organic carbon. Elementar analyzer Vario EL and Carry 50 were used for identification of nitrogen and carbon in biomass. Soil $N_{inorg.}$ was identified by these methods: N-NH_4 – spectrophotometric method; N-NO_3 – ionometric method. Soil organic carbon ($C_{org.}$) was measured by Tyurin, total nitrogen (Ntotal) – by Kjeldal method. Soil and plants' analysis were performed in Laboratories of Chemical Researches at LIA. The experimental data were processed by the analysis of variance and correlation-regression analysis methods using a software package "Selekcija".

Results and discussion

1. Biomass yield of crops intended for the green manure

Amount of the aboveground biomass, applied for the green manure, was dependent upon the productivity of grass. Significant effect was made by types of crops (P < 0.01) and ways of the aboveground mass application (P < 0.01); the interaction of these factors was not significant. It was defined that the lowest yield of aboveground mass was observed in festulolium, averagely 40.4 % significantly lower if compared to the red clover (Table 1). It was affected by the lack of nitrogen during the period of vegetation. Due to the feature to form the aboveground mass slower during the first year, the lucerne yield was significantly lower. Only the cultivation of legumes in mixtures with festulolium had the tendency to increase the total yield of the aboveground mass. Average data indicates that in cases the biomass was applied in a combined method, the yield increased significantly (averagely by 12.4%), while in case of mulching, the tendency of reduction was observed (averagely by 8.2%), if compared to cases when the whole aboveground mass of grass was removed from the field. Researchers from other countries present various data concerning the effect of mulching on the grass productivity. The reason, indicated by many authors, is that the grass cut affects the photosynthesis and biologic nitrogen fixation – they get slower. In cases the aboveground mass was applied in the combined manner, similar amount of the biomass of mixture of legumes and legumes/festulolium was incorporated. When all grass is mulched, the content of incorporated biomass can be increased 1.5–1.8 times. The majority of biomass was incorporated by mulching the red clover and mixture of red clover/festulolium, the smaller amount – lucerne. Festulolium was different: in cases of the applied combined method or the mulching method, the lowest content of the aboveground biomass of crops was incorporated to soil.

Tab 1.

Biomass yield of crops intended for the green manure, kg ha^{-1} DM, 2008

Management methods (B)	Application of the aboveground mass	Perennial grass (A)				
		F	RC	RC+F	L	L+F
Removal from field	All aboveground mass was removed from field	5253	8243	9220	6373	9239
Mixed method	Removed from field	3683	4185	5692	3095	5593
	Applied for the green manure	1934	4949	4607	4609	4710

	Total content	5617	9134	10300	7744	10304
Mulching method	All aboveground mass was applied for the green manure	4331	8142	8208	6882	7639
Total aboveground mass LSD_{05} A-873.1, B-676.3, AB-1512.3.						

Note: RC – Red clover; RC+F – Red clover + festulolium; L – Lucerne; L+F– Liucerne + festulolium ;F – Festulolium.

2. Accumulation of biogenic elements in the yield of crops

In cases the mixed method of the red clover or lucerne aboveround mass was applied for the green manure, the soil is enriched by similar nitrogen content 148–148 kg ha^{-1} (Table 2).

Tab 2.

Accumulation of biogenic elements in the biomass of crops, intended for the green manure, (average data of all harvests), **2008**

Perennial grass (A)	Management methods of aboveground biomass (B)									
	mixed					mulching				
	N	P	K	C:N	Lignin:N	N	P	K	C:N	Lignin:N
	kg ha^{-1}					kg ha^{-1}				
F	31	11	99	36	20	55	11	92	43	17
RC	148	20	186	18	10	254	22	189	17	8
RC+F	114	22	223	19/32*	9/16	219	23	210	18/28	7/12
L	149	20	166	17	9	215	23	180	15	6
L+F	121	23	221	14/33	9/17	195	23	203	15/37	6/11

Note: RC – Red clover; RC+F – Red clover + festulolium; L – Lucerne; L+F– Liucerne + festulolium ;F – Festulolium; 19/32 C:N (or lignin:N) ratio respectively in legume and grasses green masse

Mulching of the whole aboveground mass of legumes or mixture of legumes/festulolium can increase the nitrogen content to 195–254 kg ha^{-1}. The difference of the nitrogen, accumulated in the biomass of legumes or mixture of legumes/festulolium was not high (20–35 kg ha^{-1}). Our research evidence suggests that symbiotic nitrogen content, fixed from the air by red clover (underground and aboveground mass) was: if the aboveground biomass was removed from field – 137.9 kg ha^{-1}, if mixed management was applied – 182.4 kg ha^{-1}, if mulching was applied – 191.4 kg ha^{-1}; meanwhile lucerne – 206.5, 204.4 and 251.9 kg ha^{-1}, respectively. Depending on the aboveground biomass management method, symbiotic nitrogen (N_2) fixation efficiency in red clover biomass was 60.8–83.4%, in lucerne 68.1–83.6% [5]. Assessment of management methods of the aboveground biomass of perennial grass showed that the symbiotic nitrogen content in plant biomass was the highest when mulching of perennial legumes had been used. Hence, this method of the aboveground biomass management cannot be assessed unambiguously, because reoccurring legume could use mineralized nitrogen from previously spread mulch. According to Hatch et al. [4], mulching of the aboveground biomass of clover/grasses led to reduction of relative part of fixed nitrogen in biomass.

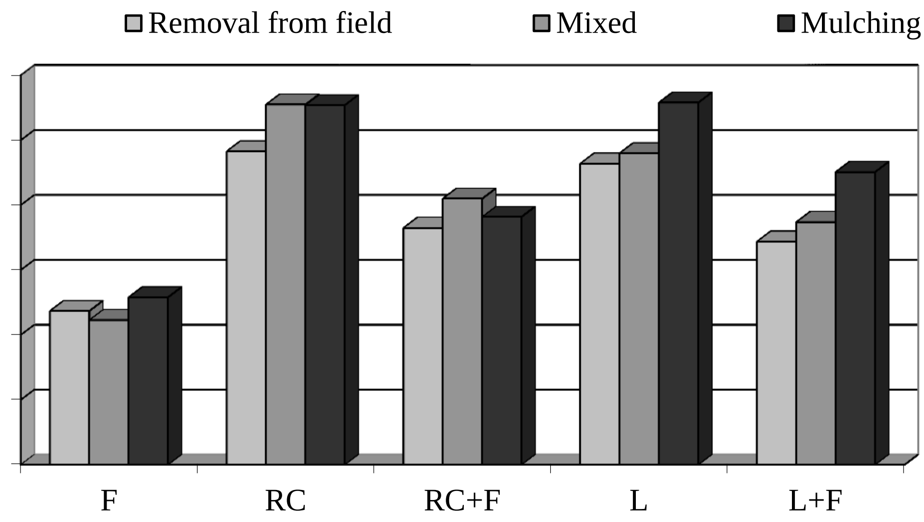
High content of potassium was identified in the aboveground mass of red clover, lucerne or their mixture with festulolium. When applying part (mixed method) or all (mulching method) aboveground mass for the manure, the content did not vary a lot. Irrespectively from ways of applying the aboveground mass and legumes' cultivation methods, the content of phosphorus was not high – 20–23 kg ha^{-1}.

Researchers indicate that the aboveground mass of crops, containing high levels of nitrogen > 2.0–2.5% (C:N ratio approximately 20), initiate the division during the first week after incorporation. The C:N ratio of red clover mulch was 17–18 and that of lucerne mulch 15–17. When the mentioned legumes had been cultivated in mixtures with festulolium, the C:N ratio of the grass mulch increased. This ratio in the mulch of festulolium was the highest (36–43). The C:N ratio of leaves of the same crop is narrower than the one of stem or roots [5]. The crop age increases this ratio [10]. Cobo et al. (2002) state that leaves are divided 5 time faster than stems. It is closely linked with the cell wall content or Lignin:N ratio [3]. In our researches, when mulching legumes (mixed method) during the second part of summer, their aboveground mass Lignin:N ratio was 9–10; in cases mulching was applied – 6–10. Lignin:N ratio in festulolium biomass, cultivated in crops with the mixed method applied, was 20. In cases they were cultivated in mixtures with legumes or with frequent mulching, the ratio was narrower.

3. Impact of green manure technologies on the cereals' productivity

The highest grain yield was produced when winter wheat had been cultivated after legumes (Figure 1). Legume/festulolium swards reduced winter wheat yield. Application of all green mass of perennial grass as green manure (mulching) significantly increased the grain yield by average 16.1% or 0.62 t ha^{-1}. When part of the aboveground biomass had been used as green manure (mixed management), the grain yield tended to increase, the increase amounted to on average 7.7% or 0.30 t ha^{-1}, compared to the treatment where all green mass had been removed from the field. The highest winter wheat grain yield was produced when the crop had been cultivated after red clover with aboveground biomass used under mixed management or mulched. The grain yield increase was by 0.72 and 0.71 t ha^{-1} respectively, higher if compared to cases when the grass was removed from field. After lucerne pre-crop, the wheat grain yield was lower (average 0.30 t ha^{-1}) than that after red clover. It might have been influenced by higher root biomass and its C:N ratio. This fact influenced slower mineralization of organic matter and reduced N_{inorg} accumulation in the soil (except for aboveground biomass mulching), compared to red clover. After lucerne sward, the greatest wheat grain yield increase was obtained when the aboveground biomass was used for mulch.

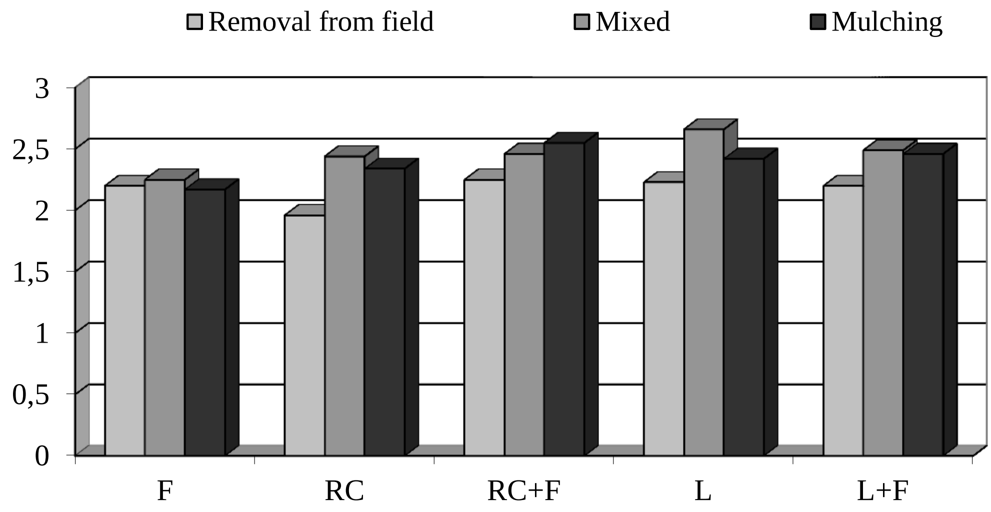
Winter wheat grain yield significantly ($P < 0.05$) correlated with soil inorganic nitrogen ($N_{inorg.}$) content. Grain yield relationship with $N_{inorg.}$ content in spring after resumption of winter wheat vegetation was strong ($r = 0.783$), with N_{inorg} determined late in the autumn the relationship was moderate ($r = 0.632$). There was no relationship between the grain yield and $N_{inorg.}$ determined after winter wheat harvesting.



Note. RC – red clover, F – festulolium, RC + F – red clover + festulolium, L – lucerne, L + F – lucerne + festulolium. LSD_{05} A-0.501, B-0.388, AB-0.868.

Fig 1. The grain yield of winter wheat as influenced by perennial grass species and aboveground biomass management methods, 2009

During the second year of effect, within cultivation of the triticale, significant effect of the grain yield was made by ways of applying the aboveground biomass only ($P < 0.05$) (Figure 2). Mulching of the whole grass aboveground biomass significantly increased the cereal yield averagely by 0.22 t ha^{-1}, and in cases the combined method was applied – averagely by 0.30 t ha^{-1} if compared to cases when the yield was removed from field. The highest winter triticale yield was observed in their cultivation after incorporation of the mulch of the whole aboveground mass of mixture of red clover/festulolium (mulching method) or the part of the aboveground mass of lucerne (mixed method) respectively by 2.55 and 2.66 t ha^{-1}. The lowest winter triticale grain yield was identified when cereals were cultivated without the green manure (except festulolium).



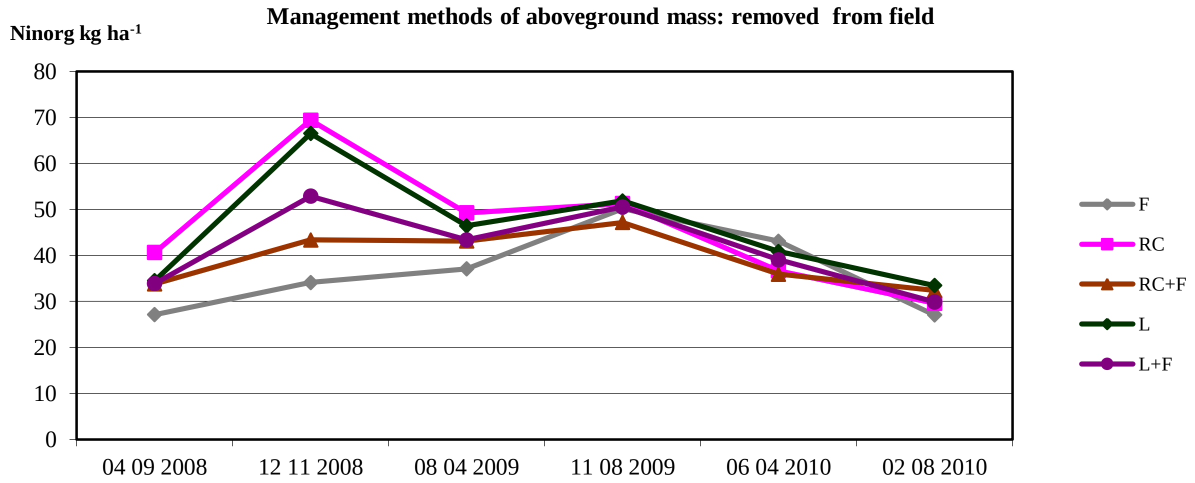
Note. RC – red clover, F – festulolium, RC + F – red clover + festulolium, L – lucerne, L + F – lucerne + festulolium. LSD_{05} A-0.214, B-0.166, AB-0.371.

