Searching for a rational schedule of a burnishing process with superimposition of ultrasonic vibrations

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Abstract. An ultrasonic finishing treatment unit was used for experimental researches to find effective burnishing modes. Based on the research findings of an obtained surfaces microtopography the following parameters were determined: Ra – arithmetical mean deviation of the profile and Pc – average number of profile end points per 1 cm of the surface length, by which the quality of treatment was evaluated.

1. Introduction
Increasing a wear resistance of the friction pairs is an actual problem of many industries as it provides a decrease of expenses for repair and restoration of worn out details and units [1].

The application of a surface hardening treatment with superimposed ultra-sonic vibrations allows obtaining a nanocrystalline structure with a grain size of 5...10 nm at a depth of 15...20 microns from the surface of the treated workpiece [2-6]. The hardness of the surface layers increases from 44...46 HRC to 54...56 HRC and above, and a residual compressive stress occurs on the surface of the part.

The purpose of the researches is to find rational modes of cylindrical surface burnishing process with the superimposition of ultrasonic vibrations.

2. Materials and methods
Surface treatment was carried out using a non-abrasive ultrasonic finishing unit NAUF-0,63/22 which was developed by the specialists of LLC “North-west Ultrasonic Technology Center” (Saint Petersburg) [7]. The main characteristics of the ultrasonic unit: power - 0.5 kW; indenter vibrations frequency - 2022 kHz; amplitude of vibrations - 1040 microns; generator mass - 7.5 kg, acoustic head mass - 4 kg. The diagram of the BUFO unit is shown on the Figure 1.
Figure 1. Diagram of the NAUF unit for the burnishing with the superimposition of ultrasonic vibrations.

The NAUF unit contains sequentially placed in the body 1 an elastic element 2, a magnetostrictive transducer 3, a waveguide 4, a concentrator 5, a rotary device 6 with an indenter 7 mounted on its end. On the body 1 on its outer side there is a removable lug 8 and a drain fitting 9 with a guide tube 10 for the supply of a liquid process cooling medium. Body 1 is coaxially mounted in housing 11 with the possibility of a movement in the guide 12. Outside the housing 11 is equipped with a bracket 13 for attachment to a machine support. An indenter 7 which affects the surface being treated is installed with the possibility of rotation and rigid fixation.

Using the NAUF unit a series of experiments have been conducted, during which the 50G steel discs with an outside diameter of 110 mm and a width of 25 mm were treated using a 1K62 screw lathe machine. The indenter material - steel SHH15 (hardness 64 HRC). During the experiments the following processing modes were varied: the initial depth of a deforming tool penetration into the workpiece material (tension) $P = 0.1 \div 0.3$ mm (measured by the circle graduation of the lathe), the workpiece rotational speed $n = 240 \div 480$ rpm at the indenter vibration frequency of 22 kHz.

Microtopography studies of the surfaces processed under various ultrasonic finishing modes were carried out using a Mahr S2 profilometer (Germany) and a Bruker GT K1 3D interferometer (USA) at the “Microtopography” research center of the Federal State Budgetary Educational Institution of Higher Education “Nosov Magnitogorsk State Technical University” [8]. The samples of the surface microtopographies are shown on the Figure 2.

![Figure 2](image)

(a) (b)

Figure 2. Samples of the surface microtopography:

a - the initial workpiece; b - burnished with superimposition of ultrasonic vibrations.

In the course of the experiments the following point roughness parameters were measured [9]: $Ra$ - arithmetical mean deviation of the roughness profile and $Pc$ - average number of profile end points per 1 cm of the surface length.
The main results of the research are presented in the Figures 3-6. In particular, the Figure 3 shows the dependency graph of the arithmetic mean deviation of the Ra profile on the tool pressing P value at the workpiece rotational speed n = 240 rpm.

![Figure 3](image1.png)

**Figure 3.** Dependence of the Ra profile arithmetic mean deviation on the tool pressing P value at n = 240 rpm. Parameter, Ra, μm, micron P, mm.

The Figure 4 shows the dependency graph of the Ra profile arithmetic mean deviation from the workpiece rotational speed n at tool pressing P = 0.1 mm.

![Figure 4](image2.png)

**Figure 4.** Dependence of the Ra profile arithmetic mean deviation from the workpiece rotational speed n at tool pressing P = 0.1 mm. Ra, μm = Ra, micron n, rpm.

The Figure 5 shows the dependency graph of the profile end points average number per 1 cm of Pc length on the tool pressing P value at n = 240 rpm.

![Figure 5](image3.png)

**Figure 5.** Dependence of the profile end points average number per 1 cm of Pc length on the tool pressing P value at n = 240 rpm Pc, 1/cm, P, mm.

The Figure 6 shows the dependency graph of the profile end points average number per 1 cm of Pc length on the rotational speed of the workpiece n with a fixed tool pressing P = 0.1 mm.
Figure 6. Dependence of the profile end points average number per 1 cm of Pc length on the rotational speed of the workpiece n with a fixed tool pressing P = 0.1 mm. Pc, l/cm n, rpm.

3. Conclusion

Analyzing the obtained results, the following conclusions can be drawn:

1. Increasing the tool pressing P improves the quality of the burnished surface as it reduces the arithmetic mean deviation of the Ra profile.
2. The workpiece rotation frequency n in the range of 280 ÷ 300 rpm provides the surfaces with the lowest possible arithmetic mean deviation of the profile Ra.
3. Increasing the pressing of the tool P to 0.25 mm reduces the number of the profile Pc end points. With an increase in tension over 0.25 mm, an increase in the Pc parameter is observed.

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