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Research on thermoplastics under impact-abrasive wear

A.Gupka[*0000-0003-0146-9540], **I. Yarema**[0000-0001-8318-1019], **I. Hevko**[0000-0001-5170-0857], **R. Leshchuk**[000-0002-0380-2063], **V. Kobelnyk**[0000-0003-0614-7487], **V. Buhovets**[000-0003-2216-8923], **T. Pyndus**[0000-0002-7269-1467]

Ternopil Ivan Puluj National Technical University , Ukraine
**E- mail : Gypkab@gmail.com*

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Abstract

The article presents the results of research into the regularities of friction processes and impact-abrasive wear of thermoplastics under cyclic and shock loads. The conditions and modes of operation of gas transportation equipment units and the reasons for the failure of the most loaded parts are analyzed in detail. The nature of the impact of the abrasive and its characteristics on the wear resistance of the working surfaces of parts of gas transportation equipment units is revealed. The choice of thermoplastic grades for the manufacture of parts of gas transportation equipment working units that operate under cyclic shock loads is justified. The designs of existing stands for the study of surface deformation and impact-abrasive wear of thermoplastics are analyzed. The design of the experimental stand is improved and a force loading mechanism is manufactured to implement the tasks set, a comprehensive research methodology is proposed. The influence of the parameters and conditions of cyclic impact loading on the wear resistance of thermoplastics under conditions of impact-abrasive wear, as well as the features of wear of previously deformed thermoplastics, are identified and substantiated. Practical recommendations have been developed regarding the possible use of the studied thermoplastics for the manufacture of parts for gas transportation equipment assemblies.

Keywords: gas transportation equipment, thermoplastics, abrasive, friction, hydroabrasive wear, shock-cyclic loading, test bench.

Formulation of the problem

A promising direction for the development of the gas transportation industry is the replacement of traditional structural materials with polymers and composites based on them, which are used to manufacture parts of gas transportation equipment assemblies and units under conditions of impact and abrasive wear. This is due to the price factor, labor intensity and cost of manufacturing parts from polymers, which are significantly lower compared to the use of steels and alloys.

The problem of increasing the operational reliability and efficiency of gas transportation equipment assemblies and units operating under conditions of variable static and cyclic loads with impact and abrasive wear of friction surfaces is urgent. Intensive impact and abrasive wear of parts of gas transportation equipment assemblies significantly reduces its operating time, increases the costs of repair, restoration or replacement of worn parts.

To date, the problem of increasing the wear resistance of gas transportation equipment parts operating in the mode of cyclic shock loading with the specifics of contact interaction in the presence of abrasive, with varying degrees of fixation, in the environment of aggressive natural gas and gas condensate has not been solved. Corrosion, erosion and cavitation should be included among the auxiliary factors that affect the intensity of shock-abrasive wear of parts of gas transportation equipment components. When operating parts of gas transportation equipment components, it is necessary that the materials of the parts are characterized by high wear resistance under the conditions of the complex action of the working environment, abrasive, temperature, shock cyclic loads during shock-abrasive wear. The principles of selecting polymer materials (thermoplastics) for parts of heavily loaded gas transportation equipment components under the action of cyclic shock loads, the presence of abrasive, and aggressive working environment are not sufficiently developed and substantiated, there are practically no results of research into the influence of the previous cyclic shock loading on their wear resistance during shock-abrasive wear.

Analysis of recent research and publications

The study of modern trends in the production and application of polymeric materials for transport equipment is an important area of scientific research. The work considers the use and efficiency of manufacturing parts from polymeric materials for gas transportation equipment. The authors analyze the technological aspects of production and operational characteristics of such materials, which allows us to assess their potential in increasing the reliability and durability of gas transportation systems [1]. Special attention is paid to the development of modified epoxy coatings that improve the protective properties of materials.

The study proposes a method for manufacturing an epoxy coating with a filler that increases its strength and wear resistance. This study is of significant practical interest, since modified polymeric coatings can be effectively used to protect parts of vehicles and industrial equipment from corrosion and mechanical damage [2]. The work highlights the process of developing a polymer matrix with improved performance characteristics for protecting vehicle components. The research is aimed at increasing the durability and effectiveness of protective polymer materials, which is important for the automotive, gas transportation and other industries [3].

In their work [4], they determined the intensity of abrasive wear of protective polymer coatings, which made it possible to assess the durability and reliability of polymers during operation. In work [5], scientists analyzed the processes of impact-abrasive wear of the working bodies of road construction machines, focusing on materials that can withstand this type of wear, including polymer composites.

In work [6], they studied increasing the reliability of gas transportation systems through the use of new materials, including polymers that demonstrate high resistance to impact-abrasive loads. In article [7], a device for studying materials under impact-abrasive wear is presented, which is an important step in the development of testing methods for polymer materials. In study [8], the processes of abrasive wear of polymer materials are studied in detail and methods for its reduction are proposed, which is relevant for increasing the service life of polymers.

In [9], a study was conducted on the abrasive wear of antifriction materials, in particular polymers, which is important for their use under shock-abrasive loads. Thus, the analysis of literature sources demonstrates that the study of thermoplastics under shock-abrasive wear is a relevant direction that has significant scientific and practical interest, especially in the context of increasing the durability and reliability of parts and equipment.

The study of the mechanical characteristics of epoxy composites is a relevant direction in modern materials science developments. The work [10] presents the results of the study of the mechanical properties of filled epoxy composite materials. The authors analyzed the influence of various fillers on the physical and mechanical characteristics of the material, which allows optimizing its composition to improve operational characteristics.

