Machinability as a Phenomenon and the Operational Methods of Its Determination

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Reliable method to detect relative machinability is based on constructing Taylor relation of tool durability on cutting speed for both observed materials. Optimal cutting speed for the observed material at constant durability can be detected from the relation. However, longterm test requires longer time of machining and consumption of material. Therefore a number of authors have observed the possibility of shortening the tests. There is a widespread opinion that shortened methods posses low reliability. On the other hand, those methods cannot be replaced in the conditions of actual operation. Some of them are analysed and modified as follows.

Keywords: workpiece, cutting tool, machinability, cutting speed

1 Introduction

Perfecting the processes of machining is conditioning on the requirements on increased productivity and quality of machined areas. This requirement stimulates the development of the processes of machining to certain extent. However, a requirement to increase productivity of operations and decrease the costs of their implementation has alsob been formed. During experimental research, many pieces of knowledge and factors which influence tool wear and its durability have been found out which enable to find ways to increase tool durability. Knowledge from the area are connected mainly with technological features of cut material, which have started to be called material machinability [1,2,3].

Recent approaches to the evaluation of material machinability differ and carry substantial subjective layers. Generally, machinability should be understood as a qualitative state of material from the viewpoint of its capability to comply with the effects of the cutting wedge [4,5,6]. Suitability of material for selected method of production with applying all standard quality and economic requirements is evaluated according to machinability. From practical viewpoint it is recent to differ between relative machinability related to basic – reference material [7,8,9] To be able to use the knowledge about machinability in a practical way, i tis necessary to formally class material into classes and groups according to relative machinability to reference material. From this viewpoint the notion of machinability belongs into the category of weldability, shapeability, etc. In comparison with those categories there exist kinds of material which cannot be welded or shaped. However there exists no kind of material which cannot be machined.

The degree of machinability of selected material is given by the ratio of costs for the production of the same part from reference material at the same cutting conditions, on the same production machinery, with the same tools and at the same requirements on quality and preciseness of machined areas.

Selected material will posses better machinability with shorter time, less consumption of tools, production machinery and energy - maintaining technical requirements on produced parts from the viewpoint of their dimension and shape preciseness and acceptable surface quality - it can be machined.

Therefore machinability is not only the function of machined material but also the way of machining, use of cut material, etc. It means it has conditional character as it expresses different material features depending on machining conditions and requirements laid on produced parts [10,11,12].

2 Modified face test

Classical test of facing turning is based on the use of workpiece with a large diameter (cca 300 mm), with an opening in the axis, which is turned from the center towards the periphery by a tool made of high-steel tool which dampens at certain diameter. This diameter is the criterion of machinability [2,3,13]. The disadvantage of this method is that such a workpiece diameter is not always available and mechanical features (resistence, hardness) differ considerably for drawn bars. This is the reason why the test has been modified to a small workpiece diameter and turning proceeds by multiple face cuts. Workpiece shape and test result is shown in Fig. 1. The test of multiple facing turning has been applied to the observation of steel with different % of manganese content. It is well-known that manganese considerably worsens steel machinability.

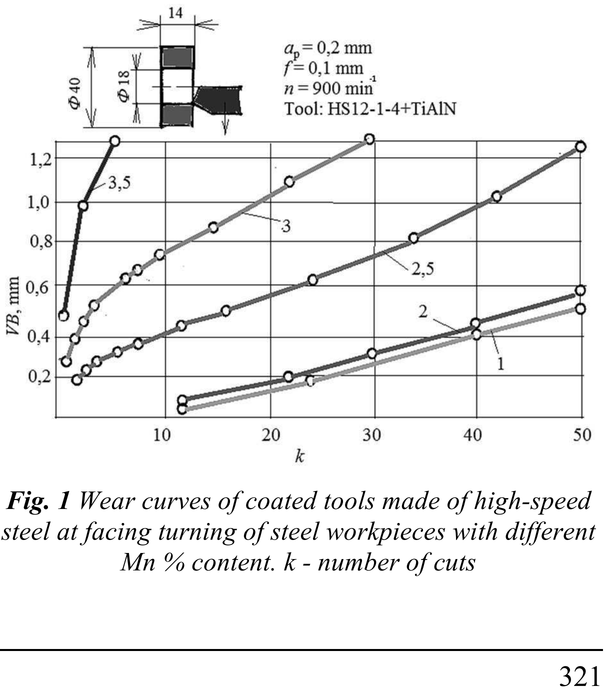
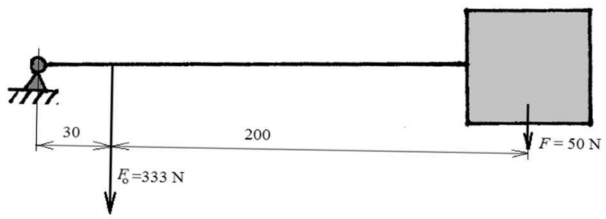


