

# Method of Rotational Turning With Multifaceted Cutters

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**Abstract.** The proposed method combines the elements of skew turning (in which a cut layer moves along the cutting edge) and rotary turning (in which the sections of the cutting edge are constantly renewed). This leads to better cooling and, hence, a longer tool life. The required cutting speed is ensured by selection of the required number of revolutions of the cutter; the rotation of the machined shaft corresponds to the rotary feed.

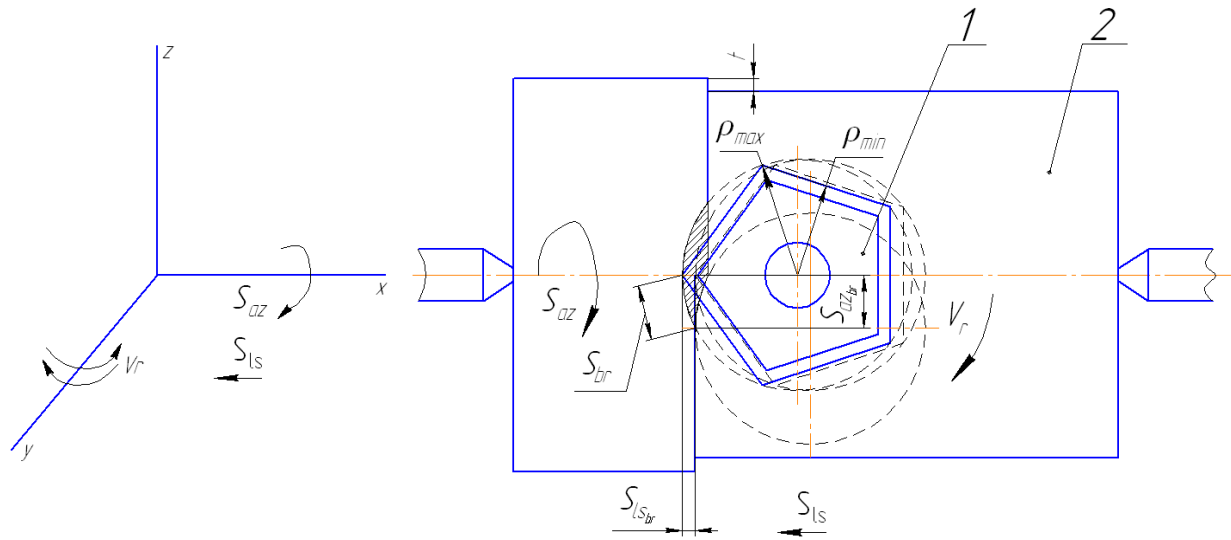
## 1. Introduction

There are known traditional methods of turning: with vertex and peak less cutters, with rotary cutters with autorotation or forced turning. Each of these methods has its reasonable use. At the same time, during the turning of products from viscous and plastic materials, alloy and heat-resistant steels, the abovementioned methods reveal some drawbacks. Among them area relatively low resistance of the vertex and oblique cutters, the use of expensive coolants, formation of flow chip, limited stroke speed due to turning machines possibilities, and in some cases due to form of work pieces (long, non-rigid and unbalanced shafts) [1-4].

A more effective method of metalworking of such shafts is the method of face milling, in which the optimum stroke speed is provided by an independent actuating device of the tool. Besides, intermittent cutting provides a guaranteed chip control. In turn, intermittent cutting leads to the formation of kinematic waviness and the appearance of shocks and vibrations of the technological system, which significantly reduces the surface quality and eliminates the possibility of using such milling as finish. Moreover, during face milling there are heavy radial forces that lead to shaft deflection [5].

In terms of the mentioned shortcomings, the method of rotational turning with multifaceted cutters, developed at Krasnoyarsk Polytechnic Institute, is one of the most promising methods [6, 7], in which one of two rotational movements is reported to the instrument, and another to the work piece. In this case the rotation axis of the instrument is installed perpendicularly to the axis of a work piece rotation and is placed in the line with the axis of centers. The cutting edge of the cutter is multifaceted and consists of N cutting blades. The cutter makes a forced rotation around its axis, what leads to constant renewal of the cutting edge in the cutting zone.





**Figure 1.** Kinematic scheme of machining with multifaceted rotational cutter.

In terms of novelty, the studied method of turning can be characterized as new, since it is based on new principles of formation of a cut-off material layer and setting of cutting modes.

The presented method enables a simultaneous production of the processed surface and chips in the form of commercial powder particles. This capability makes the method near-waste less.

