Investigation of the effectiveness of the method of finishing the inner cylindrical surfaces of machine parts with a free abrasive using the effect of vibration cavitation

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Abstract. Finishing of high-precision machine parts is one of the most labor-intensive operations in the technological process. This process becomes especially difficult when it is necessary to ensure a high-quality surface in hard-to-reach places for parts made of materials with special physical and mechanical properties. In such cases, the solution to the problem may be the use of methods of processing with free abrasive particles. Based on the foregoing, it can be concluded that improving the efficiency of methods for processing parts with a free abrasive is the most important task for researchers in the field of mechanical engineering technology.

The authors of the article carried out a series of experiments on finishing the inner cylindrical surfaces of machine parts of the “sleeve” type with a free abrasive using the effect of vibration cavitation. The study is of an applied nature - according to the design documentation for the product, it is necessary to achieve a roughness in the inner surface of Ra 0.80.

At present, more and more stringent operational requirements are imposed on products of machine-building production: it is necessary to increase wear resistance, durability of uninterrupted operation, resistance to various kinds of influences. This requires the use of expensive materials with special physicochemical properties, the processing of which often requires increased time and material costs, makes high demands on the processing equipment [1]. However, it is necessary to obtain not only a product with the required characteristics, but also to ensure its lowest cost.

In machine-building and instrument-making industries, the overwhelming part of finishing operations is the processes of abrasive processing (grinding and polishing deep, fine, finishing, etc.) and electrochemical processes. In the context of their development based on the use of alloys with increased mechanical and electrical characteristics, it is necessary to constantly improve the abrasive materials and technologies used in the finishing processing of machine parts [2].

The analysis of technological processes shows that ensuring the quality and increasing the productivity of finishing machining of machine parts with a complex surface profile and made of materials with special physical and mechanical properties is associated with a number of problems, a possible solution of which is the introduction of free abrasive machining into the manufacturing process of machine parts using the effect of vibration cavitation [3, 4].

In the process of machining machine parts using the proposed method, energy is transferred to abrasive particles from the cavitating technological medium, which is activated by applying a vibration effect. The threshold values for the occurrence of the effect of vibration cavitation can be determined based on the condition [5]:
\[ \omega z > 0.25 \]  

Where: \( \omega \) – circular frequency, \( s^{-1} \); \( z \) – vibration amplitude, mm;

The basis of the technological environment, material and grade of abrasive were selected on the basis of combinations already used in the industry for manual polishing. For the experiment, a heterogeneous technological environment was used, consisting of an aqueous solution of the AIMOL X-Cool PLUS 65 mineral concentrate with the addition of 15% SiC of the F1200 grade.

A schematic representation of the part is shown in figure 1.

![Figure 1. Schematic representation of a part.](image1)

An experimental study of the effectiveness of the proposed method was carried out on the inner surface of parts made of steel KhVG with heat treatment to a hardness of 64-66 HRC. To carry out the experiment, it was decided to use sections with a length of 50 mm (Figure 2) with an inner diameter of 14 + 0.1 mm, due to the fact that those carried out by V.O. Abramov, G.F. Balandin., A.V. Ivanaisky and A. P. Babichev's experiments confirm the possibility of scaling the results of cavitation treatment without significant changes in the results of treatment [6, 7].

![Figure 2. A detail subjected to processing with the imposition of low-frequency vibration, CVG with heat treatment to a hardness of 64-66 HRC.](image2)

A TR220 profilometer was used to assess the parameter of roughness change during the finishing treatment of machine parts using the effect of vibration cavitation. The initial roughness of the inner cylindrical surface of the part was Ra 1.343 µm (figure 3).
Figure 3. Measurement of the surface roughness of the part by the contact method.

The following vibration parameters were selected for processing: frequency - 30 Hz, amplitude - 4.7 mm. On these operating modes of the installation, a series of experiments were sequentially carried out, differing in duration. The initial processing time is 2 minutes, after processing, the surface of the part was cleaned of the process medium and measurements were taken with the above TR220 profilometer.

If the required surface quality was not achieved, the next sample was taken, and the exposure time was increased by 2 minutes (Figure 4).

Figure 4. The processing process using the effect of vibration cavitation on an electrodynamic bench.

The measurement results are summarized in table 1.
Table 1. Dependence of surface roughness on the duration of treatment.

| Duration of processing | Roughness of the inner cylindrical surface in Ra, μm | Abrasive grade |
|------------------------|---------------------------------------------------|----------------|
| 2 minutes              | 1.343                                             | SiC, F1200     |
| 4 minutes              | 1.127                                             |                |
| 6 minutes              | 1.098                                             |                |
| 8 minutes              | 1.025                                             |                |
| 10 minutes             | 0.926                                             |                |
| 12 minutes             | 0.831                                             |                |
| 14 minutes             | 0.708                                             |                |

Investigation of the state of the inner cylindrical surface of the waveguide after 14 minutes of processing by the proposed method showed that the surface roughness was Ra 0.78 μm (figure 5).

Figure 5. The process of measuring the roughness parameter of the machined part by the contact method.

The data in the table are summarized in a graph (figure 6), which reflects the dependence of the roughness obtained during processing on the processing time.

Figure 6. Graph of the dependence of the change in the roughness of the inner cylindrical surface on the processing time.

Summarizing the above, we can conclude that the proposed method of finishing with a free abrasive using the effect of vibration cavitation is sufficient. Guaranteed provision of the requirements for roughness to the workpiece (Ra 0.80 according to the drawing) is possible when processing the proposed method for 14 minutes.
Applying the proposed finishing method, it is possible to solve a wide range of problems of traditional processing that arise when it is necessary to ensure high quality of the surface of machine parts with a complex profile of internal surfaces, thin holes, thin walls, as well as made of difficult-to-machine materials.

The investigated method has the following advantages:

• The problem of chip removal is solved due to the lack of a rigid bond;
• There are practically no dynamic and shock loads;
• The heat intensity of the abrasive processing process is significantly reduced due to the complete immersion of the part in the activated technological environment;
• Lack of contact of the treated surface with the atmosphere, the components of which may have undesirable thermochemical effects;
• Reusable abrasive material, making it more efficient to use super hard abrasives such as diamond and CBN.

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