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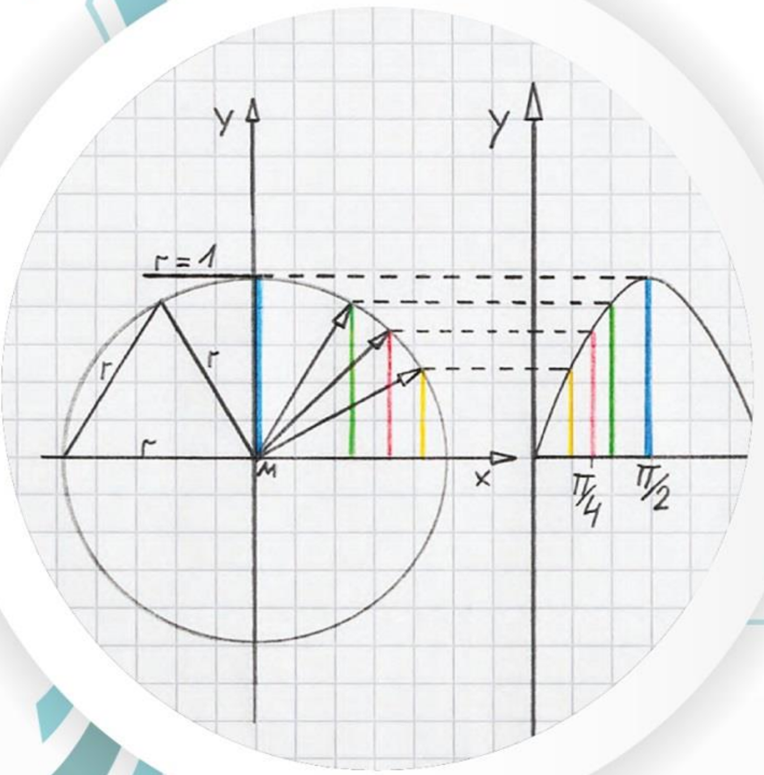

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KINEMATICS OF A SELF-ROTATTING CUTTER AS A FACTOR OF INCREASING TOOL LIFE AND PROCESS PRODUCTIVITY

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Abstract. Information is presented on the kinematics of a self-rotating cutter as a factor in increasing tool life and process productivity. According to it, it is possible to increase the productivity of the cutting process with existing tool materials if a cutting process scheme is created that allows reducing the temperature, speed and pressure in the cutting zone without reducing the cutting modes. This type of cutting is most effectively performed in cutters with a circular cutting edge when this edge rotates around its geometric axis. The results of theoretical studies are presented on the fact that in circular self-rotating cutters, the rotation of the cutting part is carried out by the moment of cutting forces relative to the geometric axis of the circular cutting edge.

Key words. material, wear-resistant, energy, aircraft industry, high-strength materials, size, detail, rotary, plate, diameter, thickness, landing diameter, feed

INTRODUCTION

New scientific and technical solutions in the field of cutting contribute to the increase of labor productivity in mechanical engineering and metalworking. Labor productivity in the processing of materials is determined, first of all, by the wear resistance of the cutting tool, which can be increased by using new wear-resistant tool materials, establishing rational geometry, the cutting part of the tools and optimal cutting modes, but without changing the cutting process itself, in essence.

The modern development of mechanical engineering, nuclear energy, aircraft construction and other industries required the creation of high-strength materials, which also included compositions of elements that previously constituted the privilege of the cutting tool. At the same time, the requirements for the accuracy and quality of the surface layer of the processed parts have increased significantly, and the dimensional accuracy of the parts themselves has increased.

LITERATURE REVIEW

Depending on the sign of the cutting edge inclination angle relative to the feed direction, cutting can be forward or reverse. During forward cutting, the active part of the cutting edge is inclined in the cutter feed direction by an angle ; the cutter rotates and the chips flow towards the workpiece. During reverse cutting, the active part of the cutting edge is inclined against the feed direction ; the cutter rotates and the chips flow towards the workpiece.

Depending on the geometric parameters and the inclination angle of the cutting edge, self-rotating cutters can operate in the following modes:

a) in the mode of forming microroughnesses of the workpiece surface by the cutting edge with complete separation of the chips from the workpiece;

b) in the mode of "rolling" the back surface of the cutter around the workpiece with some sliding, like a knurling roller;

c) in the mode of "peeling" the material with incomplete formation of chips.

