Research of thread rolling on difficult-to-cut material workpieces

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Abstract. In medicine production Ti-6Al-4V Grade 5 alloys are used. One of the most important tasks is to increase the strength of the products and decrease in value. The possibility to roll special thread on Ti-6Al-4V Grade 5 alloy workpiece on 2-roller thread rolling machine has been studied. This is wrought alloy, treatment of which in cold condition causes difficulties due to low plasticity. To obtain Ti-6Al-4V Grade 5 alloy product with thread by rolling is rather difficult. This is due to large axial workpiece displacements resulting from large alloy resistance to cold plastic deformation. The provision of adequate kinematics requires experimental researches and the selection of modes - speed of rolling and pressure on the movable roller. The purpose of the work is to determine the optimal modes for rolling thread on titanium alloy workpiece. It has been stated that, after rolling, the product strength has increased up to 30%. As a result of the work, the unit has been made and recommendations to choose the optimal rolling process modes have been offered. Keywords — plastic deformation, rolling thread, knurls, titanium alloy, thread-rolling machine.

1. Introduction

A very productive method to obtain a thread is rolling in cold condition in 2-roller thread rolling machines, instead of cutting. Medical implants for osteosynthesis periosteal equipped with special screws, conditions which require high accuracy and quality of the thread. The formation of threads on such pieces by cutting is difficult, time-consuming, and does not provide the necessary physical and mechanical properties. Therefore, processing by rolling is more efficient.

The rolling process, depending on the piece design, can be performed on different equipment: both special thread-rolling machines and versatile machine tools using a variety of technological equipment and thread-rolling tool designs. The most common is rolling on double-roller machines, where thread rolling occurs when knurls approach gradually and roll the workpieces.

As a result, the redistribution of the workpiece material from the surface into the roots of the roller threads happens.

The process continues till full thread turns filling (on closed profile tool) or obtaining full form thread on the part (on open-loop roller operating). Thus, upon rolling threads with knurls the plastic deformation of outer surface of the workpiece occurs. This causes the bend of outer metal fibers equidistantly to thread profile and the metal fibers are not cut and rolling is performed without chips. The rolled thread in compare with cut one has the increased surface hardness (up to 30%).

The papers of T.A. Sultanov, Yu.L. Frumin, I.Ya. Shnajderman and M.Z. Hostikoev et al. [1-2] take the important place in the study and practical implementation of rolling techniques.
2. Statement of problem
A number of papers are devoted to the study of titanium properties and structure during the cold plastic deformation process and its structure. In most cases, however, the papers of this kind deal with the microstructural analysis of titanium after rolling or extruding. In another case, titanium properties are given taking into account thermal effects. In this paper the possibility to roll special thread on BT 6 titanium alloy workpiece on 2-roller thread rolling machine has been studied.

Rolling is a process of plastic forming on the given workpiece surface, as opposed to the whole workpiece impact, or stamping when much smaller parts of the workpiece are acted.

The titanium alloy workpiece of 3 mm diameter was used to determine the possibility of obtaining threads. Rolling was produced on 2-roller machine. This method makes it possible to form threads on a freely rotating workpiece and is independent of the length of the rod. The objective of the research is to define optimal parameters for rolling which will allow the formation of high quality thread.

3. Theory
Figure 1 shows the dependency of the basic mechanical titanium properties, such as: yield stress, ultimate strength on the deformation speed during workpiece tensile. This dependence demonstrates that the values $\sigma_{0.2}$ and $\sigma_E$ are gradually increasing upon speed magnification. Therefore, upon deformation rate magnification, the mechanical properties increase, making machining process more difficult.

In the case of rolling thread on the rod, the following can be noted:

1. The stresses in the rod depend on rolling speed. With the die rotation speed magnification the deformation resistance increases. At higher turns, the deformation of the rod slows down due to hardening. The workpiece begins to move along the surface of the knurl cutter because the rollers interrupt introduction in the workpiece and thread helix angles on the rollers and workpiece do not match. This is a organic disadvantage of this rolling technology.

2. In the process of through-feed rolling (the rollers interrupt introduction in the workpiece due to thread surface hardening), the ply separation of the workpiece surface occurs and the husks appear, making the surface roughness of the part unacceptable and results in the destruction and folding of the thread sections.

In light of the above, it can be concluded that, with the increase of rolling speed, the indicators of thread rolling process are deteriorating. The workpiece begins to move more actively along the axis and often slides upward from the rolling zone.
4. Experiment results
To carry out the work it was necessary to modify 2-roller thread rolling machine. Frequency controller was installed on the machine to reduce head rotation speed by four times, up to 5 -7 m/min. To determine the feasibility of heating the workpiece, an analysis was made of the dependence of the mechanical properties of the three materials on temperature.

We have obtained hardening graphs depending on temperature:

![Hardening Graph](image)

**Figure 2.** Hardening of given materials by temperature.

In operating temperature range (200-600°C), steel temporary resistance reduces and remains high for titanium alloys, despite non-significant decrease (Figure 2).

For the Ti-5Al-4V Grade 5 and steel 321S51, the temperature rise affects the hardening in the same way. To a temperature of 300 - 400°C, the drop in strength is not significant, and the use of rolling liquid is not possible. But, since at high rolling speed the tool material is additionally heated in the contact zone, an irreversible drop in hardness of the tool from Cr12-M steel is unavoidable, from which it follows that, with all other similar parameters and temperature changes, it is expedient to process titanium alloys at lower speeds using rolling liquid and under higher pressure in the roller hydraulic cylinder.

5. Results and discussion
During the work process, a round thread was rolled on 3 mm diameter titanium workpiece at low speeds (Figure 2). In detailed examination, on the tread crests one can see the groove specific to rolling.
During carrying out the work it has been experimentally proved that to roll it is necessary to reduce the speed lower than the limits of the machine to 5-7 m/min. It is also worth noting that the power of roller reduction was more than rolling thread on similar steel and alloy workpieces.

Taking into account these recommendations, production of titanium screws can be implemented in this way.

6. **Summary and conclusion**

The features of selection processing modes of rolling thread on Ti-5Al-4V Grade 5 alloy have been defined.

To roll thread on titanium alloys parts, it is useful to reduce the velocity of rolling 5-7 m/min at maximum pressure in the hydraulic-circuit system of roller feeding.

7. **References**

[1] Lyashkov A A, Vasil’ev E V and Popov A Y 2017 Development of 3D modeling technology for manufacturing finned ribbons from heat-resistant steels *IOP Conf. Series: Earth and Enviromental Science. IPDME Vol. 23*. pp. 1-12. doi:10.1088/1742-6596/858/1/012017.

[2] Korovin G I, Filippov A V, Proskokov A V and Gorbatenko V V 2015 Cutting Edge Geometry Effect on Plastic Deformation of Titanium Alloy *IOP Conf. Series: Materials Science and Engineering Vol. 125*. pp. 58-64. doi:10.1088/1757-899X/125/1/012012.