Fig 2. The grain yield of winter triticale as influenced by perennial grass species and aboveground biomass management methods, 2010

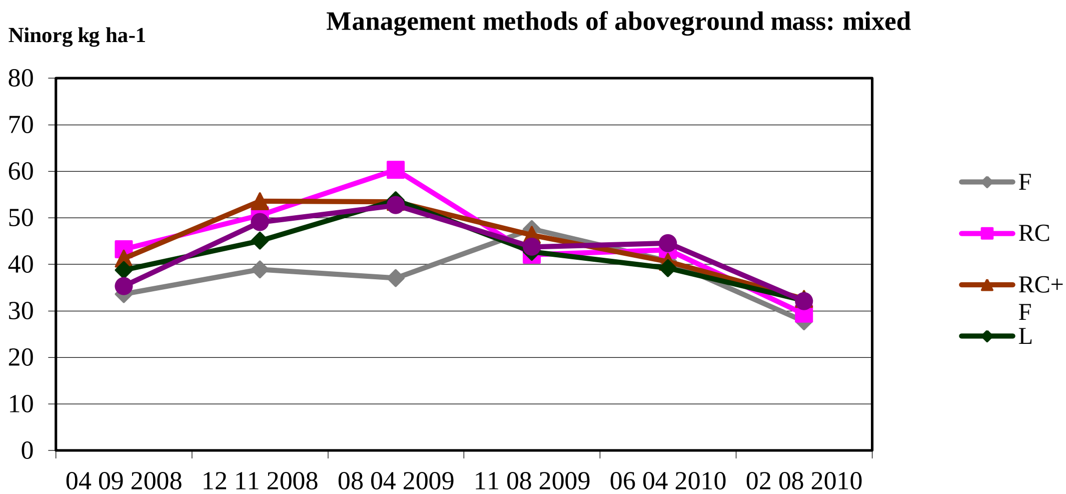
4. Impact of green manure technologies on the environment

Inorganic nitrogen ($N_{inorg.}$) in the soil. At the end of summer (04 09 2008), prior to the grass swards ploughing, the content of $N_{inorg.}$ was not high (27.1–40.6 kg ha^{-1}) in the soil layer 0–60 cm, while its highest content was in red clover and lucerne cultivation treatments (Figure 3 a,b,c). Winter wheat was sown after ploughing in perennial grasses.

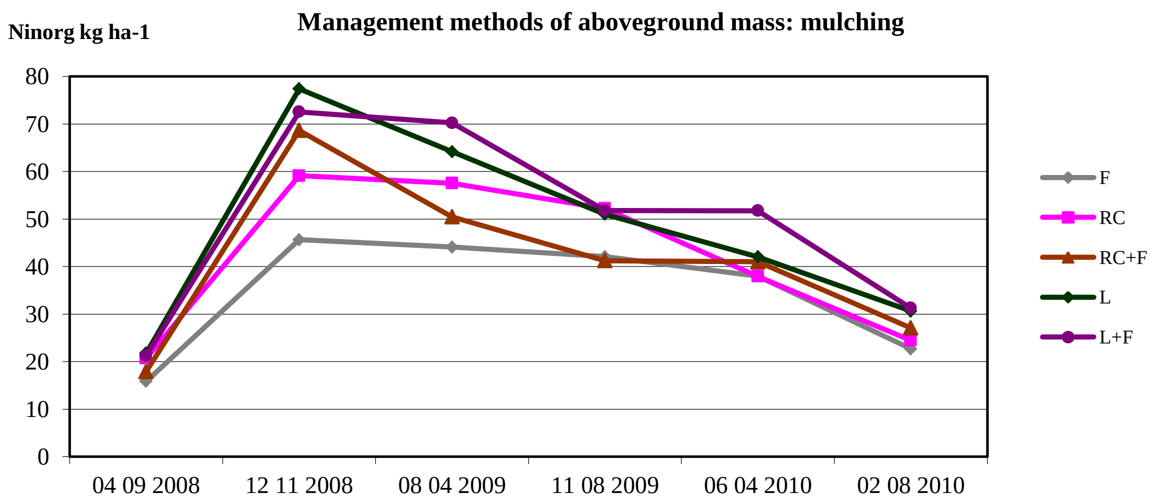
Late in the autumn (12 11 2008), $N_{inorg.}$ was measured in the 0–60 cm soil layer and the findings indicated that its content increased by 1.2–2.0 times or 9.6–39.0 kg ha^{-1}, compared to N_{inorg} content determined at the start of September. Averaged data show that the lowest N_{inorg} content in the soil was after festulolium 39.6 kg ha^{-1}, i.e. 33.7% or 37.2% less than after red clover or lucerne. When all aboveground biomass had been removed from the field, the amount of $N_{inorg.}$ varied in a similar way to that obtained prior to ploughing of grass (increased after legume crops), but when it had been used for green manure $N_{inorg.}$ content differed.



a)



b)



c)

Fig 3. The dynamics of $N_{inorg.}$ (0–60 cm soil layer) depending to species of perennial grasses and their aboveground mass management methods

If part of the aboveground biomass of perennial grass had been used as green manure (mixed management), the highest $N_{inorg.}$ content was measured after red clover or its mixture with festulolium. When all green mass had been mulched, the highest $N_{inorg.}$ content accumulated after lucerne and mixture of lucerne/festulolium. When all aboveground biomass of perennial grass, mentioned above, had been used under mixed management, $N_{inorg.}$ content was the lowest compared to that under other management methods. With increasing N_{inorg} content in the soil, the relative part of nitrate nitrogen increased in most cases.

In spring (08 04 2009), the amount of $N_{inorg.}$ in the 0–60 cm soil layer reduced (4.6–22.5%) in most cases, compared to its status in the autumn. The greatest reduction in $N_{inorg.}$ content was noted in the treatments with the highest nitrate nitrogen content in the autumn (except for the plot with incorporated mulch of lucerne/festulolium mixture). Similar research conducted in Denmark showed that mulch, incorporated into a light-textured soil increased the risk of nitrogen leaching during the autumn-winter period. Absorption of mobile nutrients is higher in heavy loam soils and the leak is lower [9]. The change in $N_{inorg.}$ content in the soil was significantly influenced by the species of perennial grass and the aboveground biomass management method. Comparison of perennial grass species evidenced significantly lower $N_{inorg.}$ content in the soil after cultivation of festulolium (on average 16.2 kg ha^{-1} or 29.1% lower) and its mixture with red clover (8.8 kg ha^{-1} or 15.9% lower), compared to pure red clover. Averaged data indicate that the effect of red clover, lucerne and their mixture with festulolium on $N_{inorg.}$ content was similar. When all aboveground biomass of perennial grass had been used as green manure (mulching), $N_{inorg.}$ content in the soil significantly increased (by on average 13.4 kg ha^{-1} or 30.5%). When only part of the aboveground biomass had been used as green manure (mixed management), $N_{inorg.}$ content increased (by on average 6.2 kg ha^{-1} or 14.2%), compared to the plot with all yield of perennial grass removed from the field.

After winter wheat harvesting (11 08 2009), soil $N_{inorg.}$ content in the 0–60 cm layer, compared to that in early spring, was a little higher when green mass of perennial grass had been removed from the field. When the biomass had been managed as mulch, the $N_{inorg.}$ content was lower, and when it had been used under mixed management N_{inorg} variem. After winter wheat harvesting, soil $N_{inorg.}$ content was significantly influenced by the management methods of the aboveground biomass of perennial grass. Soil $N_{inorg.}$ content was 42.1–52.2 kg ha^{-1} and varied a little between treatments.

During the second year of effect of applied aids, in spring (06 04 2010), during cultivation of winter triticale, the incorporated aboveground mass of legumes and legumes /grasses had a tendency to increase $N_{inorg.}$ content in soil. In cases the aboveground mass of grass was mulched, $N_{inorg.}$ content was averagely 7.9% higher than in cases it was removed from the field.

During cultivation of winter triticale, $N_{inorg.}$ content in soil was lower and after harvesting (02 08 2010) it was 21.1–36.5% lower if compared to respective data in early spring. The applied aids did not have any significant effect on $N_{inorg.}$ During this period, the highest $N_{inorg.}$ content, as well as in early spring, was identified after lucerne and mixture of lucerne/festulolium as the pre-crop (respectively 24.4% and 20.5% more if compared to grasses). According to average data, the highest $N_{inorg.}$ content in soil is identified when the aboveground mass is applied in a combined manner.

Total nitrogen (N_{total}) and humus content in the soil. Accumulation of steady compounds (total nitrogen, humus) in soil determined the mineralisation of incorporated aboveground mass of crops as well as N immobilisation and remineralisation, humification as well as intensity of these processes. These processes were directly affected by the environment – meteorological conditions, soil features and etc. Literature sources indicate that during the second year after the crops' biomass incorporation, the mineral (inorganics) nitrogen content is lower and the "ageing" or humification of incorporated organic materials initiates [9], stable humus acids are formed [1].

According to the data of our researches, the soil N_{total} and humus content is not much dependent upon the amount of incorporated aboveground mass of crops. Change of these indicators was significantly affected by the chemical content of the aboveground mass. It was defined that incorporated aboveground biomass (narrow C:N), especially its high content (mulching method), stimulates mineralisation processes as well as $N_{inorg.}$ accumulation during autumn, therefore the risk of N leak is increased. Other processes occur when biomass of festulolium is incorporated. Due to wide C:N ratio (low N), biomass of festulolium is a sufficient source of energy for microorganisms, that stimulate nitrogen immobilisation processes and the free $N_{inorg.}$ content in soil becomes lower. N immobilization occurs only during a limited period of time, sufficient to prevent part of the mineral N pool from leaching, and that net N mineralization can be expected during the subsequent cropping season, thus enhancing synchronization of N supply and demand [10].

At the end of researches, the total nitrogen content in soil was significantly dependent upon types of grass ($P < 0.05$). The highest positive total nitrogen change at the end of experiment, if compared to data when grass was cultivated, was identified within mulching of lucerne or mixture of lucerne/festulolium (Table 6).

The total nitrogen content also significantly increased by the combined application of the aboveground mass of red clover, lucerne or mixture of lucerne/festulolium.

Correlation regression analysis indicate that the total soil nitrogen correlate with the nitrogen balance of crop-rotation part and is directly proportioned ($r = 0.538$, $P < 0.05$). At the end of researches, the soil $N_{total.}$ was significantly dependent upon the Lignin:N ($r = -0.723$, $P < 0.05$) ratio in the incorporated aboveground mass of crops, i.e. together with reducing Lignin:N ratio in the incorporated aboveground mass of crops, the higher content of $N_{total.}$ was accumulated in soil. Similarly $N_{total.}$ was affected by C:N ratio in the incorporated aboveground mass of crops; though the effect was weaker and not significant.

Tab 6.

The variation of total nitrogen ($N_{total.}$) content in the soil

Perennial grass (A)	Management methods of aboveground biomass (B)								
	removal from field			mixed			mulching		
	2008	2010	differen-ces	2008	2010	differen-ces	2008	2010	differen-ces
	g kg^{-1}								
F	1.23	1.30	+0.07	1.22	1.25	+0.03	1.28	1.31	+0.03
RC	1.29	1.35	+0.06	1.28	1.36	+0.08	1.29	1.34	+0.05
RC+F	1.26	1.27	+0.01	1.25	1.26	+0.01	1.25	1.29	+0.04
L	1.29	1.32	+0.03	1.24	1.34	+0.10	1.26	1.39	+0.13
L+F	1.29	1.33	+0.04	1.26	1.34	+0.08	1.25	1.39	+0.14
2008 LSD_{05}A–0.042, B–0.033, AB–0.073; 2010 LSD_{05}A–0.055, B–0.042, AB–0.095.									

Note: RC– Red clover; RC+F– Red clover + festulolium;L – Lucerne; L+F – Liucerne + festulolium; F – Festulolium.

At the end of researches (after cultivation of crops) C:N ratio in almost all soil plots decreased, if compared to data when grass was cultivated (Table 7).

According to average data, the soil C:N ratio was the least changed after festulolium, and the most – after red clover, lucerne or mixture of lucerne/festulolium. Under the data of statistical analysis, the soil C:N ratio significantly increased together with higher C:N and Lignin:N ratio in higher incorporated aboveground mass in grass (respectively r = 0.708, P < 0.05 and r = 0.673, P < 0.05).

Tab 7.

The variation of soil C:N ratio

Perennial grasses (A)	Management methods of aboveground biomass (B)								
	removal from field			mixed			mulching		
	2008	2010	diffe-rences	2008	2010	diffe-rences	2008	2010	diffe-rences
F	13.8	13.0	-0.8	13.0	13.1	+0.1	13.7	12.8	-0.9
RC	13.5	12.7	-0.8	13.3	12.1	-1.2	12.8	12.5	-0.3
RC+F	13.6	13.1	-0.5	12.9	12.9	0	13.3	12.9	-0.4
L	13.3	12.8	-0.5	13.5	11.9	-1.6	13.0	11.9	-1.1
L+F	13.2	12.5	-0.7	12.2	12.2	0	13.5	12.4	-1.1

Note: RC– Red clover; RC+F– Red clover + festulolium;L – Lucerne; L+F – Liucerne + festulolium; F – Festulolium.

Tab 8.

The variation of humus content in the soil

Per ennial grass (A)	Management methods of aboveground biomass (B)								
	removal from field			mixed			mulching		
	2008	2010	differen-ces	2008	2010	differen-ces	2008	2010	Differen ces
F	2.93	2.91	-0.02	2.74	2.82	+0.08	3.02	2.90	-0.12
RC	3.00	2.94	-0.06	2.93	2.83	-0.10	2.84	2.88	+0.04
RC+F	2.94	2.83	-0.06	2.78	2.80	+0.02	2.86	2.88	+0.02
L	2.97	2.91	-0.06	2.89	2.75	-0.14	2.83	2.86	+0.03
L+F	2.93	2.86	-0.07	2.64	2.81	+0.17	2.91	2.97	+0.09
2008 LSD_{05} A–0.119, B–0.092, AB–0.206; 2010 LSD_{05} A–0.113, B–0.087, AB–0.195									

Note: RC– Red clover; RC+F– Red clover + festulolium;L – Lucerne; L+F – Liucerne + festulolium; F – Festulolium.

At the end of researches, the soil humus level, if compared to the one during the year of grass cultivation, varied (Table 8).

Effect of methods of applying the aboveground mass on the soil humus changes was more evident than the one of types of grass. Average data indicates that removal of biomass from the field reduced the humus content, while mulching – increased and in cases biomass was applied in the combined manner, the humus content remained almost similar. Interaction of application of types of grass and their aboveground led to the reduced humus content when legumes were processed with the combined method of aboveground mass application, while festulolium – when the whole biomass was mulched. Application of biomass of festulolium and legumes together or by applying the combined method of aboveground mass application, increased humus features of the soil.

Conclusions

1. With the aboveground biomass of red clover and lucerne used under mixed management, the soil received 148 kg ha^{-1} and 149 kg ha^{-1} of nitrogen, respectively, while in the mulching treatments – 254 kg ha^{-1} and 215 kg ha^{-1}, respectively. When the aboveground mass of mixture of legumes/festulolium was applied for the green manure, the incorporated N content decreased by 28–34 kg ha^{-1}. Symbiotically fixed nitrogen content in the biomass of legumes accounted for the largest share (60.8–83.6%) of the total nitrogen content, accumulated in the biomass. When legume mulch had been used as green manure, its C:N ratio was the lowest and more favourable for a more rapid decomposition (15–19) compared with that of festulolium mulch (C:N – 36–43).