Next, we will consider self-rotating cutters for direct and reverse cutting, installed: according to the first scheme when forming the machined surface only by the cutting edge, with rolling and with complete separation of the chips from the part. The obtained dependencies, calculation formulas and the method of their derivation are also applicable to the analysis of the cutting process by tools with forced moving cutters [1].

In the conditions of PO NMZ NGMK, the processing of such alloys is carried out using the following cutting modes: processing speed V = 2-3 m/min, reverse feed S_0 = 0.02 *mm/rev*, cutting depth t < 2 *mm*. In this case, single-carbide alloys of the VK group are used as tool material. Processing using this technology is characterized by a very high tool consumption at minimum productivity. Since the specified values of speed and feed are the minimum possible for turning machines of the NT250I type, which are used in the conditions of the above-mentioned plants. We tested the processing of these materials using rotary turning methods. The use of rotary turning, where the VK-8 alloy (produced by UzKTZhM) was used as a cutting plate with the following dimensions: outer diameter D = 50 *mm*; thickness B = 4 *mm*; landing diameter d = 27H7, showed the possibility of increasing productivity. By increasing the cutting speed to values of $V \approx 15 \div 20$ m/min and feed to $S_0 \approx 0.1$ *mm/rev*, it is possible to achieve a cutter life of $T \approx 15 \div 20$ *min*. Note that when processing in a traditional way, this value does not exceed the specified value [2].

DISCUSSION

The productivity of the cutting process with existing tool materials can be increased if such a cutting process scheme is created, in which the temperature, speed and pressure in the cutting zone can be reduced without reducing the cutting modes. Such cutting is most effectively implemented on cutters with a circular cutting edge, when this edge rotates around its geometric axis.

A self-rotating cutter, unlike a conventional one, is a mechanism with one degree of freedom and therefore existing concepts of the cutting process are not applicable to it without appropriate correction. In this dissertation, such a correction is carried out, which consists in clarifying the concepts of numerical evaluation of the trajectory, speed, angles and length of the cutting path, the ratio of the projection of cutting forces on the coordinate axes of the machine, the degree of deformation of the chip material.

The use of self-rotating cutters allows to increase the tool life, force cutting modes and control the quality of the processed surface. It has now been proven that the use of this tool, especially when cutting difficult-to-cut materials, will give a significant increase in labor productivity.

RESULTS

Factors determining high wear resistance of the cutting edge.

In round self-rotating cutters, the rotation of the cutting part is carried out by the moment of the cutting forces relative to the geometric axis of the circular cutting edge. The speed of this rotation depends on the angle of inclination of the cutting edge relative to the speed of the main working movement $\vec{v}$.

The following features of the cutting process explain the higher durability of self-rotating cutters, compared to conventional cutters.

1. With each revolution of the cutting edge, its points pass the segment AB, enclosed between the angle of active contact $\varphi_s + \varphi_t$ (Fig. 1). Within this angle, the cutting edge wears out. On the remaining part of the rotation angle, the sections of the working surfaces are in contact with

the cooling medium and, naturally, do not wear out. The amount of wear accumulated by the cutting edge over time T [3,4,5].

