Ultrasonic influence on the quality formation of surface layer when cutting thread

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Abstract. The paper deals with the issues of the quality assurance of thread surface layer during mechanical processing using forced ultrasonic vibrations. The results of the conducted research on the ultrasonic vibrations effect on the formation of thread surface layer quality characteristics are presented. Roughness, strain hardening and residual stresses are considered as the main characteristics.

1. Introduction
Currently, one of the most common kinds of joint are threaded. Accordingly, more than a half of the manufactured machine parts are threaded [1, 2]. The widespread use of this type of joint is associated with its multifunctionality, versatility, reusability, ensuring the stated loads, and so on. At the same time, the performance of threaded joints depends on the design, manufacturing technology, assembly and operating conditions. In addition, the most important and crucial stage is the thread manufacturing technology, which allows influencing the quality of the thread surface being formed.

Basically, the thread is produced in three ways: rolling, grinding and cutting with a blade tool. At the same time, in order to improve the quality characteristics of threaded parts, they may be subjected to additional strengthening operations, for example, processing with microballs, diamond smoothing and others. As a result, it is possible to significantly reduce the surface roughness, increase the degree of strain hardening and the magnitude of compressive residual stresses, which can significantly improve the performance of threaded parts, especially in conditions of operation with variable loads. In addition, to improve the performance characteristics of parts and, consequently, the reliability of products, materials with high physicomechanical characteristics, the processing of which sometimes causes serious difficulties, are becoming more widely used [1-8].

As mentioned in works [1, 2] it is possible to improve the efficiency of machining, and, accordingly, threading, through the use of various physical and technological methods, including the use of forced ultrasonic vibrations. It was found that threading with the ultrasonic vibrations introduction into the cutting zone can improve the performance of the process, the durability of the thread-cutting tool and improve the quality characteristics of the obtained threaded surface without additional strengthening operations.

2. Methodology of the experiment
Since the efficiency of threaded parts largely depends on the technological parameters of the used ultrasonic vibrations, special studies have been carried out on the ultrasonic action effect on the
formation of the surface layer of threaded parts. At the same time, the effect of ultrasound parameters on roughness, strain hardening, and residual stresses was studied. Thread cutting was carried out with the help of special ultrasonic devices developed at Samara State Technical University [1, 2].

3. Results
Figure 1 presents the results of research regarding the influence of ultrasonic vibrations on the surface roughness when cutting threads M8 on workpieces made of titanium alloy VT3-1. Threading was made with a thread chaser with a carbide plate VK8 with tangential, axial and radial ultrasonic vibrations.

![Figure 1. Change of roughness parameter Rz depending on the magnitude of the oscillation amplitude ξ: 1 – cutting with radial ultrasonic vibrations; 2 – cutting with axial ultrasonic vibrations; 3 – cutting with tangential ultrasonic vibrations.](image)

Owing to the complex spatial arrangement of the thread surface, the roughness measurement was carried out on the side of the thread profile using the optical method with a double Linnik microscope. To set the surface of interest in the horizontal plane, special equipment was used, which allows to install the threaded specimen at different angles. In this case, the roughness parameter Rz was determined within the entire length of the light section of the side profile.

From the presented dependences, it transpires that the ultrasound introduction into the cutting zone leads to a decrease in the height of asperities in comparison with the treatment without the use of ultrasound. It should be noted that with an increase in the amplitude of oscillation to values equal to 5 micrometers, the roughness value decreases, and then the process stabilizes and the values remain constant. Therefore, the optimal value in this case is the amplitude of 5 μm.

From the perspective of the ultrasonic vibrations direction, the most effective are tangential, and the minimum decrease in roughness values was observed when cutting threads with radial ultrasonic vibrations. Therefore, the use of ultrasound during thread cutting reduces the surface roughness by 20 – 30 percent.

As noted earlier, considerable interest attaches to the study of the ultrasonic vibrations effect on strain hardening.

Figure 2 provides with data on the ultrasonic vibrations effect on microhardness in the root of the thread, as it is a stress raiser and destruction occurs along the root.

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As a result of the research it was found that the maximum hardening of the surface layer occurs during processing with radial ultrasonic vibrations, and the introduction of tangential ultrasonic vibrations into the cutting zone leads to a decrease in microhardness values compared to processing without ultrasound.

The most important parameter of the surface layer, in terms of performance under alternate loads, are residual stresses. Residual stresses were also determined by the most dangerous section - along the root of the thread.
Figure 3 presents the results of a study of the forced ultrasonic vibrations effect on the formation of residual stresses in the root of a thread.

![Graph of residual stresses](image)

**Figure 2.** The influence of the ultrasonic vibrations direction on the microhardness in the root of the thread: 1 – thread cutting without ultrasonic vibrations; 2 – thread cutting with tangential ultrasonic vibrations; 3 – thread cutting with axial ultrasonic vibrations; 4 – thread cutting with radial ultrasonic vibrations.

**Figure 3.** The influence of ultrasonic vibrations direction on the formation of residual stresses in the roots of the thread M6x1 during the processing of titanium alloy VT3-1: 1 – ordinary cutting; 2 – cutting with tangential vibrations; 3 – cutting with axial vibrations; 4 – cutting with radial vibrations.

It should be noted that when cutting threads in the surface layer, compressive residual stresses are formed, that is, they have negative values. The introduction of ultrasonic vibrations has an effect as follows. When processing with tangential vibrations, the values of residual stresses decrease. The change to axial vibrations leads to an increase in the residual stresses, and when processing with radial vibrations, a maximum increase in the values of the compressive residual stresses was observed.

**4. Conclusions**

The conclusions can be summarized as follows. When thread cutting, the introduction of ultrasound into the cutting zone leads to a significant change in such parameters of the surface layer as roughness, strain hardening and residual stresses. The most significant positive factor is that when processing with radial or axial ultrasonic vibrations, the surface layer is hardened by 15–20%, and the values of
compressive residual stresses increase by 1.5–2 times. In addition, when cutting threads with ultrasonic vibrations, the surface roughness decreases with all types of vibrations. As a result, the improvement of these quality characteristics of the surface layer makes it possible to increase the efficiency and reliability of the obtained threaded parts, especially when operating with variable loads.

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