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OPTICAL DEVICE FOR THE STUDY OF THE TURNING TOOL WEAR

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Abstract. There are different modalities to study the evolution of the tool wear. In the laboratory of machine manufacturing technology from the Technical University "Gh. Asachi" of Iaşi, an optical device for the study of the turning tool wear evolution was designed and built. A microscopic tube is placed so that the flank wear land could be measured. The experimental researches proved the possibility to use this optical device.

1. Introduction

The concept of *tool wear* refers to the phenomenon by which the tool looses gradually its cutting properties, in different ways and as consequence of the influence exerted by different factors. Other definition shows [2] that the tool wear describes the gradual failure of cutting tools due to regular operation.

In a direct correlation with the tool wear, we could mention the concept of the *tool life*; this concerns the time in which the tools works in conditions accepted as normal, between two successive resharpenings of the tool.

The main effects of the tool wear are the affecting the machining accuracy, the increasing of the roughness characterizing the machined surface, an increased mechanical and energetic solicitation of the technologic system etc. There are many factors able to generate the tool wear: the friction among the active surfaces of the tool, the chips and the workpiece, the increasing the temperature due to the heat generated by friction, by the deformations specific to the cutting process, the micro-shocks exerted by different factors (the variation of the cutting force, of the machining allowance, of the material hardness, the chips fragmenting etc.), the structural changes of the tool material as consequence of the temperature increasing, the diffusion and adherence phenomena between the tool and workpiece material, certain chemical reactions at the level of the tool active surfaces etc.

There are various modalities in which the tool wear appears and develops: flank wear, notch wear, crater wear, edge rounding, edge chipping, edge cracking, thermal deformation, catastrophic (or severe or ultimate) failure etc.

Even at the first studies in the field of metals cutting, the tool wear was an object of the researchers' preoccupations.

Along the time, different mathematical relations were proposed to model the tool wear [1, 2, 3, 7].

Of course, one of the first such models was proposed by Frederick Taylor, in a book published at the beginning of the twentieth century (Taylor, F.W., 1906, On The Art of Cutting Metals, Transactions, American Society of Mechanical Engineers).

Other research area where the tool wear has a special importance is the materials machinability; we know that one of the most used criteria for the machinability evaluation is the tool wear. Indeed, the more accelerated the tool wear is, the more reduced the machinability of the analyzed material is.

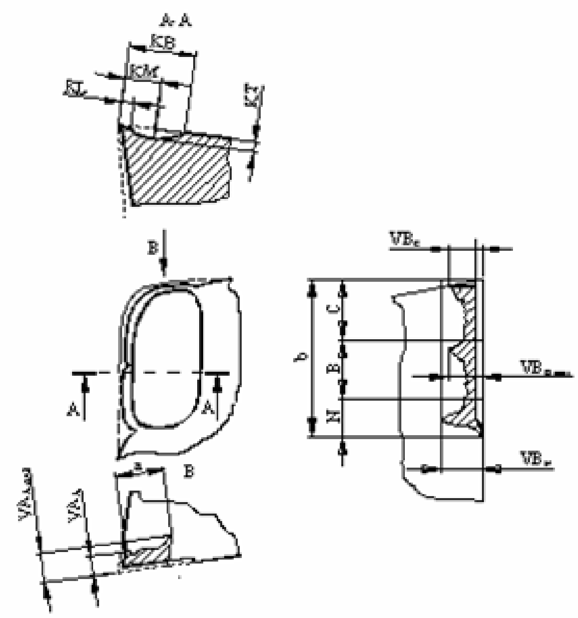

Fig. 1. Dimensions characterizing the lathe tool wear [6]

2. Specific requirements

In accordance with the settlements included in standards [6], there are many possibilities to evaluate the tool wear. In figure 1 we can see some modalities in which the tool wear appears and develops. To characterize the turning tool wear, the main parameters are the following: VB_B – width of major flank wear land (flank wear bandwidth), VB_A - the wear width on the secondary flank, *KT* –the crater depth, *KB* – crater wear width, *KM* – crater center distance, *b* – the length of the wear land on the major flank, VB_{med} and VB_{max} – the average and the maximum major wear land size, VA_{med} and VA_{max} – the average and maximum secondary flank wear land size VB_c – themaximum wear of nose radius, VB_N – notch wear etc.

