Finishing lenses and ceramic products with loose abrasive using the cavitating effect

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Abstract. The analysis of the existing technological processes of manufacturing machine parts showed that there are problems in quality assurance and efficiency improvement during finishing. A possible way to solve this problem is to use the processes of manufacturing machine parts using the cavitating effect, information about which in the technical literature is limited. The studied method of finishing machine parts with loose abrasive makes it possible to increase productivity by creating unique hydrodynamic conditions.

1. Analysis of information on this topic

According to action plan "Development of optoelectronic technologies (Photonics)" approved by the Order of the Government of the Russian Federation dated 24 July 2013 No. 1305-R (revised OG RF 23.06.2016, № 1299-R), the development of laser, optical and optoelectronic technologies is one of the important tasks implemented by the Ministry of industry and trade of the Russian Federation.

Lenses finishing, which determines the surface quality of the optical part, is one of the most time-consuming operations in the process of optical devices production. That is the reason for the technology of finishing lenses to provide a minimum of labor.

A possible way to reduce labor intensity and to increase productivity in the manufacture of lenses is to apply the method to finish machine parts with loose abrasive which uses the effect of cavituation.

Cavitation is a means of local energy concentration which is achieved due to hydrodynamic processes accompanying pulsation and collapse of cavities. Interest to the theory of cavitation is caused by finding ways of using these effects to create new technologies and ways of using opportunities that arise in the conditions of occurrence of the attached cavitation effect carried in the whole volume of the technological environment. The research of S. Sous showed that activating dynamic parameters of heterogeneous media, based on the effect of cavitation, is possible due to the following hydrodynamic processes:

- formation of the cavitation cavities, creating a high-energy currents;
- formation of turbulent zones in the flow behind a moving cavern;
- occurrence of intense pressure fields (up to 1000 atm.) and perturbation waves arising from the vapor-gas caverns pulsation;
- kinetic effect of cumulative micro-jets arising in the final stage of cavity collapse [1].

The reasons why application of existing technologies of finishing machine parts is of low productivity:

- growth of heat generation in the treatment zone with the formation of thermal defects;
• lack of universal abrasive tools and processing technology of machine parts with different geometric shapes.

2. Designing a new method
The essence of the proposed method is to process lenses using a loose abrasive that receives cutting energy from the cavitating process medium. The cutting process is carried by means of chaotic high-speed movement of abrasive grains, followed by their collision with the surface of the lens. The most important feature of the proposed method of finishing lenses with loose abrasive is their use as an activator of the working medium. The technological device, the quitting heterogeneous medium and the rotating part form a synergistic system. [2]

The basis of the technological medium, composition and grade of abrasive is selected on the basis of data used in the industry for polishing and fine finishing.

Table 1. Minimum roughness achieved in the process of finishing with the use of the fixed cavitation effect

| Abrasive/ grain sizes, mic | Surface undulation, mic |
|----------------------------|-------------------------|
| SiC F150/ 106-63           | Ra = 0.25               |
| SiC M80/ 80                | Ra = 0.17               |
| SiC F1200/ 3-1             | Ra = 0.08               |

Table 2. Usage of abrasive material

| Abrasive grain sizes, mic | Surface undulation, mic |
|--------------------------|-------------------------|
| 500-315                  | Ra = 2.5-0.63           |
| 315-160                  | Ra = 2.5-0.32           |
| 160-80                   | Ra = 0.63-0.16          |
| 80-40                    | Ra = 0.4-0.16           |
| 40-3 and less            | Ra=0.16 mic and less    |

The objects of the study are the CO2 laser lens and the covered part of the ceramic knee prosthesis.

Figure 1. Photo of lenses before and after processing

These parts are chosen for the study of the finishing process course due to the comparability of technological processes of their processing and the need to improve the efficiency of processing parts made of ceramics.

Photo of the lens, underwent to finishing treatment using the effect of cavitation to restore its performance, is shown in figure 1. As a result of finishing, the surface roughness of the lens was Ra 0.16 mic.
According to ISO 7207-2, the roughness parameter Ra for articular surface parts should be no more than 0.5 microns with a base length of 0.08 mm. According to the drawing requirements, the roughness of the lens surfaces should be less than Ra 0.36 microns.

The treatment process is shown in figure 2 and is carried using a process medium, the basis of which is distilled water with the addition of 15% diamond abrasive grade F 1200, the estimated speed of rotation of the part - 9400 rpm.

![Figure 2. Photo of lens processing with the use of the cavitation effect](image)

To estimate the parameter of roughness change at finishing processing of details of machines using the attached cavitation effect the detail of a knee endoprosthesis (ceramics) shown in figure 3 is taken.

![Figure 3. Photo of the part after processing. Material-ceramic](image)

The technological medium used for the experiment was distilled water with 7% SiC F1200 added. The roughness parameters are measured using the LEICA DCM8 SR device [3]. The surface profile of the part at various stages of processing is shown in figure 4.
Figure 4. Surface profile of the part: 1 – initial surface Ra 0.69 mic; 2 – processing 4 min, Ra 0.57 mic; 3 – processing 7 min, Ra 0.5 mic; 4 – processing 11 min, Ra 0.36 mic; 5 – processing 16 min, Ra 0.26 mic; 6 – processing 21 min, Ra 0.25 mic.

The finishing treatment result was obtaining a serviceable part of the endoprosthesis, the surface roughness of which was Ra 0.25 microns. In this connection, it is possible to evaluate the effectiveness of the proposed method of machine parts finishing to intensify physical and chemical processes, which enables to use the capabilities of modern abrasive materials and heterogeneous technological environments effectively.

Conclusions

Compared to the existing methods of processing with loose abrasive the proposed one has the following advantages:

- due to the use of the cavitation effect, the process of machine parts treatment with loose abrasive is significantly intensified, the finishing time of a knee prosthesis is reduced from 2 hours to 21 minutes;
- applying the cavitation effect arising in the whole volume of the using technological environment provides even abrasive processing of a detail surface;
- applying the developed method of machine parts finishing does not require to use of technically complex, expensive equipment.

Reference

[1] Nigmatulin R I 1978 Osnovy mekhaniki heterogennykh sred [Fundamentals of heterogeneous media mechanics]. Moscow: Nauka. 336 pp.

[2] Asaev A S, Ivanaiskij A V and Asaeva T A 2016 Finishnaya obrabotka detalej mashin svobodny`m abrazivom s primeneniem effekta prisoedinennoj kavitacii [Finishing of machine parts with loose abrasive using the effect of fixed cavitation]. Kolomna: Publishing House of Kolomna Institute of Moscow Polytechnical University. 131 pp.
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