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EXPERIMENTAL VERIFICATION OF MACHINED SURFACE ROUGHNESS ACHIEVED BY VARIOUS CUTTING TOOLS

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Abstract: *The paper contains the results achieved by optimization of tool angle of cutting tool with linear cutting edge non parallel to the axis of the workpiece. The article describes some possibilities of surface roughness characteristic improvement. Contribution deals with the verification of cutting tool geometry suggested by authors on FMT TU Košice with seat in Prešov compared with the common tools used in production. Results of the experiments show that the investigated cutting tools enable to secure the same values of surface profile characteristics of steels as a classical cutting tool at finishing with the significant increase of the feed per revolution. It directly influences on the length of the technological operation time which is several times shortened. This article originates with the direct support of Ministry of Education of Slovak Republic by grants VEGA num. 1/0885/10 and KEGA num. 270-014TUKE-4/2010.*

Key words: *roughness, machined surface, theoretical profile, cutting tool geometry*

1. INTRODUCTION

The important field of automation is the machining. It is the most common form of manufacturing technologies used in mechanical engineering. The status of manufacturing technology is discontinuous which can change the classical approach to automation. One of the parts which significantly influence the manufacturing technology is the cutting tool. It affects achieved qualitative parameters of machined parts and the machining process economy.

The improvement of the productivity at the technology automation is possible to reach:
by cutting speed increasing, which shows itself negatively on the cutting tool lifetime,

- by cutting depth increasing, which is contrary to the tendency that the semi-product have before the machining as smallest working allowance as it is possible,
- by feed values increasing, which is the most frequently allowed by the cutting tool geometry modifications.

The term cutting tool geometry means the parameters, which characterize the shape of cutting wedge, some properties of cutting part of tool or its dimensional values as are cutting-clearance angle, cutting-edge side rake, cutting edge inclination, corner radius, number of cutting wedge, the area of the tool body, diameter of milling cutter, the length of the drill cutting part and other. Geometrical parameters of cutting edge characterize the shape of cutting part of tool and its position in regard to the workpiece.

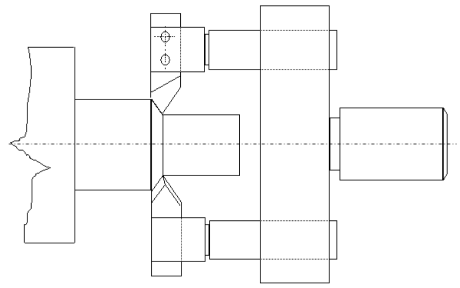
It is necessary to pay maximal attention to right choice of the geometrical parameters, because they considerably influence the labour productivity and the machined surface quality. The impact of cutting wedge angles on the cutting process parameters and some solutions of the problem relates to the observance of necessary surface roughness at the productivity increasing are shown it Table 1.

Table 1

Some solutions of surface roughness characteristic improving at lathe work

I. Multiplying of working cutting edges

a.



The machining by means of two cutting tools which are radial opposite held. The position of tools considerably eliminates radial component of cutting force. One of the tool is rougher, the second one machines finely. Both tools have to be set in order to the corner of smoothing tool was set half revolution of feed compared with the tool mark of rougher on the workpiece, what enables double increase feed at the holdback of required roughness. Within the disadvantages belongs the necessity of both cutting tool holder manufacturing, complicated tool setting up, limited length of cutting surface (in regard to the tool holder rigidity and various interval of both cutting tools life.

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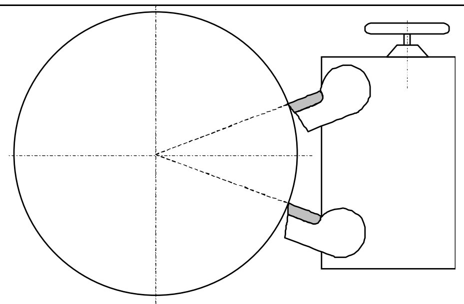
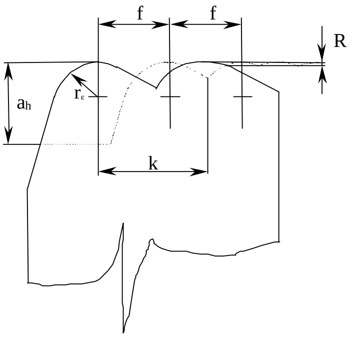
Table 1. Continuation

b.



The machining by means of two cutting tools which are held one after another in clamping head of turning carriage. By this solution it is possible to work with double feed value at the same surface roughness and considerably vibration decreasing. The tools are set up so to be achieved suitable effective angles of cutting edge, the same for both tools and so that the corner of smoothing tool was set up half revolution of feed compared with the tool mark of rougher on the workpiece.