2. Application of all aboveground biomass of perennial grass as green manure (mulching) during the first year increased grain yield by on average 0.62 t ha^{-1}; when part of the aboveground biomass had been used as green manure (mixed management) – by 0.30 t ha^{-1}, compared with the treatments with grass removed from the field. Festulolium and its mixtures with legumes as pre-crop reduced winter wheat grain yield, compared with red clover. During the second year of effect, the yield of winter triticale was significantly affected by methods of aboveground mass application (surplus of grain yield – 0.2–0.3 t ha^{-1}).

3. From environmental approach, the most sensitive period, when $N_{inorg.}$ content can leak to the subsoil, is after incorporation of the crops' biomass in autumn and early in spring. From the soil protection approach, biomass of mixture of legumes and festulolium is more appropriate for the green manure or application of the combined method of aboveground mass application.

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PREPARATION OF HOT-ROLLED ROLLING FOR THE STRENGTHENED BOLTS MADE OF THE STEEL 40X

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The major problem of development of modern fixture is improvement of quality of metal products and details made of it. The low share of application of the strengthened fixture is represented a negative technical and economic indicator as to the industry making this production, and the industry making designs, applying fixture. For the first is an unjustified increase of a material capacity of manufacture

of details. For the second – irrational overestimate of weight of designs and, accordingly, deterioration of their operational qualities.

The solution of a problem of expansion of a domestic production of the strengthened fixture represents an actual problem for the domestic industry and covers various branches.

One of priority directions in the decision of this problem is depreciation of made fixture at the expense of rationalization of technology of strengthening processing of fixture and minimization of cost of a steel, for example, the steels contain boron[1].

In respect of minimization of cost of a steel by the most preferable the standardized steel of mark 40X (GOST 4543) is represented. This mark of a steel can be is regulated on heating that has essential value in maintenance of stability of quality of thermal hardening. The steel 40X traditionally has the greatest distribution for strengthened fixing products and has proved easily mastered by manufacture. Thus corresponding maintenance of carbon and economical enough alloying chrome simplifies realization of the offered technical decision in all its technological components.

On the basis of the analysis of a condition of delivered metal rolling from the domestic and foreign metallurgical enterprises [2-4], used for manufacturing of various kinds of fixing production, laws of influence of thermal processing, its hardness, durability and plastic characteristics, considerations of the basic technological variants of preparation of detals for reception of fixing products of a class of durability 8.8 it is established that the basic way of reception of high-strength fixture is taking detail which have a microstructure of granular perlite from rolling after the drawing.

After cold volume punching (CVP) details subject to hardening and tempering. After quenching at holder may be formed microcracks and decarburization. If the train rolling with 80-100% microstructure granulous perlite studied in sufficient depth, due to the resistance of plastic deformation of a structure of sorbitol patenting insufficient attention.

General weakness thermally processed rolled into existing technologies is the local heterogeneity of mechanical properties observed on adjoining sections of details a small length and full length of coil. Therefore requires research question get details with uniform mechanical characteristics over a length of coil for long bolts with toughened the requirements of GOST R 52643-2006 "High-strength bolts and nuts and washers for steel structures" without further quenching and temper. The integrated impact of patenting and drawing with different compressing on structure, strength and plastic properties, hardness of details in the literature is not enough, therefore, requires covered more detailed study.

The complex estimation of a condition of the rolled detail received by a method of patenting and plastic hardening at drawing which considers hardness and its plastic characteristics.

In this work following problems have been put:

- To establish laws of influence of structure, mechanical characteristics and hardness hot-rolled rolling on quality of details for various modes of technological preparation;

- To investigate degree influence of compress on structure and mechanical characteristics of detail after drawing;

- To investigate influence of thermal and plastic processings on structure and mechanical properties of details and to choose their optimum modes for cold taking of fixing products.

- To establish the optimum technological scheme of preparation of the calibrated details of a steel 40X for the further manufacturing from it the strengthened lengthy bolts with the low edging head, corresponding to a class of durability 9.8.

For their decision details of the constructional alloyed steel of a class perlite a mark 40X and the details made of it for manufacturing of the strengthened fixture was investigated. Details before drawing with various hardness and the plastic characteristics, received after annealing and patenting was exposed to studying.

Details were studied in not deformed condition, and also after various degree of compressing at drawing for the purpose of definition of its suitability on hardness and plastic characteristics, and hardness for CVP lengthy of bolt products agrees GOST 10702-78 «the Steel qualitative constructional carbonaceous and alloyed for cold expression».

To research were exposed a microstructure, hardness and plastic characteristics, hardness of details before drawing and patenting operation.

Tests for a deposit were conducted, definition of quality of a surface, an estimation of structurally-power complexes of destruction, etc. Hardness ($\sigma в$, $\sigma 0,2$) and plastic (Ψ, δ,) properties, hardness of the hot-rolled and calibrated details were defined by two variants:

- Calibration of the hot-rolled and calibrated metal rolling with degree of compressing 5, 10, 20, 30, 40 and 60 % with the subsequent patenting at temperature 370, 400, 425, 450, 500 и 550^{o}C;

- Patenting at 370, 400, 450, 500 and 550oC and the subsequent calibration with degree of compressing 5, 10, 20, 30, 40 и 60%.

As a result of researches it has been established that the optimum combination of mechanical characteristics after patenting steel 40X (high durability and insignificant resistance of plastic deformation) is reached at degree of compressing 5-10 %. The subsequent increase in their degree of compressing to 60 % leads to continuous growth of strength and a limit of fluidity and decrease in indicators of relative narrowing and relative extending.

The microstructure after detail patenting at temperature 500°C represents «sorbite with sites martensite». Patenting at temperature 500°C and drawing of detail with degree of compressing 30, 40 and 60 %, leads losses of plasticity and to destruction of the sample at drawing owing to formation of internal cracks. Therefore this microstructure isn't recommended for manufacturing of a hardware by a method of plastic deformation.

Patenting details of steel 40X at temperatures 400 and 425°C, subjected to deformation by drawing with degree of compressing 5 and 10 % increase hardness and plastic characteristics, therefore it can be recommended for preparation of detail for CVP the strengthened lengthy bolts without hardening and tempering.

It is revealed that the defining factor of increase of durability of ready fixture is use of details with the increased durability which mechanical characteristics are generated at stages of technological repartition from hot-rolled details. Patenting hot rolled steel 40H at temperatures 400-425°C leads to increased strength at 190-230 Mpa, with a little lower (1%-4%) characteristics of δ and ψ. Such thermal operation with hot-rolled details at 500°C resulted in further improving crush strength and plasticity of 370 Mpa.

Conclusion

Developed and proposed a rational technological scheme of production of rolled steel 40H 11.7 and 9.65mm diameter to get toughened long bolts with low shear screw strength class of 9.8 excluding operation of quenching and tempering products. It replaces annealing on an insulated operation of patenting, that allows to reduce labour and energy costs, improve the environmental friendliness of production and operational safety bolt products without the risk of defects of carving and necessity of straightening. This makes it possible to reduce the technological chain and reduce the cost of manufacture of bolts. The developed technology of rolled steel 40H for the manufacture of toughened long bolts received a patent for the invention № 2380432.

Studies have tested and found application in the introduction of advanced technology manufacturing of coated fasteners.

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FORECASTING OF DEFORMATION PROCESSES OF COMPOSIT NONWOVEN MATERIALS AT VARIOUS ENVIRONMENTAL CONDITIONS

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In road building there was a paradoxical situation – the stream of geosynthetic materials accrues as avalanche at almost total absence of standard base on their application. About geosynthetic materials, their functions, properties and scopes service life prevent to predict this absence of trustworthy information to designers of those or other designs. At present there are only recommendatory documents on application of geomaterials, and there is no obligatory. Has ripened necessity for creation of uniform specifications on tests of geosynthetic materials, and to bring into accord ISO and EN (the international and European standards) as there is a set of divergences, both in techniques of tests, and in requirements to materials.

Experience of many countries and Russia demonstrates that application of geosynthetic materials in road building reduces terms of building, reduces the cost price at improvement of physicomechanical properties of elements of road designs, prolongation of service life of highways.

The expediency and scope of geosynthetic materials is defined in each specific case on the basis technical and economic calculations. It is possible to allocate three basic scopes of application of geosynthetics at building of highways: division of various constructive layers, a moisture filtration, road clothes.

The design of road clothes is a set of layers from various materials. Durability and durability of all design is reached by simultaneous work of all layers – an asphalt concrete, rubble, sand, a geosynthetic material. Thus, the geosynthetic material influences durability and durability of all design as a whole that allows us to reduce a thickness of layers, including asphalt concrete.

It is necessary to notice that by the current moment in scientific works influence of the factor of time on long durability of geosynthetic materials which are applied for reinforced coverings ractically isn't reflected. Therefore questions of forecasting of road coverings and cloths as a whole remain opened.

The given research work is devoted studying of deformation processes in composite nonwoven cloths in the conditions of long нагружения at various humidity.

The object of research had been presented geosynthetic materials –nonwoven materials (doronit) which have found practical application in road building.

By results of long tests mathematical models for forecasting of deformation processes in time depending on level of humidity and directions of power influence were under construction.

Let's note the basic results of the presented work received on the basis of experimental and theoretical researches.

In work features of structure of composite nonwoven materials of various fibrous structure are considered.

Composite nonwoven materials were formed of secondary raw materials. As raw materials fishing nets and ropes, which after their operation were dismissed on fibres by special cars served. Preliminary ropes were cut on pieces of 60 mm. Appointment of these nonwoven materials executed from kapron, lavsan: housing construction, strengthening of road coverings and slopes. Application of fibres in the structure of asphalt not only as filler but also as modifier there was a continuation of the given technology on use of polymeric lattices at manufacturing of roads.

Curve deformations of direct and return creep of a material which reflect features of deformation process of a composite material at different humidity are constructed. Results of research are new.

By results of deformation curves it is revealed that with increase in humidity process of restoration of a material goes more slowly.

In the course of carrying out of researches it is revealed that the greatest deformation arises at samples of nonwoven materials with different relative humidity 50, 80, 98 % found in a longitudinal direction.

The module of elasticity which has the greatest values for the material which has been cut out in a cross-section direction is defined.

Mathematical models are constructed according to influence of level of pressure on speed of development of deformation in time, taking into account humidity.

From the received mathematical dependences we had been established rheological characteristics of nonwoven materials for longitudinal, cross-section directions, and also for a diagonal direction at an angle in 45º, considering features of deformation processes in nonwoven materials.

The estimation of deformation characteristics, including, elastic constants of a composite material is given at various environmental conditions (humidity).

At present the most progressive technique on tests of geosynthetic materials are long-term tests for durability that allows to simulate real operation. On short-term tests the material can show very high indicators durabilityes, however in due course at much smaller loading can collapse. The spent experimental research works have allowed to generate and present a technique of studying of mechanical properties of nonwoven materials which can be applied and to other materials.

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COMPRESSORS WITH GAS SUPPORT OF PISTON

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Recently the main consumers of the compressed gases (mechanical engineering, instrument making, refrigerating and cryogenic technics, the chemical industry, etc.) have sharply toughened requirements for gas cleanliness, as this parameter in many respects defines such parameters as quality of related production, processes profitability and personal and environmental safety.

This problem has roots at the beginning-middle of 60th years when there was sharp acceleration of the scientific and technical progress, that, in particular, was characterized by appearance of the equipment and technologies, which did not have until then full analogues (the computer, space technics, etc.). The new technologies have shown increased requirements to all technological aspects, including to cleanliness of the compressed air widely used in the industry. During this period leading companies in the USA, Switzerland, Germany and Japan have been patented designs of piston compressors in which absence of gas pollution and deterioration of piston condensation was guaranteed by contactless work of the piston with gas bearing. First, the work on application of gas greasing between the cylinder and the piston have been begun in Russia. In OmGTU together with company "Sibkriotekhnika" in 1976-77, the breadboard model of an efficient variant of the piston compressor with gas greasing of the piston with diameter of the cylinder being 40 mm and the travel distance of the piston being 45 mm for the first time has been created. Its tests have shown basic opportunity of creation of similar machines with acceptable sizes and economic parameters for sufficiently accurate manufacturing the piston and the cylinder.

On fig. 1 the elementary constructive variants of such compressor with internal and external pressurization of the gas feeding the gas bearing are shown.

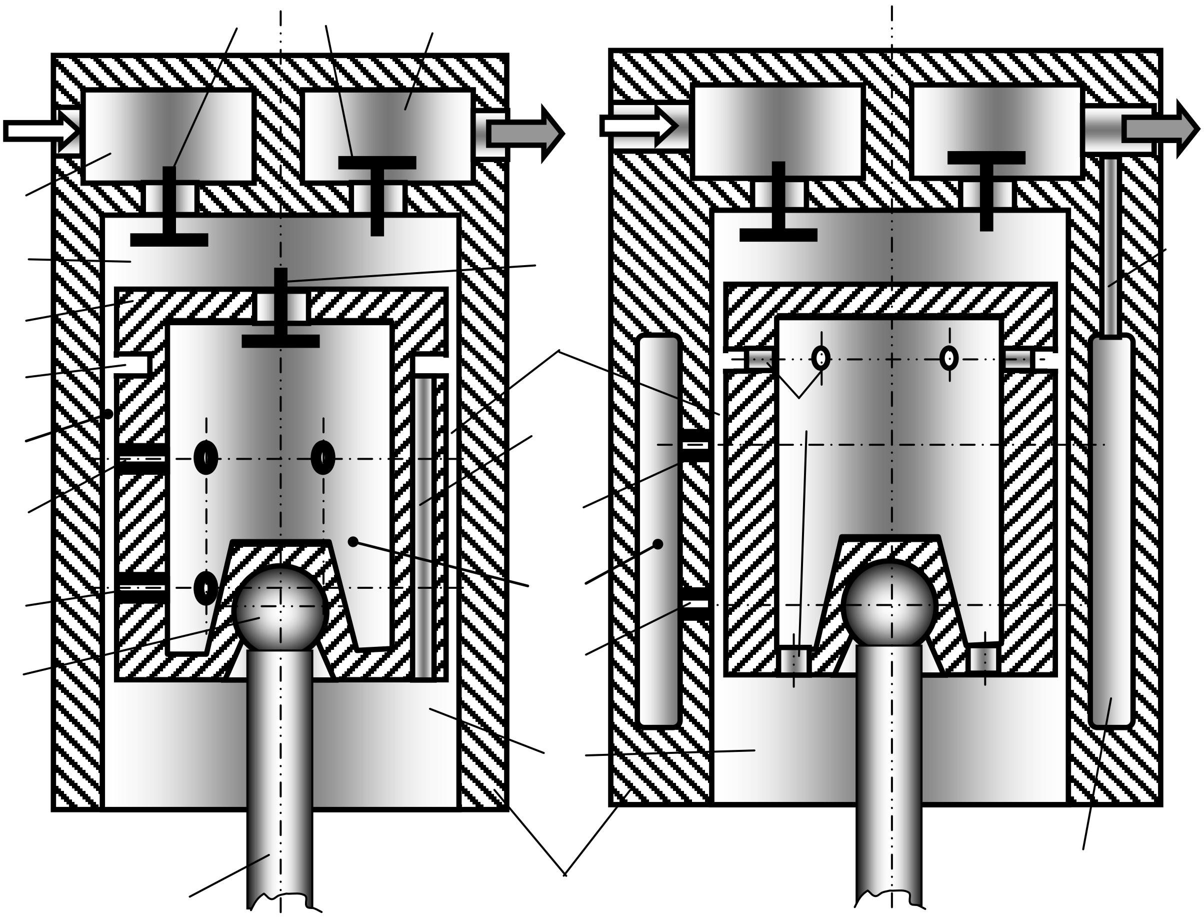

Fig. 1. Constructive schemes of the cylinder and the piston of the compressor with internal (a) and external (b) a supply of gas:

1. The cylinder. 2. A rod. 3. The hinge. 4,5. Accordingly the bottom and top belt in regular intervals located on a circle of the piston of throttle apertures. 6. A backlash of a gas support. 7. A dividing flute. 8. A condensing part of the piston. 9. The chamber of compression. 10. A cavity of a supply of gas. 11. The bringing valve. 12. The delivery valve. 13. A delivery cavity. 14. The channel for removal of a condensed stream of gas. 15,17. Accordingly the top and bottom number in regular intervals located on a circle of the cylinder of throttle apertures. 16. A cavity of a feed of a gas support of the piston. 18. Case. 19. The return valve of a cavity of the piston. 20. Apertures for removal of a condensed stream of gas. 21. The channel of an external supply of the compressed gas

At back and forth motion of the piston the volume of the compression chamber 9 of the cylinder 10 changes, therefore the working body (gas) is sucked into the cylinder through the automatic return valve 11, then is compressed in the cylinder and forced to the consumer through the return automatic valve 12. That is, the work of the compression chamber and valves of this compressor is not different from those of usual piston compressors.