Another study [11] considered the impact strength of epoxy coatings modified with silicate-containing additives. The work demonstrates that the use of such modifiers allows to significantly improve the impact resistance of coatings, which is critically important for increasing their durability and reliability in operation. In the article [12], an analytical analysis of stresses in furan-epoxy composite coatings during tension was performed.

The authors used fracture mechanics methods to assess the behavior of the material under load, which allows predicting its operational stability. In addition, the work [13] considered the issue of tribodiagnostics of damage to the surfaces of triboconnection materials during machine operation. The authors focus on the wear mechanisms of materials in contact under load and propose approaches to increase their wear resistance.

Thus, the analysis of recent studies indicates the active development of scientific approaches to optimizing the composition and mechanical properties of epoxy composites and coatings. The results obtained can be used for further development of effective materials with improved performance characteristics.

The purpose of the work

The purpose of this work is to find ways to increase the wear resistance, service life, and performance of parts of gas transportation equipment assemblies, and to select the most effective polymer materials. To achieve this goal, it is necessary to solve a number of practical research problems: to analyze in detail the operating conditions of parts of gas transportation equipment assemblies; to justify the choice of grades of polymer materials for their further study; to modernize the research stand with the development of research methods and criteria for assessing impact-abrasive wear of polymers under cyclic loading of test specimens; to investigate the effect of previous cyclic impact loading on the wear resistance of these thermoplastics; to develop practical recommendations for increasing the wear resistance and operational reliability of parts of gas transportation equipment assemblies made of thermoplastics under cyclic impact loading.

For a methodically correct assessment of the wear resistance of thermoplastics during impact-abrasive wear, it is necessary to analyze the characteristics of the abrasive, investigate the influence of the previous impact cyclic load on the nature of their deformation and the intensity of wear. Conduct a set of studies to determine the contact deformations and wear resistance of thermoplastics under their operating conditions and establish general patterns of wear and destruction mechanisms. Develop practical recommendations for the selection of thermoplastic grades for the manufacture of parts of heavily loaded gas transportation equipment components and criteria for assessing their performance.

Research results

To obtain objective, satisfactorily comparable results of experimental studies, it is necessary to use the same type of equipment, a single methodology for conducting research and data processing, and criteria for assessing the performance of thermoplastics under conditions of impact-abrasive wear. When choosing grades of thermoplastics for parts of gas transportation equipment assemblies to study their wear resistance under conditions of impact-abrasive wear, the following technical characteristics were taken into account, both for the materials of the parts and for their operating conditions: impact cyclic loading on parts (impact-deformation change in the dimensions of parts); temperature; presence of abrasive; aggressive working environment; stability of geometric dimensions of parts and minimal shrinkage of the material; stability of operation under the above operating modes; relatively low cost; low friction coefficient. Taking into account the conditions and operating modes of parts of heavily loaded gas transportation equipment units, according to the results of previous studies by the authors of the article and other researchers, the most suitable thermoplastic materials are: polyamides; polycarbonates; polystyrenes. The following brands of thermoplastics were selected for the planned set of studies: glass-filled polyamides PA66-KS, PA6-210KS, PA66-PE; unfilled polyamides P-6, UMP225.

Equipment (stands) used in the study of the wear resistance of thermoplastics under conditions of impact and abrasive wear must provide periodic (cyclic) impact loading on the part under conditions of a real working environment. Objective and reliable research results can be achieved only when using special stands that reproduce the operating mode of gas transportation equipment parts under impact and abrasive wear. The most suitable for conducting experimental studies of selected materials of parts, under given operating conditions, are stands with a crank drive mechanism and additional devices, with the ability to reproduce the required range of changes in speed, frequency and impact energy in the contact zone, to simulate the nature of impact cyclic loading. Regarding parts of gas transportation equipment, a special stand has been modernized to conduct comprehensive studies of the wear resistance of selected grades of thermoplastics under conditions of impact-abrasive wear, under cyclic loading, in the presence of abrasive with varying degrees of its fixation, the general appearance of which is shown in Fig. 1, and the loading mechanism of the stand developed by the authors of the article is shown in Fig. 2.

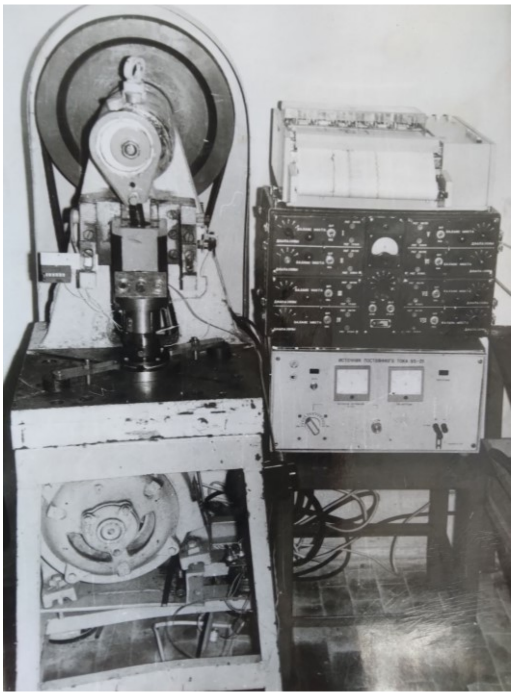


Fig. 1. General view of the stand

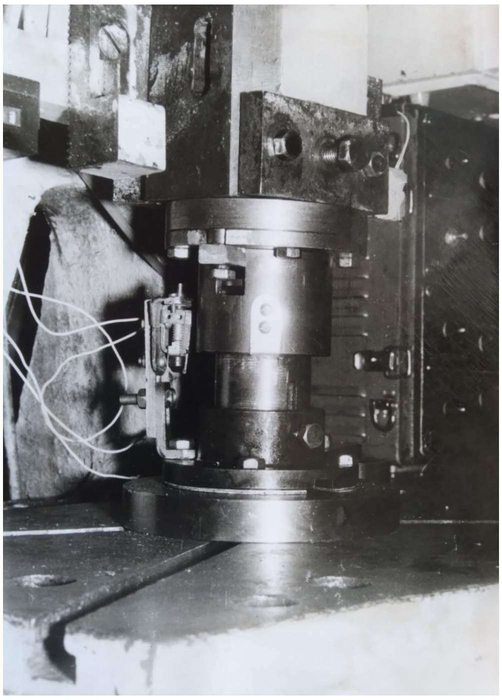


Fig. 2. Bench loading mechanism

The technical characteristics of the stand are given in Table 1.

