Cutting Temperature Study And Temperature Distribution in the Cutting Wedge

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ABSTRACT

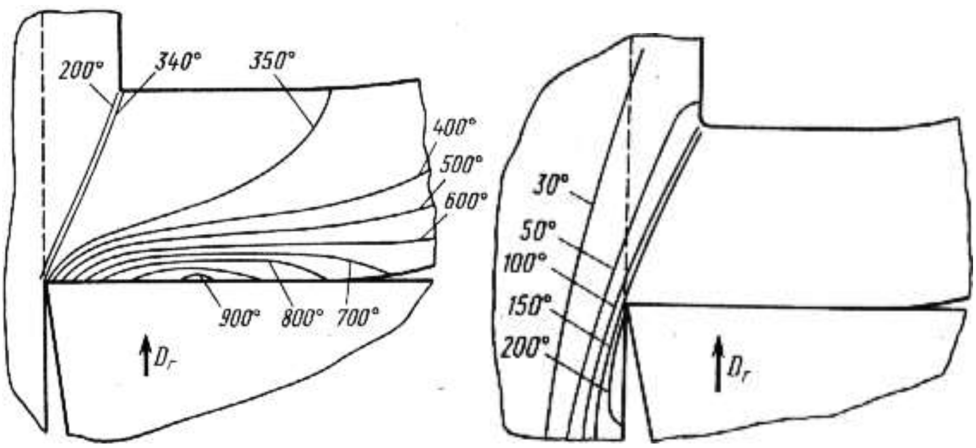
The article presents an analysis of the durability of the cutting tool depending on the temperature of the working surfaces of the tool.

Keywords: workpiece, cutting wedge, front surface, cutter, temperature, cutting tool, durability

In the research work, the calculation of temperatures will be carried out by the finite element method using computer technology.

A special computer program calculates the temperature and stresses at the center of each element. The calculation is performed repeatedly, in each subsequent series of calculations the data from the previous calculation is used, as a result of which the accuracy increases.

At the end of the calculation, points with the same temperature values are connected by a line and isotherms are obtained, which are shown in Fig. 1. The smaller the size of the elements and the greater the number of series of calculations, the higher the accuracy of the calculation, but the more time is required for the calculation. If there are reliable experimental data at some points of the tool or workpiece, the accuracy of the calculation also increases.



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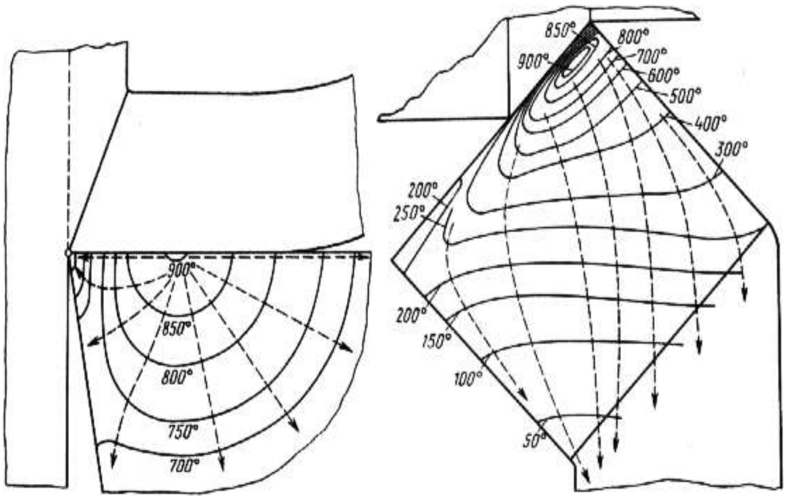

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Rice. Fig. 1. Temperature distribution in the chip (a), workpiece (b), cutting wedge (c) and on the front surface of the cutter (d) when cutting steel 45 with a cutter made of T15K6. V=150 m/min, S=0.3 mm/rev, γ=0o, α=10o, υ=45o.