Condensation of compressed gas is made by the piston condensing part 8 which can be smooth, or can contain labyrinth flutes, which possess significant resistance at rather big clearance, which for compressors of small and average productivity are inefficient. Therefore in all known experimental works with such compressors of small capacity (see, for example, [1-5], etc.), smooth slot-hole condensation of the piston is used. There are also the constructive offers related to attempts to use in the condensing part of the piston of such compressor floating self-aligned additional sealing elements [6-8]. However none of them has not been tested on natural samples.

Having passed condensing part 8, the stream of gas is dumped by an operative range of the gas support of the piston through the channel 14. This design feature requires removal of extraneous gas streams from a bearing gas layer for maintenance of normal work of a gas support of the piston.

At internal submission of gas (fig. 1a) the gas compressed by the compressor during compression-forcing gets in a gas support supply cavity 16 of the piston through the return valve 19 and is cut by this valve in processes of expansion from the dead space and gas admission. Thus in a cavity 16 some pressure of feed $\mathbf{P_P}$ is formed. Gas from a cavity16 flows into in a backlash 6 of the piston gas support through throttles 4 and 5, its pressure falls to the pressure in the bearing gas layer Pd surrounding the piston, forming a gas layer with bearing ability **W** and rigidity $\mathbf{C_P}$

Actually bearing ability **W** is formed at non-central position of the piston under action of the compelling force $\mathbf{F_{BOK}}$. arising from gas forces at discrepancy of manufacturing, assembly and deterioration of the directing mechanism, from the inertial forces $\mathbf{F_Y}$ arising at cross-section fluctuations of the compressor, or at a deviation of a rod from the position conterminous with an axis of the cylinder at use the mechanism of a drive without the directing device.

Condition of contactless work of the piston of the compressor is performance of equality $\mathbf{W = F_{BOK}}$ at relative eccentricity $\boldsymbol{\varepsilon_P} = \mathbf{e/\delta_0}$ positions of the piston in the cylinder considerably smaller units, where **e** - absolute eccentricity (a deviation of an axis of the piston from an axis of the cylinder), $\boldsymbol{\delta_0}$ - a nominal radial backlash between the piston and the cylinder. It is usually considered to be, that the gas support is efficient, if the settlement size $\boldsymbol{\varepsilon_P}$ does not exceed 0,5 [9].

At external submission of gas (fig. 1б) the compressed gas gets in a cavity 16 which is located in walls of the cylinder, is direct from a line of pressure of the compressor. It is obvious, that in that case it is easy to use for a centering of the piston the compressed gas and from an extraneous source of pressure of gas. Lack to external submission of gas is the obvious impossibility to keep symmetric (concerning a bearing gas layer) position of a point of fastening of the piston on a rod in this connection this design can be used basically for compressors with a low speed of the piston.

If at internal pressurization generally pressure of feed $\mathbf{P_P}$ is size of a variable (the cavity of a feed 16 plays a role of a receiver of small volume which alternately replenishes with new portions of the compressed gas) at external pressurization this pressure it is constant (fig. 2).

At internal pressurization (fig. 1a) the behavior of schedule $\mathbf{P_{Pi}} = \mathbf{f(\varphi)}$ depends on several factors: hydraulic resistance, weight of mobile parts and the characteristic of a spring of the valve 11, volume of a cavity of a feed 16, the charge of gas on a centering (the phenomenological analysis).

Change of hydraulic resistance of the valve (its through passage section and factor of the charge) should lead to vertical displacement of schedule $\mathbf{P_{Pi}} = \mathbf{f(\varphi)}$ **-** the below resistance of the valve, the above the schedule and above average display pressure $\mathbf{P_{Pi(cp)}}$, the it is more pressure in a number of pressurization $\mathbf{P_{di}}$, that above the charge of gas on a centering of the piston.

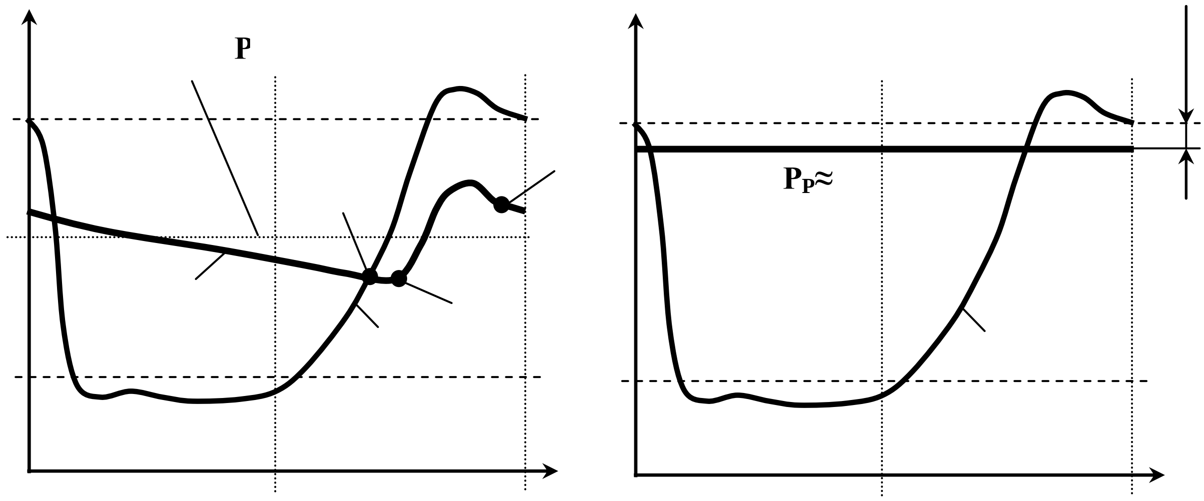

Fig. 2. The combined display diagrams of the chamber of compression and a cavity of a feed of a gas support of the piston with internal through a cavity of the piston (a) and external through walls of the cylinder from a line of forcing of the compressor (b) pressurization:

φ - a corner of turn of a cranked shaft of the compressor; P_B - pressure an admission; P_H - pressure of forcing; P_i and P_{Pi} - accordingly pressure in the chamber of compression and pressure in a cavity of a feed of a gas support of the piston during the moment of time i; A - a point of crossing of schedules P_i and P_{Pi}; points B and C - accordingly the moment of opening and closing of the valve 11 (fig. 1*a*); $P_{Pi\ (cp)}$ - average display pressure in a cavity of a feed at internal pressurization; ΔP_H - hydraulic resistance of the channel 21 (fig. 1*b*)

Such behavior of system of pressurization does not cause doubts, since it to similarly well studied phenomena in usual compressor installations. In this case the valve 11 carries out function of the delivery valve of the compressor, a cavity 16 pistons - function of a receiver, and throttle apertures - function of the consumer of the compressed gas with constant hydraulic resistance.

Change of weight of mobile parts of an element of the valve 11 (weights of laking element and a spring of the valve) should lead to change of the moment of its opening and closing. In particular, the more this weight, the is more on time delay of opening and closing of the valve.

This phenomenon is illustrated by some displacement of a minimum of function $\mathbf{P_{Pi}} = \mathbf{f(\varphi)}$ to the right from a point And in which equality Pi = $\mathbf{P_{Pi}}$ (fig. 1*a*) is observed. If the weight of mobile parts of the valve 11 is rather small, opening and closing of the valve will occur earlier and on the contrary. That is - change of weight of mobile parts of the valve probably in reasonable limits to adjust position of time piece **BC** of its open condition. It is rather probable, that thus it is possible to affect size of pressure $\mathbf{P_{Pi}}$ and $\mathbf{P_{di}}$, however, this question specially was studied by nobody. At least, in basic works [9, 10] data on similar researches are absent.

Change of characteristics of a spring of the valve 11 (rigidity $\mathbf{C_K}$ and size of a preliminary tension $\mathbf{h_0}$) is doubtless, influences, first of all, for the period of the open condition of the valve (length of piece **BC**) and the moment of opening (position of a point **B**). The above rigidity of a spring and (or) size of its preliminary tension, the opens later and earlier the valve 11 is closed, that the smaller quantity of gas gets in a cavity of a feed gas подвеса 16, that below pressure in this cavity $\mathbf{P_{Pi}}$ and size $\mathbf{P_{di}}$, the it is less charge of gas on a feed of a gas support of the piston.

Change of volume of a cavity of a feed 16 gas support leads to change of amplitude of function $\mathbf{P_{Pi}} = \mathbf{f(\varphi)}$ - the less volume of a cavity, the more amplitude and on the contrary. It should influence the charge of gas through a cavity 16. However, as shown in [10], this influence is not enough and slightly affects mass streams through a gas support of the piston.

At external pressurization (fig. 1***b***) and a feed gas подвеса from a line of forcing of the compressor pressure of feed $\mathbf{P_P}$ will depend on pressure of forcing of compressor $\mathbf{P_H}$ and hydraulic resistance $\mathbf{\Delta P_H}$ the channel 21 (fig. 2***b***).

It is obvious, that at designing the compressor with external pressurization from a line of forcing of the compressor the size $\mathbf{\Delta P_H}$ can be chosen any within the limits of (0 - $\mathbf{P_H}$), that is rather simply realized by change of through passage section and the form of the channel 21. The main condition which should be carried out thus - maintenance of necessary pressure in a cavity of 16 support $\mathbf{P_P} = \mathbf{P_H} - \mathbf{\Delta P_H}$, guaranteeing with other things being equal working capacity of system of a gas centering of the piston.

However at this scheme of pressurization there is a problem of initial start-up of the compressor when in a delivery branch pipe still there is no superfluous pressure. It is obvious, that this problem can be solved by creation of time resistance between a cavity of forcing and a receiver of compressor installation to similarly how it is made, for example, in [11].

At a feed of a gas support from an extraneous source of pressure size $\mathbf{P_H}$ will be defined by pressure of this source. It can appear very favourably from the power point of view since specific expenses of energy for reception of a stream of aligning gas in an extraneous source of pressure can be essential below, than in the compressor, especially, if optimum pressure of pressurization is less, than pressure of forcing in the compressor with a gas support of the piston.

However presence of the extraneous power supply, obviously, can be justified only at rather high efficiency of the compressor when occurrence of the additional cylinder with the piston will not affect essentially the sizes of the compressor and its cost. At the same time in works [9] it is shown, that at productivity above 1 m^3/minute and low pressure of forcing (0,3-0,7 MPa) the charge of gas on a centering of the piston and the expenses of energy connected with it are rather small in comparison with expenses of energy for compression of the gas, submitted to the consumer.

So, for example, with D_C=100 mm and productivity of 0,86 m^3/minute [10] show results of mathematical modeling of the compressor, that the attitude of expenses of energy on creation of a bearing gas layer to losses of energy with outflow $\mathbf{L_{PY}=L_P/L_Y}$ change from 1,21 at $\mathbf{P_H}$ = 0,3 MPa up to 0,34 at $\mathbf{P_H}$ = 0,7 MPa, and expenses for gas for work of a gas support of the piston make less than 1 % from productivity of the compressor.

Nevertheless, at an opportunity of essential pressure decrease of pressurization in comparison with pressure of forcing of the compressor it is necessary to consider use of highly economic extraneous power supplies perspective and assumes expediency of search of the technical decisions, allowing to simplify a design of the compressor for this power supply system of a gas support of the piston.

One of such technically offers is described in [9] (fig. 3). The idea incorporated in such design, consists in filling a cavity of pressurization with the gas compressed by the compressor, but not through the delivery valve of the compressor, and through the additional return valve established considerably below the top point (BMT).

At movement of the piston 3 downwards there is an admission of gas under pressure $\mathbf{P_B}$ in the chamber of compression 5. Thus all over again there is an expansion of gas from residual space and then receipt of a fresh portion of let in gas (line **E - H**, fig. 4).

At movement of the piston upwards (fig. 3 and 4) in the chamber of compression pressure raises, and even during compression reaches pressure $\mathbf{P_P}$ in a cavity of a feed 4 gas of support of the piston 3 (a line **H-A-B**). Thus the valve 6 opens, and the compressed gas starts to act in a cavity of a feed 4. Receipt of the compressed gas proceeds until the piston 3 does not block bore 7, cutting that the valve 6 from the chamber of compression 5 (a piece **B-C** for pressure in the chamber of compression 5 and piece $\mathbf{B\text{-}C_1}$ for pressure in a cavity of a feed 4). Thus the piston 3 passes way $\mathbf{S_P}$ from the bottom point, and line $\mathbf{B\text{-}C_1}$ is located a little below a line In-with in connection with presence of resistance of the valve 6.

Then the piston 3 continues compression of gas and further its forcing with pressure PH to the consumer (piece **C-N-D-E**), and pressure in a cavity 4 smoothly falls in connection with the charge of gas through throttles 8 to a clearance 2 where the bearing gas layer preventing a contact of the piston 3 about walls of the cylinder 1 under action of efforts is created, caused by discrepancy of manufacturing and deterioration of the piloting mechanism.