Fig. 1 Wear curves of coated tools made of high-speed steel at facing turning of steel workpieces with different Mn % content. k - number of cuts

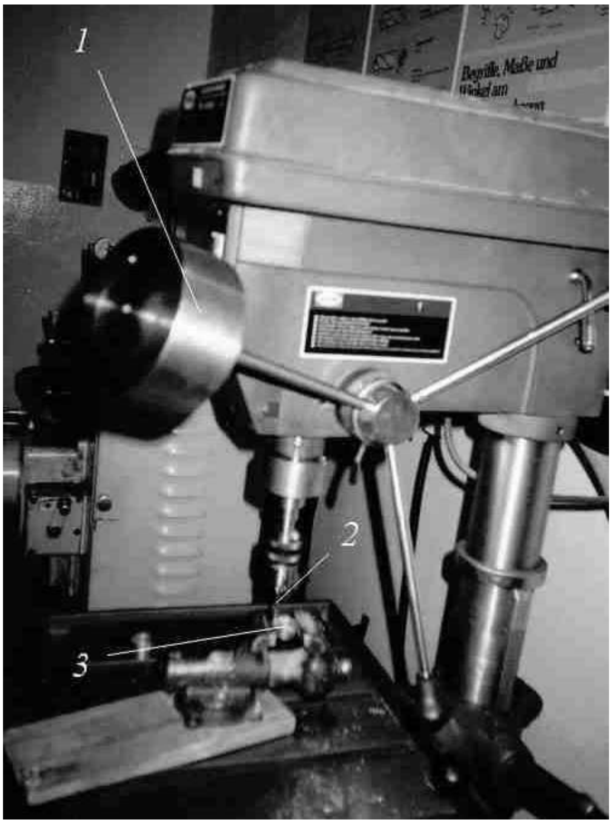
The result can be read from the diagramme. Test sensitivity is high and enables to quantifiy this technological characteristics of the material.

3 Test by drilling with constant axis load

One of the classical tests is drilling with constant axis force F_o (Fig.2).



a



b

Fig. 2 *Drilling with constant axis force with table drill. a – load scheme, b – actual drilling 1 - weight, 2 - drill, 3 - workpiece*

With the help of the weight, constant load of auger is created. (When usign the weight on the lever, drilling must always start in defined weight position). In the course of drilling the openings, as a result of auger wear, the force F_o grows. After reaching the state when $F = F_o$ the drilling process stops by itself and the auger will slide in the opening. Summary length of drilled opening up to auger blunting is the criterion of relative machinability.

In Tab. 1 there is an example of comparison of machinability of certain sorts of alloy steels according to summary length of drilled opening.

Tab. 1 *Comaprison of machinability of steels with Mn content*

Mn content,%	**Length of drilled opening up to auger blunting, *l*, mm**
1	560
2	472
2.5	75
3	14
3.5	5.8
4	1.4

Very good test sensitivity can be seen. The auger must be made from speed-cut steel so that it would blunt after several cuts.

It is more reliable to measure machining time necessary for drilling one opening. Then the machinability coefficient will be:

$$K_{\tau_s} = \frac{\tau_{s1}}{\tau_{se}} . \tag{1}$$

Where:
τ_{s1} – drilling time for tracking material, s
τ_{se} – drilling time for reference material, s

In this test series, machinability dispersion of steels for roller bearings from different producers has beeen observed. The result is shown in Tab. 2.

