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IMPROVING THE PROCESS CHARACTERISTICS OF CUTTING FIBROUS COMPOSITE MATERIALS

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This study explores the process of cutting fibrous polymer composite materials. The main reason for limiting the use of polymer composites is the deterioration of their performance properties after mechanical processing because of destruction of the surface layer.

It is high time substantiated recommendations for the mechanical processing of fibrous polymer composites (FPCs) are provided. This could reduce the depth of destruction of an FPC surface layer to 20–50 μm and expand the area of functional application of these materials.

An experimental study on the influence of cutting modes and geometric parameters of the cutting part of the tools on the technological components of the cutting force has been conducted, which made it possible to establish that the greatest influence on the cutting force when processing fibrous composites is exerted by the values of the geometric characteristics of the tool. Reducing the energy consumption for cutting to the level of 1.5 kN · m/s helps minimize the influence of mechanical, thermal, and chemical factors on the destruction of the composite.

FPCs have high elastic properties, which determines the features in the cutting process. As this leads to increased values of cutting forces on the rear surface, it is recommended to carry out processing by a sharpened tool at large values of the front γ and rear α angles of the blade.

Determining the cutting force makes it possible to correctly assign the geometric parameters of the tool and estimate the processing error. The specified machining modes make it possible to reduce the depth of the defective layer by 10 times (RZ ≤ 20 mm, KB ≤ 5%, N ≤ 1012 spin/gr, M ≤ 50 μm) and increase the stability of the cutting tool by two times.

The results could make it possible to improve the process of shaping articles from polymeric materials during production

Keywords: cutting characteristics, composite materials, machining, elastic properties, composite deformation

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1. Introduction

Fibrous polymer composite materials (fibrous polymer composites) are the main class of materials that meet such requirements as ensuring the minimum mass of structures, maximum strength, rigidity, reliability, and durability when operating under severe load conditions. The widespread use of fibrous polymer composite materials is constrained precisely because of the issues related to ensuring the quality of the surface layer during their mechanical processing. It is necessary to have substantiated recommendations for machining fibrous polymer composites. This could reduce the depth of destruction of an FPC surface layer to 20–50 μm and double the resistance of the cutting tool. Therefore, the area of such research is relevant.

2. Literature review and problem statement

Work [1] considers establishing the conditions for effective mechanical processing of fibrous polymer composites. The widespread use of fibrous polymer composite materials is constrained precisely by the problems of ensuring the quality of the surface layer during their machining. The authors state the problems that arise during the processing of composite materials. The effects of cutting modes on the creation of rational conditions for the destruction of the fibrous filler are analyzed but the work does not investigate the influence of the geometric parameters of the cutting part of the tools.

Paper [2] gives an overview of current scientific research on the milling process of composite materials. The lack of large-scale and thorough research on milling processes is revealed. Ther authors indicate the following prospects for further investigation: the search and development of new tool materials and the optimization of the design and geometric parameters of cutting tools. The cited paper is an analytical review. It describes the latest tool materials, special structures of cutting tools, and analyzes the results of scientific work to determine the main causes of intensive wear of cutters when processing composite materials.

In [3, 4], experiments were conducted on milling armide reinforced plastic to study the influence of different angles of inclination of the helix (0°, 30°, 60°) on the cutting force and quality of the machined surface. The following cutting tools were used: a conventional end mill, a multi-tooth end mill, and a compression end mill. However, the processes of turning and drilling the composite were not analyzed, which narrows the study of material processing and does not give specific recommendations on cutting modes.

In work [5], a generalizing model of practical consideration of a previously known reinforcement angle for predicting tool wear was built, but the researchers do not provide data on the geometric parameters of the tool and cutting modes.

Paper [6] reports the study of drilling carbon fiber/titanium alloy packages. The controlled parameters were drilling temperature and surface roughness. The researchers narrowed the experiment to a specific example, and milling processes as a promising type of composite processing were not considered.

In [7, 8] the authors considered the issue of ultrasonic milling. The purpose of the research, the results of which are reported in [7, 8], is to propose a basic criterion for evaluating the machined surface of fiber-reinforced composites, but without recommendations on the geometric parameters of the tool and cutting modes.

In [9], various types of cutting tools for machining metal composites are considered. However, the work does not contain the results of the study of the dependence of the influence of cutting modes on the quality of the composite surface.

Paper [10] considers the milling process of metal matrix composites. It gives a detailed review of the literature on traditional and non-conventional machining of metal matrix composites with the emphasis on aspects related to the integrity of the workpiece surface. The machining of fibrous polymer composites was not considered while it has its own characteristics.

To date, the scientific and technical literature has not formulated substantiated recommendations for mechanical machining (FPC), which would avoid the destruction of the surface layer of FPC and expand the area of functional application of these materials. This gives grounds to argue about the feasibility of studying the influence of cutting modes and geometric parameters of the cutting part of the tools on the technological components of the cutting force.

3. The aim and objectives of the study

The purpose of our study is to establish regularities in the cutting process of FPCs and their influence on the initial parameters of the processing process. This will make it possible to provide specific recommendations for ensuring effective processes of their machining – to improve surface quality and increase tool stability.

To achieve the goal, the following tasks were set:

– to investigate the influence of the geometric parameters of the cutting part of the tools on the cutting force;

– to investigate the influence of cutting modes on the quality of composite processing;

– to establish the influence of the energy characteristics of the cutting process on its initial parameters.