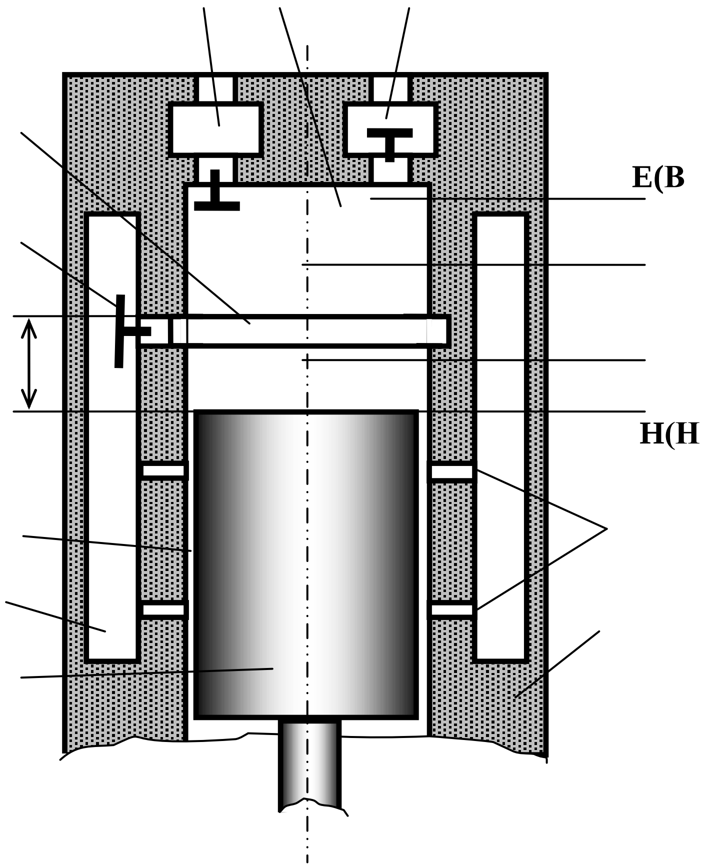

Fig. 3. The scheme of the compressor with the reduced charge of gas on a centering of the piston (the system for dump of a condensed stream by an operative range of a gas support conditionally is not shown):

1. The cylinder. 2. A backlash of a gas support. 3. The piston. 4. A cavity of a feed of a gas support. 5. The chamber of compression of the cylinder. 6. The return automatic valve. 7. Bore. 8. Throttle devices. 9 and 10. Cavities inflow and forcing

Thus, the cavity of a feed 4 appears filled under pressure, smaller, than the maximal pressure of compression (point **N**). It enables at compression of gas up to averages and high pressures in the chamber 5 to support in a cavity of 4 pistons minimally necessary for contactless work 3 pressure, reducing that the charge of capacity of the compressor on a centering of the piston 3.

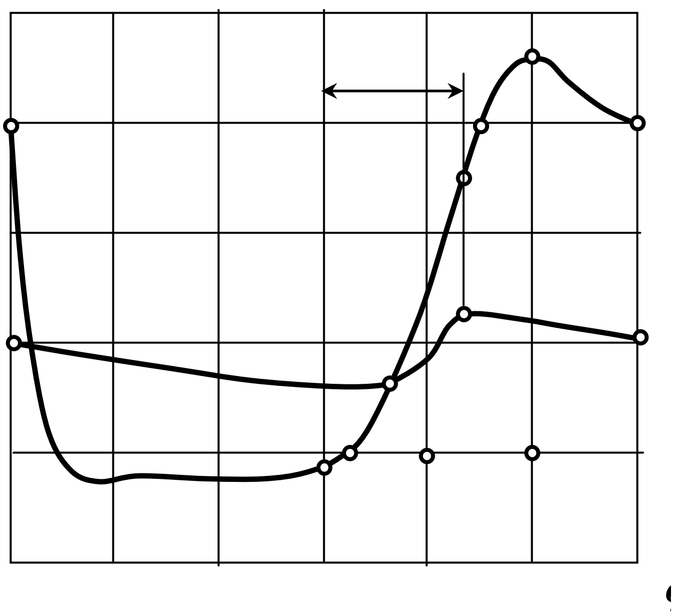

Fig. 4. Prospective display diagrams of the chamber of compression and a cavity of a feed of a gas support of the piston with the lowered pressure of a feed (P - pressure, φ - a corner of turn of a cranked shaft)

Last circumstance is well illustrated by the diagram (fig. 4). So, at a usual way of submission of the compressed gas on a centering when selection of this gas occurs in the top part of the chamber of compression 5, the work of compression accomplished above gas, acted in a cavity of a feed of a gas support of the piston, will be defined by area **A-B-C-N-D-G-K-A**, and in the described way - area **A-B-C-K-A**, i.e. the capacity spent for a feed of a gas support of the piston in the second case much less that allows to raise profitability of work of the compressor essentially.

In both ways of pressurization of gas (internal and external) for a feed of a gas support of the piston its charge essentially depends on a design of feeders - regulators of the consumption.

The most important power characteristics of gas radial support (bearing ability W and rigidity CP) to which the gas support of the piston concerns, first of all, depend on the geometrical sizes of a support, uniformity of distribution of pressure in a bearing gas layer, pressure **Pd** of gas upon an input in a lubricant backlash, pressure of pressurization $\mathbf{P_P}$ and pressure of the expiration of gas from a clearance (for compressor - pressure of case $\mathbf{P_K}$**)** [12-14, etc.].

The charge of gas $\mathbf{M_P}$ on work of a gas support of the piston in this case becomes size of a derivative (dependent). That is, at set geometry of a support of the piston and its power characteristics, at known pressure and a design of feeders the size of $\mathbf{M_P}$, at first sight, is defined unequivocally.

However, as shown in [9], for achievement of the maximal profitability of the compressor, especially at its small productivity, there is a necessity of decrease in the charge of gas on a centering of the piston by increase in hydraulic resistance of feeders which cannot be carried out, proceeding from technological opportunities of modern manufacture.

That is - is unreal to use for a feed of a gas support throttle apertures in diameter considerably less than 0,1 mm. It is especially actual for designs of the compressor with the minimal lateral loadings on the piston for which high power characteristics of a gas support of the piston are not necessary.

Thus, there is very important contradiction.

On the one hand, the designer for maintenance of high reliability of the compressor should aspire to lower lateral loadings on the piston, and for decrease in losses of gas because of outflow and on a centering of the piston - to use as it is possible a smaller clearance between the piston and the cylinder.

On the other hand, satisfied these conditions, it faces a problem of achievement of optimum characteristics gas подвеса (minimally necessary power characteristics at the minimal charge of gas on a centering) because of impossibility of reduction of through passage section of feeders.

This problem is aggravated also with that the quantity of discrete feeders in one number of pressurization cannot be (theoretically) less than three, and is real - in each number it is desirable to have from four up to six feeders even for подвесов small (20-30 mm) diameter for maintenance of the guaranteed uniform distribution of pressure $\mathbf{P_d}$ in a number of pressurization.

In this connection there is a necessity of search of the real technical decisions, allowing to make feeders practically with as much as greater hydraulic resistance.

One of possible decisions of the given problem is application of slot-hole feeders [15] which combine advantages of throttles of type « a simple diaphragm » (the charge of gas through them does not depend on size of a backlash of a support), laminar throttles (steady current of gas, without jumps and fluctuations of pressure) and porous inserts (provide uniform distribution of pressure in a zone of a supply of pressure in a backlash of a support).

Actually cracks are created at contact of two flat cylindrical surfaces, on one of which there are fine grooves [14]. At installation of details, the circular crack (fig. 5***a***) is formed faltering, with small crosspieces.

Crosspieces serve for decrease circular перетечек in crack which reduce specific elevating force of a gas support [12]. Authors [12] describe also a radial support with the slot-hole feeder formed as bore with a ledge on one two face surfaces of contacting rings (fig. 5***b***).

Lack such designs is necessity of manufacturing of grooves or bores with a ledge with very high accuracy in this connection their depth cannot be very small. It is recommended to make grooves depth 5-20 microns and more.

It is obvious, that there are no greater problems in designing gas support with slot-hole feeders and internal pressurization of gas. Much greater problems can arise at attempt of manufacturing of height h very small sizes with enough high accuracy

Authors [14], for example, inform on really used gas support with height of a crack of pressurization **h** = 10 microns. Thus, comparing resulted in [14] data about charges of practically identical support on geometrical parameters with feeding devices in the form of apertures « a ring diaphragm » and in the form of cracks, are simple to draw a conclusion that the charge of gas on work of a support with slot-hole feeders (**h** = 10 microns) are essential (in one and a half time) more, than at a support with throttles in the form of apertures (**d** = 0,4 mm, $\mathbf{n_d}$ = 12 apertures in one number).

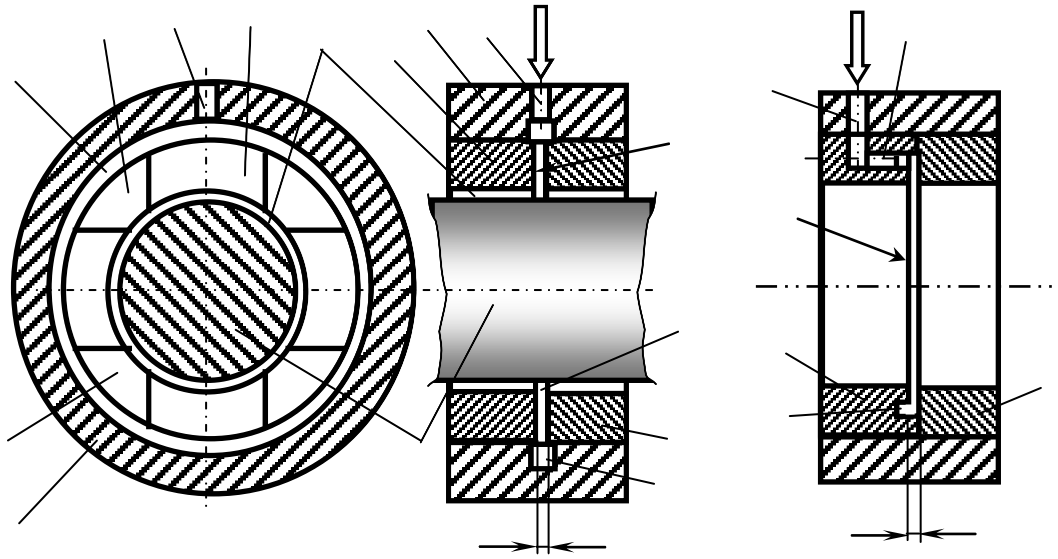

Fig. 5. Constructive schemes of gas support with external pressurization and the slot-hole feeders formed by hollows (*a*) and bore (*b*):

1. The plug. 2. A ring with hollows. 3. Distributing bore. 4. A ledge. 5. The bringing channel. 6. A hollow (дросселирующая a crack). 7. A backlash. 8. A shaft. 9. A ring with a smooth face surface. 10. A ring with bore. 11. An aperture for a supply of gas in a crack. 12. A circular (ring) crack. 13. Distributing bore. h - height of a crack

The elementary calculations by a technique stated in [9, 14] show, that, for example, at $\mathbf{D_C}$ = 40 mm, pressure difference on a feeder 0,2 MPa (pressure upon an input in feeder $\mathbf{P_P}$ = 0,5 MPa, on an output - $\mathbf{P_d}$ = 0,3 MPa), at diameter of throttles of type «a simple diaphragm» **d** = 0,1 mm, their quantity $\mathbf{n_d}$ = 6 apertures in one number, the charge of gas (air) on a feed of a support is much less, than for same in the sizes подвеса with a feed through a crack in height **h** = 10 microns and length of a crack in a radial direction of 5 mm.

However, if **d** = 0,1 mm - practically is a technological limit for manufacturing apertures of small diameter, the height of a crack can be essentially reduced if to use the idea incorporated in application, so-called, «pseudo-porous feeders», authors ОмGTU offered by collective and joint-stock company "Sibkriotekhnika" in 1978 - 1997 г.г. [16-19, etc.].

The essence of idea consists that the feeding crack is formed at contact of two rough surfaces. Thus in a zone of contact the numerous capillaries in regular intervals located on a circle (fig. 6) are formed.

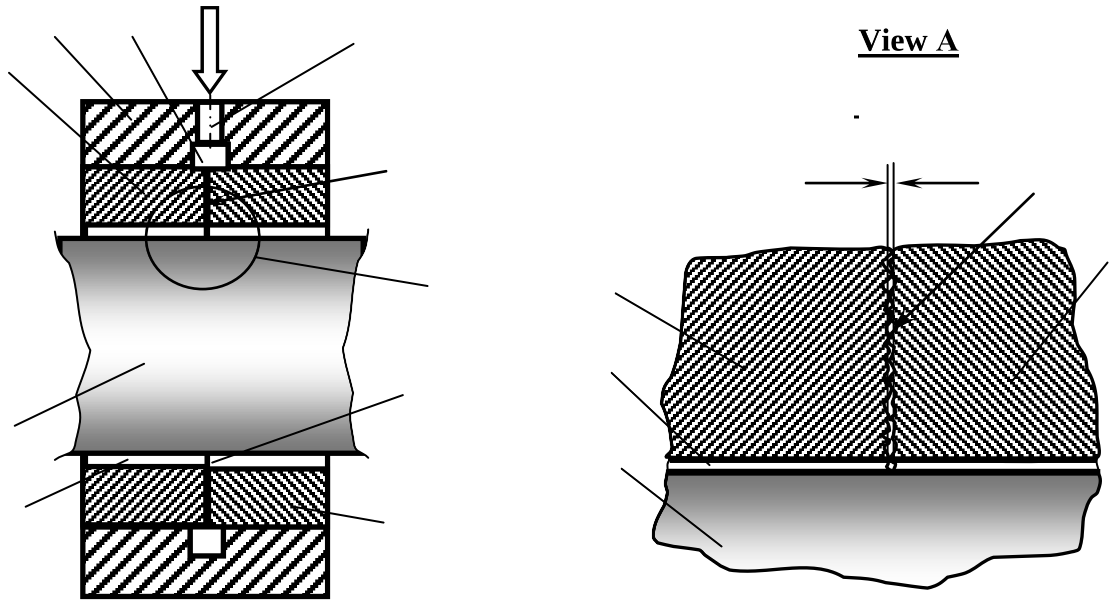

Fig. 6. The scheme of a gas support with the slot-hole feeder formed at contact of two rough surfaces:

1. The plug. 2. A ring with a rough face surface. 3. Distributing bore. 4. The bringing channel. 5. The feeding crack formed at contact of rough surfaces. 6. A ring with a rough face surface. 7. A backlash. 8. A shaft. h_m - the average backlash formed at contact of rough surfaces

The height of such feeding crack can be very small. So, for example, according to [15] on finishing operations (thin grinding and grinding in) is reached a roughness of a surface within the limits of **Ra** = 0,02-0,25 microns, where **Ra** - an average arithmetic absolute values of deviations of a structure of a roughness within the limits of base length. If in the elementary case to assume, that at contact of rough surfaces does not occur смятия tops of ledges of rough surfaces the maximal formed backlash will appear no more **2Ra**, that is - within the limits of 0,04-0,5 microns. Certainly, such sizes of bore or a groove (fig. 5) cannot achieve any dimensional processing.