In the proposed method the rotational cutter is a multifaceted bowl-shaped object with a tool bore and a cutting section consisting of  $N$  cutting blades. Each blade has a rear surface and a front surface, which together form a linear cutting edge [7]. The cutting edges formed at each blade in the plane, which is perpendicular to the cutter's axis of rotation, together constitute the cutting polygon [8].

Processing with a rotational cutter is made so that the main direction of the chip deformation occurs along the blade edge, thus the total feed to the cutter profile's face is determined by this formula [8, 9]:

$$S_{br} = \sqrt{S_{ls_{br}}^2 + S_{az_{br}}^2}; \quad (1)$$

where:  $S_{ls_{br}}$  is line feed to the face of the cutter, mm/rev;  $S_{az_{br}}$  is circular feed to the face of the cutter, mm.

Line feed to the face of the cutter is determined by the following formula:

$$S_{ls_{br}} = \frac{S_{ls_{mt}} \cdot n_b}{n_r \cdot N}; \quad (2)$$

where:  $S_{ls_{mt}}$  is line feed of the cutter to the turn of the processed shaft, [mm/rev];  $n_r$  is a turning number of a work piece, [rev/min];  $n_b$  is a turning number of the tool, [rev/min];  $N$  is a number of cutter profile faces.

The circular feed to the face of the cutter is calculated by the next formula:

$$S_{az_{br}} = \frac{\pi \cdot d_b \cdot n_b}{n_r \cdot N}; \quad (3)$$

where:  $d_b$  is the diameter of the blank, mm.

One of the most important characters of the presented method is that the constructive feed appears in the section of the profile with the increasing radius vector.

The constructive feed is determined by this formula:

$$S_c = (\rho_{max} - \rho_{min}) = (\rho_{me} + e) - (\rho_{me} - e) = 2e, \quad (4)$$

where:  $\rho_{\max}$  is the maximum radius vector of the cutting edge contour, [mm];  $\rho_{\min}$  is the minimum radius vector of the cutting edge contour, [mm];  $\rho_{me}$  is the mid-radius vector of the cutting edge contour, [mm];  $e$  is the eccentricity of the tool profile, [mm].

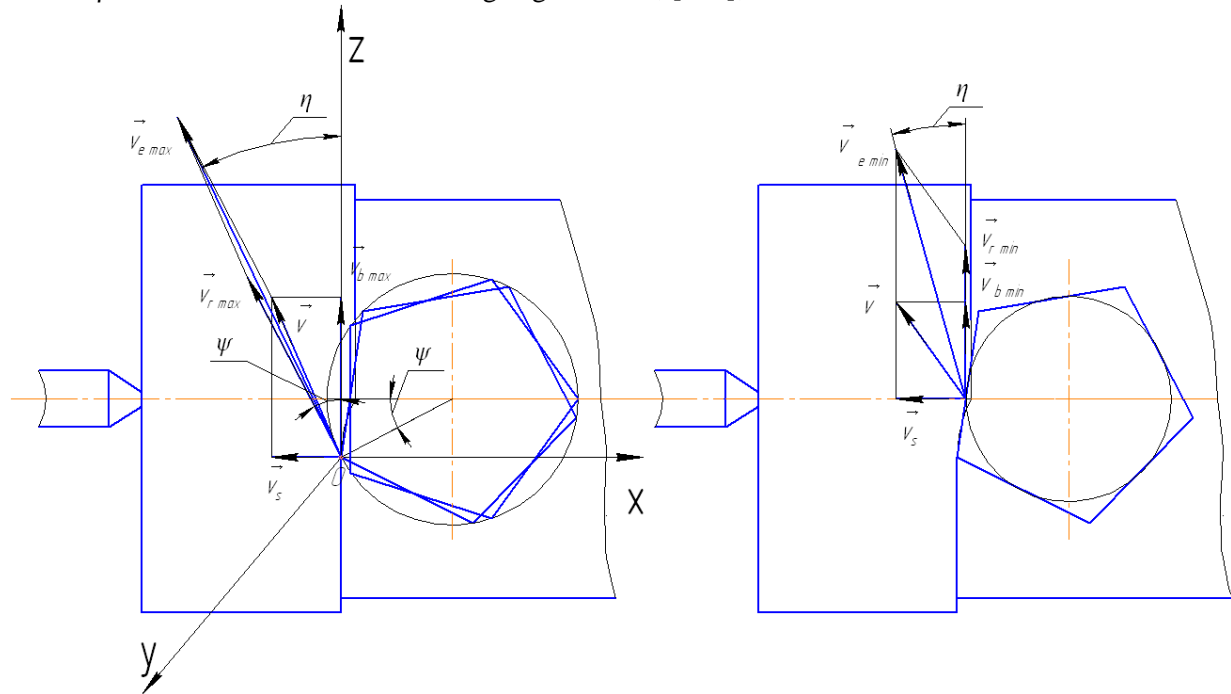
The formation of the treated surface involves three movements: principal movement  $V_r$ , linear movement or line feed  $S_{ls}$  and circular feed  $S_{az}$ .