4. The study materials and methods

The object of our study is the cutting process of fibrous polymer composite materials. The subject of the study is the formation of the surface layer of fibrous polymer composite materials during the cutting process.

The hypothesis of the study assumes that the formation of the surface layer of fibrous polymer composite materials during the cutting process is determined by the combined effect of cutting modes and cutting tool geometry, and the rational choice of these parameters enables an increase in surface quality.

The following assumptions were adopted: the cutting tool during a series of experiments has a stable state and a controlled level of wear, which does not significantly affect the measurement results; machine tool vibrations and external mechanical vibrations do not have a significant effect on the quality of the surface layer.

The following simplifications were accepted – all test specimens are made of the same material and have the same preliminary surface preparation; experimental measurement errors are considered independent, random, and normally distributed.

Our study of physical phenomena accompanying the cutting process was based on the fundamental principles of the theory of cutting materials, the theory of elasticity, and the fracture mechanics of anisotropic materials using mathematical modeling of processes. The data from theoretical studies were verified experimentally; all experimental results were subjected to statistical analysis.

An experimental study was conducted to determine the influence of processing conditions on the force characteristics of the cutting process. All experiments were carried out at the HSC 600CNC HSC machine. The machine has a fully isolated working area of 500 × 600 mm, a spindle speed range of 1000 ÷ 21000 min^{-1}, feeds of 20–1000 mm/min, positioning accuracy of 5 μm, maximum tool diameter of 20 mm, power of 2 kW. Milling cutters and drills by the Kennametal and Mitsubishi companies were used as tools.

The cutting force components were measured using strain gauge and piezoelectric dynamometers with real-time digital data recording. Wear and the radius of rounding of the cutting edge were measured using optical microscopy by the company and preventive maintenance. The depth of the defect layer was determined by two methods: by oblique section using scanning electron and optical microscopy (manufacturer "Olympus", Japan) and using acoustic emission. All measurements were carried out on certified instruments.

All dependence plots were constructed in Matplotlib (for Python) based on experimental data.

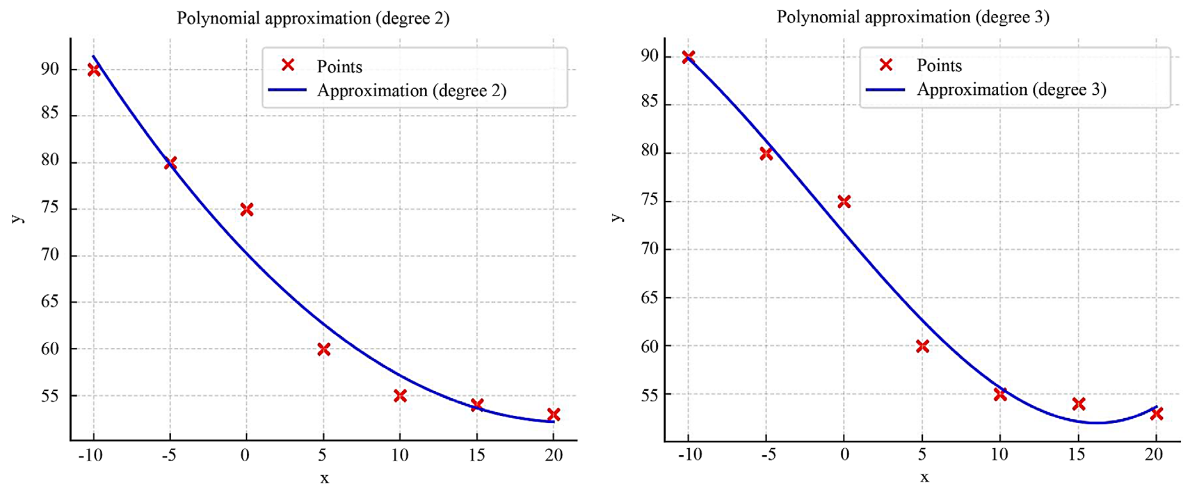
5. Results of investigating the treatment modes of fibrous polymer composites

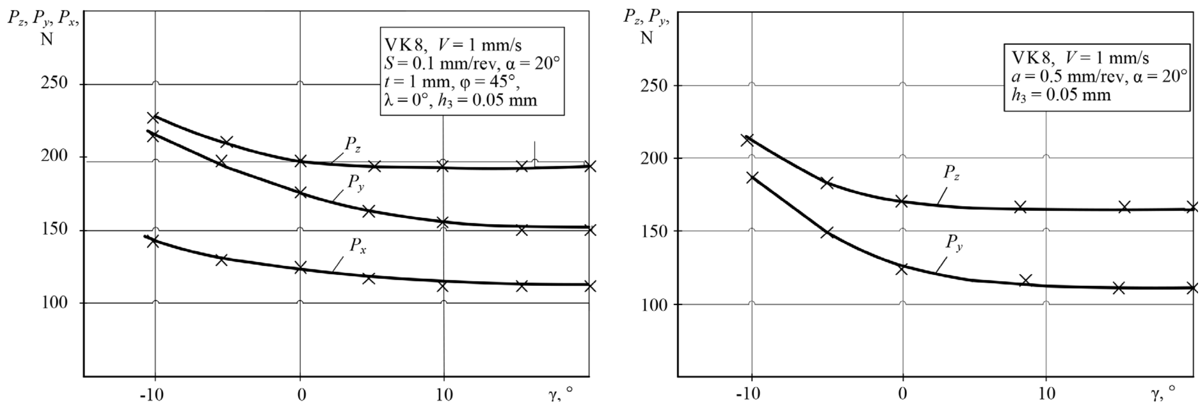
5. 1. Influence of geometric parameters of the cutting part of tools on the cutting force.