With the purpose of studying of opportunities of use of pseudo-porous feeders in a gas support of the piston stand for a purge of the cracks formed at contact of surfaces created three methods of processing - by usual thin grinding, send-jetting by thin abrasive and a laser irradiation (fig. 7 and 8) has been created.

The stand works as follows. The compressed gas (air) from a cylinder 1 through a reducer 4 and the regulator 6 moves to the adaptation 12 (fig. 7), passes through it and is pitted through a regulator of pressure of the expiration 8 in tight capacity against a liquid 9. Neglecting pressure of a water column of a liquid in capacity 9, it is possible to consider, that air is in it under atmospheric pressure. Further air supersedes a liquid in measured capacity 10. Measuring volume of a liquid and time during which this volume was filled, it is possible to define the charge of air through the adaptation 12.

In the adaptation (fig. 8) air under pressure $\mathbf{P_H}$ passes through an aperture in the big disk 15 and further moves on a micro-clearance $\mathbf{h_m}$ between face surfaces of the big and small disks within the limits of their overlapping. Then air leaves in a cavity of the case 1 where pressure Pd is supported, and further through the union 12 expires from the adaptation.

Effort, with which spring 4 (fig. 8) compresses contacting surfaces, creating planimetric pressure $\mathbf{P_C}$, is adjusted by size of its tension due to change of distance **L**.

Neglecting force of weight of disks 16 and 15, and also weight of a cartridge 6 in connection with their obviously small size in comparison with effort of a spring 4, it is possible to define contact pressure in a crack between disks as follows:

$$P_C = [C_{PR} \cdot h_P - (P_H - P_d) \cdot f_d - W_K] / F_K \, , \qquad (1)$$

where $\mathbf{C_{PR}}$-rigidity of a spring, $\mathbf{h_P}$ - its tension, f_d - the area of internal diameter of a greater disk (it is equal to the area of internal bore of a small disk), F_K - the nominal area of contact, $\mathbf{W_K}$ - reaction of a gas layer in the circular crack formed at contact of two disks, is defined on the equation

$$W_K = \frac{\pi}{6}\left(D^2 - d^2\right)\frac{P_P^3 - P_d^3}{P_P^2 - P_d^2} \, , \qquad (2)$$

Where D and d accordingly external and internal diameters of a ring 15 at which end face microroughnesses are put.

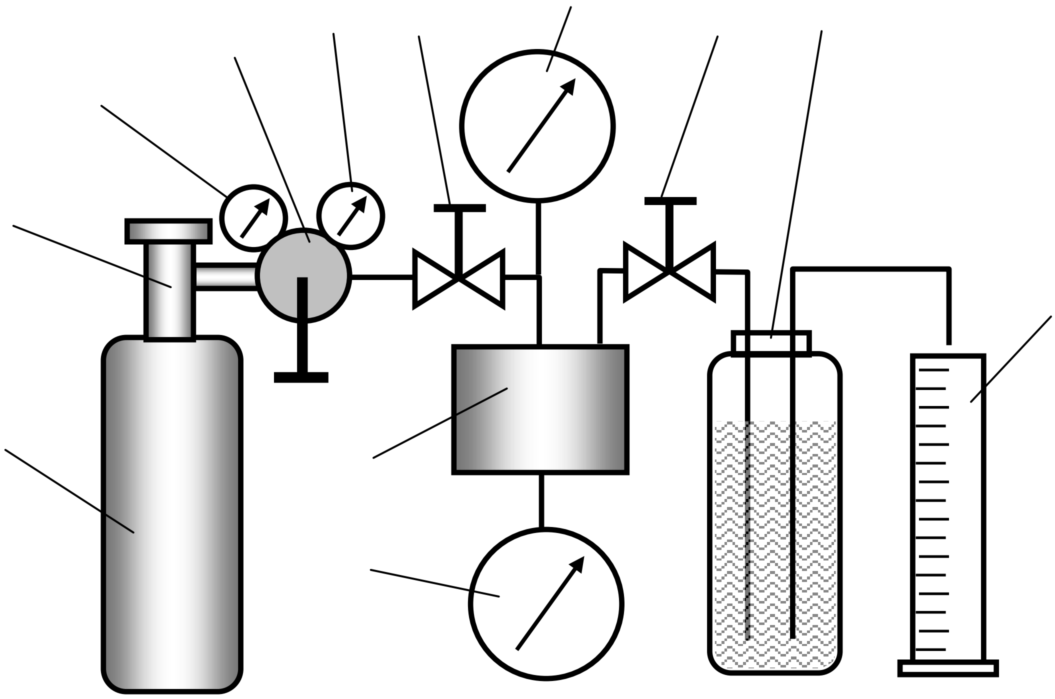

Fig. 7. The scheme of installation for a purge of pseudo-porous feeders:

1. A cylinder with compressed air. 2. The gate of a cylinder. 3. A rough manometer of a high pressure. 4. A reducer of pressure. 5. A rough manometer of pressure P_H of submission. 6. An additional regulator of pressure of submission. 7. An exact manometer of pressure of submission. 8. A regulator of pressure P_d of the expiration. 9. Capacity with a liquid. 10. Measured capacity. 11. An exact manometer for measurement of pressure of the expiration. 12. The adaptation for fastening elements of a crack (fig. 8)

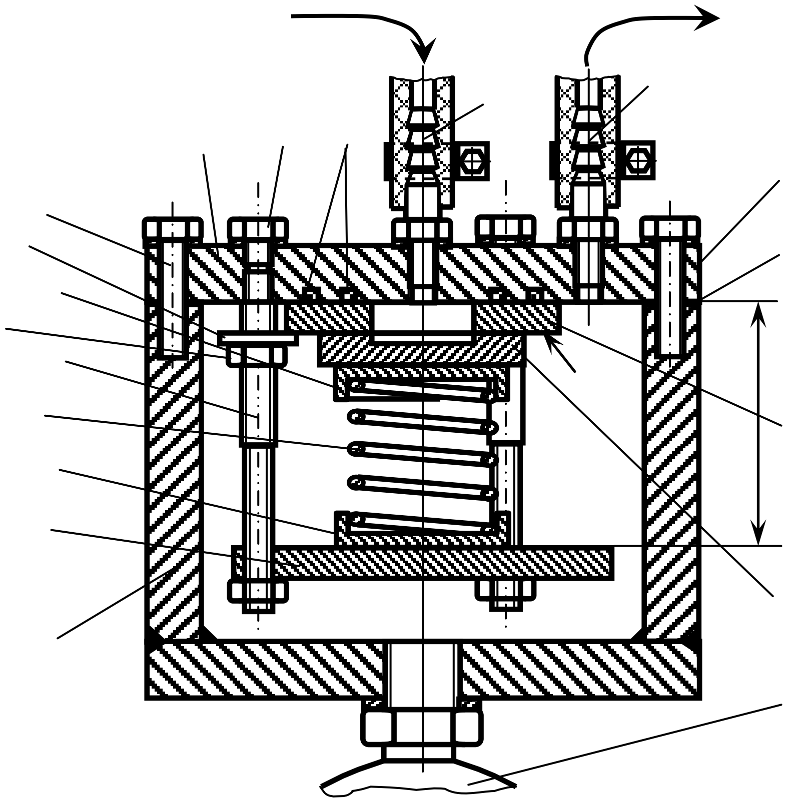

Fig. 8. The adaptation for fastening elements of a crack:

1. The case. 2. Clamping a disk. 3. The bottom glass of a spring. 4. An exemplary spring of compression. 5. Tension screws. 6. The top glass of a spring. 7. Bolts of fastening of a cover. 9. A tight fuse. 10. Elastic sealing rings. 11. The union of a supply of pressure. 12. The union of tap of gas. 13. A cover. 14. A lining. 15. The big disk. 16. A small disk. 17. A manometer for measurement of pressure P_d. 18, 19. A nut and a washer of fastening of a disk 15. A - a free surface for the control of a direction of a stream

In view of that curvature of a surface of contact is insignificant, the equation of the mass charge of the gas proceeding through a micro-clearing $\mathbf{h_m}$, will be defined, how

$$\boldsymbol{M} = \frac{\boldsymbol{\pi} \cdot \boldsymbol{D_{CP}} \cdot \boldsymbol{h_m^3}\left(\boldsymbol{P_H^2} - \boldsymbol{P_d^2}\right)}{24 \cdot \boldsymbol{\mu} \cdot \boldsymbol{R} \cdot \boldsymbol{T} \cdot 0{,}5\left(\boldsymbol{D} - \boldsymbol{d}\right)}, \qquad (3)$$

where D_{CP} - average diameter of a surface of contact, $\boldsymbol{\mu}$ - dynamic viscosity of air passed through a micro-clearing, **R** and **T** - accordingly a gas constant and temperature of air.

From the equation (3) it is possible to receive expression for definition of size $\mathbf{h_m}$ on known geometrical parameters of the disks forming this micro-clearing:

$$h_m = 1{,}563 \cdot \sqrt[3]{\frac{M \cdot \mu \cdot R \cdot T(D-d)}{D_{CP}\left(P_H^2 - P_d^2\right)}} . \qquad (4)$$

Before carrying out of experiences the made 20 pairs disks with the ground in working surfaces (height of microroughnesses **Rz** less than 0,1 microns, a deviation from a plane less than 0,2 microns) have been checked up on tightness of a joint. Suitable for the further carrying out of experiments pairs disks at which compression with the minimal contact pressure and submission 2 bar of superfluous pressure $\mathbf{P_P}$ at pressure $\mathbf{P_d}$ equal atmospheric (1 bar), the charge through contact it was not observed at several any positions of one disk of relative another are recognized. Defective pairs disks have been processed repeatedly before achievement of tightness of a joint. Working off of experiments is lead on two pairs disks.

After drawing a roughness the disk was established in the adaptation with the pair disk, clamped by a spring with measurement of a degree of its preliminary tension, and (fig. 8) was put by a smoking flame on a surface **A** rather uniform layer of soot. Further the adaptation gathered completely and was connected to the pneumatic scheme. Then the step increase in pressure $\mathbf{P_P}$ was made at pressure $\mathbf{P_d}$ equal atmospheric. At each fixed pressure the system of measurement of the charge was connected.

It is established, that to growth of pressure $\mathbf{P_P}$ there is all over again a smooth growth of the charge of gas, but at the certain pressure the charge sharply increases. Calculations with use of the equation (1) have shown, that sharp growth of the charge occurs at negative value of size $\mathbf{P_C}$, i.e. when forces of reaction of a gas layer in a backlash formed by a rough and smooth surface, in the sum with the force caused by pressure of gas in a cavity between disks exceed effort of a spring. During this moment set of disks turns to a gas support with a free backlash, contact of surfaces stops.

Non-uniformity of the expiration of a stream of gas was made planimetric method for what on the increased facsimile of a disk the zone and the zone which has fallen outside the limits concentric a circle was allocated concentric to its aperture. Also it is possible to consider the attitude of the areas of these zones a measure of non-uniformity (fig. 9). The error of such method can be estimated in 2-3 %.

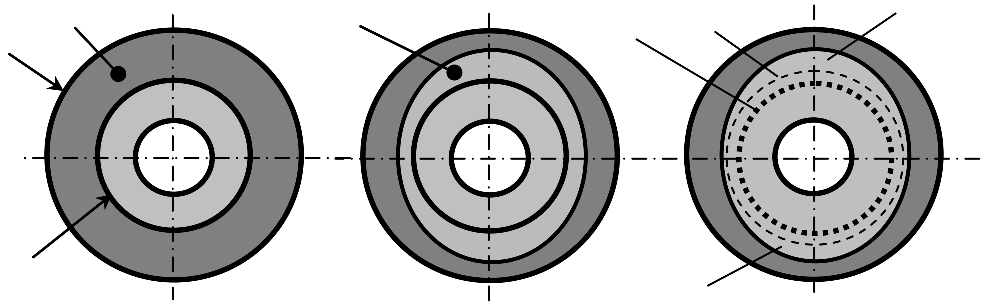

Fig. 9. The scheme of a method of definition of non-uniformity of the expiration of a stream of gas through a crack of a feeder: and - primary installation of disks; - disks in gathering after carrying out of experiment; in - measurement of non-uniformity on a print:

1, 2. Disks. 3. A surface A. 4. A zone of removal of soot a stream of air. 5. Diameter of a small disk. 6. A circle, concentric circles of a small disk. 7. The platforms describing non-uniformity of a stream

According to earlier described technique the made pairs rough disks, i.e. pairs in which both surfaces have been covered by roughnesses and each of rough disks with a smooth disk have been tested all.

As a whole the following is established:

A. Test of disks with both rough surfaces

1. Non-uniformity of the expiration at the first contact of two surfaces processed by usual polishing reaches 25-30 % in that case when both surfaces are ground, and directions of microroughnesses coincide. At re-testing this parameter improves and reaches 12-15 % at 3-rd - 4-th test then improvement stops.

At contact of two ground surfaces with perpendicularly located microroughnesses occurs similar, but more favorable picture, however at 3-rd – 4-th test non-uniformity of a stream does not decrease less than 10 %.

It is established, that the maximal non-uniformity is shown at the most rough processed surfaces with **Rz** = 6 and more microns. At **Rz** = 2-4 microns (the least grindings of microroughness received by used way) and perpendicular position of traces of polishing the minimal non-uniformity at re-testing can make 6-8 %.

Any position of directions of microroughnesses practically does not affect the results described above.

Attempt to improve the given parameter easy grinding in of rough surfaces by "zero" paste does not lead to improvement of result, and on occasion even worsens it on 2-3 %.

2. Non-uniformity of the expiration at the first contact of the surfaces received by sandblasting makes no more than 10-12 % at any relative district position of surfaces and at any **Rz**. The increase in quantity of the appendix of loading improves this parameter, leading up it up to 3-4 % a little. Thus if still up to tests to make easy grinding in of surfaces by "zero" paste, this parameter at repeated appendices of loading decreases to 2-3 % that is, in essence, a limit of accuracy of an estimation of non-uniformity of the expiration.

3. At tests of the surfaces received by laser processing and at any relative district position of rough disks, it is established, that the quantity of repeated appendices of loading practically does not influence result, and non-uniformity of the charge on a circle is within the limits of an error of measurement of 2-3 %.

B. Test at one rough and one smooth disk

At carrying out of experiences as smooth the same disk in pair with rough disks was used.

1. It Is established, that at the disks received by usual grinding, non-uniformity of distribution of a stream in a crack is practically proportional to height of microroughness and practically does not depend on mutual radial position of disks. So, at height of microroughness **Rz** = 12-20 microns non-uniformity at any mutual position of disks is within the limits of 12-15 % at 3-rd - 4-th appendix of loading. At height of microroughnesses **Rz** =8-10 a micron and the same test specifications non-uniformity makes 8-12 %, and at **Rz** = 3-4 microns - about 2-3 %, i.e. within the limits of an error of measurements.

