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Research of the Contact Voltages Distribution on the Front and Back Surfaces of the Cutter

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Annotation. The methods for measuring contact stresses (loads) on the working surfaces of the tool are covered and analyzed in the article.

Keywords: model, polarization-optical method, interference method, cutter, plastiglass, tool, contact voltage**.**

Contact voltages (loads) on the working surfaces of the tool [1] can be measured by three methods: polarization-optical, interference, and the cutting tool method. Each of these methods has its own advantages and disadvantages.

The polarization-optical method can be used in the manufacture of a cutter from a polarization-active material, such as plastiglass or plexiglass, which changes its optical properties when the internal voltage changes. Such materials can only be used to cut soft material, such as lead, at low cutting speeds v to prevent softening of the plastic (usually $v \leq 5$ m/min). The low hardness and strength of such a tool material does not allow measuring contact loads in the processing of materials used in industry. When passing through a transparent flat cutter made of optically active material, polarized monochromatic light forms alternating bands on the screen due to light interference. The closer the bands are to each other, the greater the gradient of stress change, the more bands in the area under consideration, the greater the stress there.

The interference method allows measuring the internal stresses in the tool by the interference pattern of the fringes on the side surface of the tool due to its elastic deformation under the action of the cutting force. The internal stresses near the working surfaces of the tool determine the contact loads on these surfaces. The lateral surface of the tool should be at some distance from the point of contact of the material being processed with the tool, which introduces errors in the determination of the actual internal stresses, and hence the contact loads.

The split (composite) cutter method is devoid of this shortcoming, but requires the creation of highly rigid dynamometers.

To study the distribution of contact loads on the surfaces of the cutter, a very wide cutter (50–100 mm wide) is used, which cuts in such a way that the size x_i (Fig. 1), or η (Fig. 2) discretely changes from 0 to a value slightly greater than the length of contact with the chip with the front surface of the tool. To increase the strength and rigidity of the working plate A, stiffening ribs (2) are located on its rear surface.

The width of the disc should be 2…3 mm less than the distance *I* between the stiffening ribs of the plate A. When machining, the chips will have the same length of contact with the front surface of the cutter, no matter what section is machined. However, on different sections, the length of contact of the chip with the surface of the insert B will be different (Fig. 1).

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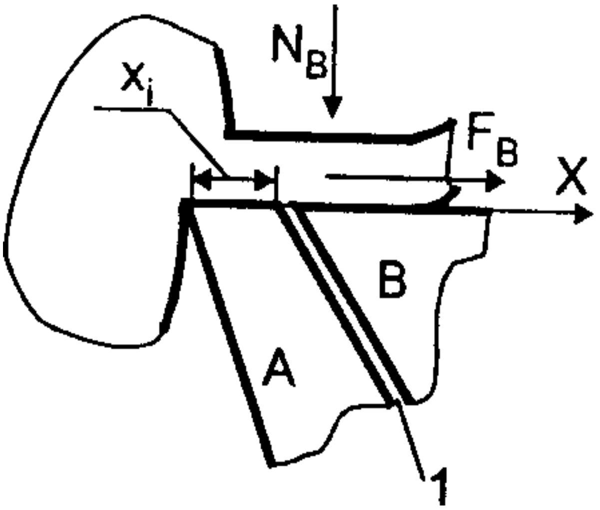

Fig. 1. Scheme explaining the principle of measuring with a cutter

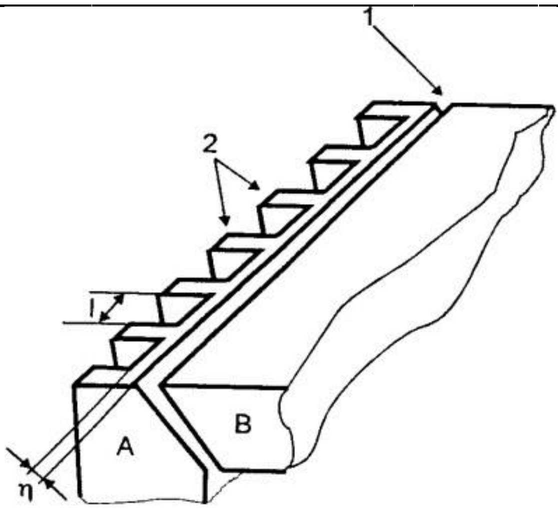

Fig. 2. Scheme of the arrangement of working plates of increased rigidity during the study by the method of a split cutter. 1 - gap between working plates A and B; 2 - stiffeners

Plate B is fixed on the upper belt of the dynamometer, which will take the load acting only on plate B. Based on the results of measuring the normal N_B and tangential F_B cutting forces in each section of the cutter, it is possible to calculate the normal σ_N and tangential τ_F contact loads using the formulas:

for normal voltages

$$\sigma_N(x) = \frac{1}{b_1}\frac{dN_B}{dx} \quad (1);$$

for tangential voltages

$$\tau_F(x) = \frac{1}{b_1}\frac{dF_B}{dx} \quad (2)$$

In formulas (1) and (2), b_1 is the chip width.