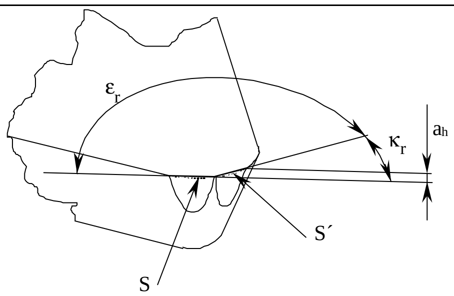
c.



Solution applies the cutting tool with two corners. The corners are moved each other at the multiple of feed in feed direction. The radii of the both corners are the same or various. The requirement is to set up both corners in the same plane parallel to the workpiece axis. The additional corner equalizes the irregularities formed by the first corner. This tool can be used for the roughing.

II. Geometrical characteristics modification of cutting wedge

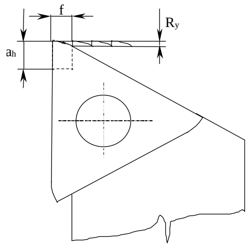
a.



The modification of rounded corner by grinding of two flank surfaces. One of them (*S*) is inclined in tool cutting edge angle $\varkappa_r$. The second one creates the small cutting edge parallel with axis of workpiece (*S´*). It causes the face smoothing and big decreasing of surface roughness. This tool is suitable only for very fine surface finishing with little cutting depth.

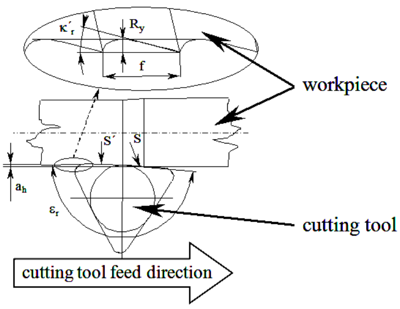
Table 1. Continuation

b.



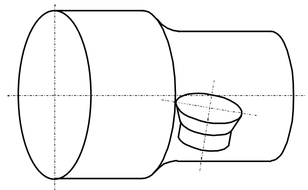
The next suggestion is the modification of *a*, *b* and *e* solutions. Designed cutting tip has secondary linear cutting edge in arc shape with big radius. Optimal radius is $R = 0.15 \div 0.5L$, where *L* is the width of cutting tip. This solution removes the deficiencies of previous cases and it can be used for higher cutting depth.

c.



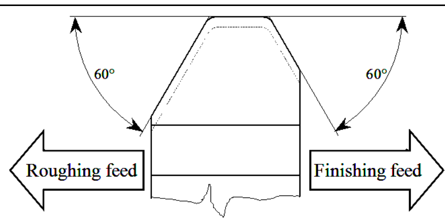
This solution is based on the using of special cutting tip with six cutting edges. Major and minor cutting edges on the corner contain the angle about 180º. Minor cutting edge *S*, which is parallel with the workpiece axis smoothes the machined surface. The disadvantage of this solution is increased intensity of the friction on minor cutting edge. This solution is suitable only for finishing operations and little cutting depth.

d.



The cutting tool with circle cutting tip with big radius (about 10 mm) This solution markedly decreases the roughness of machined surface at the turning (about ten times). If the tool is located fulcrumed, it is possible to work with double cutting speed compared with the using of normal cutting tool. The feed can be higher by 50% and the cutting life increases ten times.

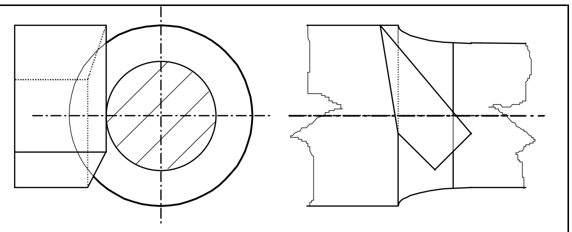
e.



The cutting tool with linear cutting edge parallel to the workpiece axis. This tool is used for high feed values (also 3 mm per revolution) at 1.5 mm cutting depth. Concrete presented tool enables to work in one direction as rougher and in reverse direction as finishing tool.

Table 1. Continuation

f.



The tool with linear cutting edge not parallel toworkpiece axis. This solution represents very good relationship between feed and surface roughness, however the disadvantage is the necessity of major run-in and run-out of cutting tool. It enables to machine only bottomless cylindrical surfaces without the shoulders. In spite of disadvantages of this tool, the next variants were looking for, which would keep the advantages of tool and eliminate its disadvantages.