The main lead angle of the cutter.

Given that the treated material is brittle, i.e., there is no chip deformation and the thickness of the cut for real composites processing processes is comparable to the radius of the cutting edge rounding, the influence of the lead angle on the components of the cutting force for most blade processing processes is quite insignificant, contrary to the opinions by some researchers.

The main lead angle has a more noticeable effect for the turning process and orthogonal cutting – planing (the scheme of which was chosen as the estimated one when studying the stressed-strained state of the processed material): Fig. 1.





a *b*

Fig. 1. Influence of the lead angle on the components of cutting force: *a* – during planing; *b* – turning of fiberglass

An example of plotting is shown in Fig. 1, *a* for P_x in Matplotlib (for Python). The first value is the main rake angle of the cutter (x-axis), the second value is P_x (y-axis).

For a quadratic polynomial

$$y = 0.0405x^2 - 1.7119x + 70.215, R^2 = 0.971663. \quad (1)$$

For a cubic polynomial

$$y = 0.002x^3 + 0.0105x^2 - 1.9119x + 71.715, R^2 = 0.981895. \quad (2)$$

A more intensive increase in the radial component of the cutting force occurs when the lead angle decreases. When the angle decreases to 15°, the fracture occurs due to reaching the compressive strength limit at the contact of the cutting blade and the material being processed.

Given the insignificant effect of changing the lead angle on the cutting force, it is possible to recommend (including for cutters) its value, which is acceptable for technological reasons and to ensure sufficient strength of the cutting wedge.

The main rear angle of the cutter.

The influence of the lead angle on the components of the cutting force is determined by the elastic effect (restoration) of the machined material. With a change in the rear angle, the radial component changes more intensively due to a change in the normal force on the rear surface. There is an increase in the actual area of contact of the rear surface of the tool with the material being machined when the rear angle decreases.

The principal component of the cutting force increases with decreasing rear angle due to the increase in friction force on the rear surface, and with a lower intensity than the radial component in Fig. 2.

When drilling, increasing the rear angle from 10° to 30° leads to a 1.5-fold decrease in torque and a 2-fold decrease in axial force (for twist drills with normal sharpening) when drilling fiberglass.

For cutting conditions other than the constant ones adopted for the studies, the above ratios change, but the pattern of decreasing axial force and torque with increasing rear angle remains.

As strength calculations show, it is not recommended to use rear angles greater than 25° (for milling cutters) and 30° (for cutters and drills) because of a decrease in the bending strength of the cutting blade.

The main angle in the plan.

An increase in the main angle in the plan at constant cutting depth and feed leads to a decrease in the ratio of the width to the thickness of the cut, which in turn leads to a decrease in the P_z component: Fig. 3.

The non-monotonicity of the influence of angle φ on the P_z component is associated with a decrease in the ratio b/a with an increase in angle φ and an increase in the ratio of the length of the curved transition blade to the working length of the main blade.

Component P_x is the projection of horizontal resultant P_{xy} onto the X axis; therefore, with an increase in angle φ, it increases.

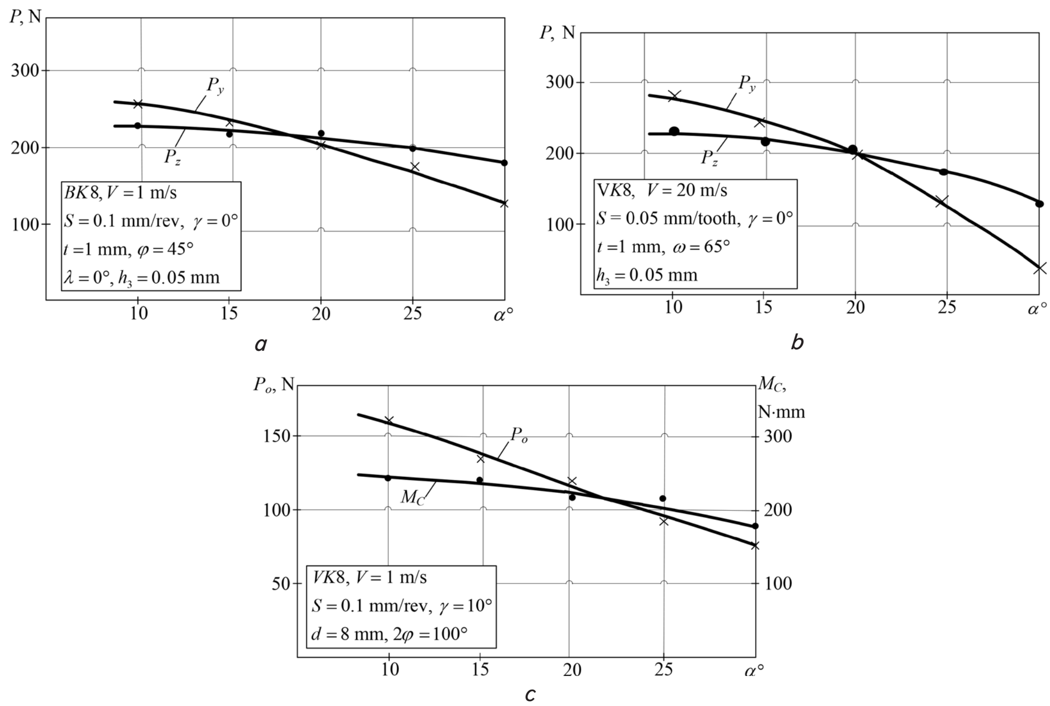


Fig. 2. Influence of the rear angle on the components of cutting force during: *a* — turning; *b* — milling; *c* — drilling of glass-plastics