The smaller the difference $x_i = \eta$ of formulas (1) and (2) for neighboring sections, the higher the accuracy of research, but the greater their labor intensity.

The largest value of the normal contact load σ_N is observed at the cutting edge, with distance from which the load decreases, but there is a horizontal section in the middle part (Fig. 3).

The tangential contact load τF has a horizontal section at the cutting edge and in the middle part of the graph, indicating the plastic nature of the chip contact in this area.

The horizontal axis has a dimensionless scale (*x/c*) in order to show on one graph the results of experiments carried out with different cut thicknesses *a*, and, therefore, having different chip contact lengths with the tool front surface.

Using the split cutter method, we can also study the temperature distribution on the front surface of the tool if the plates are electrically isolated from the dynamometer.

The results of this study are presented in Fig. 3 at the top, and the temperature scale for this graph is shown on the right.

Similarly, research of the distribution of contact loads on the rear surface of the cutter are carried out. For a sharp, unworn cutter, the contact of the tool flank with the blank surface is too small to detect load changes. In this regard, the loads on the back surface of a sharp tool are considered negligible compared to the forces on the front surface.

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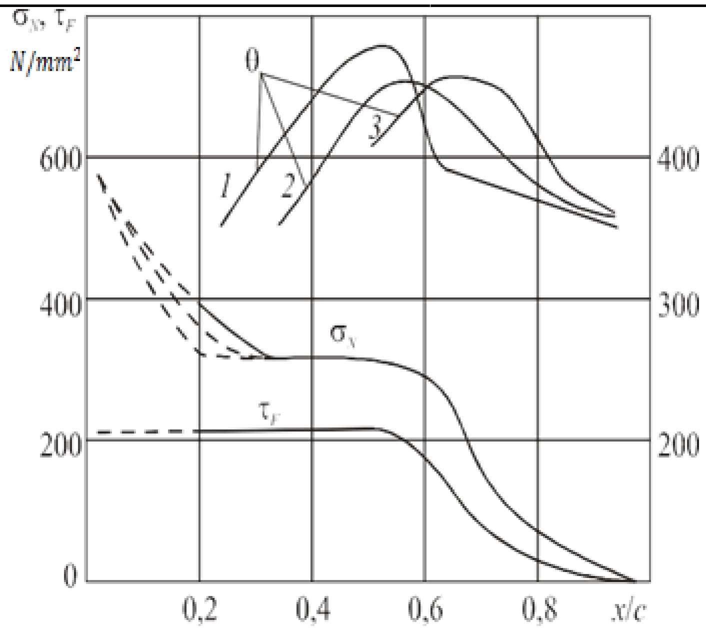

Fig.3. Distribution of contact loads and temperature on the front surface of the tool, obtained by the split cutter method. Steel 45 - VK8, rake angle γ=0º, cutting speed V=200 m/min; cut layer thickness: 1 – a=0.39 mm; 2 –a=0.2 mm; 3 – a=0.1 mm (Poletika M.F., Butenko V.A.).

However, as the tool wears, the wear face along the flank increases so much that the loads on it become comparable to the loads on the front surface, and sometimes even exceed them. Studies have shown that the nature of the distribution and the magnitude of the contact loads on the wear chamfer along the back surface are similar to the loads on the front surface.

A large value of normal contact loads leads to intense wear on the front and back surfaces, however, high temperature, as studies show, increases the wear rate much more.

Contact loads affect the internal stresses in the cutting edge and hence the safety margin of the tool. The margin of safety of the tool $K_{пр}$ is the ratio of the maximum allowable stresses $\sigma_в$ or $\sigma_{-в}$ from the point of view of the destruction of the tool material to the actual stresses $\sigma_д$ during processing: $K_{пр}= \sigma_{-в}/\sigma_д$. The lower the margin of safety, the more likely the local or general destruction of the tool [2].

It is believed that for the reliable operation of the tool $K_{пр} \geq 1.5 ... 1.8$. The greater the instability of the cutting forces, or, moreover, the presence of vibration, the greater should be $K_{пр}$. With a pulsating load, the safety margin is assessed not by statically determined maximum allowable stresses, but by fatigue stresses, which are 2 ... 3 times less than static ones, depending on the tool material.

Fig. 4 shows the results of an experimental determination of normal contact loads on the rear surface chamfer, performed by the split cutter method during free turning of L63 brass under confluent chip formation conditions. The extreme character of dependence is clearly revealed in all cases.

According to the authors, Poletika M.F. [1] and Kozlov V.N., [3] this is due to the deflection of the cutting surface under the action of the radial component of the cutting force $P_{y\ п.п.}$ acting on the front surface of the tool.

Research of the distribution of internal stresses in the cutting wedge.