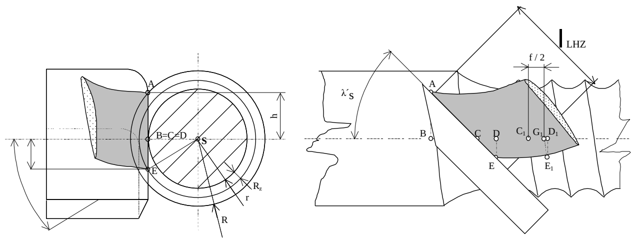


Fig. 1. Scheme of selected turning tool working.

2. MACHINING PRODUCTIVITY INCREASING

For experiments the tool was selected according to Table 1, II *f*. The geometrical dependency of the surface roughness characteristics on the cutting edge angle for this kind of tool is shown on the Fig. 1. During next verification it was used, on the basis of research, the value 45º for cutting edge angle. It was demonstrated at experimental verification that the surface characteristics at the machining by tool with linear cutting edge not parallel to workpiece axis are several times lower compared to the classical tools.

By help of scheme in Fig. 1 the Eq. (1) was obtained for calculating of theoretical value of tool from.

$$Rz = \sqrt{\left(\frac{f\tan\lambda_s}{2\left[1-\tan\lambda_s\tan\left(\arctan\dfrac{f}{2\pi r}\right)\right]}\right)^2 + r^2} - r. \quad (1)$$

3. EXPERIMENTAL EVALUATION OF TOOLS

During experiments it was observed that cutting tool achieves better work results if active length of cutting edge is not too big. However the tool, suggested according to Fig. 1, is unprofitable in term of low brittle rupture resistance. The tool corner that is set up a little bit above the workpiece axis has a part in the cutting process in this case, therefore it was suggested the modification of primary geometry by zero face strengthen. The values 1, 2 and 3 mm were suggested for the zero face width. Various combinations of values were verified for cutting depth during experiments as are setting up of the corner above workpiece axis and zero face depth. The best results of surface roughness values were achieved at following combination of values:

- tool setting up 1 mm above workpiece axis and
- strengthen zero face width 1 mm.

The determinant causes that lead to very high vibration, are the big length of active cutting edge and very great change of tool angles by setting up the tool above workpiece axis. It is evident from Fig. 1 that the point of the cutting edge that generates the maximal diameter (radius R_{max}) has very unfavourable geometrical parameters. At unsuitable combination of parameters (as are part radius R_{max}, cutting depth and the setting up of the tool corner above workpiece axis) it comes to such change of tool flank angles (in angle η), which considerably make worse the cutting process, respectively they re not able to do it. The increasing of flank angles also cannot take big values, because it greatly decreases the strength of cutting wedge.

At first experiments for tool according to Table 1, part II f were achieved.

Results obtained during these experiments for effect of cutting edge inclination angle to *Rz* were compared with values according to theoretical dependency in Eq. (1) [3]. That is shown in Fig. 2.

Next step was comparison of tools with linear cutting edge skew of workpiece axis and tools for current industrial using. Machined material was steel C45.

One tool with linear cutting edge skew of workpiece axis was designed by authors, second tool was originated by Professor Karol Vasilko – tools Fig. 3,*a* and *c*. First tool was uncoated. Coating of second tool was prepared according to recommendation of [2].

Tools for current industrial using were chosen from two points of view:

- WNMG 080416 - coated tool tip oriented for excellent roughness of machined surface – tool *b* in Fig. 3.
- TCM 16 T308 - coated tool tip specialized for roughing machining with higher rate of feed – tool in Fig. 3,*d*.

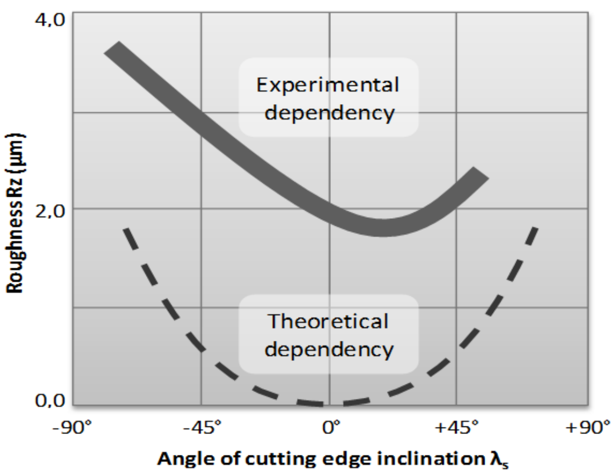


Fig. 2. Theoretical and experimental dependency of roughness values *Rz* (machined material C45).

