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USING AND EFFICIENCY MANUFACTURING OF POLYMERIC MATERIALS PARTS FOR GAS TRANSPORTATION EQUIPMENT

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Summary*. The paper deals with the applied using of polymeric material parts in gas transportation equipment as well as calculation of their efficiency of manufacturing. In this way basing on the results of previous known researches the basic questions of polymeric material parts using in gas transportation equipment are discussed. The manufactured and tested in practical application parts of gas transportation equipment elements of different purpose are exemplified. The possibilities of such parts using in existing equipment are presented. Much attention is paid to polymeric material parts manufacturing as well as to the calculation of its efficiency. The multi edge devices with kinematic inter tool links are proposed to use them in mechanical machining of such parts. The integral technology efficiency indexes of manufacturing and machining of polymeric material parts for gas transportation equipment are developed. The increase in productivity, accuracy and quality of polymeric material parts machining is being proved.*

Key words*: gas transportation equipment, polymeric material parts, efficiency, machining, multi edge devices, kinematic links.*

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Introduction. Without the use of polymeric materials, it is difficult and sometimes impossible to solve important technical tasks. This is due to the properties that are inherent only in plastics [1, 2]. Some of them in other materials appear themselves very insignificantly or do not appear at all. Replacing metal parts with plastic, as well as substituting one polymer material by another gives a positive effect only when the design of the workpiece changes at the same time so that the positive characteristics of the selected material can be manifested as much as possible. At the same time, the developed design should prevent the negative properties of a polymeric material. Currently, it is quite effective to use parts from polymer composite materials in the manufacture of elements of gas transport equipment which is developing intensively [4, 5, 6]. Therefore, the problem of studying of use and efficiency of manufacturing gas transportation equipment from of polymer materials is relevant.

Analysis of the investigations and statement of the problem. In the technological equipment of the main gas pipelines, a considerable number of parts and units of polymer composite materials (PCM) operating in the conditions of dry and semi-dry friction, at relatively low temperatures and differential pressure, shock-abrasive wear [3], namely in joints with reciprocating rotating movement and in fixed joints of pneumatic and hydraulic systems, etc.

The peculiarity of use of PCM piston seal is the problem of removing the heat from the friction zone in the pair ‘piston ring – sleeve’ and ‘plastic ring – stem’ [16, 20]. As the temperature rises, there is a sharp decrease in the magnitude of the elastic module of the friction pair material, which is negatively reflected in their performance. One of the effective options of seal design for ‘piston ring – stem’ is installation of a metal and polymer composing ring in the clamp.

In gas-motor compressors (MMC) MK-8, the replacement of metal valve plates with polymer composite has improved the reliability and durability of the valve, reduced manufacturing and repair costs [19].

The reliability of ball valves on the technological lines of compressor stations (CS) largely depends on the condition of the seals of the ball valve and rod [16, 21]. The loss of tightness of the valves is mainly due to wear of the sealing surface of one of the seals of the ball valve or damage to its solid mechanical particles, which are carried in the transported gas. Depending on the type of crane, functional purpose, country of manufacture the seal is made of many types of PCM, such as fluoroplastic, fluoroplastic compositions, polyamides, polyurethanes, rubber and other polymer composite materials [4, 14].

The use of thermoplastic polyurethanes for the manufacture of seals, couplings, diaphragms, anti-vibration buffers and other parts of gas transmission equipment is effective [2, 4, 5].

The analysis of the literature shows that of the large number of existing polymer composite materials, it is advisable to consider only a certain number of materials that can be used in movable and immovable joints of gas transmission equipment. The choice of material type depends on the operating conditions, its resistance to aggressive environments, the properties of the material and the peculiarities of its use in certain components and parts.

The purpose and objectives of the study. The purpose of the study is to develop and present the development of scientifically sound recommendations for application and effective evaluation of the manufacture of parts made of polymer composite materials for units of CS gas transmission equipment and main gas pipelines.

The objectives of research are:

- to reveal the main problematic issues of the use of polymeric materials in the parts of gas transmission equipment;
- consider the examples of implementation of original parts made of polymeric materials in the elements of gas transmission equipment;
- to obtain analytical dependences for estimation of indicators of surfaces processing efficiency if the parts made from polymeric materials at their use in the gas transport equipment;
- to conduct an integrated analysis of the efficiency of the developed technologies for the manufacture and processing of parts from polymeric materials for the equipment of main gas pipelines.