Table 1

Technical characteristics of the stand

Operating parameters of the stand	Value
Maximum working force, N	30000
Impact velocity, m/s	1-10
Impact frequency, Hz	1-5
Number of research cycles	1-100000
Working stroke of the slider, m	0-0,04
Working medium	Air
Condition of the abrasive	Free layer
Control parameters	Impact force Impact velocity Impact pulse length Deformation magnitude

The stand consists of a mechanism that performs multiple actions of the striker and the forge during the reciprocating motion of the striker slider; a control system, control and measuring equipment; replaceable auxiliary devices to expand the technological capabilities of the stand. The kinematic diagram of the stand for the study of thermoplastics under cyclic impact loading is shown in Fig. 3.

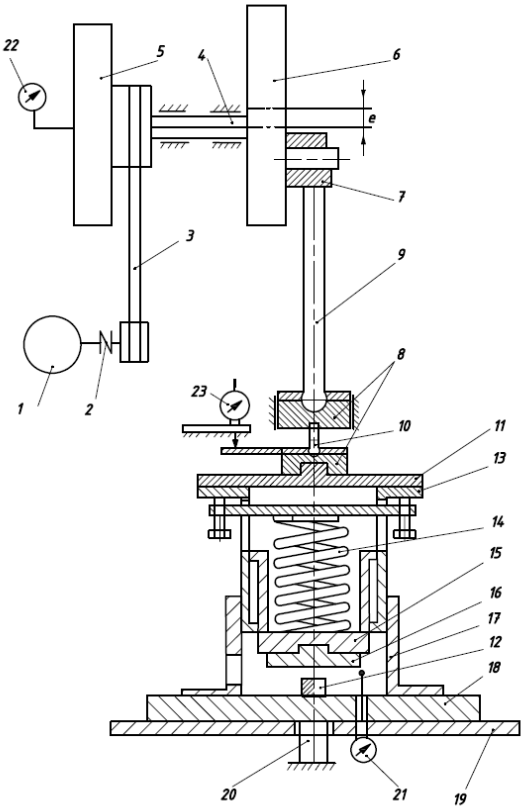


Fig. 3. Kinematic diagram of the stand for studying impact-abrasive wear of thermoplastics under impact cyclic loading conditions

Structure and principle of operation of the stand. The stand is mounted on a common frame with all working units and mechanisms placed on it. The electric motor 1 is connected to the shaft 4 through an electromagnetic clutch 2 and a V-belt transmission 3, on which a flywheel 5 is placed with a system of two mutually crossed eccentrics 6 and 7. The axis of rotation of the eccentric 6 is located at a constant distance e from the axis of the shaft 4. In the body of the eccentric of large geometric dimensions 6, an eccentric 7 is placed, with the help of which the stroke of the slider 8 is regulated. When the eccentric 7 is rotated and fixed at a certain angle relative to the initial position, the radius of rotation of the end of the rod 9 relative to the axis of rotation of the shaft 4 changes. The rod pivotally connects the eccentric 7 and the slider 8, which consist of two halves connected by an adjusting screw 10. In addition to the existing load schemes, this stand uses an elastic attachment that allows you to implement the static component of the force of interaction of the samples. The spring attachment is fixed in the seat of the lower half of the slider 8. The device consists of a shank 11, which acts through a tension beam 13 and a spring 14 on the striker 15, in which the indenter 16 is fixed. The guide cup 17 is used to center the striker and fix the samples on the anvil 18. The lower part of the device is mounted on a table 19, in which holes are provided for installing a piezo sensor 20 and a clock-type indicator 21. The torque from the electric motor through the electromagnetic clutch and V-belt transmission is transmitted to the crank mechanism, which converts the rotational motion of the drive into the reciprocating motion of the striker 15 with a given frequency and amplitude of the load on the sample 12. The given shaft rotation frequency is set using a variable drum of the V-belt transmission 3 and is controlled by a tachometer 22. The load amplitude, which determines the time of loading the sample and the time of its unloading, is set by the mutual arrangement of the eccentrics 6 and 7, i.e. by changing the radius of rotation. To create a given load force on the sample, at the initial moment, a spring 14 serves. The magnitude of this force depends on the stiffness of the spring, the magnitude of its preliminary pressing by the tensile beam 13, and the speed of contact of the indenter with the sample. The design of the striker 15 provides for the possibility of attaching indentors 16 of various shapes: flat, cylindrical, prismatic for modeling the contact interaction of parts of various configurations. The stand allows for the study of impact-abrasive and impact-fatigue wear of polymeric materials under different loading conditions, in different working environments. This paper presents the results of the study of impact-abrasive wear, which is implemented in the case of feeding the abrasive into the impact zone of the indenter 16 with the sample 12. To study samples of different thicknesses under the same power load parameters, an adjusting screw 10 is used. The difference in the height of the samples is controlled by a watch-type indicator 21 with a measurement accuracy of 0.001 mm and a bar attached to the lower moving part of the slider 8. When developing a method for measuring contact parameters in the process of impact-abrasive wear, all the requirements that are put forward for studies of this nature were taken into account. The measuring complex of the stand includes: a system for measuring dynamic impact characteristics, a system for determining the initial static load, a system for automatically setting the number of load cycles. Fig. 4 shows a scheme for measuring dynamic impact characteristics in the study of impact-abrasive wear of thermoplastics.