When studying the stress state by the polarization-optical method, samples are used from a homogeneous, isotropic transparent material, for example, glass, celluloid, xylolite, phenolite and bakelite. Under the action of stresses, these materials become birefracting.

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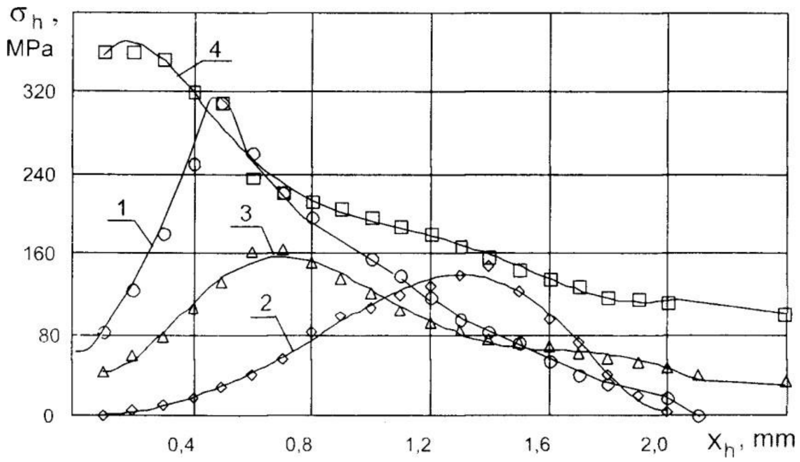

Fig. 4. Distribution of normal contact loads on the chamfer of the rear surface of the tool, γ = 0°, α_ϕ = 0°. L63-R6M5: 1 - S=0.06 mm/rev, V=100 m/min; 2 - S=0.21 mm/rev, V=100 m/min; 3 - S=0.21 mm/rev, V=217 m/min. 4 - 3LMtsA 57-3-1 - P6M5, S=0.41 mm/rev, V=100 m/min.

Research of the distribution of internal stresses in the cutting wedge

If a beam of polarized light is passed through a transparent model in a stressed state, a colored image is obtained, from which the stress distribution can be found (Fig. 5).

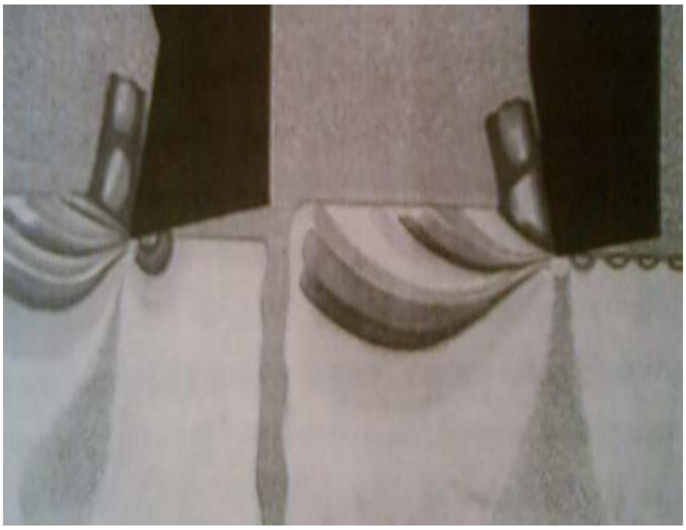

Fig. 5. Isochromes when cutting celluloid with cutters with different front angles.

The method of laser interferometry (Fig. 6) consists in the fact that a polarized monochromatic laser beam is directed to the side surface of the blank and tool. Monochromatic light is used to ensure that the light does not split into a spectrum, which reduces the clarity of the fringe patterns. The light reflected from the cutter and the blank hits the screen, where the interference of light waves (superposition) of the base and reflected radiation occurs.

During deformation, the side surface of the cutter and the blank broadens slightly and the distance to the laser decreases by hundredths and thousandths of a micrometer, which is reflected on the screen. The greater the deformation of the object of study, the greater the number of bands will be observed on the screen.

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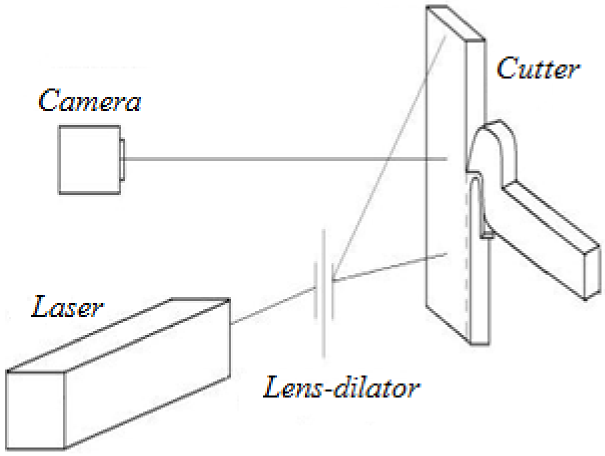

Fig. 6. Scheme of shooting speckle photography

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