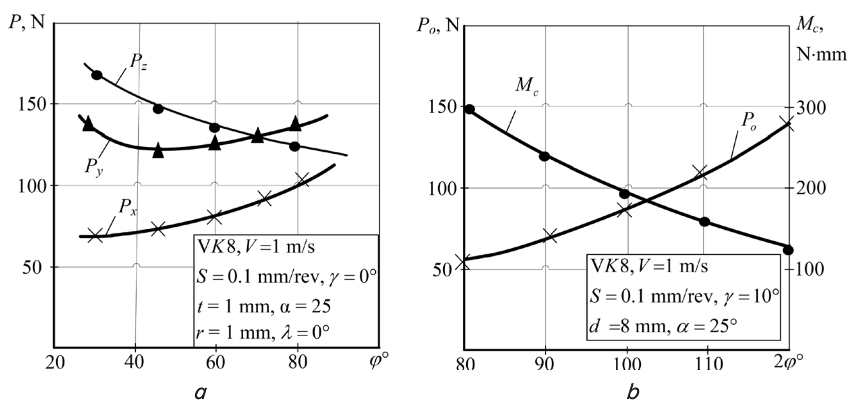


Fig. 3. Influence of the main angle in the plan on the cutting force during: *a* — turning; *b* — drilling of fiberglass

The influence of the double angle in the plan on P_o and M_c during drilling of composites is similar to the influence of 2φ during metal machining. With an increase in angle 2φ, the ratio b/a – width to thickness of the cut decreases. This reduces force P_z on the main blade and, as a result, the magnitude of the torque.

Just as in turning, an increase in 2φ during drilling leads to an increase in the angle between the main blade and the direction of feed movement, which increases the axial force. Given that composites have a layered structure, the axial force should be minimized to avoid delamination of the boundary layers and overall delamination of the material. It is recommended that the value of 2φ be within 100°. For drilling organoplastics, 2φ should not exceed 90° or use the cutting part of the tool with undercut cutting edges.

The radius of the cutting edge and the amount of wear on the rear surface of the tool.

In the processes of machining the composites, the thickness of the cut is comparable to the radius of the cutting edge (in order to ensure the required quality of processing). The radius of rounding has a significant impact on the forces acting on the cutting wedge, especially on the rear surface and its edge area. Usually, an increase in the radius of rounding of the cutting edge is the result of tool wear and has the greatest impact on the cutting forces of all the geometric parameters of the cutting part. This is explained, first of all, by the increase in the friction area of the rear surface of the cutting wedge and the increased lifting action of the cutting edge with an increased radius of rounding.

An increase in the amount of wear on the rear surface from 50 to 250 μm increases the normal force on the front surface when milling fiberglass by $1.5 \div 2$ times. On the rear surface, due to the strong elastic aftereffect of the polymer composite, by $3 \div 4$ times (and for composites with a high modulus of elasticity – by $5 \div 7$ times). When machining composites with a worn tool, the radial component of the cutting force exceeds the main one. This leads to a violation of the adhesive bonds between the matrix and the fibers in the surface layer and to an increase in temperature and thermal destruction of the polymer binder.

5. 2. Influence of cutting modes

Cutting speed.

The influence of cutting speed on the components of the cutting force for different types of machining has a number of features.

Increasing the cutting speed during milling leads to a noticeable decrease in the components of the cutting force when machining polymer composites: Fig. 4, 5. The relative stabilization of cutting forces in the absence of noticeable vibrations occurs in the range of 900 ÷ 1300 m/min depending on the material being machined.

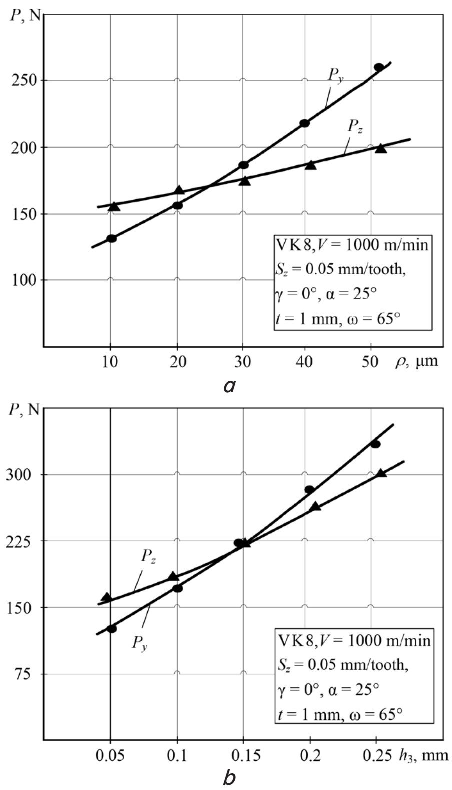


Fig. 4. Influence on the components of cutting force when milling fiberglass: *a* — radius of rounding of the cutting edge; *b* — amount of wear on the rear surface