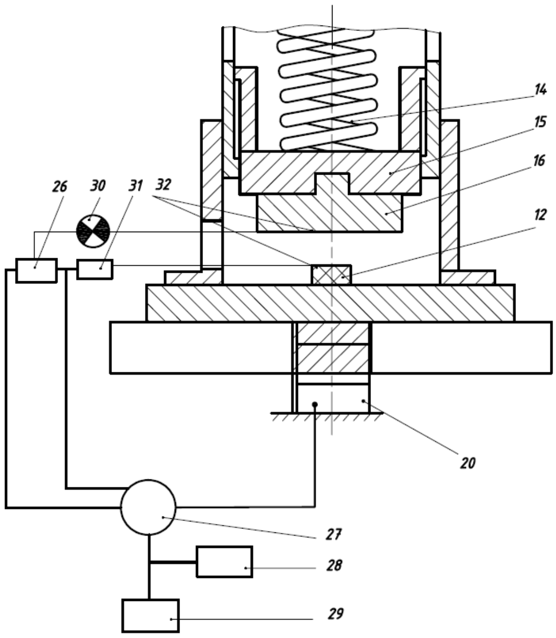
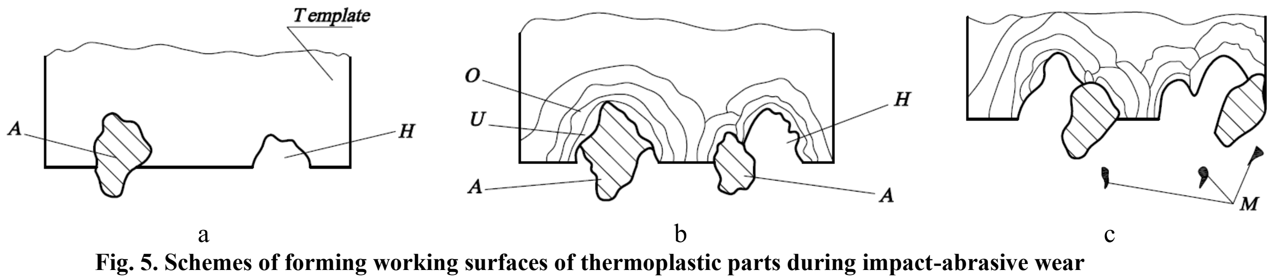


Fig. 4. Scheme of measuring dynamic impact characteristics when studying impact-abrasive wear of thermoplastics

The measuring circuit consists of a piezoelectric sensor 20, a synchronization unit 26, a universal oscilloscope 27 model S8-13, with an output to a high-speed recorder 29 model H338-6N, a digital automatic integrator 28 model I-02 and a current source 31. The initial moment of contact of the indenter 16 with the sample 12 is recorded by a light bulb 30, which is connected via a power supply to point contacts 32, which are placed on the contacting surfaces. The synchronization unit includes recording the signal on the oscilloscope 27 with its subsequent processing on a digital integrator 28 and visual reproduction by a high-speed recorder 29.

The system for setting the initial statistical parameters of the load consists in creating a preliminary force of the spring 14 on the striker 15 by pressing the strain gauge 13, on which the strain gauges are glued, with the help of two screws. The system for automatically setting the number of load cycles includes an electromechanical counter 22, which sends a signal to trigger the electromagnetic clutch of the main drive of the stand. To measure the magnitude of the deformation of the sample from the number of load cycles, a clock-type indicator 21 is fixed on the stand table 19. When studying the impact-abrasive wear of thermoplastics, cylindrical samples were used, which allow the most accurate assessment of the behavior of materials during this type of wear. A cylindrical sample with a diameter of 10 mm and a height of 18 to 30 mm was studied. The cylindrical shape of the thermoplastic sample provides higher strength compared to rectangular and triangular samples. The study of impact-abrasive wear was carried out under the action of external force factors on the samples while maintaining the specific energy of a single impact, the frequency and speed of co-impact, and the temperature. Silicon carbide with a grain size of 0.63 mm was used as an abrasive material. Impact-abrasive wear of parts of gas transportation equipment assemblies occurs mainly when they hit loose abrasive and abrasive mass contained in the gas medium being transported. In some cases, impact contact can also occur on resinous deposits of the working medium (gas) fixed on the working surfaces. The main principle schemes for the study of thermoplastics for parts of gas transportation equipment are studies on abrasive mass and loose layer of abrasive of a certain thickness, which is placed on a metal base.

Fig. 5 shows the formation of working surfaces of thermoplastics during impact and abrasive wear.



a b c

Fig. 5. Schemes of forming working surfaces of thermoplastic parts during impact-abrasive wear

When the abrasive hits, its individual grains A penetrate directly into the surface of the sample and at the first stage are wedged in the body of the sample (Fig. 5 a). Subsequent impacts of the abrasive lead to their further pressing into the sample material (Fig. 5 b) with the formation of a zone of volumetric deformation (O) and surface compaction (U) of the material under it when the wedged area expands under the action of tangential forces. The process of accumulation of the abrasive occurs in the surface layer of the sample material. Part of the abrasive, when in contact with the surface of the thermoplastic, does not wedge in it, but leaves behind characteristic holes H on the surfaces of the sample (Fig. 5 b). The subsequent impact action of the abrasive leads to repeated entry of abrasive particles into the previously formed holes on the surface of the sample and the process of removal of the sample material M from the contact zone in the form of chips or microparticles occurs (Fig. 5 c). The number of holes on the surface of the sample constantly increases, which leads to complete damage to the entire surface with the formation of wear particles. At this point, the period of running-in of the sample surface ends and the period of its stable wear begins. The dynamics of the wear mechanism of the surface of a sample made of thermoplastic PA66-KS on a layer of unbonded abrasive is presented in the photographs (Fig. 6).

