METHODS OF PRELIMINARY LOCAL PHYSICAL ACTION ON THE WORKABLE SURFACE OF THE BLANK

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Abstract. Theoretical and experimental studies of the behaviour of the technological system of machine tool with the cutting-edge machining of blank with the local action are given. In the research paper one of the most effective methods is proposed, which makes it possible to reliably control the process of continuous chip breaking; the creation of preliminary local plastic action (LPA) and local thermal action (LTA) on the external surface of the cut off layer appears, produced according to the specific laws.

Key words: cutting, chip breaking, local plastic and thermal action, mechanical engineering.

Introduction

Machining blanks by cutting is one of the main methods of forming in the field of mechanical engineering. The process of cutting is one of the complex physical processes, with which appear elastic and plastic deformations; this process is accompanied by large friction, heat emission, built-up edge formation, curling and shrinkage chips, by an increase in the hardness of those deformed it is layer metal and by the wear of cutting tool.

At present in mechanical engineering with machining of articles made of corrosion-resistant high-temperature (strength) steels and alloys essential difficulties in connection with the formation of continuous chip encounter, which lead to ineffective operation of the highly productive automated technological equipment. One of the most effective methods, which makes possible to reliably control the process of continuous chip breaking, is the method of preliminary local-action plastic deformation. The application of this method consists in the fact that the surface layers of metal, contacting with the hard metal tool, as a result of pressure, are in a state of comprehensive compression and undergo plastic deformation. Because of this, the pressure under the tool is formed only in the contact area, creating internal structural changes in the zone of preliminary local action on the blank surface.

Subjecting the workable material to local preliminary physical action [5], and then, accomplishing the cutting off this surface layer, it is necessary to ensure a greater depth of cutting than the depth of the action itself. The non-observance of this condition will lead to two undesirable consequences:

- the processed surface will have local zones with other physical-mechanical properties than the material of billet, thus negatively affecting the performance properties of the detail;
- the service period of the cutter will be lowered considerably, since its edge is subjected to periodic impacts during the working process.

From other side, significant exceeding of the depth of cutting relative to the depth of local physical action will not give the expected effect on chip breaking.

The area of continuous chip breaking. under the local physical impact functionally depends on many factors – the depth of action and brand of workable material, and also the regimes of cutting with the subsequent treatment.

Research object and methods of LPA

The preliminary local physical action produced on the external surface of the cut off layer in accordance with the specific laws enables to change the conditions of metal deformation by cutting [1, 2]. Alternations in the conditions of cutting, in comparison with the source material, form the specific features of the grinding process of the billets, subjected to this action. Physical action on the surface of material in the local zone leads to changes of structure and mechanical properties of the workable metal in this zone.

In the working process the zone of local action, being in the metastable state in comparison to the base metal, leads to an instantaneous change of the stress-strained state in the zone of chip formation [2].

The local metastability, created in the area of predetermined stock removal of the cut-off material layer on the billet external surface along the specially predetermined trajectory by the point *C* (Fig. 1, a), which in the preparation stage is formed with the frequency of the rotation of blank n_m and with the device feed S_m for the creation LPA, takes effect on the rheological parameters of the process of chip formation [1, 2].

Physical action on the surface of material in the local zone leads to a change in the density of the defects of crystal lattice, forming high-energy configurations and leading to the origination of increased metastability of structure in this locality. Subsequently with cutting-edge mechanical processing by the billet rotation frequency n_p and the feed $S_{m,}$ the tool's cutting edge in the cutting plane intersects at point *C* with the zone of the local physical action (Fig. 1, b). The zone of local action ($h_m \times b_m$) with distorted crystal lattice, which has other mechanical properties in comparison with the basic material, leads to an instantaneous change of the stress-strained state in the zone of chip formation (Fig. 2).

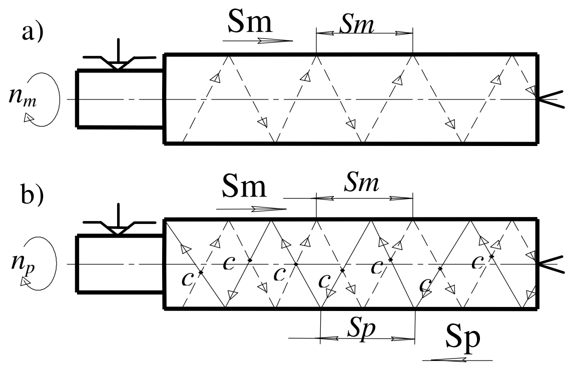

Fig. 1. **Diagram of creation of local metastability in the workable material (a) and the blank turning process after preliminary plastic effect on the material (b)**

Theoretical results of LPA

In the zone of preliminary local action internal structural changes occur on the billet surface. It is known [3] that the plastic surface deformation in the local zone of the not heat-treated metal already at a temperature of $T = +20$ °C leads to a change in the structure and properties of material. Deformation is accompanied by origination, slip and accumulation of dislocations in the metal being deformed. With an increase in the dislocation density and imperfections of crystalline structure free displacement of dislocations is hindered.

