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HOW THE PRESCRIBED TOLERANCES OF THE PROFILED LATHE TOOL INFLUENCE THE MACHINING ACCURACY OF THE PART

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Abstract: *Most of the tools used in cutting can be rich on the profile market in a wide variety of shapes, features and prices. Nevertheless, a separate category of cutting tools that require design to the theme and then, a tailor-made execution there is in the field. These tools are the profiled knives, either prismatic or disc. The execution of the tool, compliance with the precision prescriptions of the piece, requires the collaboration of the expertise of the three actors directly involved: the designer of the part, the form tool designer and the manufacturer. We can help them meet to agree on their goal and that is exactly what we are going to do in this paper.*
Key words: *profiled tools, accuracy, tolerances.*

1. INTRODUCTION

Even though a number of new technologies have come out of the research laboratories and successfully entered the industrial production of metallic and non-metallic parts - some of them proving their economic efficiency and others the versatility of spatial forms - cutting has remained one of basic procedures. Whether it is classic machine tools or we have CNC Machines in stock, they need high-performance cutting tools as well as material characteristics and precision execution. Most of the tools used in cutting processes can be rich on the profile market in a wide variety of shapes, features, type-dimensions and prices. However, a separate category of cutting tools is know that require design to the theme and then a tailor-made execution. These tools are the profiled knives, either prismatic or disc. For the design of the profile of the tool, corresponding to the profile of the part there is the possibility of using specialized computer programs. Also when choosing the clamping-fixing system in the tool holder already established solutions can be used. In the tool execution, compliance with the precision prescriptions that make possible the precision of shape, dimensions and quality of the surface on the execution drawing of the piece, requires the collaboration of the expertise of the three actors directly involved: the designer of the piece, the designer of the tool and the manufacturer of the profiled knife. Can we help them meet to agree on their goal? Most often No. Can we help them understand each other by providing a series of check rules and best practice examples? Yes, that is right, and that is exactly what we are going to do in this paper for the topic of manufacturing profiled prismatic knives.

2. MOTIVATION

2.1 What is the use?

A profiled tool has a cutting edge that mirrors the contour of the part to be manufacture. This tool can be used as a single operation and therefore eliminate many other operations from the slides and the turret, such as box tools. A form tool turns one or more diameters while feeding into the work. Before the use of form tools, diameters were turned by multiple slide and turret operations, and thus took more work to make the part. For example, a form tool can turn many diameters and in addition can also cut off the part in a single operation and eliminate the need to index the turret.

On long-running jobs, it is common to use a roughing tool on a different slide or turret station to remove the bulk of the material to reduce wear on the form tool. A drawback when using form tools is that the feed into the work is usually slow, 0.012 mm to 0.32 mm per revolution depending on the width of the tool. Wide form tools create more heat and usually are problematic for chatter. Heat and chatter reduces tool life. Also, form tools wider than 2.5 times the smaller diameter of the part being turned have a greater risk of the part breaking off. [1], [4], [5] When turning longer lengths, a support from the turret can be used to increase turning length from 2.5 times to 5 times the smallest diameter of the part, and this also can help reduce vibrations. Despite the drawbacks, the elimination of extra operations often makes using form tools the most efficient option.

2.2 Statement of reasons

Profiled tools are expensive because, among other things, they require highly complex individual design and high precision execution for each part type, size and shape. At least, for this reason, they can be used only for large series and mass production of parts of relatively small dimensions and of medium complexity and precision. The phase of manufacturing preparation that consists of the execution of test pieces is a particularly demanding one. That is because it requires adjustments of the machine tool and adjustments of at least the position of the tool in relation to the blank. So that after the capability tests, the resulting part falls within the prescriptions technical specifications from the execution drawing, both as nominal dimensions and above all within the tolerances of the tolerances of the tolerances for functional conditions in higher precision classes, most often IT 8 and rarely IT 7.

An additional weight in the performance of this phase occurs when the batch of parts is very numerous and several workstations are required to carry out the quantitative task. This is because settings, adjustments, capability tests must be done for each individual machine tool. Therefore, we will have a high consumption of materials, technical resources, time and, last but not least, the nerves of the staff.

Researching the possible causes, we can list:
a) machine-tool – wear of the guides and the lead screw, joints wear or in the tool holder;
b) tool – design or execution errors;
c) half-finished product - inadequate hardness, dimensions outside the tolerance limits, inhomogeneity of material or structure due to improper heat treatment.