The principal movement is tool rotation. Its turning speed must be at least by far greater than the turning speed of the work piece.

The cutting speed is found by the formula:

$$V_r = \frac{2\pi \cdot \rho \cdot n_r}{1000}; \quad (5)$$

where:  $\rho$  is the radius vector of the cutting edge contour, [mm];



**Figure 2.** The scheme of a speed vector determination for resultant cutting motion

The speed of the resultant cutting motion is found from the formula:

$$\vec{v}_e = \vec{v}_b + \vec{v}_s + \vec{v}_r; \quad (6)$$

$$\begin{aligned} \vec{v}_e &= (0; \frac{S_{az}}{1000}; 0) + (\frac{-S_{ls} \cdot n_b}{1000}; 0; 0) + (-V_r \cdot \sin \psi; V_r \cdot \cos \psi; 0) = \\ &= (\frac{-S_{ls} \cdot n_b}{1000} - V_r \cdot \sin \psi; V_r \cdot \cos \psi + \frac{S_{az}}{1000}; 0); \end{aligned} \quad (7)$$

$$|\vec{v}_e| = \sqrt{(\frac{-S_{ls} \cdot n_b}{1000} - V_r \cdot \sin \psi)^2 + (V_r \cdot \cos \psi + \frac{S_{az}}{1000})^2}; \quad (8)$$

where:  $\vec{v}_b$  is a speed vector of the work piece circular feed, [m/min];  $\vec{v}_s$  is a speed vector of the tool line feed, [m/min];  $\vec{v}_r$  is a speed vector of the principal movement (movement of shaping), [m/min];  $\psi$  is a slope angle between the speed vector of principal movement  $\vec{v}_r$  and coordinate axis  $y$ .

Slope angle  $\psi$  is calculated by the following formula:

$$\sin \psi = \frac{S_{az}}{\rho_{\max}}; \quad (9)$$

The upward angle of the result ant motion's screw trajectory in M point is determined by the formula:

$$\cos \eta = \frac{V_r \cdot \cos \psi + (S_{az} / 1000)}{|\vec{v}_e|}; \quad (10)$$

The experimental research was carried out on the turning lathe of 16K20 model with the use of the tool drive consisting of an electric spindle, a supporting arm, a mandrel and specially refined (typical multifaceted hard-metal) plates, modified by ceramics nanoparticles. The final physical and mechanical properties of hard-metal composites, modified by nanoparticles, depend directly on their microstructural parameters, the proportion of volume ratios and the size of carbide and ultrafine particles. Nanoparticles, introduced into a binder, decrease the thickness of the metal interlayer and therefore ensure the strength increase of the binder and composite as a whole. The stable reduction of the carbide grain's average size was found out as well (due to a nanoparticles blocking influence on the recrystallization process). The test results show that modification by nanoparticles enables the improvement of the main properties: service durability – by 1.3...4 fold; wear resistance – by 1.6...2 fold; fracture toughness – by 1.8...2 fold; flexing strength – by 25...50 % fold [10].

Tests were carried on the basis of the aluminum samples with grades A6 and A0. The preliminary range of cutting modes was detected. The cutting depth varied in the range from 0.1 mm to 2 mm. The feed of pieces (circular feed) varied from 0.2 millimeter per revolution to 3 millimeter per revolution. The speed of the tool rotation changes in the range from 12000 to 18000 turns of the electric spindle by changing the frequency of the supply voltage through the inverter Altivar 31. The tool drive is installed in the tool-holder of the turning lathe.

The line feed values are determined by adjusting the feed gear-box of the working machine 16K20, and the circular feed values are determined by corresponding setting of the speed gear-box of the working machine.

The offered method of rotational turning with multifaceted cutters allows increasing the tool life and improving the quality of processing when turning the viscous and plastic materials, alloyed and heat-resistant steels, as well as providing the guaranteed crushing and removal of chips. In this case, there is no need to use toxic and expensive coolants.

Rotational turning with multifaceted cutters allows obtaining chips in the form of particles of small-sized space forms with complex geometry for powder metallurgy and composite materials from various constructional materials, including viscous, plastic metals (zinc, aluminum, copper).

## 2. Conclusion

Carrying out the corresponding researches allows revealing the optimal processing modes and providing practical recommendations on their choice for various conditions and materials. In general, the conducted researches have confirmed the prospectively of the proposed method.

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