Basic issues of using polymers in parts of gas transmission equipment

When using a combination of metal and polyamide rings to seal the rod, heat dissipation is improved, and the polyamide ring is deposited by a thin film on the working surface of the metal rod due to the phenomenon of friction transfer, reducing the coefficient of friction.

Experience shows that for the effective use of polyamide piston rings in gas compressors it is necessary to take into account the operating conditions (temperature, pressure) and specifically select one or another PKM to them. For example, for the 4HR3KN compressor unit (manufactured in the former GDR), which is installed at automotive gas filling stations, polyamide piston rings can be used for the 1-st, 2-nd and 3-rd compression stages, and for the 4-th, where temperature and pressure are significantly higher, the use of heat-resistant antifriction materials such as "Flubon" will be more effective.

The practice of using plastic valve plates made of glass-filled PA6-210 KS polyamide in gas-fired compressors MMC-8 showed that in the initial period of valve operation there is an increase in temperature by 10-15^{0}C, and after 30-50 minutes the temperature drops to normal. This is due to the fact that plastic plates after manufacturing and the necessary heat treatment may have a slight loss of geometric dimensions, warping and, consequently, leaks in the plate to the valve seat, which in the process leads to increased temperature and loss of efficiency. When heated, the modulus of elasticity of the plastic material decreases, and under the action of the pressure drop at the time of closing the valve, there is a thermomechanical fit of the plate to the seat. As a result, the tightness of the valve is improved and its operating modes are stabilized.

The use of fluoroplastic seals of the ball valve helps to increase its tightness, significantly reduce torque due to the low coefficient of friction of the fluoroplastic on the metal. At the same time, fluoroplastic seals are unstable to abrasive, gas-abrasive and shock-abrasive wear [3] and are subject to destruction by erosive high-speed gas flow. Fluoroplastics are characterized by a low yield strength, and the absence of elastic and viscoelastic components of deformation does not lead to the restoration of dents, cuts and bursts caused by pressing into the sealing surface of solid particles. More promising and stable to work in such conditions is the group of PKM «polyamides», which are processed by injection molding [17] (which allows to significantly reduce costs and time for the manufacture of ball valve seals of different sizes) and their subsequent machining with multi-blade tools and metal-cutting machines [8, 9, 10, 11].

When designing and manufacturing seals to ball valves of large diameters from polyamides, it is necessary to take into account the property of increased water absorption of this material, as this leads to increasing of geometric dimensions of the seal and deterioration of cranes. In the laboratory of gas transportation equipment of Ternopil National Technical University seals with PKM [16, 21] were developed for repair of more than 20 standard sizes of cranes, such as Du-13, Du-25, Du-50, DU-80, Du-100 of «Bitter» company (Germany), Du-25, Du-50 of «MAREGAS» (France), Du-50, Du-100 of «Grove» (Italy), Du200 of «Fischer» company (Germany) [21], Du-50, Du-80, Du-100 of the plant «Tyazhpromarmatura» (Russia), Du-15 of the plant «Alfa-Gazkomplekt» (Ukraine) and others.

Studies of the relaxation characteristics of polyamides have shown that in the seals of flange and fittings, which are loaded with a constant load, the stresses decrease over time, and then reach almost constant value. If, after some stress stabilization, the flanges are re-tightened to the initial stress value, then after relaxation, in some time the residual stresses will be higher than after the first tightening. Therefore, for polyamide seals, it is advisable to re-tighten the bolts, which contributes to better sealing of the joint.

Fluoroplastic seals can be used for long-term operation in the temperature range from -60^0C to +120^0C and specific pressure drops up to 7.5 MPa. At higher temperatures and pressure drops, the material loses its properties and sealing ability. Flat fluoroplastic seals are used for sealing smooth flanges and flanges with grooves (leaks) at specific pressures up to 7 MPa and temperatures up to 120^0C.

It is also possible to use polyethylene (PE) to seal fixed joints. It should be taken into consideration that the disadvantage of polyolefins is their ability to oxidize and degrade. Prolonged heating in air and direct sunlight lead to deterioration of their properties due to thermal oxidative degradation. Polyethylenes are also characterized by the phenomenon of cracking of the material under the action of stresses and the environment.

The combination of strength, elasticity and oil and petrol resistance is typical for the Polyurethanes PCM group. Solid polyurethane seals can withstand pressures up to 4.0 MPa and are characterized by high wear resistance. When using polyurethanes as structural materials, it is necessary to take into account their limited hydrolytic stability. The maximum allowable operating temperature in a humid environment should not exceed 70^0C.