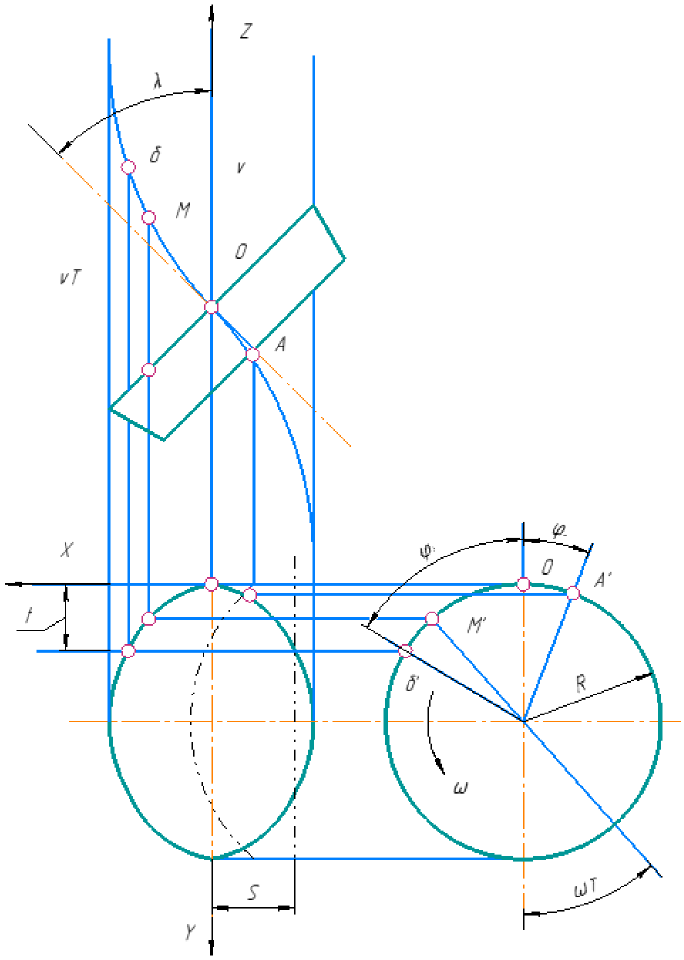

Fig. 1. Trajectory of the edge point of a self-rotating cutter in the workpiece

$$h = L_i n_p a T,$$

where, n_p – is the cutting edge rotation frequency;

L_i – is the cutting path length of a cutting edge point during one revolution (section AB, Fig. 1);

a – is the average wear intensity on section AB. Life time before wear [6,7]

$$T = \frac{h}{L_i n_p a} = \frac{h_i}{a_s v}, \qquad (1)$$

where, $i = \frac{v}{L_i n_p}$ – is the coefficient of reduction of the cutting path length for the cutting edge points of a self-rotating cutter. For tools with fixed cutting edges i = 1.

2. For a self-rotating cutter, which is a mechanism with one degree of freedom, the circumferential speed of the cutting edge v_0 is set in accordance with the principle of "least action", i.e., according to the minimum energy consumption for cutting. This means a decrease in the speeds of sliding friction, specific pressures and heat generation on the cutting surfaces of the self-rotating cutter, and, consequently, a decrease in the wear intensity a [8,9.10].

3. Continuous alternation of heating of the cutter material upon contact with the part and cooling upon contact with the cooling medium promotes better heat exchange of the cutter and formation of protective films on its working surfaces. These films prevent juvenile contact between

the materials of the cutter and the workpiece, which reduces the intensity of adhesion and diffusion processes that determine the wear intensity *a*.

These features should be taken into account when determining the coefficient of reduction of the path length by the cutting edge point and the wear intensity *a*.

Geometrical parameters of self-rotatting cutters.

The first setup scheme has the initial position of the axis parallel to the velocity vector $\vec{v}$. The end surface of the round cutter is the front surface, and the side surface (conical or cylindrical) is the rear surface. The main geometric parameter of the cutter setup, which determines the angle of inclination of the active part of the cutting edge, is the angle λ.

In the second scheme, the edge axis in the initial position is set along the normal to the machined surface, i.e. perpendicular to the vector $\vec{v}$. The end surface of the rotating cup of the cutter is the rear surface, and the side surface is the front surface. The inclination of the cutter axis in the vertical plane *yz* by angle β_b and the rotation in the horizontal plane *xy* by angle β_g ensure a change in the angle of inclination of the active part of the cutting edge [11,12].

The angle of inclination of the cutting edge axis λ when installing the cutter according to the first scheme is also the angle of inclination of the cutting edge itself relative to the vector $\vec{v}$ at point *O* (Fig. 2).