Taking into consideration such parameters for tool wear characterization, different apparata were designed and used.

We could remark that there are methods which permit the tool wear evaluation without the cutting tool interruption and methods in which the cutting process must be stopped, to measure the wear affecting the active zone of the cutting tool. For the last case, usually optical devices are used [3, 4].

2. Device for measuring the turning tool wear

Some researches concerning the steels and irons machinability were made in the laboratory of machine manufacturing technology from the Technical University „Gh. Asachi” of Iaşi; within these researches, a device for measuring the turning tool wear was designed and built.

The device (fig. 2 and fig. 3) could be assembled on the lathe tool holder slide *2* by means of the basis plate *1* and some screws *3*, nuts *4* and washers *5*. We could mention that the screws 3, the nuts *4* and the washers *5* are not parts of the device; they are currently used to clamp the guide of the tool holder slide on the transversal slide 6 of the lathe.

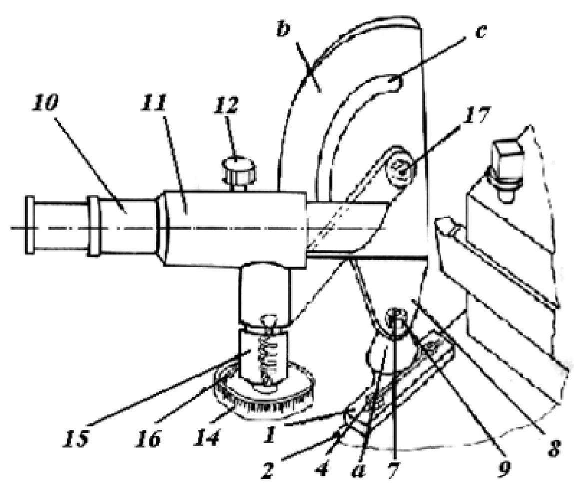

Fig. 2. Front view of the optical device for the study of the lathe tool wear

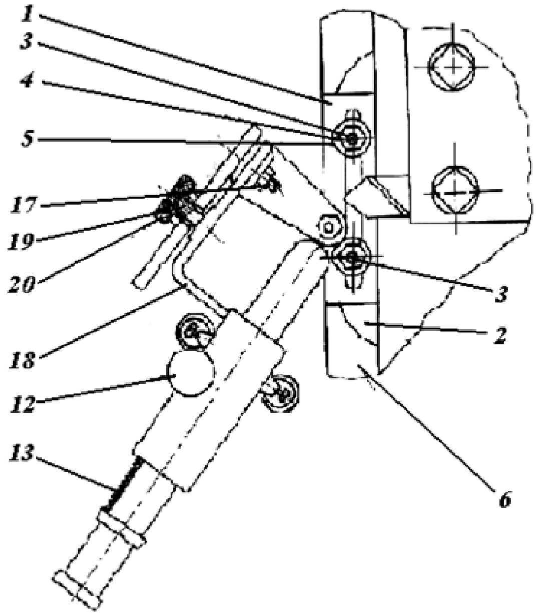

Fig. 3. Plan view of the optical device for the study of the lathe tool wear

The pin *7* is welded to the basis plate *1*; we can rotate the device body *8* round of the pin *7*, by the using of the conical piece *a*. To clamp the device body *8* in a certain position, the nut *9* is used.

The microscopic tube *10* is clamped in a sleeve *11*, in which it can be moved along its axis, by the using of the gear 12 – rack *13* mechanism. To achieve also the motion perpendicular on the microscope axis, the screw *14* is used; the microscope tube was taken from a machine for fatigue testing type Amsler. The indicator needle *16* permits to control the motion of the microscope tube 10. The sleeve *11* can be rotated round of the bolt *17*, welded to the frame *b* of the device body *8*. The rotation is possible by means of the arm *18*.