Therefore, of the large number of existing polymeric construction materials, it is advisable to consider only a number of materials that can be used in movable and immovable joints of gas transmission equipment. The selection of material type depends on the operating conditions, its resistance to aggressive environments, properties of the material, peculiarities of its use in certain components.

5. Introduction of plastic parts on gas transportation equipment

As a result of a number of researches, including those with the participation of the authors, a number of structures were developed, experimental batches of parts made of polymeric materials were made and implemented at compressor stations of main gas pipelines of PJSC Ukrtransgaz NJSC Naftogaz of Ukraine.

Manufactured by energy-efficient mechanical processing method with multi-blade cutting tools [9, 10, 11, 22] parts made of polymeric polyamide material PA-6 (Kaprolon-B) guide rings of cable holder of the electric hoist of the Demag crane were introduced on the main gas pipeline «Soyuz» in UMG «Prykarpattransgaz» (Fig. 1).

Figure 1. Guide ring and cable holder of the electric hoist of the Demag crane

Guide rings have shown their efficiency, reliability and durability in operational conditions.

New design of gas labyrinth seals [14, 15, 20] of centrifugal supercharger Demag 655 P2 of gas pumping unit No/ 3 at the compressor station of the gas pipeline «Soyuz» UMG «Cherkasytransgaz» (Fig. 2) is developed and made by the method of multi-blade mechanical processing from the polymeric material.

Figure 2. Labyrinth seals of centrifugal supercharger Demag 655 P2

During operation, the seals showed their reliability, durability (operating time was more than 19 thousand hours) and efficiency compared to standard branded seals.

The result of such indicators was the correctness of the developed design, the selection of rational material of the labyrinth insert and the technology of manufacturing multi-blade tools profile of the seals. This comprehensive approach to design and manufacturing technology can be similarly applied to other types of labyrinth seals of Cooper Bessemer main pipeline compressor stations (US), Demag (German), Nuovo Pignone (French) and others.

On the technological equipment of compressor stations of UMG «Prykarpattransgaz» seals of the centrifugal compressor of the gas pumping unit GTK-25I and guide rings of 5-tonne (Fig. 3) were developed and manufactured from composite polymeric materials using machining [11, 17, 22].

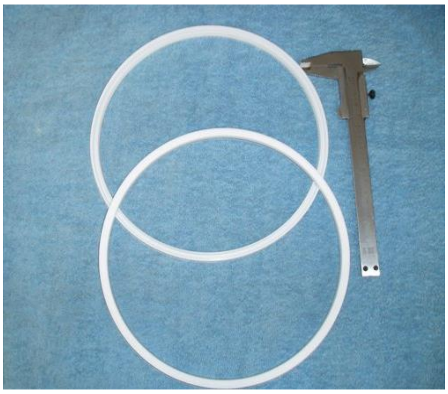

Figure 3. Anti-surge valve seal VK GTK-25 I

Implemented parts of the technological equipment of compressor stations allowed to increase the efficiency, durability and restore the operability of the units.

A new design of polymer-composite rings of the ball valve of the gas valve Du-15 Ru-80 produced by the plant «Alfa-Gazpromkomplekt» (Fig. 4) is created. Seals are made by a highly efficient method of injection molding on a thermoplastic machine. After casting such seals, their further processing is carried out mechanically on a lathe to remove the casting system and achieve accurate geometric results and the sealing surface.

Selected polymeric material (foundry unfilled polyamide PA-6) and manufactured ball valve seals can increase the service life by 1.5–1.8 times and reduce the cost of manufacturing the entire valve.

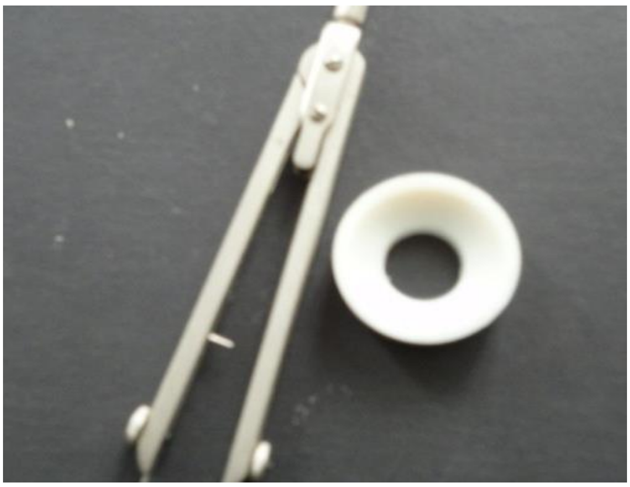

Figure 4. Ball valve seal Du-15 Ru-80

The selection of polymeric materials depending on the operating conditions and the application of the technology of manufacturing ball valve seals can be applied to other seal designs and the size of ball valve designs [16].