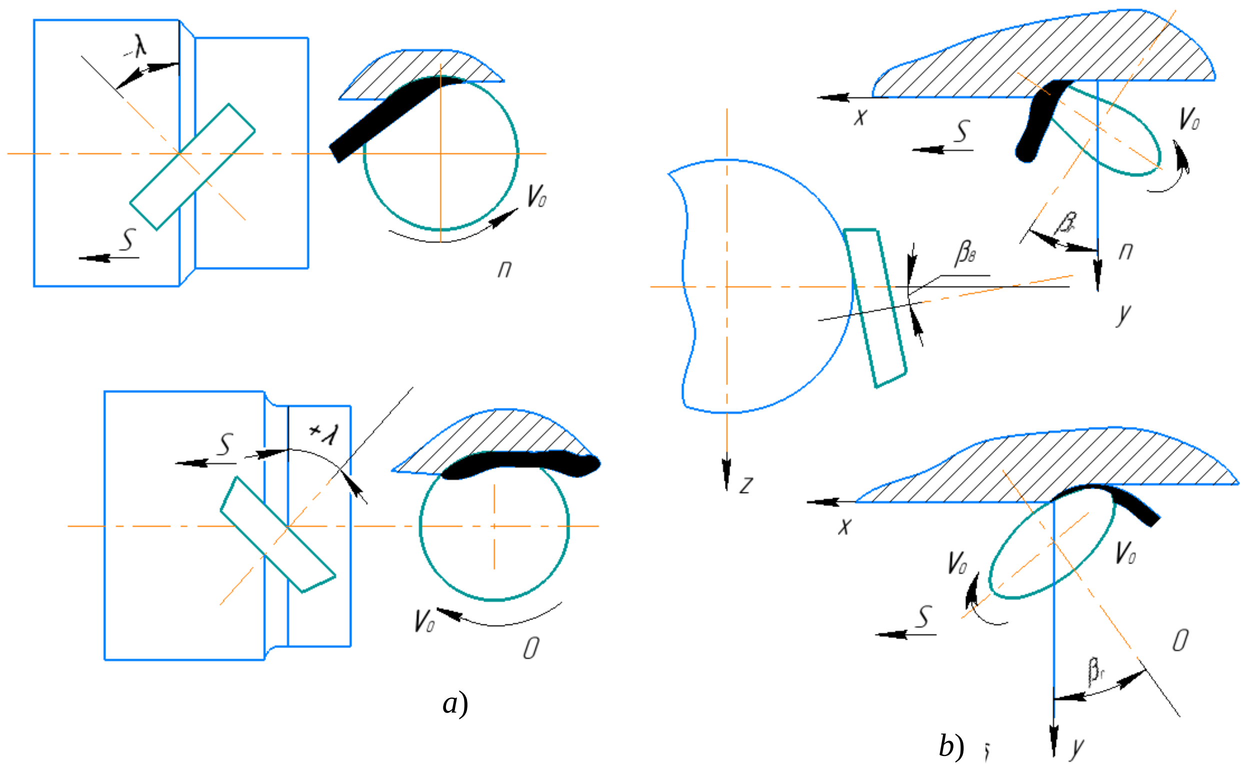

Fig. 2. Schemes of installation of turning cutters for direct *P* and reverse *O* cutting:
a – first; *b* – second cutting scheme.

When installed according to the second scheme, the angle of inclination of the cutting edge at point *O* is determined by the dependence

$$tg\lambda = \frac{tg\beta_g}{sin\beta_b} \quad (2)$$

Using formula (2), it is possible to compare the cutters installed according to the first and second schemes according to their kinematic parameters, with a common parameter – the angle of inclination of the cutting edge λ [13,14].

CONCLUSION

An attempt to use high-speed steel P9K5 as a tool material did not give a positive result. This attempt was explained by the fact that during processing in the conditions of the AMMP, the beating of the workpiece after casting and the use of equipment that has lost rigidity due to long-term operation; leads to significant vibrations. The reliability of hard alloys in such conditions, according to, is very low. The wear resistance and red hardness of high-speed steel, under rotary turning conditions, turned out to be low and it was not possible to achieve a resistance of more than 5 minutes. To increase the resistance of the hard alloy, under conditions of vibrations, it was necessary to introduce very strict requirements for the design of the tool spindle. In order to increase accuracy and introduce damping elements. Various schemes for basing a round cutting plate on a mandrel-axis of the tool spindle, as well as methods of fastening, were analyzed. This analysis showed that the most rational arrangement is the use of roller and needle bearings installed after the radial bearing with the support of the end of the spindle axis on a radial thrust roller bearing. The clearances are selected in the latter by means of an adjusting sleeve.

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