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EXPERIMENTAL RESEARCH ON WEAR IN THE CUTTING PROCESS

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ABSTRACT

Cutting tools are subject to several types of wear. The rate at which the wear process occurs has a decisive role on the machining costs. Many of the parameters that determine production costs, such as machining time, part failure rate and tool replacement interval, are affected by how well the cutting tool is working. Damage to the cutting tool due its wear occurs to the cutting edge surfaces of the tool that come into contact with the workpiece and with the chips. With the experimental data from this study, groups of values such as feed, depth, speed and durability corresponding to a certain practical permissible of wear cutting tool value were determined, in order to be able to optimize in practice the values of the cutting regime parameters so as to ensure a imposed durability and wear of cutting tool.

KEYWORDS: cutting tool wear, cutting process, tool life, machining process

1. INTRODUCTION

During the cutting process, due to contact pressures and high temperatures, relative speeds and shocks between the tool-part contact surfaces, cutting tool wear occurs.

Cutting tool wear has a negative influence on the cutting process, on the dimensional and surface accuracy of the parts, as well as on the material consumption. The production of high-quality parts, the establishment of more productive cutting regimes, as well as the rational and efficient use of cutting tools require knowledge of their wear behavior. In the case of cutting, the wear of cutting tools is favored by the particularly high pressures in the tool-chip-workpiece (which can be 300÷400 times higher than in mechanical joints), by the dry or semi-dry friction conditions on the contact surfaces. As a result, the wear process of the cutting tool is much more intense than the similar process in the case of general purpose machine parts.

The main forms of wear are shown in figure 1, the wear noted with *VB* on the tool flank surface (fig.1.a),

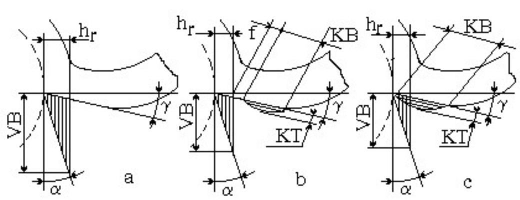


Figure 1 The main forms of cutting tools wear

on the tool rake surface the wear noted with *KT*, at a distance *f* (fig.1b) from the cutting tool edge. By increasing the dimensions of the two wears over time, they overlap on a certain portion (fig.1c).

2. TYPES OF WEAR OF THE CUTTING TOOL EDGE

Adhesive wear is based on the molecular adhesion between certain constituents of the tool material and the workpiece material. This type of wear is very common and occurs as a result of welding and breaking of weld bridges between the contact areas, being characterized by high friction forces and the occurrence of high-intensity wear.

Abrasive wear consists of the presence and interaction of hard particles, which are in the tool material (carbides, nitrides, etc.) and some hard metallographic constituents existing in the semi-finished material. The abrasion process accompanies the cutting process and therefore it is dependent on the physical-mechanical properties and geometry of the two surfaces in contact.

Diffusion wear is considered as a process of transfer of carbon atoms between the irregularities of the contacting surfaces, i.e. it is a pure diffusion process. This type of wear occurs when one metal is in sliding contact with another, and the temperature at the interface becomes high enough to allow atoms from the harder material to diffuse into the matrix of the softer material. Fatigue wear is caused by cyclic stresses of contacting surfaces, which are followed by plastic deformations in the atomic network of the surface stratum, cracks, pitting, or exfoliation.

Thermoelectric wear in tools is based on the high temperature in the contact zone (tool and chip), which produces a thermoelectric current in the tool-chip-workpiece-machine-tool circuit. It has been shown that this current has a double effect, namely: a purely electronic one, without mass transport, and an ionic current, with atom transport between the two surfaces.

Oxidation wear is specific to cutting tools with the active part made of sintered metal carbides and consists of the following: at cutting temperatures between 700^0-800^0C, oxygen from the air enters into a chemical reaction with cobalt and with tungsten and titanium carbides, resulting in oxides.

In the process of cutting, the different types of wear rarely occur separately, they usually occur simultaneously, one type or another of wear having a preponderance depending on the cutting conditions. These conditions are mainly the type of pairing of the material of workpiece and tool, the speed and cutting temperature, as shown schematically in the principle diagram in fig. 2.

