Influence of cutting modes on power characteristics of rotational turning by multifaceted cutters

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Abstract. New data on the effect of technological modes (depth cutting, a_{mf}, longitudinal feed, f_n; azimuthal feed, f_{az}; cutting speed, V_r) and constructive factors (geometric and kinematic parameters of the tool) on cutting forces have been obtained. On this basis, semiempirical computational formulas $Pz = f\,(a_{mf}\,,\,f_n,\,\,f_{az}\,,\,V_r)$ for the assignment of rational modes of processing by the method of rotational turning multifaceted cutter (RTMC) are proposed. The obtained numerical values of the cutting forces for PTMC (up to 900N) are much lower than for conventional turning (up to 4000N) at similar values of a_{mf} and f_n.

1. Introduction

In machining processing of metal cutting the methods of edge cutting machining, including lathe machining, are mostly wide-spread. In lathe machining of outer cylindrical surfaces there are the following known basic methods of turning: by apical cutters, by non-apical cutters, by rotatory cutters with auto- or forced turning, face milling (milling). However, their usage has a number of meaningful constraints: decrease of tool-life at increased cutting speed, formation of flow chips during processing of the workpieces from difficult-to-cut materials and, as a result, increase of friction force and temperatures, therefore the necessity for using lubricating-cooling technological agents (LCTA) etc. The abovementioned technological problems lead to the production loss of metalworking, but they can be solved by new methods of rotational turning by multifaceted cutters (RTMC), based on the kinematics combination of non-apical oblique turning, which main advantage is the movement of the cut layer along the cutting edge, and traditional rotational turning [1-3].

In this case, one of the two rotational movements is communicated to the tool in the form of a multifaceted plate, and the other to the processed workpiece. The axis of a tool's rotation is set perpendicular to the axis of a workpiece's rotation and is placed on the line of the axis of centers. The closed cutting edge of a multifaceted cutter is forcibly rotated around its axis, that leads to the constant updating of the cutting edge areas at contact with the workpiece – this is the fundamental difference from the multi-toothed tool used in the milling method (similar in kinematics) [4, 5].

As the RTMC method is new and under examined, both theoretically and experimentally, therefore its practical use requires the conduction of advanced complex studies aimed at modeling and mathematical description of complicated forming movements of the tool and the workpiece, as well as the study and analysis of power characteristics, chip morphology and processed surface of a workpiece, which appear during the RTMC process. Basing on the abovementioned, the methods of

calculating and assigning rational cutting modes can be determined (established), which allow to increase cutting speeds, improve machining performance and surface quality at the same time.

2. Research methods and equipment

Experimental research of the power characteristics was carried out on a screw-cutting lathe 16K20F1 with the use of the original measuring tool unit [1, 6-8].
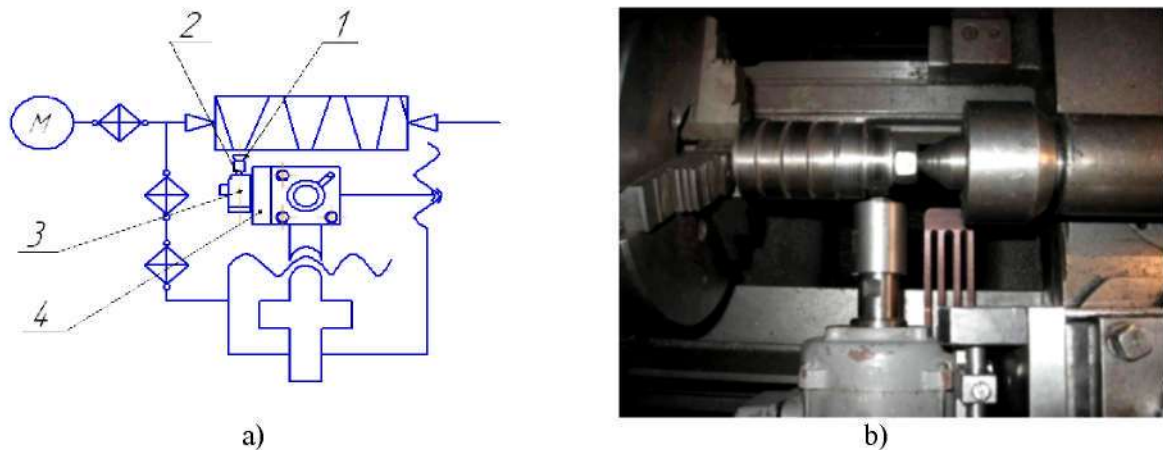

a)   b)

Figure 1. The scheme of machining with a multifaceted rotational cutter: a) a kinematic scheme of installation on the lathe: 1 − rotational cutter; 2 − tool head; 3 − electro spindle E-18 / 0.63; 4 – bracket; b) a general view of the experimental setup.