On fig. 1. shows the temperature distribution in the chip, workpiece and turning tool, obtained by the finite element method according to the thermal imager and artificial thermocouples. The highest temperature on the surface of the cutter is observed not at the cutting edge, but at a small distance from it (Fig. 1, a, c, d). This confirms the version that heat does not immediately reach the cutting edge of the chip and the front surface of the tool from the middle part of the chip formation zone.

Among the numerous methods for determining the cutting temperature, four groups can be distinguished.

The first group includes methods by which only the average temperature of a chip, product or cutter is measured: the method of natural thermo-EMF, the calorimetric method.

The second group includes methods by which the temperature of narrowly limited sections of the cutting zone or cutter is measured, for example: the method of artificial thermocouples; optical and radiation methods.

The third group includes methods that allow you to immediately experimentally determine the temperature distribution in certain areas of the product or cutter (temperature fields): the tint color method, the thermal paint method.

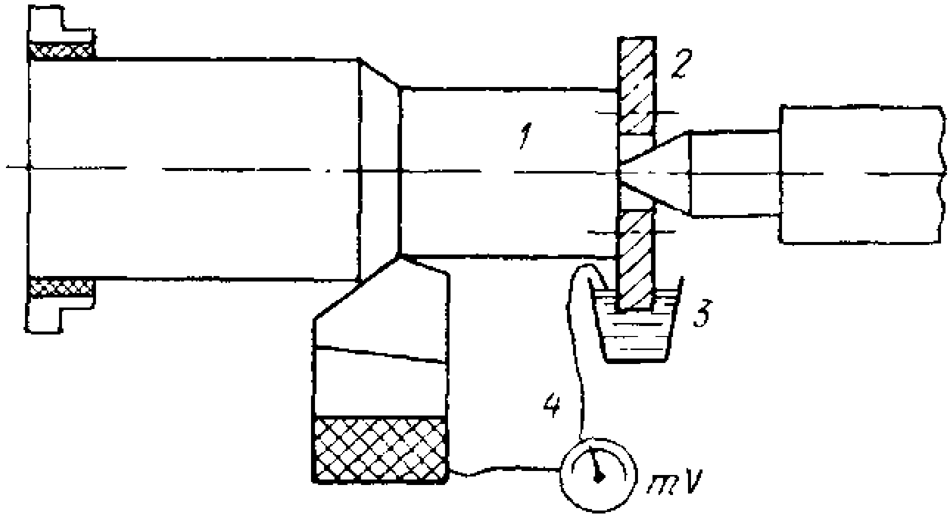
The fourth group includes computational and analog methods that require initial experimental data obtained directly during cutting.

The simplest way to determine the average temperature of the working surfaces of the tool (cutting temperature) is the method of natural thermo-EMF (electromotive force), which is based on the physical effect of the occurrence of a potential difference when the junction of dissimilar materials is heated.

The durability of the cutting tool largely depends on the temperature of the working surfaces of the tool, so much attention is paid to its study. When calculating strength, an increase in temperature causes not only a decrease in compressive, tensile, and shear strength (negative factors), but also a decrease in brittleness (due to an increase in plasticity), which reduces the likelihood of micro- and macrocracks [1,2]. When the temperature rises above 600 ºC, "self-healing" of the formed and emerging microcracks occurs, which favorably affects the strength of the tool.

The simplest and most easily implemented method for measuring the average cutting temperature is the method of natural thermo-EMF (Fig. 2).

With this method, the role of a natural thermocouple is played by the contact between the tool and the chip. In the process of cutting, at the point of contact of dissimilar materials of the product and the cutter, an electromotive force arises due to heating.



Rice. 2. Diagram of a natural thermocouple.

In this case, the thermal current is directed along the workpiece 1 through the copper ring 2, and then through mercury in the bath 3, which serves to contact the rotating ring 2 with the wire 4. In this case, the millivoltmeter will show the thermal current voltage, which can be used to judge the cutting temperature. The workpiece is isolated from the chuck and rear center, and the cutter from the caliper using dielectric spacers, such as plain paper.

