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Analysis of Plastic Deformation of the Cut Layer

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Annotation. The article discusses cutting metals using a cutting tool under a complex physical process. The elastic - stressed state and deformations of the surface layer of the workpiece in the cutting zone are analyzed. The graphs and conclusions from the results obtained are presented.

Keywords: elastic and plastic deformation, shrinkage of chips, heat generation, build-up, work hardening, tool wear.

Introduction. Cutting metals is a complex physical process in which elastic and plastic deformations occur. The cutting process is accompanied by friction, heat generation, build-up, shrinkage of chips, work hardening of the machined surface and tool wear [1,2].

Methods and object of research. At the initial moment, when the moving cutter under the action of the force P comes into contact with the metal. Under the action of force, the cutter is pressed into the metal, elastic deformations appear in the cut layer, which transform into plastic deformations with further movement of the cutter (Fig. 1, a).

Plastic deformation consists in the shear of some layers relative to others along the so-called slip planes, which basically coincides with the direction of the greatest shear stresses. Such shifts are observed between individual particles of a crystal grain and the grains themselves [3,4].

Let us analyze the complex elastic stress state of the workpiece material near the cutter, where tangential τx and normal stresses σy arise. The greatest tangential stresses are at the tip of the cutter A, decreasing to zero with distance from it.

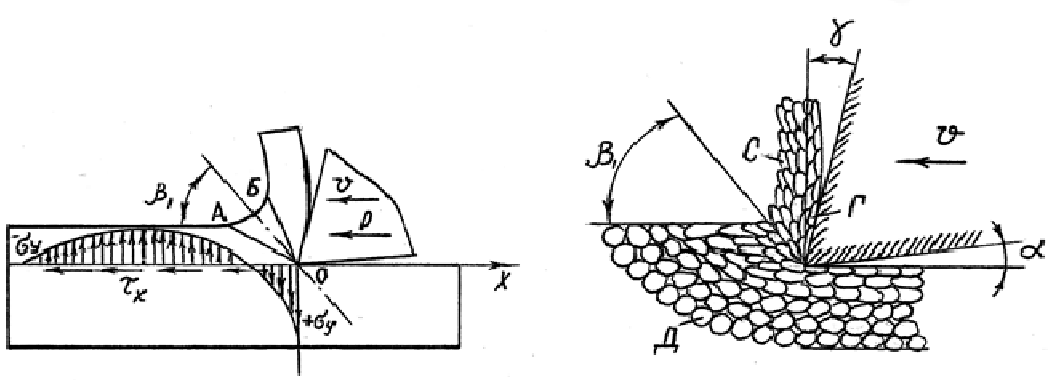
Normal stresses σy at the tip of the cutter are tensile ($+ \sigma y$) and at point O have the greatest value. Under certain conditions, this causes a tear in the metal in the cutting zone and a leading crack appears. Moving away from the top, σy decreases and, passing through zero, turns into a compressive stress ($- \sigma y$).

Under the action of normal and tangential stresses, the sheared layer is plastically deformed. The maximum plastic deformation occurs in the OAB chip formation zone and its result is shear deformations in the cut layer. They cause the sliding of individual parts of the grains along the crystallographic planes and stretch the grains [5, 6].

The circles (D) denote the undeformed grains of the processed metal (Fig. 1, b). The grains in the cutting zone are deformed by the cutter and take an elongated shape (D). By the time of destruction, these grains are additionally deformed by friction against the front surface of the cutter, the grains are stretched even more (C).

Rice. 1. Elastic - stress state (a) and deformations of the surface layer of the workpiece (b) in the cutting zone

At this moment, elastic deformations turn into plastic ones, which end in the destruction of the cut layer. The study of the microstructure of the chips and the surface layer of the processed surface of the workpiece showed that their



microstructure changes in comparison with the original microstructure of the workpiece [7].

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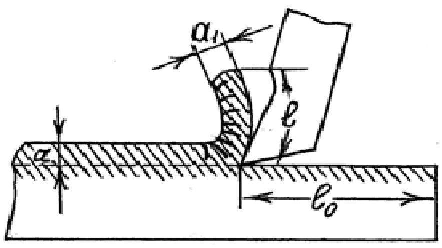
Results. The analyzes carried out showed that the cutting tool moving under the action of the force P deforms the surface of the workpiece. At the moment of the greatest deformation, the workpiece is sheared off in the direction of the plane OA, forming a chip element. It makes an angle β1 with the tangent to the cutting surface, after cleavage of the first chip element, the cutting tool deforms the next metal layer with its front surface, as a result of which a second element is formed, which is separated from the bulk of the metal along the plane of maximum tangential stresses at the same angle β1.

The sliding plane is a plane in the direction of which a relative shift of the metal layer occurs during its plastic deformation before separating the chips from the bulk of the metal along the shear plane [8]. As a result of elastoplastic deformation, the size of the chips changes, in the cutting zone the length of the chips l0 turns out to be less than the length of the cut layer l, the thickness of the chips a1 is greater than the thickness of the cut layer a (Fig. 2).



Rice. 2. Plastic deformation of the metal layer prior to separation of the chip element.

Based on this, we will build a graph of the compression process of a metal layer during its plastic deformation. It can be seen from the graph that initially the cutting tool subjects the cut layer to elastoplastic deformation to point O. Then a chip element is formed up to point A, after cleaving the first chip element, the cutting tool deforms the next metal layer, as a result of which a second chip element is formed from point A to point B (Fig. 3).

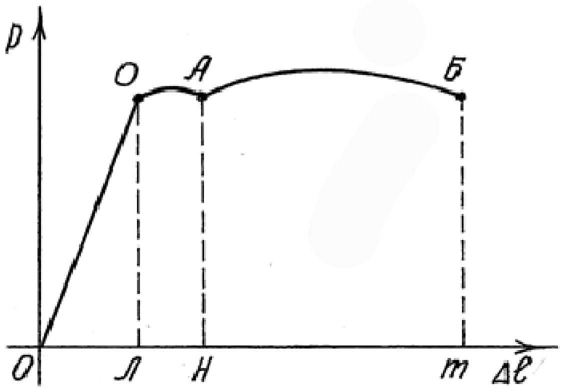


Fig. 3. Graph of the compression process of a metal layer during its plastic deformation

Conclusions. Analyzing the results obtained, we present the following conclusions:

- in the process of forming a chip element, the cutting force increases;
- the less the shrinkage of the shavings, the less plastic deformation;
- by decreasing the rake angle γ, the shrinkage of the chips increases;
- an increase in the thickness of the cut layer will lead to a decrease in the shrinkage of the chips.

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