The following parameters of cutting modes were taken as independent variables: f_n - longitudinal feed of the cutter per revolution of the machined shaft, 0.2…1 mm/turn; f_{az} - azimuthal feed circular feed of a workpiece. n_r - the number of revolutions of a workpiece, 315…1000 turn / min; n_b - tool speed, 6000…18000 turn / min; a_{mf} - cutting depth, 0.1…0.9 mm (with pre-optimized geometric parameters of the tool). The research was carried out using special samples mounted on the mandrel. Samples material is steel 45. Plates tooling material T15K6. The number of faces of the tool component plate is 6.

3. Results and discussion

For the effective implementation of a new method of rotational turning by multifaceted cutters [9-11] it is necessary to study thoroughly the influence of geometric and kinematic factors, as well as the cutting modes, on cutting forces and temperatures acting on the cutter in course of RTMC. In order to determine the functional relationships between one of the parameters of the cutting modes and the variable component of the cutting forces, a set of single-factor experiments $P_z = f (a_{mf})$ and from f_n, f_{az}, V_r, respectively, were carried out. Such relationships can be well represented by parabolic or exponential curves. They are most conveniently approximated by the exponential function of the form $y = Cx^\kappa$. Measurement results of cutting forces depending on the cutting modes are graphically shown in figure 2.
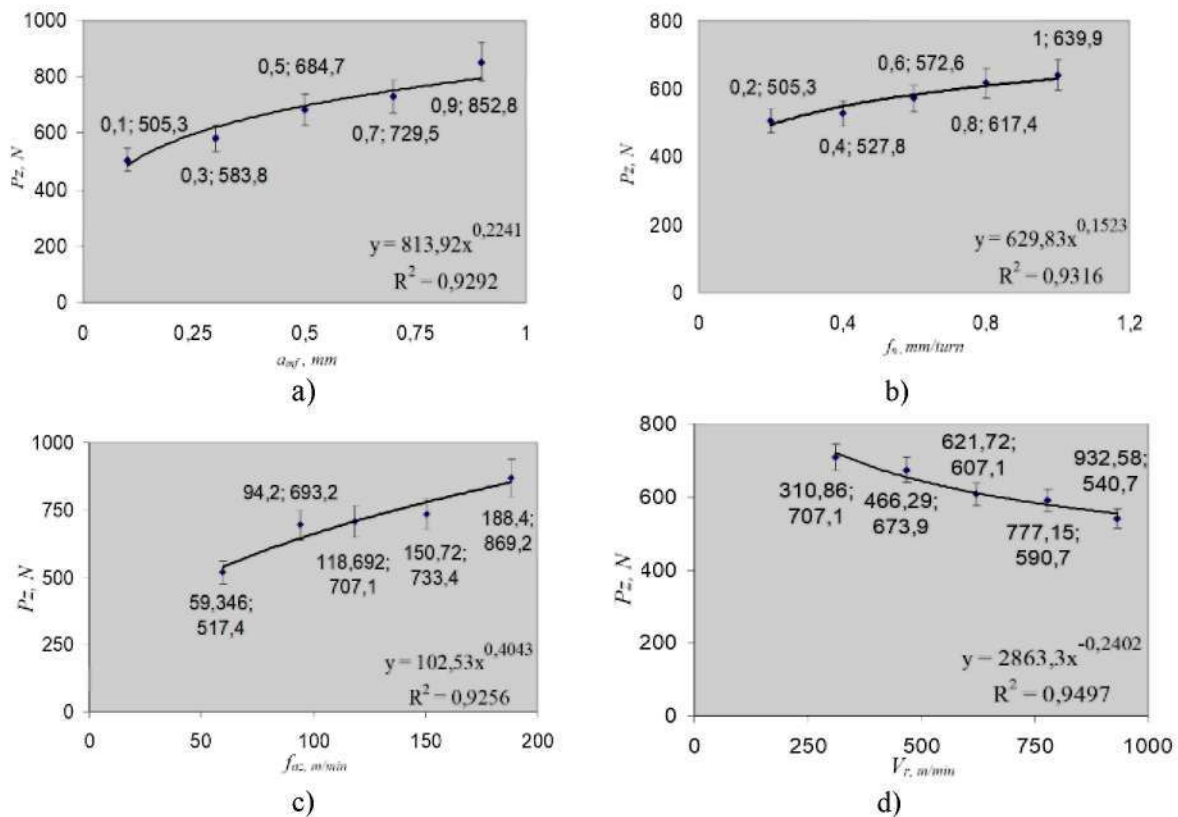
Figure 2. Change of the main component of the cutting force Pz depending on the cutting modes: a) – cutting depth a_{mf}; b) – longitudinal feed f_n; c) – azimuthal feed f_{az} ; d) – cutting speed V_r

