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Improving the quality of manufacturing parts from titanium alloys using the method of preliminary local plastic deformation

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Abstract. This article covers one of the main problems of manufacturing parts from titanium alloys. It proposes a method for local plastic deformation. This method improves the quality and the precision of the manufactured part surface. The use of the method ensures uniform segmentation of chips and increases productivity.

1. Introduction

The engineering industry currently has a wide range of items that require special machining. These machining methods improve the efficiency of the cutting of parts made of hard-to-machine-material, including titanium alloys [1].

It would be better to have a continuous chip during cutting from a technical viewpoint.It is an indicator of the process system stability, ensures high quality of the machined surface and guaranteed instrument stability [2]. Under real conditions of part manufacturing, formation of a continuous chip corresponds to a very narrow range of the process system during cutting.

It should also be noted that a continuous chip significantly impairs operation of automated process equipment. Formation of segments of an assigned length is therefore very important in cutting.

A number of problems occur when manufacturing machine parts made of titanium and its alloys. Due to the strong adhesion and high temperatures during machining, titanium adheres to the cutting tool, which increases the friction force significantly. Adhesion and clinging of titanium to the cutting tool contact surfaces changes its geometric parameters [1-5]. Deviation in the geometric cutting tool parameters from their optimal levels results in a further increase in the processing stresses and higher temperature in the cutting area. This leads to faster wear and tear on the tool. The temperature in the cutting area increases the most strongly as the cutting speed rises, and to a lesser degree as the feed increases. The cutting depth has a lesser impact compared to the speed and the feed [1, 4, 5, 6]. During processing, approximately 85-90% of all the cutting work is converted into heat. The quantity of heat in the cutting area has a significant impact on the tool’s durability, and consequently, on the roughness of the processed surfaces of the machine part blanks. An important objective of modern mechanical engineering is to improve the quality and precision of manufacturing machine parts made of titanium and titanium alloys [2, 7].

The task of ensuring the processing quality of machine part blanks made of titanium and its alloys may currently be solved by stabilizing the cutting process using two main approaches:

- changing the geometric parameters of the processed surface or tool, i.e., creating on the surface pits, spurs, edges, etc. (non-kinematic methods);
- ensuring oscillations in the tool or blank processing by applying these oscillations on the equipment servo mechanisms[6, 8].

2. Materials and methods

The method of local plastic pre-deformation is one way to improve the cutting processability of titanium and titanium alloys and increase tool durability. The method essentially alters the macrostructure and mechanical properties of the processed material in the local area, i.e., concentrates the plastic deformation in certain individual deformation foci [7].

The local metastability affects the rheological parameters of the chip-formation process. It is created in the area of the hypothetical allowance of the material cut layer on the outer surface of the blank on an especially assigned trajectory at the blank preparation phase (Figure 1).It should be noted that the depth of local metastability$b_m$should be less than the cutting depth t.

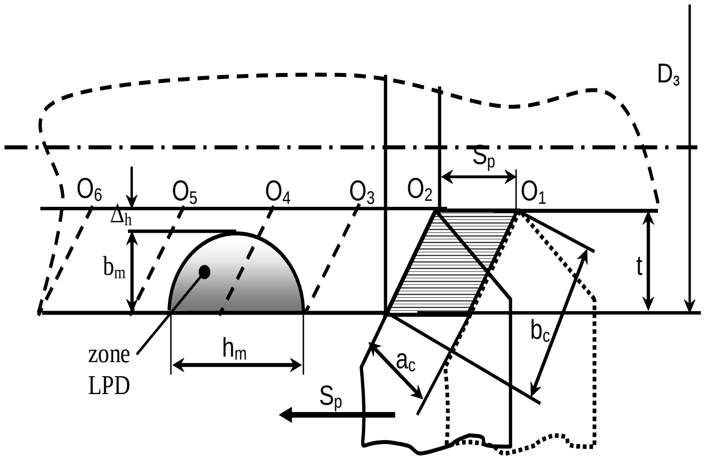

Figure 1. Diagram of the mutual arrangement of the local plastic deformation zone and the cross-section area of the chip cut layer

The preliminary local plastic deformation (LPD) conducted by certain laws on the outer surface of the blank cut layer allows frequent changing in the metal deformation conditions during cutting (Figure 2).

The plastic effect on the material surface in the local zone leads to cold-hardening. Cold-hardening forms high-energy configurations. This results in elevated structural metastability in this local region. Subsequently, during cutting machining, the tool's cutting edge in the cutting plane intersects with the local plastic effect zone.

During processing, the local effect zone, which is in a metastable condition compared to the base metal, results in an instantaneous change in the stressed-deformed state in the allowance zone. The change in the stressed-deformed state leads to separation of the chip segments and cleaning of the cutting tool of adhesion material from the blank.