Of the three categories of possible causes, we will pay attention in this paper to the tool. Considering that design errors of the profile are improbable due to the existence of specialized computer programs for this type of tools, we turn our attention to the technical prescriptions in the execution drawing. If the dimensional tolerances are usually in agreement with those of the standards and the accuracy class, and the errors is found regularly and identically on the machined part, in terms of the effects of the tool angle tolerances, it seems that things do not seem to be way. This is because, consulting many cases from industrial practice, the prescribed angular tolerance is $\pm 30'$ regardless of the value, dimensions and precision class indicated on the execution drawings of the profiled knife, be it prismatic or disc type.

Let us take a mathematical look at the design phase and see what would be the influence of the angle tolerance α_f and γ_f of the profiled knife on the depth of the workpiece.

3. MATHEMATICAL ARGUMENTS

3.1 Pre-conditions

In this phase, in order to make the demonstration in conditions as close as possible to those in practice, we will start by choosing the constructive type of tool. The choice is made according to the characteristics of the surface to be processed and the machine on which the processing will be done. The surface to be processed is the external profiled surface, with an average profile width of 40 mm (figure 1) the precision and quality of the functional surfaces being IT 8 and of the other surfaces IT 12. The material of the workpiece is a usual steel, indicated on the part drawing of medium hardness and structural homogeneity. The tool will work on an normal or automatic lathe.

Taking into account these characteristics, the prismatic profiled tool is chose. These profiled tools have the following characteristics:

Benefits:

- can be used for external or internal turning of profiles with a maximum width of 60÷80 mm;
- occupies a relatively small space;
- can be mounted on a high rigidity support;
- more secure fixation than disc profiled tool;
- have a large re-sharpening reserve that is only made on the clearance face.

Disadvantages:

- the positioning of the tool relative to the axis of the piece, after repeated resharpening, requires increased attention.

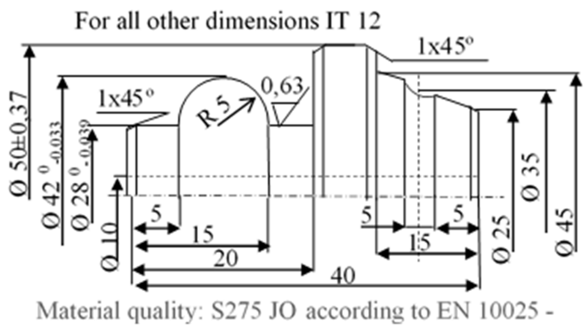

Fig. 1. Exemplification for the specification of geometric tolerance requirements for part shape

3.2 The influence of the tolerance of the angles α_f and γ_f of the profiled prismatic tool on the depth of the machined part

Using the drawing in figure 2, the size of the profile depth variation range t_{pi} at the part will be calculated for the characteristic radius points r_i. The size variation is due to the minimum and respective maximum values that the angles α_f and γ_f can have after the execution of the tool, where these depths will be t_{si}. However, due to the positioning of the tool so that there are cutting angles α_f and γ_f, the profile depth on the workpiece t_{pi} differs from the profile depth on the tool edge t_{si}. In the design, the cutting angles α_f and γ_f are considered for the exact end of the turning operation – when the tool tip has exactly touched P on the piece of minimum radius r_{min}. Under these conditions, using the notations in the calculation scheme, the profile depth on the part for the characteristic point I on its surface, compared to the minimum radius point of the part P, is calculate as below.

Since the angle γ_f can take values in the tolerance field of ±30´, we will have:

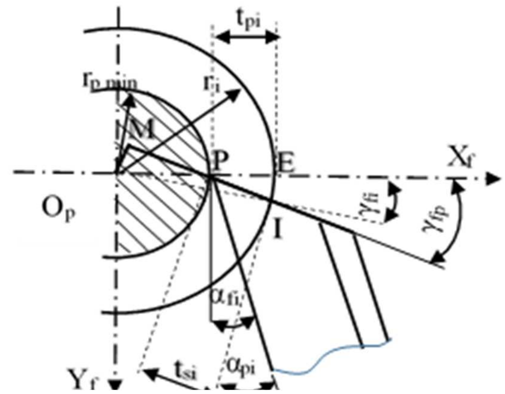

Fig. 2. Exemplification for the specification of geometric tolerance requirements for part shape

Since the angle γ_f can take values in the tolerance field of ±30´, we will have:

$$t_{pi+} = \frac{r_i}{\cos\gamma_{fi}} - \frac{r_{min}}{\cos\gamma_{fp+}} \tag{1}$$

$$t_{pi-} = \frac{r_i}{\cos\gamma_{fi}} - \frac{r_{min}}{\cos\gamma_{fp-}} \tag{2}$$

$$\Delta t_{pi} = t_{pi+} - t_{pi\_} = \frac{r_{min}}{\cos\gamma_{fp+}} - \frac{r_{min}}{\cos\gamma_{fp+}} =$$

$$= \frac{r_{min}(\cos\gamma_{fp+} - \cos\gamma_{fp-})}{\cos\gamma_{fp+}\cdot\cos\gamma_{fp-}\cdot} =$$

$$= \frac{2r_{min}\sin\frac{\gamma_{fp+}+\gamma_{fp-}}{2}\cdot\sin\frac{\gamma_{fp+}-\gamma_{fp-}}{2}\cdot}{\frac{\cos(\gamma_{fp+}+\gamma_{fp-}) + \cos(\gamma_{fp+}-\gamma_{fp\_})}{2}}$$