Plastic spark plug extensions of the MK-8 gas-motor compressor ignition system are also being tested (Fig. 5). Extension blanks are made of glass-filled polyamide with subsequent machining by multi-blade devices [8, 9, 13, 18].

Figure 5. Plastic extenders of spark plugs GMC MK-8

The selected polymeric material meets the requirements of operation in terms of dielectric and strength characteristics. These extension cords are operated on the units of Bohorodchany gas storage station UMG «Prykarpattransgaz» NJSC «Naftogaz of Ukraine».

6. Analysis of the efficiency of the developed technologies of manufacturing and processing of parts from polymeric materials for the equipment of main gas pipelines

The efficiency of manufacturing and processing of parts depends on a number of factors [7, 8].

The production of blanks [4, 5, 6] from polymeric materials is mainly based on the use of injection molding methods using thermoplastic machines. At the same time, in the manufacture of parts of gas transmission equipment there is a need to achieve a fairly high level of accuracy and quality of treated surfaces. This is possible when using primarily the process of machining by cutting with blade tools.

For the general assessment of machining, the most important characteristics such as increased productivity and increased machining accuracy (reduction of macro-errors), stabilization of cutting forces and others should be considered.

Machining of parts made of polymer-composite materials is accompanied by difficulties caused by the heterogeneity of these materials, their variable stiffness and dynamic instability, insufficient productivity of traditional single-cutter cutting [12]. Due to these facts, the authors proposed to carry out such cutting with the use of multi-blade self-adjusting lathe cutters. The cutters in the respective heads are placed opposite to each other along the perimeter of the machined surface and are connected by kinematic inter-instrumental connection (KMIC) [8, 10, 18].

Simultaneous use of several cutters during machining can stabilize the machining process and significantly increase cutting productivity. This value is one of the most important characteristics of such multi-blade equipment [7]. In mechanical engineering technology, it has been proven that the productivity of processing is directly related to the rigidity of the technological system. Thus, when turning, the processing time of a unit of surface is directly proportional $\sqrt{\Delta/\delta}$ and inversely proportional to $\sqrt{j}$, where j is the radial rigidity of the technological system; Δ is inaccuracy of the workpiece in cross-section; δ is specified error of the workpiece. Thus, with traditional cutting to increase productivity twice it is necessary to increase the rigidity of the system by four times.

We compare this productivity with one-cutter processing to the productivity of two-blade cutting with KMIC by the method of feed separation [12]. In this case, the radial deformation of the TOC will be determined only by the stiffness j_k of each of the carriage calipers (these stiffnesses are considered to be the same). Then we can come to the dependence that describes the duration of treatment of a unit of surface in one pass:

$$\tau_M = \frac{10 \cdot t^{0,28}}{2^{0,4} \cdot C_v \left[\left(\frac{2,5}{C_p} \right) \cdot j_k \cdot \left(\frac{\delta}{\Delta} \right) \right]^{0,53}} . \tag{1}$$

Therefore, a reasonable (in terms of ensuring the accuracy of processing) increase in productivity of two-blade turning with KMIC compared to single-blade (with the same refinement and depth of cut) can be written as

$$\upsilon_{prII} = \tau_{MI} / \tau_{MII} = 1,32 \cdot \left(\frac{j_k}{j} \right)^{0,53} \approx 1,32 \sqrt{\frac{j_k}{j}} . \tag{2}$$

When processing in the centers, this value can be represented as follows

$$\upsilon_{npII} = 1,32 \cdot \sqrt{\frac{j_k}{j_{sp}} \left(1 + \frac{j_{sp}}{j_v} + \frac{j_{sp}}{2 j_b} \right)} \tag{3}$$

where j_v, j_{sp}, j_b are the stiffness of the part, caliper, and latches given.