2. At test of disks which roughnesses are received by processing by sand under pressure of air, similar dependence (item 1), but with smaller sizes of non-uniformity has been received at greater **Rz** (10-15 microns) when at the quadruple appendix of loading non-uniformity within the limits of 10 % has been received.

3. At tests of disks which roughness has been received by laser processing, it has been established, that non-uniformity of distribution of gas in a crack sharply falls with reduction **Rz**, and at **Rz** = 0,5-2 microns is close to zero at the first test and at any relative positioning of surfaces of disks.

All experiments by definition actual clearance, arising at contact of rough surfaces have been lead in the field of elastic loadings, as metal elements of a gas support of the piston of the compressor most really arising at assembly without distortion of their form.

Final results of calculations and experiments were represented in the form of schedules, and for approximation of the received results it is offered to use the equation of a kind

$$h_m = A \cdot (R_{Z1} + R_{Z2})^M \qquad (5)$$

Results of approximation have allowed to receive the following equations of a kind (5):

- For the surfaces received by grinding

$$h_m \approx 0{,}9(Rz_1+Rz_2)^{5/6}. \qquad (6)$$

- For the surfaces processed by sand under pressure of air

$$h_m \approx 0{,}95(Rz_1+Rz_2)^{0{,}8}. \qquad (7)$$

- For the surfaces processed by a laser beam

$$h_m \approx 1{,}2(Rz_1+Rz_2)^{0{,}9}. \qquad (8)$$

It is necessary to make a reservation at once, that yielded results are fair only for the surfaces received by rapprochement of roughnesses, put on tempered steel surfaces - the steel 45 tempered up to HRc 35-40 in this case was used.

In all other cases carrying out of experimental researches on the chosen materials on described, for example above is necessary, for a technique.

With the purpose of approbation of the received expressions (6-8) comparison of the working processes of the compressor received at modelling by a technique [9] in view of use of pseudo-porous cracks in a gas support of the piston with results of the experiments lead by A. Bolshtyansky [9] has been lead. Comparison of results of numerical modelling and experiences with the compressor with diameter of the piston 40 mm and two feeding cracks formed by face surfaces of three plugs from which the piston has been collected, has shown satisfactory concurrence (fig. 10, 11).

At work of the compressor the compressed gas through the valve 14 gets in a cavity of the piston 15 and expires from it through apertures 8, facets 6 and pseudo-porous cracks 5 in a backlash **δ** where pressure Pd is formed. Further gas expires through a backlash **δ** directly in картер through the bottom part of a gas support, and from the top part of a support - in case through a flute 10 and a dumping aperture in the plug 5 (conditionally it is not shown). External diameter of piston $\mathbf{D_C}$ = 40 mm, internal diameter of a pseudo-porous crack 5 in view of facets 6 - 32 mm. The effort of a coupler provided planimetric pressure in contact of rough surfaces 100-120 bar and was provided with an inhaling of a bolt 13 wrench at measurement of the twisting moment. The roughness of face surfaces of plugs made **Rz** = 2,5 microns and has been received by grinding in with the subsequent drawing roughnesses by a grinding paper.

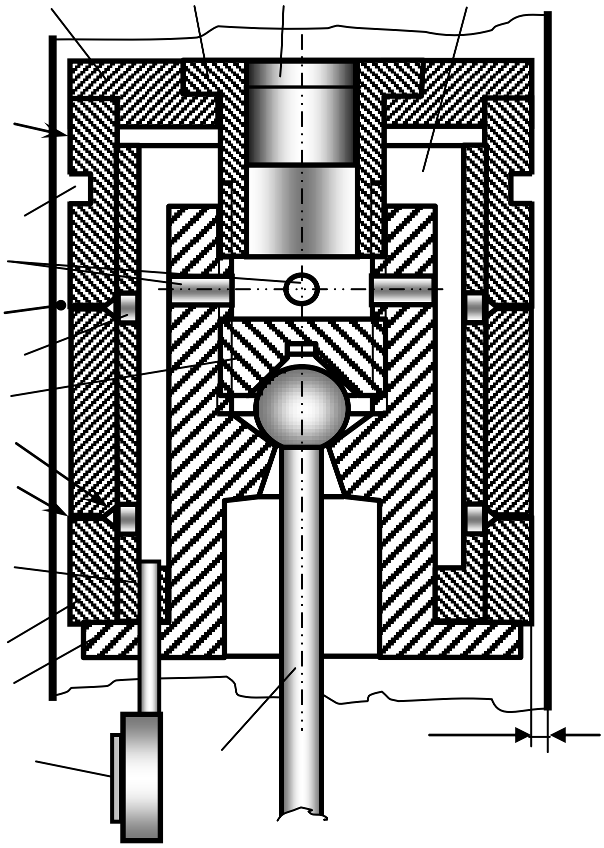

Fig. 10. Schematically section of the experimental piston with pseudo-porous feeders of a gas support [9]:

1. A rod with a spherical tip. 2. The basis. 3. Plugs with rough face surfaces. 4. The aligning plug. 5. A pseudo-porous crack. 6. A facet. 7. A nut of the hinge. 8. An aperture. 9. An aperture. 10. A dividing flute. 11. A sealing part. 12. A cover. 13. A coupling bolt. 14. The return automatic valve. 15. A cavity of the piston. 16. The gauge of pressure of a cavity of the piston

Display diagrams (it is especially important - the diagram of an internal cavity of the piston) show satisfactory concurrence.

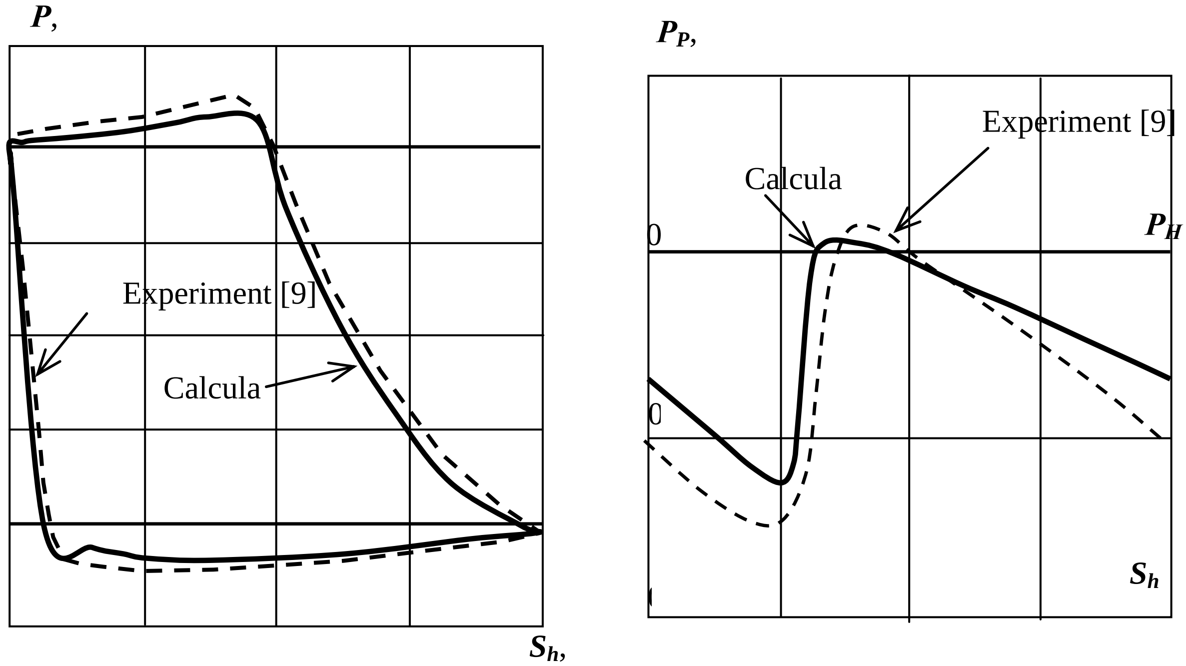

Fig. 11. Curtailed on a course of the piston the display diagram of the chamber of compression of the compressor with pseudo-porous feeders of a gas support of the piston and developed on a course of the piston the display diagram of an internal cavity of the piston

The maximal deviation on productivity in a range of pressure of forcing 3, 5 and 7 bar has made 15 %, under the charge on a centering of the piston and outflow through smooth piston slot-hole condensation - no more than 20 %, that also it is necessary to recognize satisfactory.

For an estimation of effect from application of pseudo-porous feeders with the purpose of decrease in expenses of gas on a centering of the piston and improvement of characteristics of a gas support of the piston calculations which results are shown on fig. 12 and 13 have been lead.

Here **A** and **ω** - amplitude and frequency of cross-section fluctuations of the cylinder, $\overline{P}_d$ **-** the attitude of pressure in a backlash of a gas support of the piston in a zone of slot-hole feeders to pressure in a cavity of the piston - one of base characteristics of the gas support, having an optimum in a range 0,75-0,85.

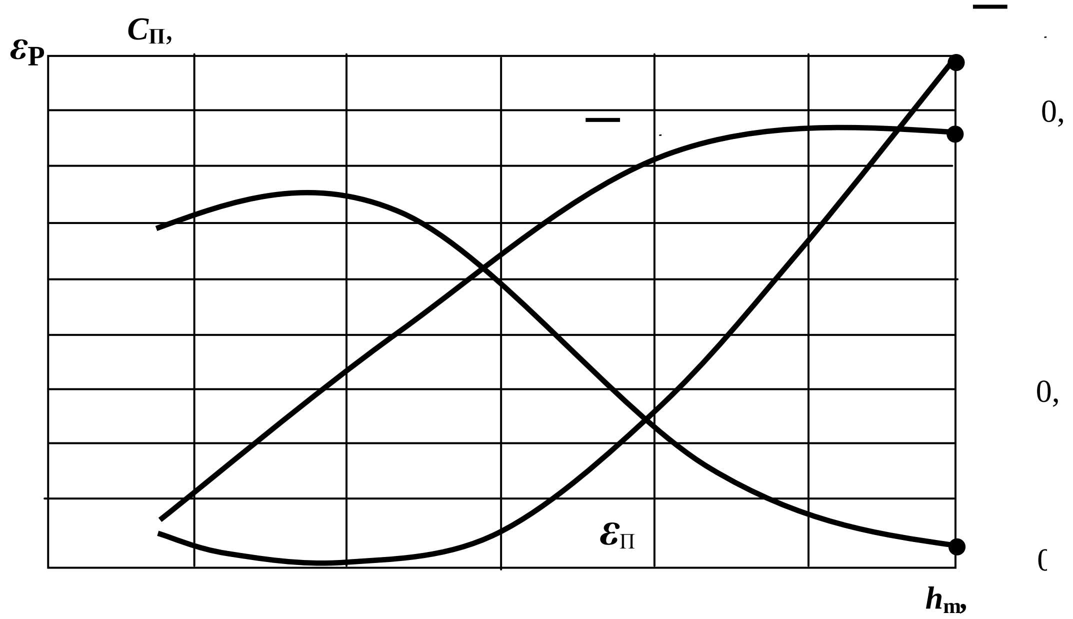

Fig. 12. Dependence maximal relative concentricity ε_{Pmax}, rigidity of support C_P and relative pressure of pressurization from an average backlash in a feeding crack at n_{OB} = 1500 mines^{-1}, δ_0 = 10 microns, ω = 50 Hz, A = 1 mm, P_B = 1 bar, P_H = 3 bar. Points designate parameters at use of a support with throttles in the form of apertures with a diameter 0,1 mm (6 aperture). D_C = 40 mm

As on the piston variable lateral loading (it is considered, that cross-section fluctuations of the cylinder have sine wave character) operates, relative concentricity ε_P (the attitude concentricity positions of the piston concerning an axis of the cylinder to a radial backlash δ_0 at ε_P = 0) is size of a variable in this connection the size maximal concentricity has the greatest importance, i.e. ε_{Pmax}. Gas support it is considered efficient, if ε_{Pmax} <0,5.

For research the compressor with diameter of the cylinder 40 mm and with nominal a backlash in a gas support of the piston, equal 12 microns has been chosen. Calculations are made for backlashes 10 and 14 microns, i.e. of the assumption that thermal deformations and accuracy of manufacturing are provided within the limits of ±2 a micron.

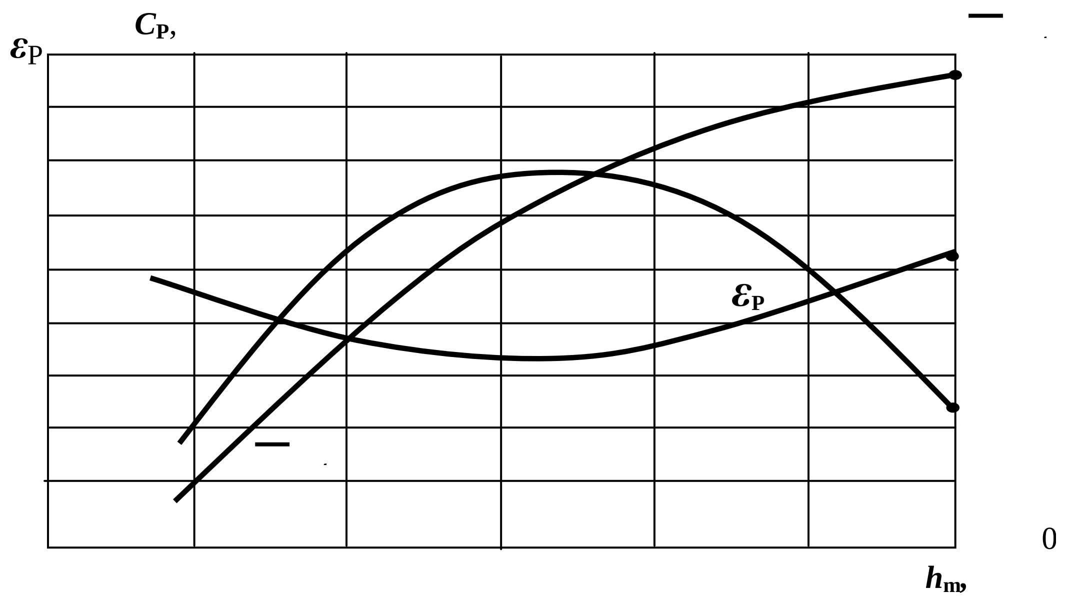

Fig. 13. Dependence maximal relative concentricity ε_{Pmax}, rigidity gas support piston C_P and relative pressure $\overline{P}_d$ of pressurization from an average clearance in a feeding crack at n_{OB} = 1500 mines^{-1}, δ_0 = 14 microns, ω = 50 Hz, A = 1 mm, P_B = 1 bar, P_H = 3 bar. Points designate parameters at use of a gas support with throttles in the form of apertures with a diameter 0,1 mm (6 aperture.). D_C = 40 mm

On fig. 12. the basic characteristics of a gas support of the piston, designs providing working capacity, with a backlash 10 microns, i.e. with a backlash, which on 2 microns less nominal are shown.