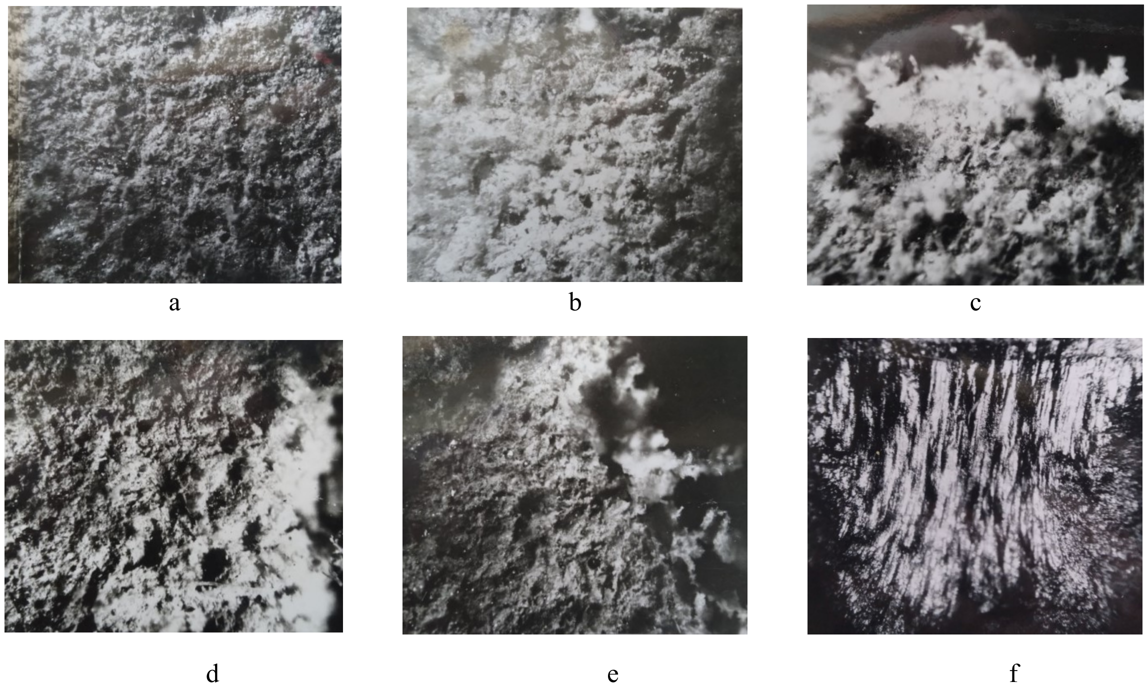


Fig. 6. The relief of the wear surface of a sample made of thermoplastic PA66-KS when hitting a layer of abrasive, depending on the number of hits: a – 50; b – 500; c – 1000; d – 1500; e – 2000; f – 3000

The parameters and conditions of the impact cyclic nature of the load on the intensity of wear of parts made of thermoplastics were studied. According to the results of the analysis of the operating conditions of parts of gas transportation equipment assemblies, it was found that most parts and assemblies are operated mainly in the range of change in the energy of a single impact from 1.3 J/cm^2 to 2.0 J/cm^2. The frequency of mutual impacts was taken as such, which did not lead to noticeable self-heating of the materials of the parts. Fig. 7 presents graphs of the dependence of the magnitude of impact-abrasive wear of the studied thermoplastics on the number of load cycles.

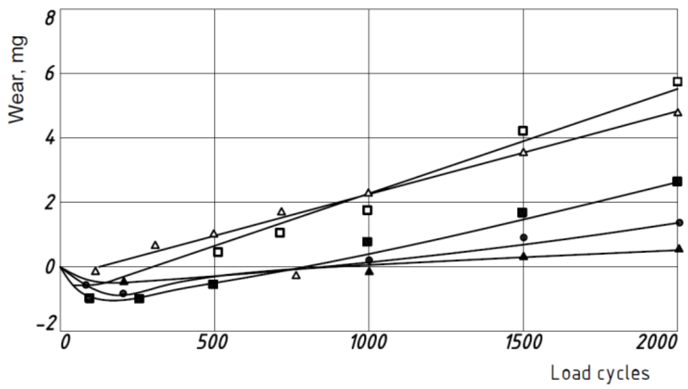


Fig. 7. Graphs of the dependence of the wear value of the studied thermoplastics on the number of loading cycles at a constant energy of a single impact: □ – PA66-PE; ● – P6; Δ - PA66-KS; ▲ – P6 (secondary); ■ – PA6-210-KS

At the initial stage, in almost all thermoplastics, a relief is formed on the contacting surfaces, during which intensive penetration of abrasive particles occurs (the process of drawing), as evidenced by an increase in the weight of the samples and the formation of a negative area on the graph. In this case, the drawing process dominates over the process of wear of the material of the parts - the running-in process. Depending on the characteristics of the material under study, the running-in period is different: in unfilled thermoplastics it is longer in comparison with glass-filled thermoplastics. The running-in process in all considered thermoplastics does not exceed 700 impacts on the abrasive.