Tab. 2 *Examples of times necessary for drilling one opening into developmental steel samples*

Steel sample label	**τ_s, s**	**Average value τ_s, s**
100Cr6	50; 46; 44; 40	45
100CrMn6	48; 48; 50; 46	48
LH15	48; 45; 45; 42	45
ŠCH15	86; 84; 82; 84	84
SKF-3	96; 78; 84; 80	84.5

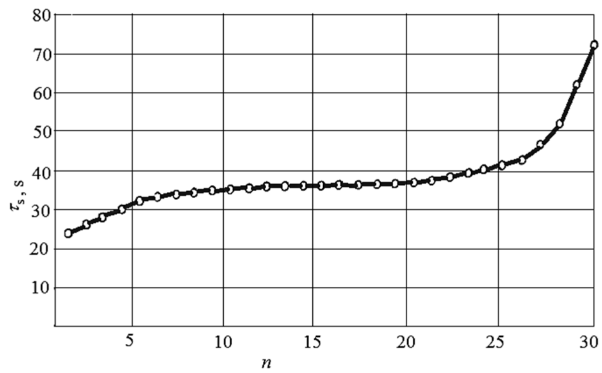


Fig. 3 *Experimental dependence of drilling time (s) on number of drilled openings. n – number of drilled openings*

Different sorts of steel do not have considerable differences in chemical composition. E.g. steel 100Cr6 has a little less Mn (0.3-0.5%). Steel 100CrMn6 has 0.9-1.2 % Mn and more Si (0.35-0.45). As it can be seen from the table, they differ more in the dispersion of machinability than in absolute values. This is probably caused by the pureness of steel and arrangement of inclusions.

Footnote: It is necessary ro realisye that during the tests there occurs auger wear which can influence test results. This fact is documented by an experiment during which a sample with thickness 10 mm, steel C45, has been drilled continually by one auger made from high-cut steel with 3 mm diameter at constant load force. Relevant time of drilling dependance on number of drilled openings is shown in Fig. 3.

The diagramme shows that machining time required for drilling an opening increases according to typical wear curve. Therefore it is necessary to always use a new auger made of high-speed steel for each test or use one auger made from carbide for whole test.

4 Test of tool embedding into workpiece

According to one of the definitions of machinability, this characteristics expresses the resistance of material against the immanation of the cutting wedge. Based on that, the author has developed a test of continual embedding of the tool into slanting workpiece (Fig. 4).

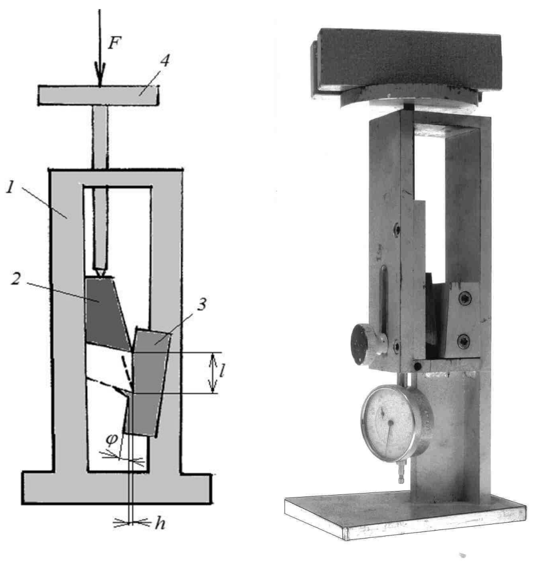


Fig. 4 *Appliance for embedding test. 1 - holder, 2 - knife, F – loading force, l -course of tool, h – instantaeous thickness of cut-off layer, φ -workpiece inclination angle*

At certain loading force F the tool cuts into the inclined workpiece located under the angle $\varphi = 5\,°$, while it creates the chips, until it reaches the thickness of cut-off layer h, which corresponds the loading force. To determine h more precisely, the sample is located under the angle 5°, the tangent of which is 0.1. Timing gauge registers the size of tool course l. It applies that

$$\mathrm{tg}\,\varphi = \frac{h}{l} \Rightarrow h = 0{,}1\,l\,. \qquad (2)$$

Machinability coefficient is:

$$K_{\mathrm{vr}} = \frac{h_e}{h_1}\text{, resp } \frac{h_{pe}}{h_1} \qquad (3)$$

An example of obtained dependence F_c on h for observed sorts of material is shown in Fig. 5.