Additional barriers for the dislocations are created due to the grain deformation and splitting of blocks. An increase in the quantity of point and linear defects of structure and volumes with the incoherent connection of crystals increases strength and hardness of material and decreases its plasticity (i.e. capability for further deformation). Because of this, the work hardening along the predetermined trajectory on the external surface of billet is formed in the local zone of working by plastic deformation.

With the compression in the local working zone in the point of contact within each grain many intersected strips of shift in several parallel slip planes are formed. In this case the turning of the disorderly oriented grains by the axes of the greatest strength along the direction of deformation occurs – grains are deformed and flattened, being drawn out in the direction of deformation. The metal under the action of tool in the local zone forms the deformation texture of fibrous nature with predominant crystal orientation.

The specific volume of the strain-hardened metal because of the increased quantity of defects of atomic-crystalline structure is greater than that of the annealed; therefore beside the increase in hardness and yield point of metal, in the surface layer of metal in the zone of local plastic action residual stresses are created. Increase in the number of defects of crystalline structure and formation of internal stresses as a result of work hardening leads to the growth of free energy in metal, and this in turn creates the non-equilibrium and unsteady state.

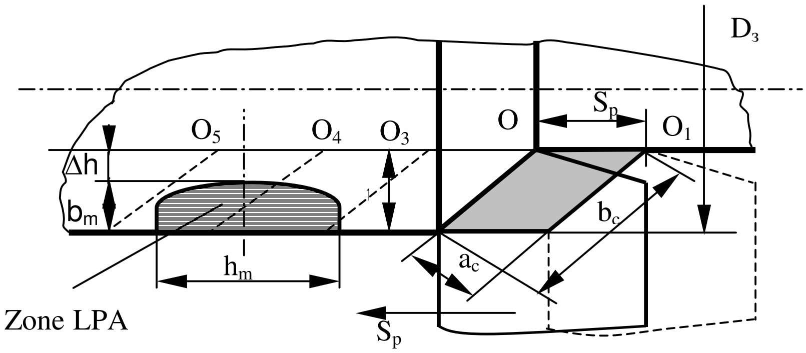

Fig. 2. **Diagram of the bilateral layout of the local plastic action zone and area of the transverse cut off layer of the shaving**

A rational change in the physical-mechanical properties of the material of the cut off layer in the zone of local plastic action (zone LPA) ensures an improvement in the conditions for chip formation with the subsequent machining, which is accomplished with a frequency of rotation n_p and a supply S_p. By mechanical processing of plastic materials most of the work of cutting is spent on the plastic deformation of the removed metal. In the zone LPA the part of work, spent on plastic deformation, has already been executed during the preliminary action by the contact tool.

Consequently, in the process of cutting in the zone LPA the cutting tool will accomplish only the part of the cutting work spent on the plastic deformation of the basic cut off layer of metal. This will result, in the process of cutting in the zone LPA, in local variation of the volume of the plastically deformed material, angle of displacement, shrinkage of shaving, force and temperature of cutting. The method indicated can be used for all steels, capable of plastic deformation; however, the best results are obtained on steels with the hardness up to HB 280.

The picture of work hardening with cold plastic deformation described above is observed in annealed carbon and alloy structural steels with the structure of ferrite, ferrite-pearlite and finely dispersed sorbite. In high-alloy corrosion-resistant (stainless), high-temperature (strength), nonmagnetic and other steels and alloys more complex picture is observed. In special alloy steels because of the influence of the alloying elements on the expansion of γ - region (which in iron-carbide steels as stable structural constituting exists only at a temperature higher than Ac_3) [3], to an increase in the stability of super cooled austenite and to lowering the martensite point, austenite can be one of main structural components of steels in the state of their operation.

Alloyed austenite is subdivided into the stable and the unstable. Unstable austenite is capable of phase transformation - formation of martensite as a result of the application of external load (deformation) [4]. Thus, the local surface deformation of steel of unstable austenite structure causes, besides work hardening, a martensite transformation, which to an even greater degree strengthens the difference in the structure and the properties of the base metal of the blank processed and also that of zone LPA. Stable austenite does not undergo phase transformation under the effect of the deformation, which leads to a change only in its structure. In steels with the structure of stable austenite, just as in steels of ferrite and ferrite-pearlite classes, plastic action leads to an increase in the density of the defects of crystal lattice, which form high-energy configurations.

Experimental study of LTA

Experimental studies were conducted for different brand of steels, as which were used, steels of the mark of 3X13, 08X18H10T, also, for the comparison widely used structural steel 45, which made it possible to obtain the necessary data for determining the area of continuous chip breaking under the local thermal influence on the workable material depending on the regimes of the subsequent working.