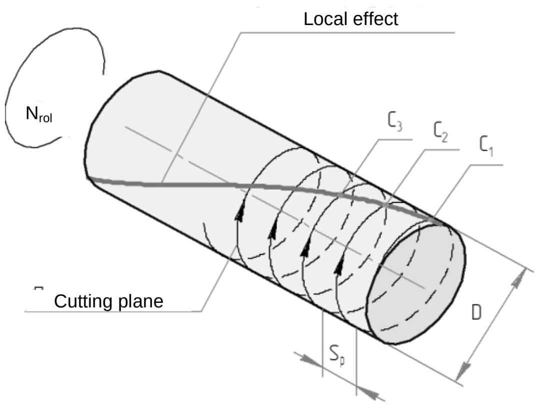

Figure 2. Diagram of creating local plastic deformation with subsequent cutting

When machining a blank that has been pre-exposed to local plastic deformation, it is necessary to simultaneously ensure the cutting process and obtain chip segments of reasonable length. The length of the chip segment L_{flat} that is formed during intersection of the local plastic deformation zone with the cutting plane is regulated (GOST 2787-75) and is determined by the formula:

$$L_{flat} = \frac{\pi \cdot D \cdot n}{60 \cdot f \cdot \xi}, \text{ mm},$$

where - frequency of intersection between the cutting plane and the local plastic deformation zone, Hz;

ξ - chip longitudinal shrinkage coefficient;

n - rotation frequency of the blank, rpm;

D - diameter of the blank, mm.

The intersection frequency of the cutting plane of the local plastic deformation zones, f is determined by the formula:

$$f = \frac{\pi \cdot D \cdot n \cdot \sin[arctg\left(\frac{s_m - s}{\pi \cdot D}\right)]}{60 \cdot \xi \cdot s_m \cdot \cos[arctg\left(\frac{s_m}{\pi \cdot D}\right)]}, \text{ Hz},$$

where s_m - the frequency of the local plastic deformation, mm;

s – the frequency of the cutter when machining of the workpiece.

The length of the segments L_{conv}, conv twisted chips formed when turning of workpieces with pre-applied local thermal effects using the well-known expression [9]

$$L_{conv} = \frac{L_{flat} \cdot h_c}{\pi \cdot d_c}, \text{ mm},$$

where h_c and d_c - the step and the diameter of the chip turns, mm.

or

$$L_{conv} = \frac{s_m \cdot h_c \cdot \cos[arctg\left(\frac{s_m}{\pi \cdot D}\right)]}{\pi \cdot d_c \cdot \sin[arctg\left(\frac{s_m - s}{\pi \cdot D}\right)]}, \text{ mm}.$$

Visualization of the turning process with a local plastic impact are shown in figure 3.

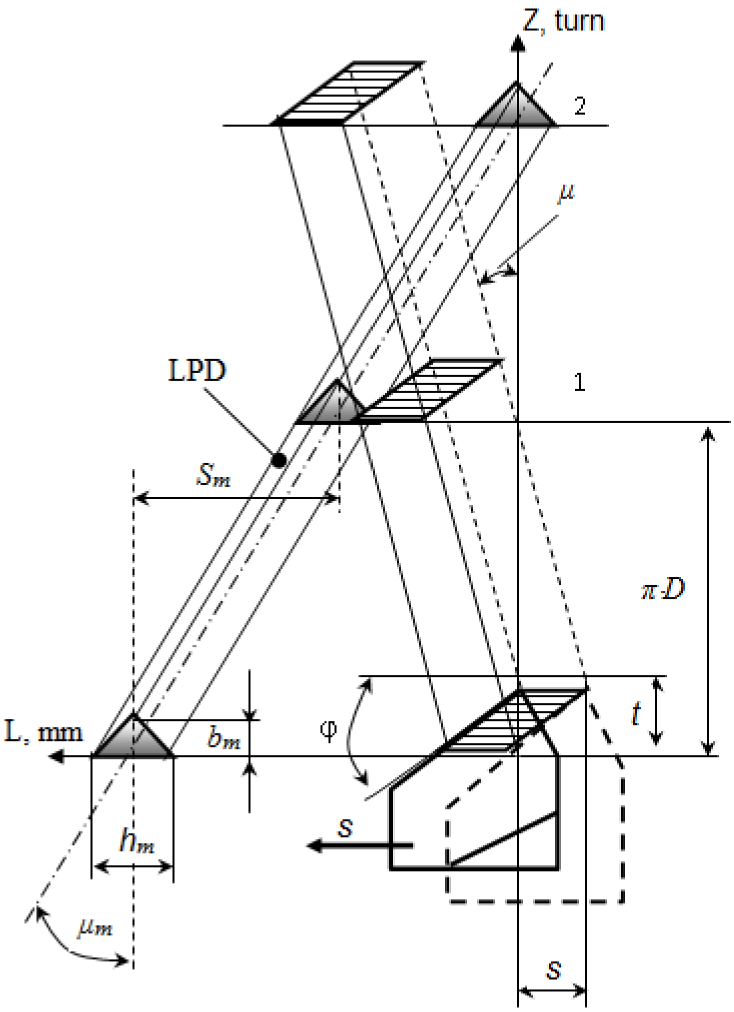

Figure 3. The unfolding of the turning process from a local plastic impact

3. Conclusion

A chip-segmentation method was developed, based on changing the blank material hardness in the local area. The hardness change is due to the formation of cold-hardening during plastic deformation in the local zone of the blank. During subsequent processing, the routine change in cutting conditions ensures a stable process of chip segmentation.

The resulting kinematic sharpening characteristics with local plastic deformation ensure chip segmentation on a piece 100-200 in length.

Further studies should conduct experiments to reveal the functional relationship between the plastic deformation stress and the penetration depth of cold-hardening, and find the area of stable segmenting of a chip under different processing conditions of titanium and titanium alloy parts.

Processing a blank with preliminary plastic deformation is accompanied by routine changes in conditions. Studies should be conducted on the kinematics of the process.

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