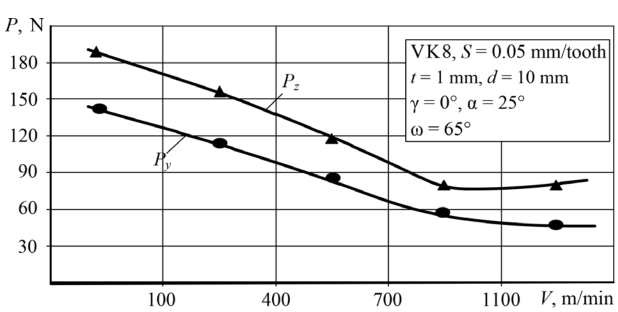


Fig. 5. Effect of cutting speed on the components of cutting force when milling glass-plastics

The decrease in the components of cutting forces with increasing cutting speed in different speed ranges has a different nature. When machining glass-organic plastics at speeds from 100 to 500 m/min, with increasing cutting speed, the temperature in the cutting zone increases (Fig. 6), which increases the degree of polymer destructuring, the products of which, being a surface-active substance, reduce the friction force, generally reducing the cutting force.

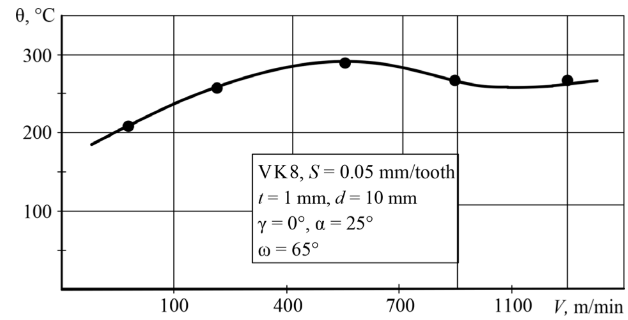


Fig. 6. Effect of cutting speed on cutting temperature when milling fiberglass

In the range from 500 to 900 m/min, increasing the cutting speed (composite deformation speed) contributes to an increase in the yield point of the polymer components and a decrease in the work of plastic deformation and, consequently, the cutting temperature. Due to the increase in fracture brittleness, the actual contact area on the rear surface decreases, which contributes to a decrease in the work of the friction force on the rear surface. Increasing the specific energy of the impact of the contact surfaces of the cutting tool on individual fibers and microvolumes of the matrix and reducing the yield point provides a decrease in the magnitude of stresses, deformations, and cutting forces.

Turning and especially drilling are more thermally stressed treatment processes due to continuous contact of the tool with the material being machined and with compressed cutting edges (for drilling). Therefore, an intensive increase in temperature with an increase in the cutting speed does not allow for the use of high-speed machining.

The decrease in the components of cutting forces from an increase in cutting speed in the entire range of applied speeds is associated with a decrease in the friction force due to a decrease in the friction coefficient caused by an increase in the temperature of the cutting zone. When drilling with an increase in cutting speed, the torque decreases several times, and the axial force in Fig. 7, 8.

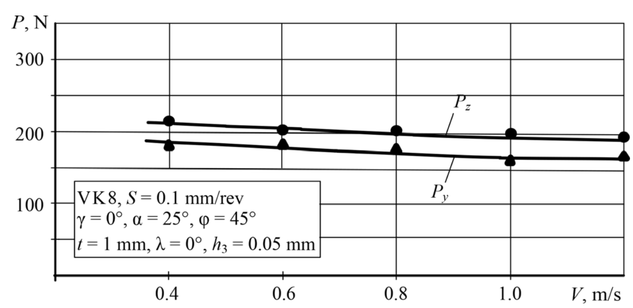


Fig. 7. Influence of cutting speed on the components of cutting force when turning glass-plastics

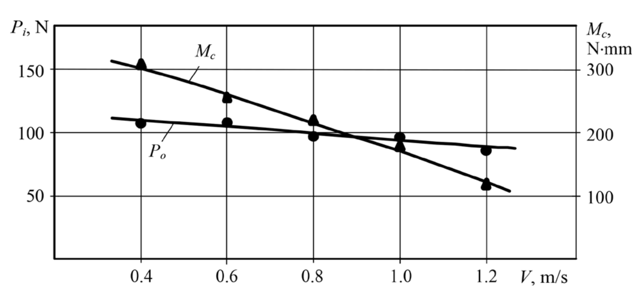


Fig. 8. Effect of cutting speed on axial force and torque when drilling fiberglass

The more active influence of cutting speed on torque than on axial force is explained by a more intensive change in cutting conditions and friction on the periphery of the drill, which determine the torque.

As an alternative to turning in order to increase productivity, reduce cutting forces, and temperature, the milling-turning process can be proposed.

Sectional parameters of the cut.