To avoid the harmful effects of mercury, you can use a simple contact of a copper plate, which is attached to the wire on a millivoltmeter or microammeter, with the treated surface of the workpiece.

To study the influence of cutting conditions or tool geometry, it is enough to be able to know the data on changes in current or voltage. For quantitative analysis, it is necessary to calibrate the thermocouple material of the workpiece - material of the tool in the furnace.

A long bar (400-500 mm) from the material of the workpiece is welded at one end with a parallel bar of the same length from the tool material by argon welding. The bars are electrically isolated from each other (except for the place of welding), the place of welding is placed in the furnace. The opposite ends of the bars, taken out of the furnace, are connected by wires to a microammeter.

The temperature in the furnace rises as quickly as possible to 800-1200 ºC, while the current strength in the resulting thermocouple is measured. The higher the heating rate, the less oxidation of the welding site and the greater the reliability of the resulting calibration. It is especially difficult to obtain such an artificial thermocouple from a hard alloy, moreover, it oxidizes very quickly and turns into powder, therefore, after calibrating, it is necessary to immediately remove the rods from the furnace.

The temperature distribution in the cutting wedge can be obtained using a thermal imager by observing the side surface of the tool. Infrared radiation from the observed object is converted by the device into the spectrum visible to the human eye. This method can be most easily implemented with free turning of the disk. The main problem is that the observation area is very small - only 2-5 mm, which must be taken into account when choosing an instrument. It is desirable to have a range of measured temperatures from 300 to 1200 ºC.

In a cheaper and quite easily implemented way, it is possible to study temperature fields using heat-sensitive coatings (thermal paints) that are applied to the side surface of the cutter. Almost all heat-sensitive coatings record the highest temperature in a particular area due to a change in color. Of great importance is the fact that the speed of color transformations is very high (several tenths of a second), which allows the cutting to be carried out in the shortest possible time (usually 5-15 seconds to achieve a steady heat exchange). The coated side surface is examined on an instrumental microscope, the coordinates of the color transition lines are measured at the corresponding temperatures.

On fig. Figure 3 presents the results of Proskokov's study of measuring temperature fields on the surfaces of the SMP using four thermal indicator paints with different temperature transitions. As shown by these experiments, the temperature on the trailing surfaces along the cutting edge is variable. Temperature changes in the color of TIK thermal paint:

1) when the temperature reaches 155°C, the color of TIK thermal paint changes from magenta to blue;

2) when the temperature reaches 190 °C, the colors of TIK thermal paint change from white to green-brown;

3) when the temperature reaches up to 255°C, the color of TIK thermal paint changes from green to dark brown;

4) When the temperature reaches up to 305°C, the colors of TIK thermal paint change from yellow to red-brown;

5) When the temperature reaches up to 440°C, the color of TIK thermal paint changes from purple to white.

For a more complete comparative understanding of the temperature fields on the surfaces of the NSR, temperature isolines of 230°, 456°, 510°, 570° were shown on one model (Fig. 3). It can be seen from the figure that with decreasing temperature, the gradient of temperature change decreases.