To fix the arm *18* in an established position, the screwed stop pin *19* is used. The screwed stop pin *18* can be moved along of the groove *c*, existing in the frame *b* and having a circle arc shape.

To establish the width *h* of the flank wear band, firstly the tool holder must be rotated with 180 degrees, in comparison with its normal work position; the device body *8* should be also rotated in horizontal plane, so that the microscope axis to be in the plane perpendicularly on the tool main flank. The arm *18* is fixed by means of the pin *19* and the nut *20*.

Afterwards, the tool holder is placed in a normal work position and the cutting process could be developed for an established duration. To evaluate the wear on the side flank, after the stopping the cutting process, the tool holder is rotated until the tool corner arrives along the axis of the microscope tube.

By the rotating the shaft including the gear *12*, we can obtain a clear image of the tool corner. To valuate the tool wear, the microscope tube *13* is moved on the vertical direction, following the superposition of the horizontal line from the microscope eyepiece on the limits of the tool flank wear.

If previously a mark was traced on the tool flank, the tool wear band size could be evaluated. When the metal carbide tips are used for the tool active part, as measuring base just the tip limit could be used. Initially, we thought to use the device for measuring yet the width of the crater generated on the flank face, but supplementary control activities makes difficult this action.

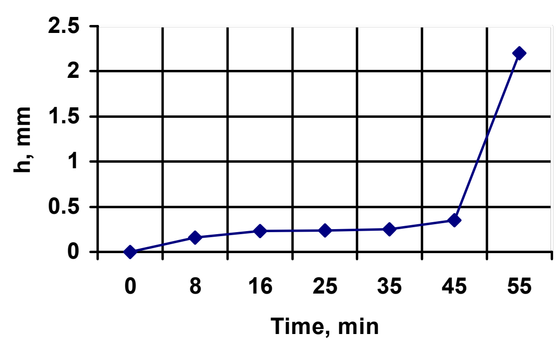

Fig. 4. Evolution of the tool side flank wear in the case of turning a workpiece made of stainless steel (tool of rapid steel Rp 2; α=8°, γ=12°, λ=-4 °, κ=70°, κ_1=10 °, r_ε=0.5 mm)

To obtain an information about the precision of the device, we made 15 measurements of the same tool side flank wear band (wear generated by cutting a workpiece of steel containing 0.45 % carbon, the work parameters being v=95 m/min, a_p =2.5 mm, f=0.1 mm/rev. The tool wear average size was $\bar{x}$=0.3046, and the mean square deviation was s=0.0092. By the using of the Student criterion, we can mention that the interval (0.2996, 0.3096) will contain the true size of the tool wear with the precision of 95 %.

3. Experimental remarks

By the using of the device previously mentioned, we made different experimental tests. We measured the tool side flank wear after established cutting durations; thus, we succeeded to elaborate diagrams similar to that presented in figure 4.

If we limit the size of the tool side flank wear band at a recommended size, we can estimate the tool life. Afterwards, by modifying the sizes of the work parameters and by the using a specialized software to process the experimental results, we established some experimental relations type Taylor.

Such an empirical model (valid in the case of the steel containing 0.4 % carbon and 13 % chromium) is the following:

$$v = \frac{45.28}{T^{0.23} a_p^{0.21} f^{0.402}} \tag{1}$$

where T is the tool life, min, a_p – the depth of cut, mm, f – feed, mm/rev.

Generally speaking, we can remark an important dispersion of the experimental results; although the image could be very clear in the microscope eyepiece, the flank wear band presents a variable width and distinct persons could evaluate in different manners the size of the flank wear.

4. Conclusions

The evolution of the tool wear could be made by means of different devices and apparata. In the laboratory of machine manufacturing technology from the Technical University "Gh. Asachi" of Iaşi, an optical device was designed and built to evaluate the tool flank wear. The experimental tests proved the possibilities to use the device for measuring the tool flank wear. In the future, we intend to use a video camera instead the microscope tube, to take concrete images concerning the tool wear evolution.

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