The thickness of the cut significantly changes the normal and tangential components of the force on the front surface of the cutting wedge. In unworn tools, their absolute values are approximately the same. The intensity of the change in the normal force in unworn tools is significantly greater than in worn tools. This is explained, first, by the change in the actual lead angle on the edge section of the front surface of the worn cutting wedge and the increase in its radius of rounding of the cutting edge. Second, by increasing the degree of polymer destructuring and, consequently, changing its adhesive and chemical bond with the contact surfaces of the tool, friction is made more difficult. The chip formation force changes when the thickness of the cut is varied to a greater extent due to a change in the normal force. Thus, a threefold increase in the thickness of the cut causes a one and a half to twofold increase in its projection onto the cutting plane and a threefold increase onto the main plane. This is more evident in a worn tool. In proportion to the change in the magnitude and direction of the chip formation force, the normal and shear forces in the conditional shear plane change. The thickness of the cut practically does not change the normal force and the friction force on the rear surface of the cutting wedge. The plots of influence of the thickness of the cut on the cutting force are shown in Fig. 9.

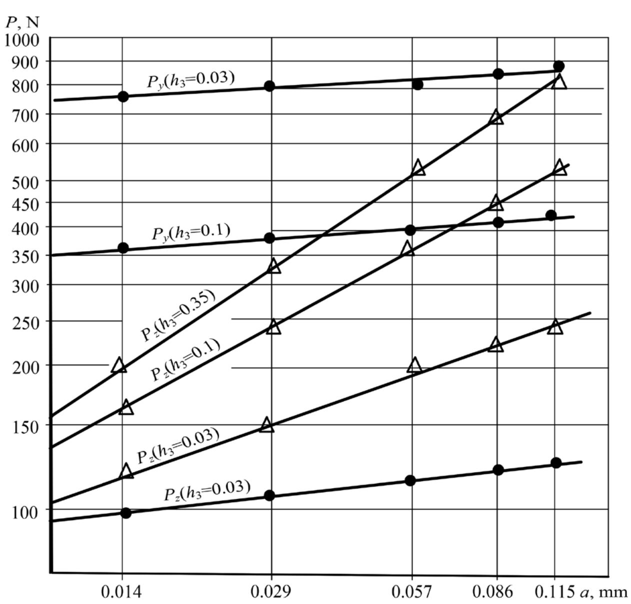


Fig. 9. Effect of slice thickness on cutting force

Feed and depth of cut.

With increasing cutting depth and feed, the cross-sectional area of the cut layer increases, which causes an increase in all components of the cutting force similarly to when machining metals. The depth of cut affects the components of the cutting force almost directly proportionally since the specific work of deformation and the specific work of friction do not change: Fig. 11. Feed as a factor of the cut thickness when cutting polymer composites has a much weaker effect than the depth of cut: Fig. 10.

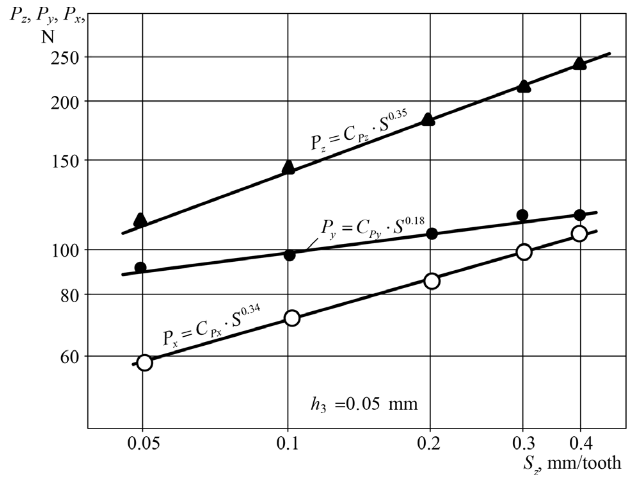


Fig. 10. Influence of feed on the components of cutting force when milling glass-plastics

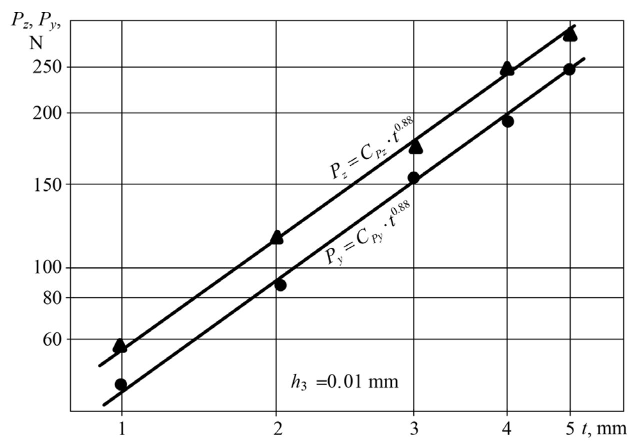


Fig. 11. Influence of cutting depth on cutting force components when milling glass-plastics

Thus, our experimental study allowed us to establish that the greatest influence on the cutting force during the machining of FPCs is exerted by the amount of tool wear on the rear surface, the radius of the cutting edge rounding, and the value of the rear angle. The cutting speed has a noticeable effect on the cutting force in the ranges of more than 10 ÷ 15 m/s, while the degree of influence of other parameters is reduced due to changes in the dynamic physical and mechanical properties of the machined material.

5. 3. Establishing the influence of energy characteristics of the cutting process on its initial parameters

When determining the influence of the energy characteristics of the cutting process on the initial quality parameters, the values of the second work spent on cutting and the specific cutting energy under different processing conditions were considered.