Local physical action on the workable billet surface was realized before the phase transition. This action it was materialized at different depths, which enabled to conduct a study of the process of continuous chip breaking with different relations of the depth of action *b* and the depth of the cut off layer *a* (Fig.3).

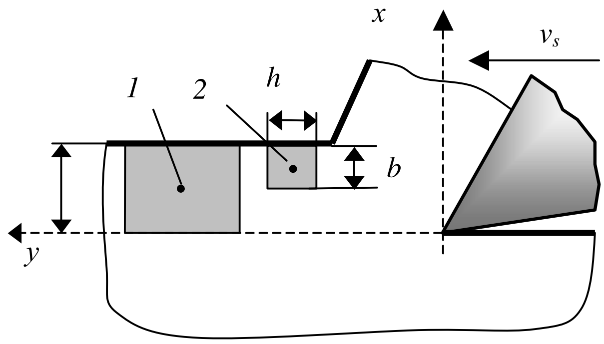

Fig. 3. **Diagram of the layout of the local action zones in the cut off layer with different relations of the depth of action *b* and of the depth of the cut off layer *a*: 1–*b* ≥ *a*; 2–*b* <*a***

According to the experimental data the graphic dependences were built, represented in Fig. 4.

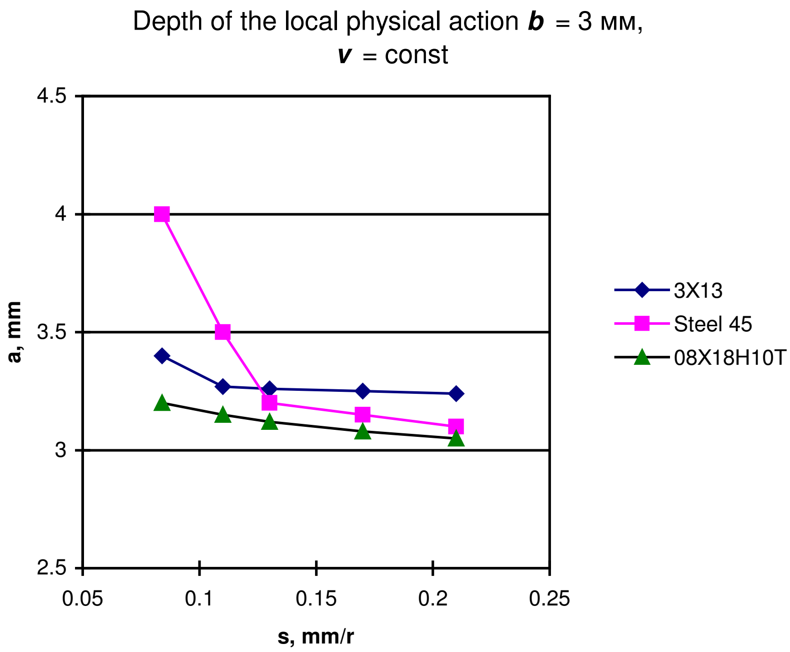

Fig. 4. **Area of continuous chip breaking by changes of feed *s* for different materials**

Theoretical results of LTA

The analysis of the obtained experimental experiments made it possible to make the following conclusions:

1. With an increase in the depth of the cut off layer and by feed *s* = 0,12 mm/r the levelling off of the boundary of the continuous chip breaking area for all mark of materials investigated occurs, but in the further range to *s* = 0,21 mm/r, usual constructional steel 45 and stainless steel 08X18N10T, belonging to austenitic class have identical tendency toward decreasing of this area, and for 3X13 of martensite-ferrite class - certain stable value of continuous chip breaking.
2. With an increase in the depth of the cut off layer *a* and also the depth of the local action *b* the rapprochement of properties occurs, which essentially decrease the area of continuous chip breaking; moreover in usual construction materials, this tendency in its nature is analogous to the stainless steel 08X18N10T.

Conclusions

1. The method of chip breaking is developed, based on the local plastic action on the surface of material, which leads to a change of the density of the defects of crystal lattice in the local zone, which form high-energy configurations, which leads to the appearance of that increased of the metastability of structure in this local region. All this makes it possible to ensure an alternation in the conditions of cutting in comparison with the source material with the subsequent working.
2. It is established that in the zone of local plastic action a change in structure and mechanical properties of the workable metal occurs, also, in the process of working the zone LPV, being in a metastable state in comparison with the base metal, leads to an instantaneous change of the stress-strained state in the zone of chip formation, thus ensuring the process of the shaving segmentation.
3. Under the thermal influence in the area of predetermined stock removal of the cut off layer a temperature source leads to the change of mechanical properties and residual stresses, the distortion of crystal lattice [6] in the local zone in comparison with the basic material, leading to instantaneous change of the stress-strained state in the process of chip formation and its separation from basic material in the form of cuts of predetermined length.

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