The analysis of these formulas shows that the use of KMIC equipment can increase the cutting productivity from 1.8 to 4.5 times, and the most effective is the use of KMIC in the processing of low-rigid parts. Moreover, the coefficients of productivity increase are important: β_n=1.32 for two-blade processing; β_n=1,55 tor three-blade processing.

Consider also the calculation of productivity of cutting in turning in terms of ensuring given accuracy along the length of the workpiece. After all, even in the case of «ideal» workpiece due to the fact that the elastic imprints of the machine elements change along the length of the workpiece, its diameter and shape are variable in length (machined part becomes either barrel-shaped or concave). At multi-blade turning with KMIC in the centers, elastic imprints of TOS do not depend on a place of application of efforts and rigidity of a blank. Then we get that

$$\tau_{Mn} = \frac{10 \, t_1^{0,28}}{n^{0,4} C_v \left(\frac{2,5}{C_p} \cdot j_k \cdot \frac{\delta}{\Delta} \right)^{0,53}} \tag{4}$$

Accordingly, the estimated coefficient of productivity increase for two-blade processing with KMIC:

$$\upsilon_{prn} \approx 1.32 \cdot \sqrt{\frac{t_1}{\Delta}} \cdot \sqrt{\frac{j_k}{j_v} + \frac{3 j_k}{j_{sp}} \left(\frac{\Delta}{t_1} - \frac{1}{4} \right)}\,. \qquad (5)$$

The analysis of the presented dependences shows that the increase in productivity with two-blade turning is most appropriate for non-rigid parts (in particular for the case jsp $j_{sp}/j_v \geq 0{,}75$).

These dependencies are evaluation criteria for determining the cutting modes of multi-blade equipment, which increase the productivity of processing parts made of polymer composite materials while meeting the requirements for the accuracy of the shape in longitudinal section.

In the process of multi-blade cutting with the use of KMIC, self-adjustment is constantly carried out, cutting forces change over time and their ratio is regulated [8,14]. Operation of KMIC in order to equalize the cutting forces between the various cutting elements of the system leads to additional constant changes in the thickness of the cut layer and, accordingly, the dynamics of the process. Thus, multi-blade adaptive machining is characterized by continuous mutually agreed regulation of cutting forces.

Let us estimate such change of efforts of cutting numerically.

In the first approximation we will limit ourselves to the static formulation of the problem of machining a workpiece with a depth of cut variable according to the harmonic law. Consideration of physical laws will be carried out on the example of turning on the basis of the analysis of power dependences of cutting force on cut thickness.

Having denoted the steady-state value of the cutting force $C_P \cdot t^{x_P} \cdot s^{y_P} = P_0$, we will have the following dependence on time to change the cutting force during one-blade maladaptive machining

$$P_I(\tau) = P_0 \cdot (1 - a_e \cdot \sin \omega\tau)^{x_p}, \qquad (6)$$

where a_e is a relative amplitude of change of cutting depth. The average value of the cutting force at depth fluctuations does not differ from the generalized value P_0.

Using this approach, we consider the nature of changes in cutting forces, for example, in two-cut machining. We obtain a dependence that describes the behavior of the cutting effort on each of the cutters over time

$$P_I(\tau) = P_0 \cdot (1 - a_e^2 \cdot \sin^2 \omega\tau)^{x_p} \cdot [(1 + a_e \cdot \sin \omega\tau)^{\frac{x_P}{y_P}} + $$
$$+ (1 - a_e \cdot \sin \omega\tau)^{\frac{x_P}{y_P}}]^{-y_P}.$$

These dependences show a significant reduction in the amplitude of oscillations of cutting forces.

Let us also calculate the average value of the cutting force when machining using KMIC

$$P_{av} = \frac{P_0}{\sqrt{2} \cdot (1 + a_e^2)} \quad (7)$$

It can also be shown that, respectively, the maximum and minimum values of the cutting forces on each cutting element during machining with KMIC

$$P_{max} = \frac{P_0}{\sqrt{2}} \text{ and } P_{min} = \frac{P_0}{\sqrt{2}} \cdot \frac{1 - a_e^2}{1 + a_e^2} \quad (8)$$

At the same time at nonadaptive one-blade processing

$$P_{cp} = P_0;\ P_{max} = P_0 \cdot (1 + a_e) \text{ and } P_{min} = P_0 \cdot (1 - a_e), \quad (9)$$

These dependences clearly show that dutring the processing with KMIC it is possible to significantly reduce the values of maximum and average values of cutting forces and virtually eliminate the amplitude of oscillations compared to both traditional single-blade and double-blade machining with rigidly fixed cutting elements.