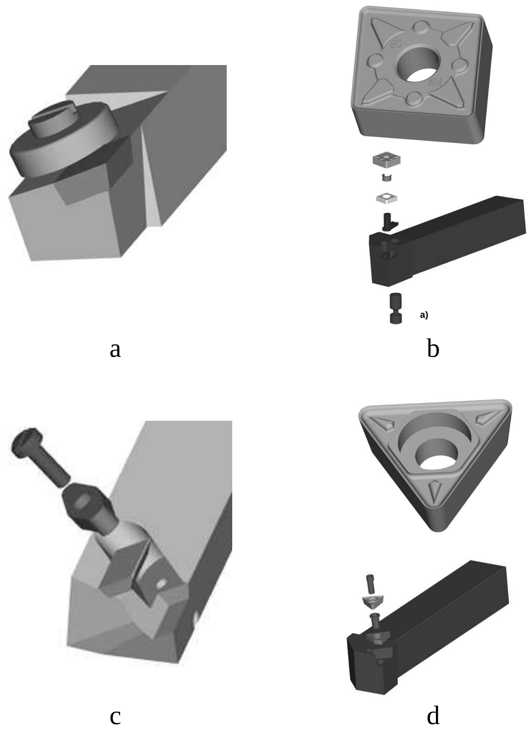


Fig. 3. Tools used for experimental verification:
a – Prof. Vasilko tool; *b* – mass produced tool for soft finishing; *c* – authors tool; *d* – mass produced tool for roughing.

Other conditions of experiments were:

- Feed (per revolution) 0.2 / 0.4 / 0.8 mm.
- Cutting speed 70 / 100 / 145 m.min^{-1}.

All experiments were done repeated and obtained results were statistically processed.

4. COCLUSIONS

The relationship of theoretical and experimental dependencies for the examined tools follows from the graphical relations of the arithmetical average deviation from a mean line on the feed per revolution and on the cutting speed in Fig. 4.

From these graphical relations it is evident that the best tool from roughness point of view is professor Karol Vasilko's tool. This tool achieves the values of the arithmetical average deviation from a mean line *Ra* sometimes lower as a finishing tool (Fig. 4,*b*) at the same cutting conditions.

The tool with linear cutting edge unite roughing and finishing cut, what enables to reduce the number of manufacturing operations and the direct manufacture time.

Next researches of authors are oriented to:

- properties of evaluated tools for different machined materials according to [1],
- finding of efficiency method of evaluation following of article conclusions [4 and 7],
- evaluation of modern approach in ranking of machined surfaces by turning tools oriented to increasing of productivity and good quality of machined surfaces [5].

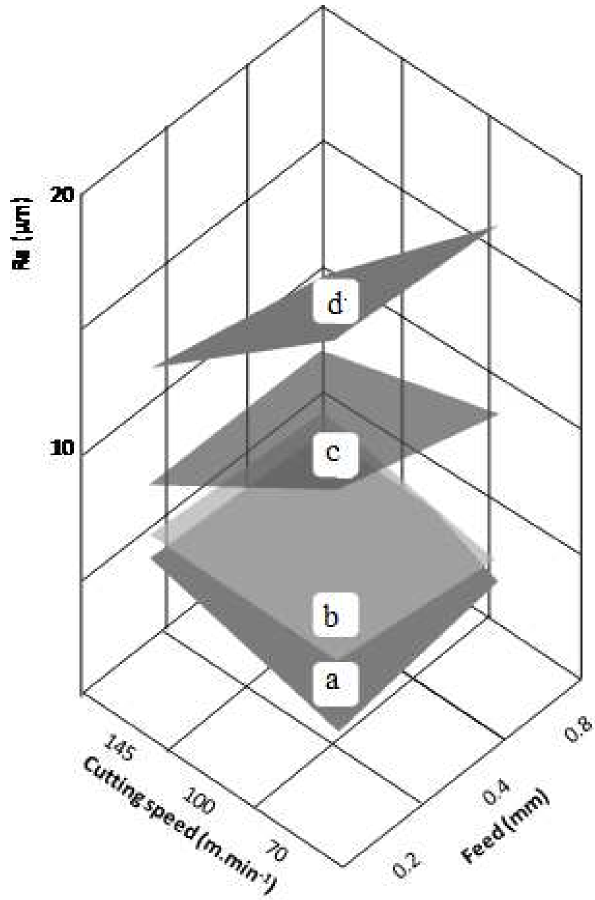


Fig. 4. Results of experiments for all cutting tools:
a – Prof. Vasilko tool; *b* – mass produced tool for soft finishing; *c* – authors tool; *c* – mass produced tool for roughing.

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