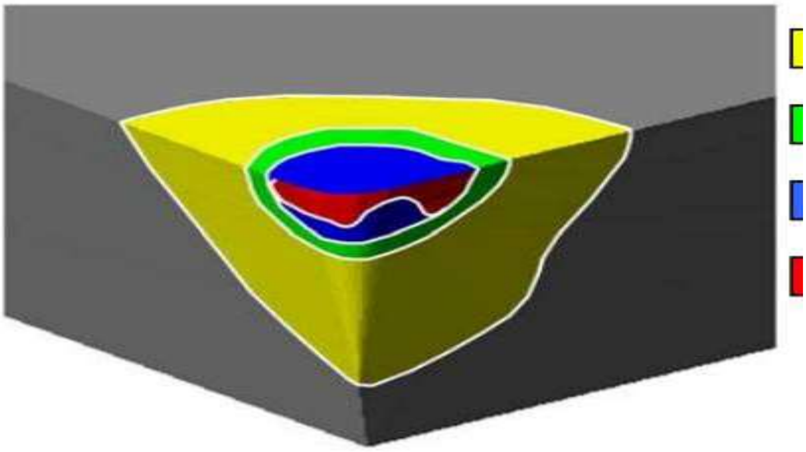
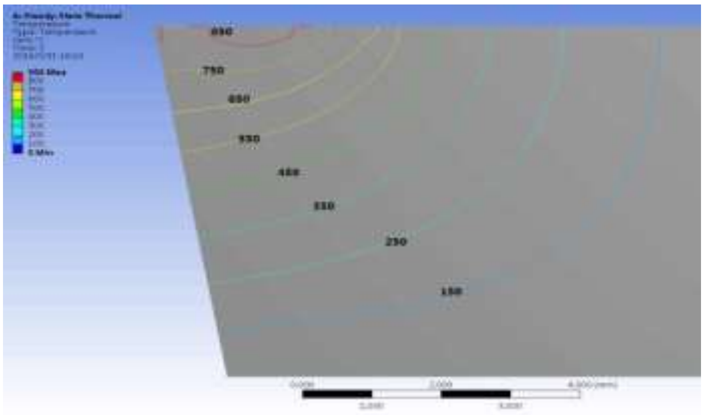


Fig.3. Experimental temperature distribution on the surfaces of the SMP.

Temperature distribution on the working surfaces of the tool

The cutting temperature when machining titanium alloys is higher than when machining steels by 100-200 ºC due to the low thermal conductivity of titanium alloys. From the experimental data obtained by V.N. Kozlov [3] when studying the temperature fields in the cutting wedge by the method of heat-sensitive coatings when turning titanium alloy VT3-1, we set the temperature on the working surfaces of the cutting insert. The results of calculating the temperature distribution using the ANSYS program are shown in fig. four.



Rice. Fig. 4. Temperature distribution in the cutting wedge obtained by calculation using the ANSYS program with a plate thickness h=6 mm. VT3-1 - VK8, γ=0°, v=1 m/s, s= 0.21 mm/rev, hz =0.2 mm

The results of the calculation are consistent with the results of studies of the temperature distribution during the turning of steel 45.

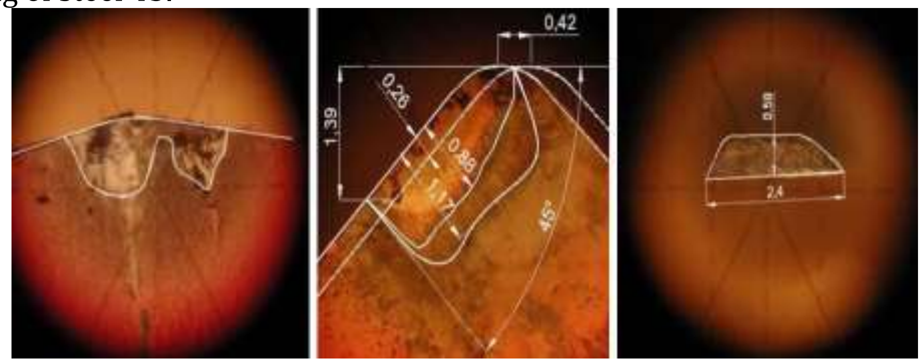


Fig.5. Isotherm of thermal indicator paint TIK No. 14 TU 6-09-79-76 with color transition temperature Tper = 570°C. Steel 45 - T5K10, υ=45˚, γ=0˚, α=10˚, r=0.8mm; V=160 m/min, t=1.3 mm, S=0.39 mm/rev.

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