Further, during impact-abrasive wear of thermoplastics, after the accumulation of the maximum amount of abrasive on the surfaces of the samples, determined for each material, a decrease in the weight of the sample is observed and the amount of wear becomes proportional to the number of impacts - the period of established wear, which is linear in nature. The beginning of the established nature of wear is the inflection point of the curve in the negative section of the graph. The wear rate of glass-filled thermoplastics is greater than the wear rate of unfilled thermoplastics (determined by the angle of inclination of the curve on the graph). One of the main reasons is that unfilled thermoplastics with a linear molecular structure are characterized by more developed forced elasticity. These thermoplastics are able to resist repeated deformation, and therefore impact-abrasive wear, for a longer period of time compared to glass-filled thermoplastics, which are harder and more brittle materials.

In parts made of glass-filled thermoplastics, unlike unfilled ones, a patterned layer of abrasive does not form on their surfaces, i.e. its particles do not wedge in and do not remain in the surface layer. In unfilled thermoplastics, the patterned layer counteracts the penetration of new abrasive particles into the material, taking on the initial impact load at the moment of contact of the part surface with the abrasive.

The intensive wear of glass-filled polyamides is also facilitated by the fact that glass fibers oriented in the direction of the impact force contribute to the fragmentation and damage of the original structure of the material, thus reducing its integrity and uniformity. When the energy of a single impact (A_{im}) increases to 2 J/cm^2, a more intensive wear process of the studied thermoplastics is observed (Fig. 8).

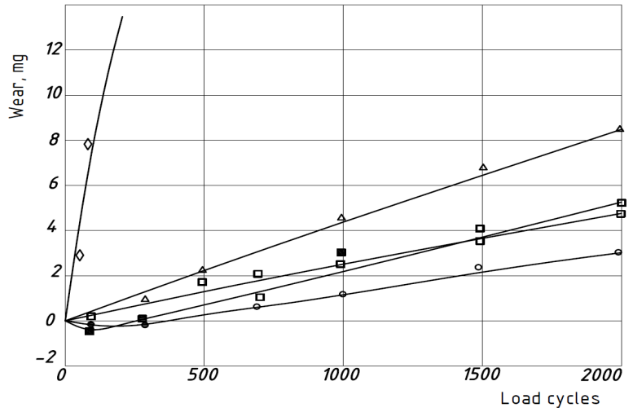


Fig. 8. Graphs of the dependence of the magnitude of impact-abrasive wear (by mass of silicon carbide) of the studied thermoplastics on the number of load cycles: A_{im} =2,0 J/cm^2; □ – PA66-PE; ● – P6; Δ - PA66-KS; ◊ – P6 (secondary); ■ – PA6-210-KS

The period of the running-in process of thermoplastics decreases both in terms of the amount of wear and in terms of its length, and for glass-filled thermoplastics it is absent (PA-KS, PA66 PE) or insignificant (PA6-210KS). An increase in the energy of a single impact does not lead to a proportional increase in the amount of wear. An increase in the energy of a single impact by 35% increases the amount of wear of the PA66-KS thermoplastic by 40%, of the PA-210KS thermoplastic by 51%, of the P6 thermoplastic by 59% (Fig. 9).

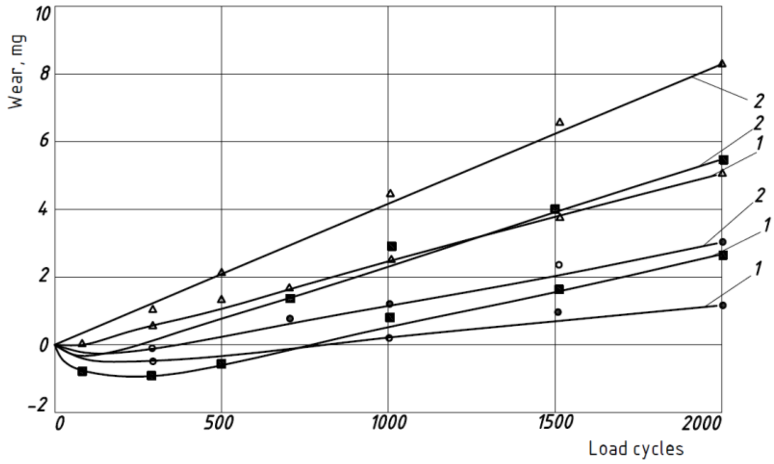


Fig. 9. Graphs of the dependence of the wear value of the studied thermoplastics on the specific impact energy (based on the abrasive mass of silicon carbide): ● – P6; Δ - PA66-KS; ■ – PA6-210-KS; 1 - A_{im} = 1,3 J/cm^2; 2 - A_{im} = 2,0 J/cm^2

The disproportionate increase in the wear rate of thermoplastics with increasing single impact energy is mainly due to the different nature of the abrasive action on the surface of the parts. The mechanism of formation of holes and partitions during the dynamic penetration of solid particles of unfixed abrasive into the sample material is associated with the change in single impact energy. It is obvious that the abrasive particles do not wedge into the surface layer of the thermoplastic, but mechanically destroy it, while the intensity of the abrasion of these surfaces is much lower compared to low impact energies.

Under the operating conditions of gas transportation equipment components in the shock-abrasive wear mode, the surfaces of the parts wear out both in terms of the layer and the mass of the abrasive. Fig. 10 shows the graphical dependences of the wear value of glass-filled polyamide PA66-KS in the above conditions.