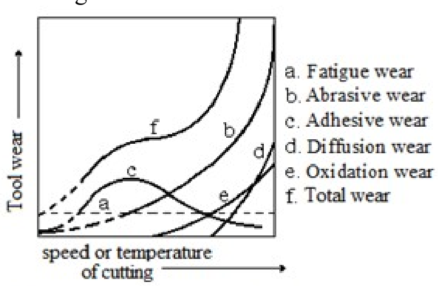


Figure 2 The influence of partial wears on total wear

A crater of dimensions *a x KB* appears on the rake surface of the tool at a distance *f* from the cutting edge and a depth *KT*. The dimension a is, with a very good approximation, equal to the width of the chip detached in the cutting process.

The characteristic dimension of the crater is its depth, *KT*, and its evolution over time is relatively rapid in the first moments of the cutting process, after which it becomes almost constant (it stabilizes).

The wear of the tool rake surface is favorable to the cutting process, leading to an increase in the rake angle from the value γ to the value γ', contributing to the reduction of the cutting effort, to a more convenient guidance of the chip, more as its characteristic size, *KT*, is stabilizes.

The *f* facet has the role of vibration damping. A disadvantage, of lesser importance, can also be mentioned, namely the reduction of the caloric capacity of the cutting edge, respectively the susceptibility of its excessive heating, but the reduction of the energy load of the cutting edge due to the reduction of the cutting effort have to also be taken into account. On the flank face, a wear facet appears on an edge length corresponding to the chip width and whose characteristic width is noted by *VB*, fig. 3.

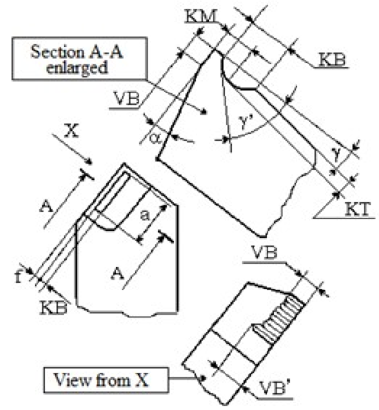


Figure 3 Cutting tool edge wear

On the wear facet, the flank angle is null, a value unfavorable to the cutting process.

In operation, three distinct zones with different evolutions of the VB dimension value are observed. A first zone characterized by a rapid increase of the VB dimension value in the first moments of cutting, a period in which running-in wear occurs. This is followed by a zone corresponding to a period of time in which the VB dimension value increases relatively slowly, called the state wear region, after which a very rapid increase in the VB dimension occurs until the total loss of the cutting capacity of the tool edge, during which catastrophic wear occurs.

The wear of the rake face, faster in the first moments of the cutting process, stabilizes over time, while the wear of the flank face evolves continuously and leads to the loss of the cutting capacity of the tool cutting edge. Therefore, as a criterion for assessing the wear of the active part of a tool was chosen the medium width of the wear facet, *VB*, as its medium value on the cutting edge length, excluding the maximum value *VB'*, fig.3. The *VB'* value does not characterize the real wear of the tool cutting edge.

It is usual to represent the evolution of tool edge wear *VB* in wear-time coordinates, the influence of other factors such as cutting speed *v* or feed rate s being presented through families of curves, fig.4, called wear characteristics.

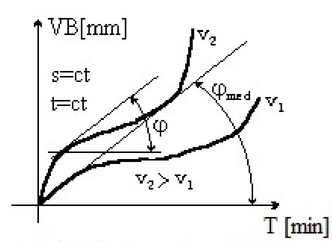


Figure 4 Wear characteristics

The following elements are defined on a given wear characteristic:

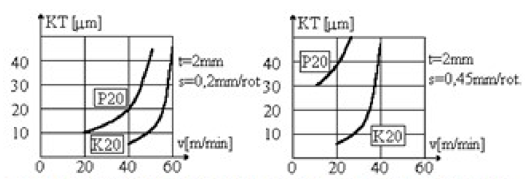
- wear rate, *I*, as the value of the inclination of the characteristic in a certain point, $I = tg\varphi$;

- medium wear rate, I_{med}, as the value of the slope of a line passing through the origin and tangent to the wear characteristic, $I_{med} = tg\varphi_{med}$.