The degree of destruction of the polymer components of the composite was determined by the number of stable macroradicals using electron paramagnetic resonance; the depth of the defective layer was determined by a known methodology. The number of uncut fibers on the processed surface was determined using the phase ratio; the roughness of the processed surface was estimated by a standard methodology.

The basic type of machining for which the study was conducted was milling. Control experiments were performed for turning and drilling to establish general patterns. The ranges of values of parameters that make up the treatment conditions are given in Table 1.

The ranges of changes in the values of the initial parameters of the machining quality of fibrous polymer composites are given in Table 2.

Table 1

Ranges of parameter values during milling

No.	Parameter name and designation	Dimensionality	Measurement limit
1	Cutting speed – V	m/s	1 ÷ 30
2	Feed – S_2	mm/tooth	0.01 ÷ 0.5
3	Cutting depth – t	mm	1 ÷ 10
4	Milling width – B	mm	2 ÷ 30
5	Cutter diameter – D	mm	6 ÷ 250
6	Number of cutter teeth – Z	pcs.	2 ÷ 36
7	Lead angle – γ	degree	–10 + 20
8	Rear angle – α	degree	10 ÷ 30
9	Helical tooth pitch angle – ω	degree	10 ÷ 70
10	Cutting edge radius – ρ	micron	5 ÷ 80
11	Amount of wear on the rear surface – h_3	mm	0.05 ÷ 1.0
12	Roughness at the edge areas of the rear and front surfaces – R_a	micron	0.08 ÷ 10
13	Tool material – IM	–	VK8
14	Machined material – OM	–	fiberglass, glass organoplastic, carbon organoplastic, organoplastic

Table 2

Ranges of change in the values of initial parameters for machining quality when changing the energy parameters of the cutting process

No.	Quality parameter under investigation	Measurement range and dimensions	Estimation error
1	Roughness – R_z	(2 ÷ 100) µm	± 10%
2	Hairiness – K_B	(0 ÷ 100)%	± 5%
3	Degree of polymer degradation – N	(10^{12} ÷ 10^{12}) spin/g	± 10%
4	Depth of the defective layer – H	(40 ÷ 400) µm	± 10%

The dependence of the initial parameters of machining quality of fibrous polymer composites on energy characteristics of the cutting process is shown in the plots below in Fig. 12, 13.

It is obvious that the influence of the energy characteristics of the cutting process on the initial parameters of machining quality occurs indirectly, through the parameters of the cutting process. However, analysis of the above dependences allows us to conclude that there is a pattern that characterizes the decrease in energy consumption for the treatment process and an increase in the specific cutting energy. At the same time, all the studied parameters of the machining quality of fibrous polymer composite materials tend to improve. This can be explained by the peculiarities of the properties of polymer composites and their changes under different treatment conditions.

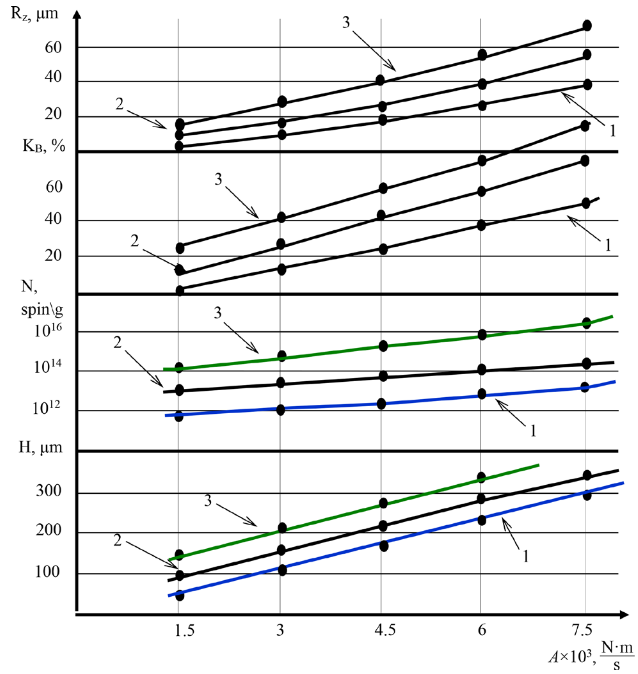


Fig. 12. Dependence of initial parameters of the quality of machining fibrous composites on energy consumption of the cutting process during milling: 1 – fiberglass; 2 – glass-organic plastics; 3 – organic plastics