To assess the energy efficiency of the use of multi-blade adaptive equipment with KMIC, it is advisable to compare other indicators of such equipment.

Notably, the increase of static accuracy of processing using multi-cutter equipment with KMIC can be estimated by comparing the macro-errors of the machined part in the radial as well as in the longitudinal directions [8].

In particular, when turning in the centers of the shaft of low rigidity increase the accuracy of processing in the radial direction will be

$$Y_p = 1.4 \cdot n \cdot \frac{j_d / j_v + 1}{j_d / j_k}.$$

where j_d is respectively, the stiffness of the part at the position of the cutter in the middle of the workpiece, and j_v is the equivalent stiffness of the machine; j_k is the stiffness of the carriage with the cutting element, n is the number of cutting elements. Processing at small values j_d / j_v is the most effective, but even at considerable stiffness of a part $j_d / j_v > 1$, increase in accuracy of processing in the radial direction is considerable enough.

The variability of stiffness of the machine-tool-tool-part system along the coordinates of the machining zone distorts the shape of the part, in particular the rigid cylindrical part machined in the centers by one cutter is corset, and the pliable cylindrical part is barrel-shaped.

After calculations, we find that the increase in the accuracy of multi-blade machining with KMIC compared to single-blade turning, due to the longitudinal processing error associated with changes in the rigidity of the system, can be expressed by the ratio

$$Y_{ac} = 4.44n \frac{j_{sp}}{j_{zb}}$$

Thus, in the case of equality of stiffness of the caliper $j_{сп}$ and the rear center $j_{зб}$ we obtain that the static value of macro-errors along the axis of the part with two-blade adaptive turning will decrease by about 8.8 times, and with three-blade one – by 13.3 times. Meanwhile, the same productivity of cutting, as well as at single-blade turning by the rigidly fixed tool is provided.

Essentially important characteristics of the quality of the treated surface are roughness and undulation. The process of occurance of microroughness for geometric reasons is the copying of the trajectory on the treated surface and the shape of cutting blades. At single-cut turning, the height of microroughnesses can be estimated by the formula $R_z=s^2/8r$, where s is the feed of the caliper, and r is the radius of rounding of the top of the cutter. Due to the fact that the operation of the leveling KMIZ mechanism of multi-blade equipment in the cutting process due to fluctuations in the feed elements of the cutting elements leads to the fact that the roughness of the treated surface becomes heterogeneous [8, 9].

Thus for two-blade self-adjusting processing with KMIZ, the greatest possible height of geometrical microroughnesses can be estimated on expression

$$(R_{z\max})_{II} = \left(s/_{8r}\right)\left(s/_{4} + s_{af}^{\max}\right),$$

where s_{af}^{max} is the maximum feed change peak from the average rate.

In this case, the increase in accuracy at the micro level of multi-blade machining with KMIZ compared to single-blade turning can be calculated as

$$\text{for } n=2 \quad H_{II}=4k/(4+k); \quad \text{for } n=3 \quad H_{III}=9k/(12+k),$$

where $k=s/s_{af}^{max}$, when $k\geq 1$.

The analysis shows that with two-blade treatment the roughness of the treated surface can be reduced by at least 1.3 times, and with three-blade – by more than 1.8 times.

8. Discussion of the results of studying the efficiency of manufacturing parts of gas transmission equipment from polymeric materials

As a result of the analysis of existing technologies of processing and treatment of parts from polymeric composite materials of various design, their manufacturing by methods of pressing, extrusion, injection molding and with use of machining is studied.

Due to the peculiarities of the structure and physical and mechanical properties of the polymeric composite materials for manufacturing parts from such materials, including machining, has a number of specific features. As the consequence of the improvement of machine-tool equipment for processing parts from these materials based on the use of kinematic inter-tool connections in the equipment, energy-efficient technologies have been proposed that provide improved quality and accuracy of parts.

The conducted research contributed to the development of characteristics that allow an integrated approach to assessing the effectiveness of the use of parts made of polymeric materials in gas transmission equipment when used in their manufacture and processing of the proposed technical solutions.

Thus, integrated indicators of energy efficiency of manufacturing and processing technologies, can be shown as diagrams, in which the following characteristics are taken into account

- quality of making workpieces by casting;
- increase of productivity and accuracy of machining due to multi-cutter self-adjusting cutting;
- reducing the roughness of the treated surface;

- stabilization of cutting forces by eliminating unwanted oscillating processes.