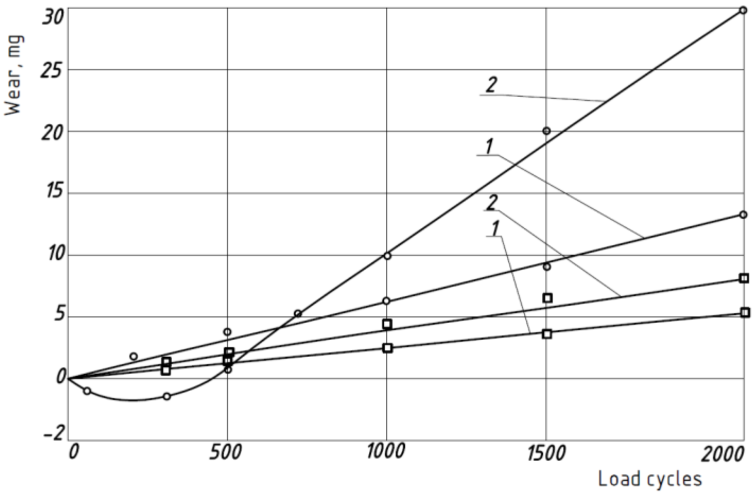


Fig. 10. Graphs of the dependence of the wear value of the PA66-KS thermoplastic on the type of abrasive and the energy of a single impact: ○ – by a layer of abrasive; □ – by mass; 1 - A_{im} = 1,3 J/cm^2; 2 - A_{im} = 2,0 J/cm^2

The results of the conducted studies and their analysis showed that the most dangerous type of wear for thermoplastics is the wear of working surfaces by the abrasive layer than by its mass, even at lower energies of a single impact (for PA66-KS by 2.4-3.3 times). It should also be noted that along with the thermoplastic, the metal surface on which the abrasive is placed also wears out. The characteristic relief of the surface on the forge (steel45) is shown in Fig. 11. The features of this type of wear include the formation of holes and bridges, the shape and size of which are much smaller than similar ones that form on the surfaces of thermoplastics and have a more oval shape and smoothed tops of the protrusions.

Fig. 11. Surface relief on a forge (steel 45) as a result of the action of an abrasive

When changing the characteristics of abrasive parts (hardness, dispersion, concentration), the most significant effect on the wear intensity of thermoplastics is the increase in the hardness of the abrasive. As a rule, the hardness of thermoplastics is insignificant compared to the hardness of abrasives, so the presence of any abrasive in the contact zone leads to the destruction of the surfaces of thermoplastic parts.

The final cycle was the study of the influence of the preliminary deformation of thermoplastics on the features of their wear. The contact time of the surfaces of thermoplastic parts in the presence of an abrasive is significantly shorter than when they are in contact without an abrasive. Such conditions of impact-abrasive wear are preceded by a cyclic impact interaction of the surfaces of the parts without the presence of abrasive parts in the contact zone. In this regard, it was necessary to assess the influence of the preliminary cyclic impact load on the wear resistance of thermoplastics.

During the study, the surfaces of thermoplastic samples were loaded by preliminary deformation with a given frequency and magnitude of impact energy. Fig. 12 shows graphs of the dependence of the wear value of preloaded (load cycle up to 5x10^3) unfilled polyamide P6 on the study time during impact-abrasive wear.

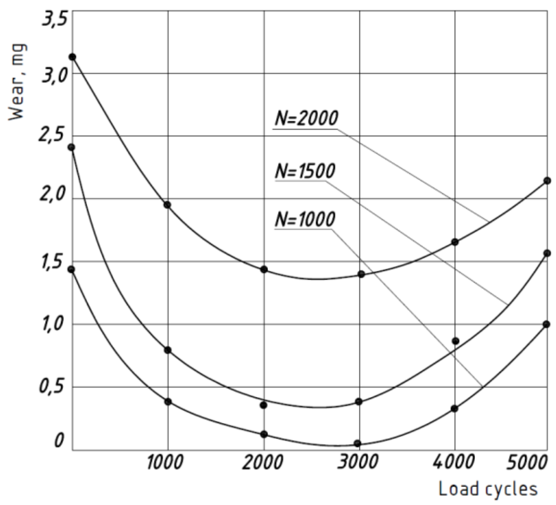


Fig. 12. Graphs of the dependence of the wear value of polyamide P6 on the number of pre-load cycles N: 1 - A_{im} = 1,3 J/cm^2; 2 - A_{im} = 2,0 J/cm^2; V = 5 Hz

As can be seen from the graph, the wear value of polyamide P6 decreases with increasing number of pre-load cycles only up to a certain value. This limit for the parameters of external action at a single impact energy of 5 J/cm^2 and a frequency (V) of 5 Hz for polyamide P6 is equal to 3x10^3 cycles of pre-load, which determines the appearance of the minimum value on the graph. After reaching this limit, the wear value of polyamide P6 slowly increases, however, even at 5x10^3 cycles of pre-load, the wear value of this thermoplastic is smaller in comparison with a similar material that was not subjected to pre-impact loading.

The decrease in the wear value of polyamide P6 preloaded to 3x10^3 cycles is explained by the fact that under these parameters of external action, the contact surfaces and subsurface layers are strengthened, due to the orientation and ordering of the structure.

With a further increase in the number of cycles of the pre-impact load, a gradual decrease in strength occurs, microcracks are formed and the surface layer of the part material is destroyed. The number of cycles of pre-loading on the sample can be determined by the magnitude of the relative deformation of the material. In this regard, the wear resistance of the material can be characterized as a function of the magnitude of the previous relative deformation (Fig. 13).