3. THE INFLUENCE OF VARIOUS FACTORS ON CUTTING TOOL WEAR

Researching the cutting tool wear depending on the elements of the cutting regime is an activity that consumes a lot of time and materials (semi-finished products, tools).

For example, the experimental drawing of a single wear curve of the type of those figure 4 assumes cutting for a duration of tens of minutes. In this time, the process is periodically interrupted to measure the wear of the tool edge (a measurement can last 1...3 minutes). Also added is a consumption of about 1...10kg of semi-finished product and the consumption of a tool edge, unusable further without resharpening (with geometry, roughness, metallographic structure identical to the previous edge) or replacement.



cutting material:x5NiCrTi26 15 hardened, cutting time 15 minutes

Figure 5 Wear on the rake face of the cutting tool

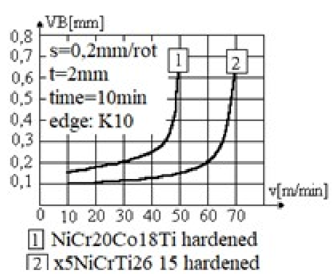


Figure 6 The influence of cutting speed on tool edge wear VB

A complete study, only for a single pair of workpiece-tool materials, involves drawing at least 10 wear diagrams. So, this clearly shows the great effort that have to be made for this.

The cutting speed has the greatest influence on the characteristic dimensions of wear, as shown in the diagrams in Fig. 5 and 6.

Experimental laboratory research as well as the practice of using cutting tools have highlighted the fact that among the elements of the cutting regime, speed has the greatest influence on the wear rate and tool life of cutting tools. The mathematical expression of the functional link (Taylor's equation), still accepted today has the form:

$$VT^n = C \quad (1)$$

where n and C are constants, whose values depend on cutting conditions, work and tool material properties, and tool geometry; T is tool life of tool; V is cutting speed. These constants are well tabulated and easily available.

The equation 1 is approximate over large domains of values of the variables t (cutting depth), s (cutting feed), v (cutting speed) but has the merit of establishing a functional link between the tool life value and the values of the cutting regime parameters.

Research carried out by the German engineer Carl Salomon has shown that at very high speeds there is an obvious decrease in the cutting temperature, resulting in a corresponding reduction in wear and an increase in the durability of the tool edge [2]. Carl Salomon came to the conclusion that, depending on the material of the part, from a certain value of the cutting speed upwards, there is no longer an increase in the cutting temperature, even a very significant decrease of this temperature appears, fig. 7.

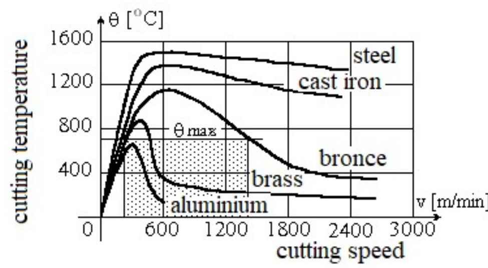


Figure 7 Influence of cutting speed on cutting temperature for different materials

4. EXPERIMENTAL RESULTS ON TOOL EDGE WEAR

Researching the wear process is a very laborious and long-term operation (months or years) which, as a rule, is carried out when assimilating into manufacturing of new types of tools or tool materials. The results of the experimental research are similar regarding the qualitative evolution of wear, the differences consisting in the concrete values that appear in various cases.

For the research, a normal lathe adapted for continuous speed variation was used with the possibility of permanent display of the effective speed and its rapid adjustment during work, in order to maintain a certain cutting speed constant. Wear measurement on the flank face (VB) was done with a universal microscope using auxiliary devices for