Considering $\gamma_{fp\pm} = \gamma \pm u$, where u is the value of the angular tolerance prescribed in the tool drawing, and using the trigonometric formulas, the final form of the size of the tolerance field to the part dimensions is reached:

$$\Delta t_{pi} = -2r_{min}\frac{\sin\gamma\cdot\sin u}{\cos 2\gamma + \cos 2u} \tag{3}$$

3.3 Results in the particular case considered

Let us consider the case of the part shown in figure 1 which has r_{min}=12.5 mm and the conditions presented in paragraph 3.1. From the existing tables in the specialized literature [2], [3] we choose the geometric parameters of the prismatic profiled tool: α_f =8°÷15°, we choose α=14°; γ_f=20°÷25°, we choose γ=20° and the angular tolerance on the tool drawing is ±30´ and therefore u=30´ in relation (3).

Substituting the values in relation (3) we get:

$$\Delta t_{pi} = -2 \cdot 12{,}5 \frac{\sin 20° \cdot \sin 30'}{\cos 40° + \cos 1°} = 0{,}0974\ mm$$

Table 1

Numerical values of IT fundamental tolerance steps for nominal dimensions - extracted from the SR EN 20286-1 standard

Nominal dimensions	IT fundamental tolerance steps				
	IT 6	IT 7	IT 8	IT 9	IT 10
Ranges	Values µm				
≤ 3	6	10	14	25	40
3÷10	8	12	18	30	48
10÷18	11	18	27	43	70
18÷30	13	21	33	52	84
30÷50	16	25	39	62	100
50÷80	19	30	46	74	120
80÷120	22	35	54	87	140

In the following we will compare the result obtained above, for the dimensions of the part studied - see figure 1 - with the values of the fundamental tolerances for IT8 from table 1.

It can be easily observed that in the real case considered, the part will not fall within the tolerance field of ±IT8/2 regardless of the efforts made by the persons who have to make adjustments or by the operators.

4. CONCLUSION

The precision of the tool is the essential element that influences the precision of the part. To obtain the desired result, it is necessary to ensure the precision of the generating surfaces of the tool edges in relation to the basic surfaces of the piece.

Because the primary cause of the fact that the measured values of deviations of the dimensions of the characteristic points on the part will exceed those expected is due to the wideness with which the tolerances on the angular sizes are prescribed. Therefore, to eliminate this cause of inaccuracy, the authors recommend going the other way. This means that, after choosing the cutting angles, choose the tolerance field at the profile depth of the part and then calculate from relation (3) the angular tolerance that will be written on the tool execution drawing.

5. REFERENCES

[1] Pillet M., Adragna P-A., Germain F., *Inertial Tolerancing: "The Sorting Problem",* Journal of Machine Engineering: Manufacturing Accuracy Increasing Problems, optimization, Vol. 6, No. 1, 2006, pp. 95-102.

[2] Graham T. S. *Cutting Tool Technology: Industrial Handbook*. Igarss, 2014.

[3] Armarego, E., Brown, R.H., *The machining of metals.* Prentice-Hall Inc., 1969.

[4] Prakash, L., *Fundamentals and General Applications of Hardmetals*. Elsevier, 2014.

[5] Voigt, R.C., Marwanga, R.O., Cohen, P.H., *Machinability of Gray Iron-Mechanics of Chip Formation.* International Journal of Cast Metals Research, 11:567 572 1999

CUM INFLUENȚEAZĂ TOLERANȚELE PRESCRISE CUȚITULUI DE STRURG PROFILAT PRECIZIA DE PRELUCRARE A PIESEI

Rezumat: Majoritatea sculelor folosite la așchiere pot fi găsite pe piața de profil într-o mare varietate de forme, caracteristici și prețuri. Cu toate acestea, există în domeniu o categorie separată de scule așchietoare care necesită proiectare la temă și apoi, o execuție pe măsură. Aceste scule sunt cuțitele profilate, fie prismatice sau disc. Execuția sculei și respectarea prescripțiilor de precizie ale piesei necesită colaborarea expertizei celor trei actori direct implicați: proiectantul piesei, proiectantul sculei și producătorul. Îi putem ajuta pentru a conveni asupra scopului lor și exact asta vom face în lucrare.

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