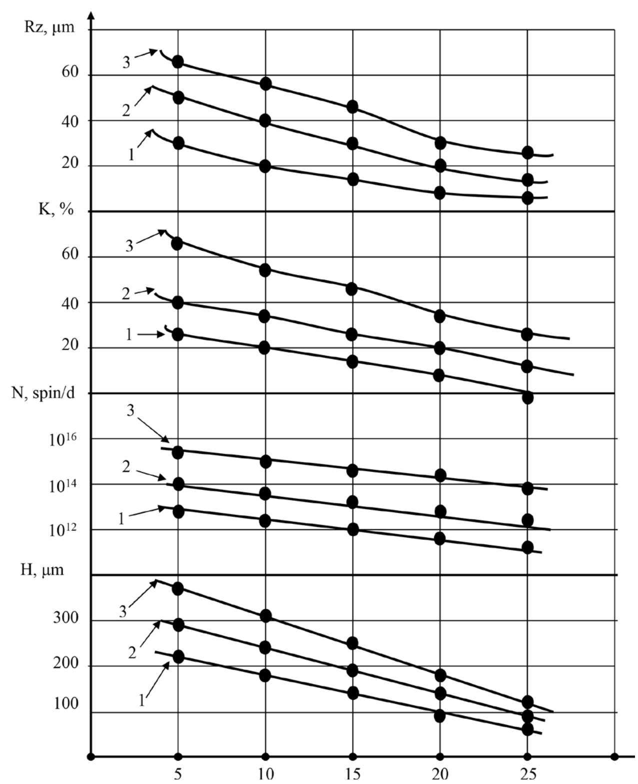


Fig. 13. Dependence of initial parameters of the quality of machining fibrous composites on the specific cutting energy during milling: 1 – fiberglass; 2 – glass-organic plastics; 3 – organic plastics

An increase in the specific energy of the impact of the contact surfaces of the tool on individual fibers and microvolumes of the matrix minimizes the influence of the mechanical factor, which is accompanied by a decrease in the depth of the defect layer, hairiness, roughness, and the processed surface. An increase in the specific energy also contributes to an increase in fracture fragility, a decrease in the work of plastic deformation and cutting temperature, which reduces the influence of thermal and chemical factors, and the process of destruction along the interface and a decrease in the degree of destruction of the polymer components of the composite.

The reduction in the deformation at which fracture occurs is accompanied by a decrease in the actual contact area on the rear surface.

The reduction in the destructive stress enables a decrease in the cutting forces on the rear surface and the localization of crack propagation on the interface surface. This process is accompanied by a decrease in cutting costs.

6. Results of investigating machining modes of fibrous polymer composites: discussion

Analysis of our research results allows us to identify the features and patterns of the impact of the cutting tool on the fibrous polymer composite. The influence of the lead angle on the cutting force components for most blade processing processes is quite insignificant (Fig. 1). This can be explained by the fact that the machined material is brittle. The pattern of decreasing axial force and torque with increasing rear angle is preserved (Fig. 2), which can be explained by the elastic effect (restoration) of the machined material. An increase in the main angle in the plan at constant cutting depth and feed leads to a decrease in the P_z component (Fig. 3). This can be explained by a decrease in the ratio of the width to the thickness of the cut. The cutting force components in the processing of polymer composites decrease with increasing cutting speed during milling (Fig. 4). This may be due to a decrease in the friction force due to a decrease in the friction coefficient caused by an increase in temperature in the cutting zone. The more active influence of the cutting speed on the torque than on the axial force is explained by a more intensive change in the cutting conditions (Fig. 7, 8). The feed during cutting of polymer composites has a much stronger effect than the cutting depth: Fig. 10, 11. With increasing cutting depth and feed, the cross-sectional area of the layer being cut increases, which causes an increase in all components of the cutting force. As for the influence of the energy characteristics of the cutting process on the initial quality parameters, it occurs indirectly, through the parameters of the cutting process: Fig. 12, 13.

Unlike work [1] in which the authors consider the influence of cutting modes only on the surface quality, our results from investigating the machining modes of fibrous polymer composites allow us to establish the regularities of the cutting process. This becomes possible due to the determination of the influence of the geometric parameters of the cutting part of the tools, cutting modes, and energy characteristics of the cutting process on its initial parameters.

Our study was conducted in a limited range of cutting speeds, feeds, and cutting depths. Expanding the range of parameters may lead to other patterns of surface layer formation. It should be noted that the recommendations given will be valid only when machining glass-plastics.

The disadvantages of this study are due to the fact that the experiments were carried out on samples of simple shape (plates, bars). For complex spatial parts or different thicknesses, additional effects of deformation and fracture are possible. The effect of tool wear was taken into account only at fixed stages of the experiment (new or worn tool) and the dynamics of wear under an actual operation process were not considered.

Further studies may involve determining cutting modes for machining metal matrix composites.

7. Conclusions

1. We have established that the increase in the radius of the cutting edge rounding as a result of tool wear has the greatest impact on the cutting forces of all geometric parameters of the cutting part. The increase in the amount of wear of the rear surface from 50 to 250 μm increases the normal force on the front surface when milling fiberglass by 1.5–2 times. This is explained by the increase in the friction area of the rear surface of the cutting wedge and the increased lifting action of the cutting edge.

2. It was established that the greatest impact on the cutting force when machining fibrous polymer composites is exerted by the amount of tool wear on the rear surface and the increase in the radius of the cutting edge rounding, cutting parameters, and the value of the rear angle. The cutting speed noticeably affects the cutting force in ranges of more than 10–15 m/s, while the degree of influence of other tool parameters and cutting modes is reduced due to changes in the physical, mechanical, and thermal physical properties of PC.

3. It has been established that reducing the energy consumption for cutting in combination with increasing the specific energy of the impact of the cutting wedge on the separated layer helps minimize the impact of mechanical, thermal, and chemical factors on the destruction of the composite. Reducing the energy consumption during cutting to the level of 1.5 kN · m/s and ensuring the specific energy of the action of the contact surfaces on the separated layer of at least 2–2.5 kJ/mm make it possible to maintain the depth of the defective layer no more than 50 μm.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The manuscript has associated data in the data warehouse.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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