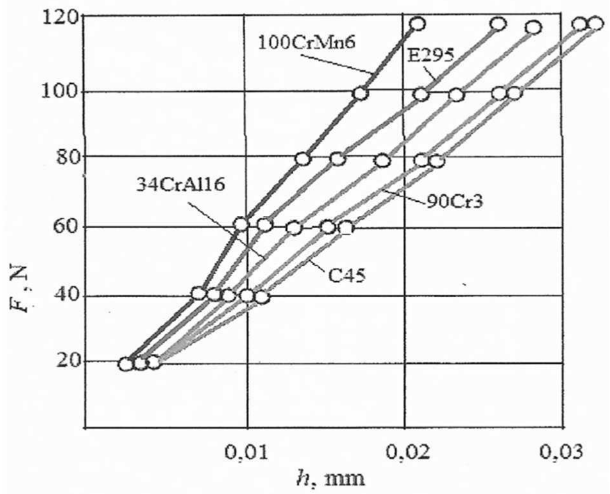


Fig. 5 *Example of experimental dependence of loading force and thickness of cu-off layer for some sorts of steel.*

In Fig. 6 there is an experimental dependence of loading force on the thickness of cut-off layer for different sorts of cut material. The course of dependence is almost linear. However, the differences are considerable which enables to identify k_d.

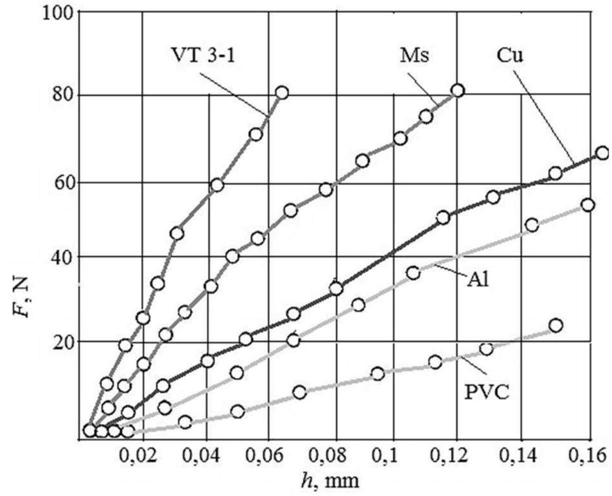


Fig. 6 *Dependence of loading force and obtained thickness of cut-off layer for different sorts of material*

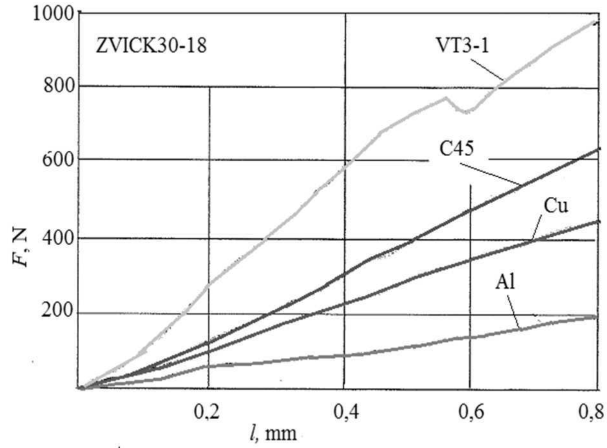


Fig. 7 *Records from tensile machine*

The appliance from Fig. 4 can also be used under tensile machine. During pressure test a graph for some sorts of materials has been obtained and is shown in Fig. 7.

The course for titanium seems interesting as at certain moment, there occurs adiabatic slide in the chip. In Fig. 8 there is a metallographic V-cut of the sample from VT 3-1 after embedding of the tool. Bending of the curve is caused by periodic slide which is typical for titanium alloys.

***Fig. 8** Photo of V-cut of titanium sample after tool embedding*

The test actually models the process of planing or pulling over. During its movement the tool touches cut material and as early as the first touch, deformations occur. After reaching slide limit there occurs plastic deformation.

5 Conclusion

The assortment of methods for the identification of machinability is wide. Particular application of the test depends on the requirements on operationability and preciseness. Longterm test of machinability can be realised on the newly-developed material in lab conditions. Accelerated tests are suitable for operational detection on particular sample of supplied material.

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