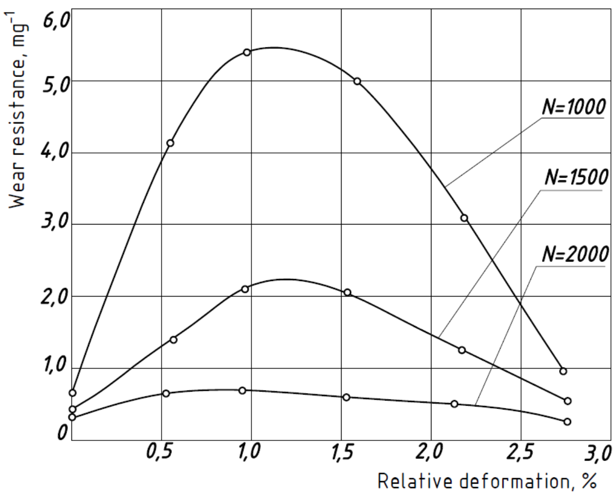


Fig. 13. Graphs of the dependence of the wear resistance of polyamide P6 on the previous relative deformation and the number of cycles of impact-abrasive wear N

According to the results of the research, it was found that preliminary deformation of polyamide P6 by 1.0-1.5% increases its wear resistance by 6-8 times. With a further increase in the time of impact-abrasive wear, its wear resistance decreases, which is explained by the gradual destruction of the upper strengthened layer of this material and the removal of destruction products from the contact zone. The insignificant difference in the value of the wear resistance of polyamide P6, which was not subjected to preliminary impact loading, is explained by the fact that during impact-abrasive wear, not only the wear of the surface layers but also the strengthening of the lower layers of the material occurs. The optimal deformation in terms of increasing the wear resistance of the surface layers for polyamide P6 is within 1.5-2.0%. The specified deformation range is achieved under conditions of cyclic shock loading on the sample with a frequency of 5 Hz, impact energy of 5 J/cm^2 and the number of cycles of 2x10^3–3x10^3.

Conclusions

1.The selection of thermoplastics for parts of gas transportation equipment assemblies of a specific purpose should be carried out based on the results of research into their wear resistance during impact-abrasive wear with different characteristics of the abrasive and the degree of its fixation, the nature of the impact of the aggressive working environment, and the previous shock cyclic load.

2.The operational reliability and performance of parts of gas transportation equipment assemblies depends mainly on the selected brand of thermoplastic and its characteristics, the nature of the force load (cyclic, shock), the presence of the type of abrasive, the degree of aggressiveness of the working environment, which lead to loss of tightness of the working assembly, surface destruction of parts, and changes in their geometric dimensions as a result of shock-abrasive wear.

3.The operational (research) reliability of the developed stand for studying impact-abrasive wear of polymeric materials of different brands in wide ranges of load force parameters with obtaining objective, satisfactorily comparable and reproducible results of experimental studies has been confirmed.

4.Preliminary deformation of the surface layers of thermoplastics under the action of cyclic impact loads increases the strength characteristics of these materials (hardness, tensile strength) and wear resistance. For the studied thermoplastics, the values and ranges of preliminary deformation, the frequency of cyclic impact loading, impact energy and the number of load cycles have been determined from the point of view of increasing their wear resistance. A series of studies of glass-filled polyamides PA66-KS, PA6-210KS, PA66-PE and unfilled polyamides P-6, UMP-225 was conducted to identify the main factors that significantly affect their wear resistance during impact and abrasive wear.

5.The mechanisms of impact-abrasive wear of thermoplastics have been identified and must be taken into account when selecting materials for parts for gas transportation equipment assemblies and units in order to ensure the specified operational characteristics.

6.The peculiarities of the impact of abrasive on the processes of drawing of working surfaces of parts of gas transportation equipment assemblies made of glass-filled and unfilled thermoplastics have been identified.

7.It has been confirmed that a more intensive type of abrasive wear of the surfaces of thermoplastic parts is their wear by layer and not by mass of abrasive, even at lower energies of a single impact.

8.It has been experimentally confirmed that the main parameter that affects the intensity of impact-abrasive wear of the surfaces of thermoplastic parts is the energy of a single impact.

9.Practical recommendations have been developed for the use of thermoplastics for the manufacture of parts of working units of gas transportation equipment that operate under impact-abrasive wear conditions. Parts for gas transportation equipment units of new designs that are operated under cyclic impact loading under impact-abrasive wear conditions have been designed and manufactured (parts of spherical ball joints for the drive mechanism of the gas inlet valve of a gas motor compressor, valves of gas motor compressors, anti-pumping ball valves, seals of ball valves, seals of the rotor shaft of centrifugal gas pumping units).

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Гупка А., Ярема І., Гевко І. , Лещук Р., Кобельник В., Буховець В., Пиндус Т. Дослідження термопластів при ударно-абразивному зношуванні

У статті представлено результати досліджень закономірностей процесів тертя та ударно-абразивного зношування термопластів при циклічних та ударних навантаженнях. Детально проаналізовано умови та режими експлуатації вузлів газотранспортного обладнання та причини виходу з ладу найбільш навантажених деталей. Виявлено характер впливу абразиву та його характеристик на зносостійкість робочих поверхонь деталей вузлів газотранспортного обладнання. Обгрунтовано вибір марок термопластів для виготовлення деталей робочих вузлів газотранспортного обладнання, які працюють при циклічних ударних навантаженнях. Проаналізовано конструкції існуючих стендів для дослідження поверхневої деформації та ударно-абразивного зношування термопластів. Вдосконалено конструкцію дослідного стенда та виготовлено механізм силового навантаження для реалізації поставлених задач, запропонована комплексна методика проведення досліджень. Виявлено та обґрунтовано вплив параметрів та умов циклічного ударного навантаження на зносостійкість термопластів в умовах ударно-абразивного зношування, а також особливості зношування попередньо деформованих термопластів. Розроблено практичні рекомендації, щодо можливого застосування досліджуваних термопластів для виготовлення деталей вузлів газотранспортного обладнання.

Ключові слова: газотранспортне обладнання, термопласти, абразив, тертя, гідроабразивне зношування, ударно-циклічне навантаження, дослідний стенд