Analysis of experimental data shows that the most significant in the context of the influence on cutting forces are the cutting speed Vr and the longitudinal feed fn. Basing on the processing of experimental data, a expression was obtained to determine the main component of the cutting force in process of RTMC:

$$P_z = 662.12 \cdot \frac{f_n^{0.1523} \cdot f_{az}^{0.4043} \cdot a_{mf}^{0.2241}}{V_r^{0.2402}} \tag{1}$$

The comparison of calculated and experimental data shown in figure 3 indicates satisfactory convergence and possibility of using the obtained semi-empirical dependence for predicting power characteristics.
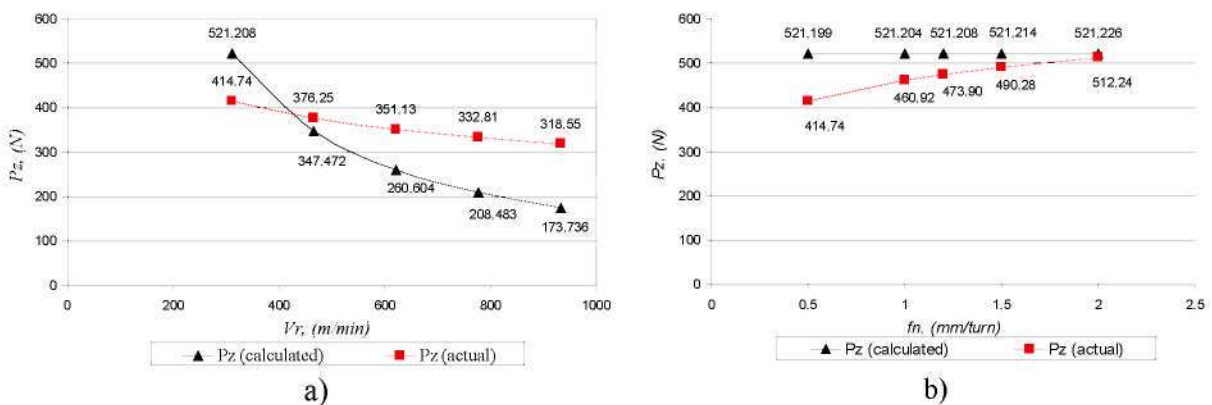

Figure 3. Influence of the cutting modes on the main component of the cutting force: a) cutting speed V_r; b) longitudinal feed f_n.

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The results of experimental studies allowed to determine the nature of the influence of technological (cutting depth, a_{mf}; longitudinal feed, f_n; azimuthal feed , f_{az}; cutting speed, V_r) and design factors (geometric and kinematic parameters of the tool) on the main component of the cutting force. In combination with a similar formula for predicting the roughness of the machined surface, it allows to establish the rational cutting modes for improving performance of the RTMC process while ensuring the required quality of the machined surface. The relatively low values of the cutting force in terms of RTMC (up to 900N) should be noted, which is significantly less than when turning with apical cutters (up to 4000N) with similar values of a_{mf} and f_n. This can be explained by the chips flow with an additional relative slip along the cutting edge (due to large values of the oblique angle λ (from to) as with oblique turning), a decrease in friction forces, and therefore the resulting cutting force.

4. Conclusion

Kinematic characteristics of the RTMC method provide the constant change of the cutting force in value and direction, what provides the increase of deformation processes intensity in course of cutting the layer of a workpiece material, change of the shape and size of the cross section chips. In this case the unit load on each cutting edge is significantly lower than for the traditional apical turning. The results of the experimental studies allow to determine the nature of cutting modes impact in terms of RTMC on the main component of the cutting force P_z. The obtained numeric values of cutting forces in RTMC (up to 900N) is significantly lower than in case of turning by apical cutters (up to 4000N) with similar values of a_{mf} and f_n. This is a prerequisite for increasing the cutting speed, productivity and quality of surface machining of rotation bodies.

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