Such integrated pictures for the details of the main gas pipelines made of caprolon-B and fluoroplastic 4 are shown in Figures 6 and 7, respectively.

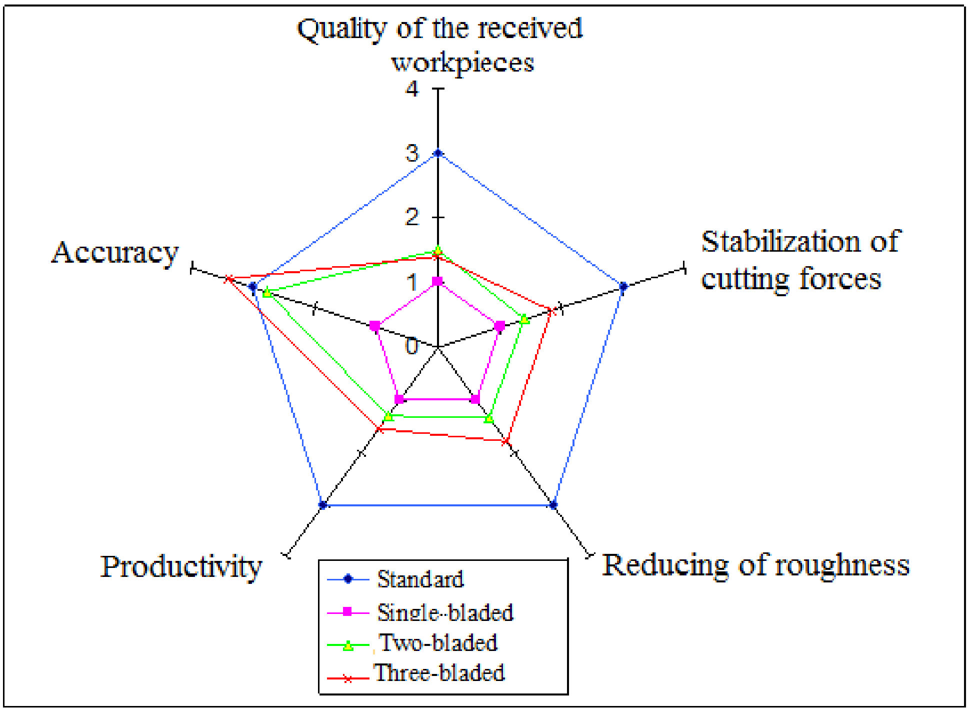

Figure 6. Integrated indicators of energy efficiency of technology of manufacturing and processing of details for the main gas pipelines equipment

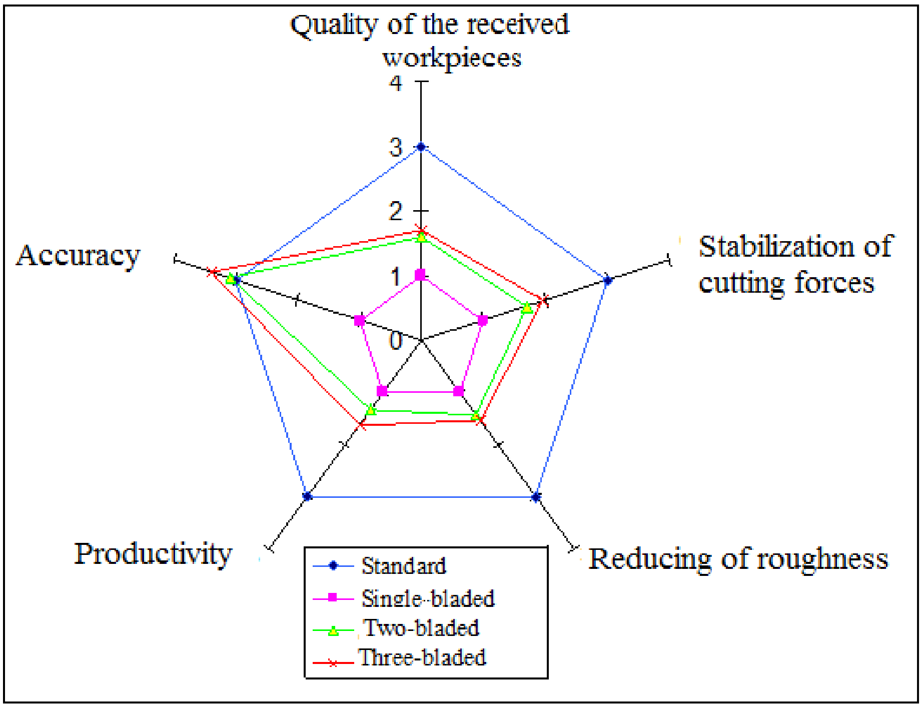

Figure 7. Integrated indicators of energy efficiency of technology of manufacturing and processing of fluoroplastic 4 parts for the main gas pipelines equipment