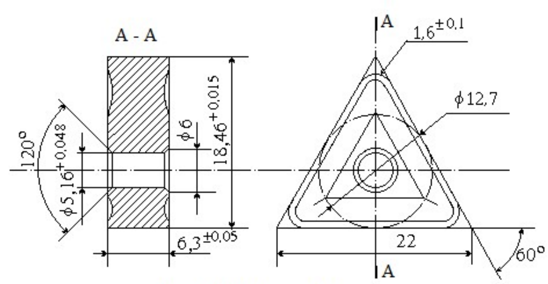


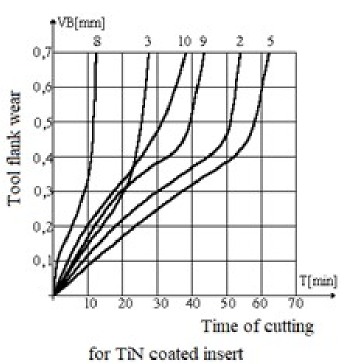
Figure 8 Interchangeable insert Material groups P and K

orienting and fixing the insert, and on the rake face, *KT*, using a spherical comparator.

The edge of cutting tool variants investigated correspond to the types of inserts shown in fig. 8. Because the respective inserts were to be used for machining steels alloyed with chromium, nickel, molybdenum and for gray or malleable cast iron, were analyzed the materials currently used from the point of view of chemical composition and hardness during the machining phase with the respective inserts. The 8550 steel was chosen for the research.

The experimental program, as the number of samples and as the values of the cutting regime parameters for each sample, was established based on statistical methods of data processing and experimental planning. Having three independent parameters (speed, feed, depth) and giving values each one results in a large number of experiments for a sample. Reducing the number of experiments and maintaining their accuracy is done through the planning method. Having three independent parameters (speed, feed, depth) and giving values each one results in a large number of experiments for a sample. Reducing the number of experiments and maintaining their accuracy is done through the planning method. For each interchangeable insert, as type and use group, an experimental research program consisting of 12 samples was established, from which six samples were selected.

The data collected during the experiments were synthesized in wear diagrams $VB = f(T)$ for different working conditions, diagrams like those shown in figure 10. It can be observed that the shape of the curves $VB = f(T)$ in almost all cases is normal, but especially in machining with speeds and feeds cutting lower (samples 5). In general, when the VB wear reaches values within the limits of 0.3…0.4mm, the allure of the curves takes on the form corresponding to catastrophic wear, characterized by its sudden increase in a very short cutting time. This behavior can be explained by the fact that, within the limits of the mentioned wear, the extra-hard layer resulting through the coating is exceeded and the base



for TiN coated insert

Sample	v[m/min]	s[mm/rot]	t[mm]
2	350	0,16	0,5
3	275	0,315	0,5
5	275	0,16	1
8	350	0,315	1
9,10	310	0,224	0,7

Figure 9 VB wear of TNGG22 04 12/P10 at 8550/197HB steel cutting

plate material is reached, which no longer withstands the high cutting speeds with which it was worked.

With the data from figure 9 the dependence curve of the medium wear intensity, I_{med}, as a function of the cutting speed can be drawn, figure 10. The values of the medium wear rate: *a*, *b*, *c*, *d*, *e* are results from the experiments presented in figure 10 [1], [3].

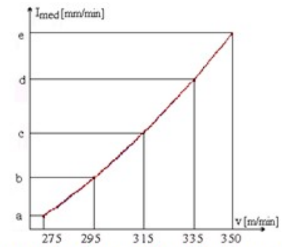


Figure 10 Variation of medium wear rate with cutting speed

5. CONCLUSION

With the experimental data from this study, groups of values such as feed, depth, speed and durability corresponding to a certain practical permissible of wear cutting tool value were determined, in order to be able to optimize in practice the values of the cutting regime parameters so as to ensure a imposed durability and wear of cutting tool.

The fact that there are continuous wear curves over time allows the study of its evolution and not only of moments when the maximum allowable wear was obtained.

The elements that contribute to realization of the cutting process have smaller or larger influences on tool wear and therefore on their durability. Analyzing the influence of the same elements of the cutting regime on the tool cutting edge temperature, a similarity of the shape of the curves with those regarding their influence on the wear rate is noted.

Comparative analysis leads to the conclusion that the variation of the medium wear rate depending on the elements of the cutting regime is similar to the variation of the tool edge temperature depending on the same elements of the cutting regime.

Experimental laboratory research as well as the practice of using cutting tools have highlighted the fact that among the elements of the cutting regime, speed has the greatest impact on the wear rate and tool life of cutting tools.

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