From schedules it is well visible, that the support with throttles in the form of diaphragms (an aperture with a diameter 0,1 mm - 6 apertures) at reduction of a backlash by 2 microns from nominal appears disabled (ε_{Pmax}> 1) since in this case the support has very low rigidity because of too big relative pressure of pressurization which value is close to unit.

Application of pseudo-porous feeders with the size of a crack $\mathbf{h_m}$ about 1,8-2,2 microns allows to satisfy practically the requirement to the maximal relative backlash, having approached $\boldsymbol{\varepsilon_{Pmax}}$ to size 0,2. In this case the maximal rigidity of a bearing gas layer owing to relative pressure of pressurization close to an optimum is observed.

On fig. 13 characteristics of a gas support of the piston for a case when the backlash between the piston and the cylinder is increased in comparison with nominal by 2 microns are shown.

From consideration of schedules it is possible to draw a conclusion that the compressor with diaphragm throttles and in this case does not provide set relative eccentricity position of the piston in the cylinder. The condition $\boldsymbol{\varepsilon}_{\mathbf{Pmax}}$ <0,2 is carried out only at use of pseudo-porous feeders in a range of an average backlash in a crack 1,8-3,25 microns

Thus, use instead of throttles of type a diaphragm of pseudo-porous feeders (in this case with an average backlash in a crack about 1,8-2,2 microns) it is possible to satisfy requirements on maximal relative eccentricity at discrepancy of manufacturing of a backlash in a gas support of the piston ±2 a micron.

Besides results of mathematical modelling have shown, that application of pseudo-porous feeders instead of diaphragm throttles allows to lower essentially the mass charge of gas and the work spent for it, that essentially raises profitability of work of the compressor.

Conclusion: application of slot-hole feeders of a gas support of the piston of the compressor which are executed in the form of contacting rough surfaces, expediently and allows to provide economic work of the compressor with a gas support of the piston.

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Kryvda V.I.

THE NETWORK OPTIMIZATION OF THE HEAT EXCHANGE EQUIPMENT INSTALLATION ELOU-AVT

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All over the world sharply there is a problem economy of primary power resources. Various plans and strategy are developed. So, for today in Ukraine the power efficiency program for 2010-2015 which is directed on perfection system standardization in the field of power efficiency and renewed power operates; on optimization structure of the energy balance, and also on reduction volume of technological expenses and losses of power resources as a result of modernization and equipment reconstruction, introduction of the modern power effective technologies [1].

Increase of efficiency use of the heat exchange equipment on operating petroleum refineries is important power saving up action. The economy primary power resources at such factories allows to lower cost of a finished stock from 10 to 20 % that is natural, should will be reflected in economy of the manufacturer and the country as a whole.

What criterion providing an effective utilization of power resources, it is necessary to use at a choice of the best variant? Probably, the criterion a minimum resulted expenses is the most known and standard. The method of the pinch-analysis [2,3] allows to execute integration of technological processes on electrodesalinating installation (ELOU) atmosferno-vacuum unit (AVT), using as criterion optimization a minimum of the resulted expenses. However, it is necessary to pay separate attention at a choice an optimum variant exergy to a method which allows to consider factor of the useful use of fuel at definition energy consumptions on various objects [4].

For analysis carrying out the mode operation of installation ELOU-AVT located in Odessa with the expense of petroleum crude 302,6 m^3/h that there correspond 81,4% of designed capacity has been considered [5,6].

At use a method of the pinch-analysis optimization consists in minimization a time recovery of outlay capital investments that is reached by reduction of a temperature pressure, and leads to reduction of the brought quantity energy. And it is already reflected in economy fuel which is used in furnaces. The quantity of energy which is recuperated in installation from hot to cold streams at the same time increases. The additional areas of heat exchange which increase as well because reduction of a temperature pressure are necessary for realization it.

Studying of technological process ELOU-AVT allows to reveal the difficult technological knots and to track movement of heat fluxes in installation.

Integration of technological process by a method of the pinch-analysis existing flow diagramme of installation ELOU-AVT allowed to define a real temperature pressure in area «pinch» at level 52°C, and the carried out technical and economic analysis showed that value a temperature pressure equal 30°C will be optimum. A recoupment of the project under such circumstances makes 1,3 years.

On the modern operating installations the temperature pressure between cold and hot streams reaches 10°C. It is expedient to consider optimization of a temperature pressure depending increase in a surface of regenerative heat exchange and reduction quantity of brought primary energy to installation.

At use exergy an analysis method [7] it is confirmed that the variant with smaller specific energy consumptions demands less expenses of primary power resources. It is necessary to notice that exergy analysis method allows to consider life time object and energy consumption on its creation.

Decrease in losses exergy is possible at the expense of temperature difference reduction in the heat exchanger, a current density in a conductor, speed of a liquid in the pipeline that is in turn accompanied by growth expenses of an exergy on creation of the heat exchanger or network of heat exchange devices.

The combination of the considered methods of the analysis allows to use advantages each of them to reception optimum results.

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UDC 614

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RESEARCH OF THE INFLUENCE OF HARMFUL FACTORS OF MANUFACTURE AND THE SOCIAL AND HYGIENIC ENVIRONMENT ON THE WORKERS OF THE OIL REFINING COMPLEX

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Introduction. In the course of industrial activity a person constantly contacts with the environment which exercises harmful and dangerous impact on the functional condition of the worker's organism and his health. To protect the person from all dangerous and damaging production factors of oil refining mills and to preserve his workability is an actual task. The results of the research work presented in this paper are aimed at providing safety during labor activity and increase of labour productivity of the person in the oil and gas branch of the economy.

1. The characteristic of conditions of the industrial environment at oil refining mills

The enterprises of oil and gas industry are sources of pollution of the atmospheric air as well as the working zone with various chemical substances that makes them a constant source of damaging impact on a worker. This fact allows to make a conclusion that the work connected with oil refining is one of the most harmful and dangerous. The most widespread pollutants are flying organic compounds, connections, hydrogen sulfide, sulphurous anhydride, nitrogen oxides, carbonic monoxide [1]. Almost all emissions of the refining enterprises belong to basic pollutants of the air promoting the increase of transgene pollution, aid rains, destruction of an ozone layer, accumulation in of toxic and chemical harmful substances in the atmosphere [2].

In the course of labor activity workers of an oil refining complex are under the influence of variety Dangerous harmful production factors (DHPF): noise, vibration, discomfort able microclimatic conditions, the combined influence of several chemical substances, physical, psychological and emotional loadings (fig. 1).

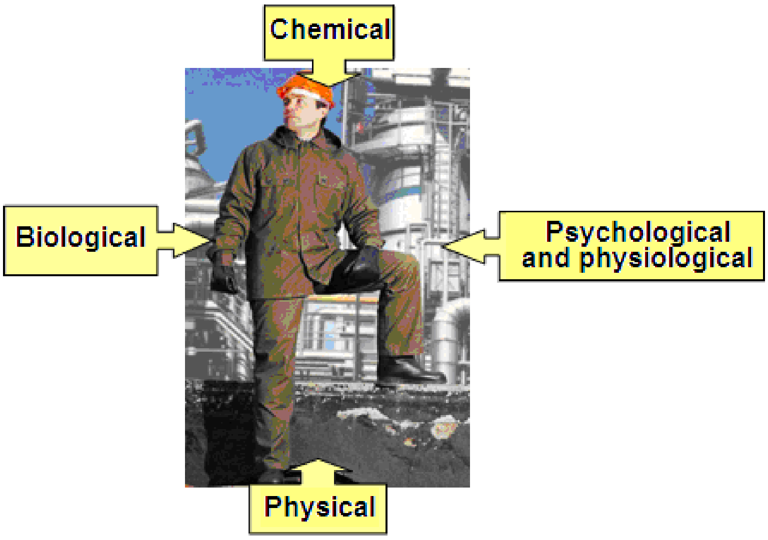

Fig. 1 Scheme of the influence of DHPF on the workers of oil refining (factories) mills

2 The influence of DHPF on the physiological condition of the workers of the ORMs

The main indicator of the health condition of the workers at the ORMs is a professional disease which proves the direct influence of production factors on the worker's organism. As it is known harmful substances can get into a human organism through respiratory ways, a mouth, mucous membranes and skin (fig. 2). In order to protect the person from penetration of harmful substances into his organism the main attention should be paid to the first two ways.

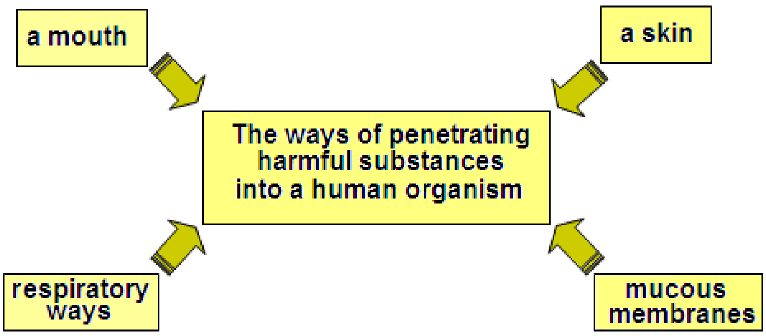

Fig.2 The ways of penetrating harmful substances into a human organism

At can be explained by the fact that penetration through the skin harmful substances do not as quickly display thus activity as in the case when they penetrate through respiratory ways and a mouth. However, penetrating into the organism through a skin they cause even more harmful damage. Taking into consideration good solubility of many chemical substances in fat-containing secretion of the skin we may assume that it is the penetration of chemical substances into a person's organism through the skin that causes irreversible changes [1, 3]. The influence of factors of the industrial, social and hygienic environment on the process of forming sick rate of the workers at oil refining mills is given on fig. 3.

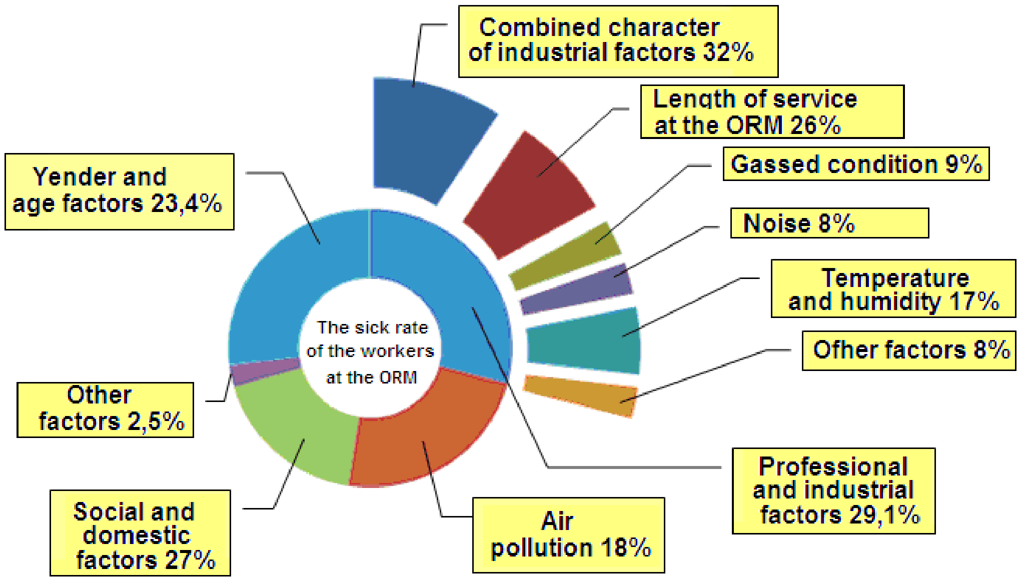

Fig. 3 The influence of the factors of the industrial, as well as social and hygienic environment on the formation of disease of the workers of ORM [4]

The researches have found out that the joint influence of chemical, physical, biological as well as and psychological and physiological factors strengthens their negative influence on the health of a working, person and also reduces protective functions of special clothes.

3 The analysis of the protective systems of a person's body surface from DHPF of oil refining mills

The use of the means of individual protection (MIP) is a unique way of protecting a person from harmful factors of the industrial environment which can cause the disturbance of working capacity and the health of a worker.

The basic means of individual protection can be divided into classes (fig. 4) according to the peculiarity of their usage and damaging factors [5].

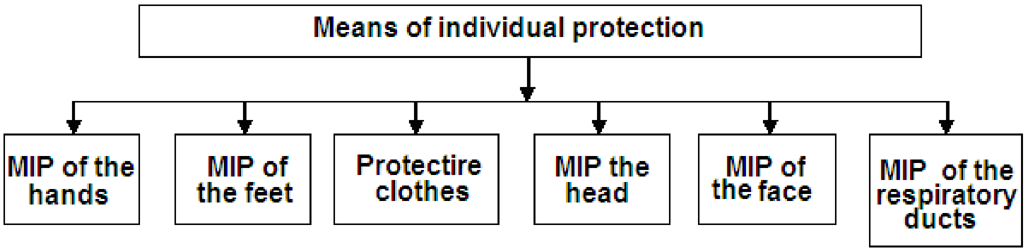

Fig. 4 Basic means of individual protection of the person

To protect the person from the influence of various DHPF of oil refining mills means of individual protection (MIP) which include special protective clothes and means of individual protection of respiratory organs, heads, hands and feet are more often used.

The petro protective properties of special clothes of workers of ORMs are the important indicator of their protective properties.

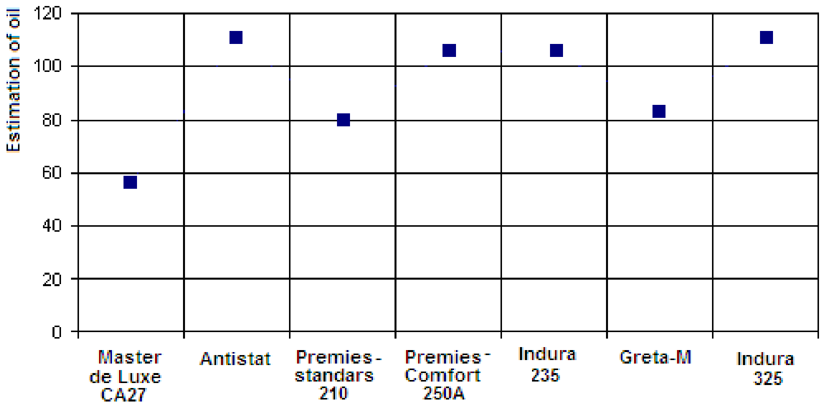

Fig. 5 Estimation of oil repellent properties of materials

The define oil resistant properties of garment fabrics the researchers applied the visual method of definition of fabric oil resistance by covering it wits mineral (vaseline) oil and n-geptana C7H16 in various parities. The estimation of oil repellent properties of the materials used for manufacturing special clothes for the workers ORM is presented in fig 5.

Conclusions

On the basis of the presented material the researchers have come to a conclusion that joint influence of climatic, physical, biological, as well as psychological and physiological factors strengthens their negative influence on the functional condition of the organisms of workers the oil and gas complex, and also reduces protective properties of special clothes that demands the optimization of working conditions, perfection of means of individual protection and the improvement of the industrial environment.

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