These pictures clearly demonstrate the possibilities of effective application of the developed technologies in comparison with traditional technology with the use of turning with one cutter and is even close to the standard of threefold improvement of integrated efficiency where three cutter turning heads with self-adjustment are used.

Conclusions. The main perspective approaches to developing of technological equipment for the manufacture of parts of gas transmission equipment from polymer composite materials (fluoroplastic 4, polyamide PA-66KS, caprolon-B, etc.) using methods of injection molding and pressing, as well as machining taking into account geometric features of relevant parts, functional and operational characteristics and other factors. In consequence of developing practical recommendations on use of parts from polymeric composite materials, the prototypes are made: a directing ring and a clip of a paver of an electric hoist of Demag crane; labyrinthine seal of the centrifugal supercharger 655P2; sealing of the anti-surge valve VKGTK-251; sealing of ball valves DU-15RU-80; plastic extensions of spark plugs of MK-8 gas-motor-compressor and others. Most of these details have been implemented at UMG «Prykarpattrangas», «Cherkasytransgaz», «Alfa-Gazpromkomplekt». Based on the proposed principles of creating multi-cutter tooling for high-precision and low-vibration machining of gas transmission equipment parts from polymer composite materials, new equipment is developed, characterized by the use of inter-tool connections for various types of removing the cut layer; multi-cutter heads of adaptive type for machining of gas transmission equipment parts are designed, which makes it possible to improve the accuracy and quality of multi-blade cutting of polymer composite materials. Particularly, for details from fluoroplastic-4, macroerrors in cross section are reduced by 1.6–3.8 times, in parts from kaprolon-B by 1.2–1.6 times, indicators of accuracy qualities by 10–12 times, roughness of Ra by 1.8–4.1 microns and other positive effects are reached. On the basis of theoretical calculations and practical experiments, in the form of diagram the main indicators of energy efficiency of developed technologies for manufacturing and processing of polymer composite materials in terms of quality of workpieces, improving processing productivity, stabilizing cutting efforts, reducing errors and roughness.

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ЗАСТОСУВАННЯ Й ЕФЕКТИВНІСТЬ ВИГОТОВЛЕННЯ ДЕТАЛЕЙ ГАЗОТРАНСПОРТНОГО ОБЛАДНАННЯ ІЗ ПОЛІМЕРНИХ МАТЕРІАЛІВ

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Резюме. *Розглянуто прикладне використання деталей із полімерних матеріалів у газотранспортному обладнанні, а також розрахунок ефективності їх виготовлення. В цьому аспекті на основі результатів попередніх відомих наукових досліджень наведено основні особливості використання деталей із полімерних матеріалів у різних вузлах газотранспортного обладнання. На прикладах показано практичні зразки виготовлених і випробуваних на виробництві деталей різного призначення, що входять до складу елементів газотранспортного обладнання. Представлено характеристичні можливості використання таких деталей в існуючому обладнанні. Значна увага приділена виготовленню деталей із полімерних матеріалів, а також розрахунку ефективності* *технології такого виробництва. Запропоновано багатолезові пристрої з кінематичними міжінструментальними зв'язками для їх використання у виготовленні в плані механічної обробки вказаних деталей. Виведено залежності для розрахунку показників ефективності інтегральної технології виготовлення деталей із полімерних матеріалів для газотранспортного обладнання. Доведено зростання продуктивності, точності та якості механічної обробки відповідних деталей із полімерних матеріалів. Наведено інтегральні якісні картини ефективності виготовлення деталей із капролону В та фторопласту 4, що застосовуються для елементів газотранспортного обладнання.*

Ключові слова: *газотранспортне обладнання, деталі з полімерних матеріалів, ефективність, механічна обробка, багатолезові пристрої, кінематичні зв'язки.*

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