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Study Regarding the Influence of Technological Parameters on Performance of Vibromechanical Finishing Method

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Abstract

The paper refers to a method for finishing metal surfaces by plastic deformation and a device specifically developed, equipped with a vibrator head holding the tool, acted through a cam. The device is adaptable on universal lathe. A microrelief (MR) is generated on cylindrical parts. The influence of technological parameters as the rotational speed and the feed rate, on maximum height of surface micro irregularities, is discussed for three materials under study: aluminium, brass and carbon steel. The simulated shapes of microrelief resulting on the part surface are, also, presented. Depending on the area covered by microrelief per area unit of the part (A), a reduction of the surface roughness or its texturing is obtained.

Keywords: *vibromechanical finishing device, plastic deformation, lathe, technological parameters*

1. Introduction

It is well known that two surfaces having the same roughness (for example, R_a = 0.4 μm), but obtained through different methods, such as two cylindrical parts made from duralumin, one of them finished through turning with monocrystalline diamond tool bit, and the other one through grinding with an abrasive wheel as cutting tool, have prooved a big difference as concerns the friction coefficient on starting and operating, the portance capacity and durability, meaning maintain the surface size a longer time [1]. The best part was the grinded one. This is due to the surface aspect, obtained during the grinding process when is produced an overlap of many traces of abrasive grains, whose sense is modified at performing the double stroke and which intersect, generating on the part surface a very fine regular network.

But sometimes, at grinding of soft materials, thermally untreated, a drawback of surface layer's contamination with abrasive particles appears. So, a new method was patented [2], that ensures a regular network of equidistant traces through the vibratory movement of a tool on the feed direction of generating a surface, by which the tips of roughness resulted from previous mechanical machining operation are deformed elasto-plastically. This is the vibromechanical finishing method. The resulting microrelief has been classified as: MR I, particularly recommended for increasing the wear resistance, MR II for reducing the friction coefficient in operation, and MR III for reducing the friction coefficient on starting. Any of microreliefs, corelated to A, can be used for decreasing the surface roughness, reducing the dimensional tolerances and hardening of surfaces, as well as for decorative applications.

The area unit of the part occupied by the resulting microrelief can varies between 5 % to 90 %; the lower values are favorable to the friction coefficients reduction, while the higher values provide reduction of roughness and dimensional tolerances, as well as increase of surface layer hardness [3]. The method can be encountered, also, as a texturing procedure, with beneficial effects on the tribological behavior of the surface: vibro-grooving process [4] or vibromechanical texturing method [5].

In this paper, a method for finishing metal surfaces by plastic deformation and a patented device, adaptable to an universal lathe and equipped with a vibrator head holding the tool, which is acted through a cam, are presented. The simulated shapes of microrelief resulting on the part surface and the influence of technological parameters, as the rotational speed and the feed rate, on maximum height of surface micro irregularities are given. The experiments have been performed on three materials, such as: aluminium, brass and carbon steel. Interesting results and future research directions have been inferred.

2. Method and the Used Device

The principle scheme of processing, as well as the technological parameters, for an outer cylindrical surface, are shown in Fig. 1: n – rotation speed of the lathe's principal spindle, necessary for the generating of cylindrical surface together with the feed rate, s of deforming tool; r_{sf} – spherical radius of the deforming tool, which can be made from diamond, metal carbides or hardened alloy steel; n_L – frequency of the tool vibrations; e – vibration amplitude; P – pressure force; A – area unit of the part occupied by the resulting microrelief.

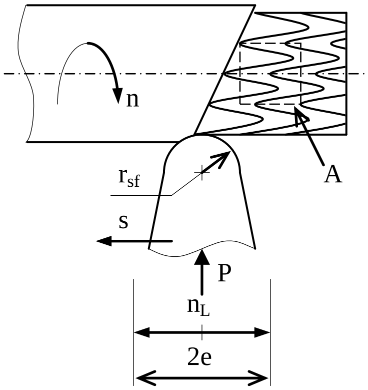

Fig. 1 The technological parameters for a cylindrical part processed through vibromechanical finishing method

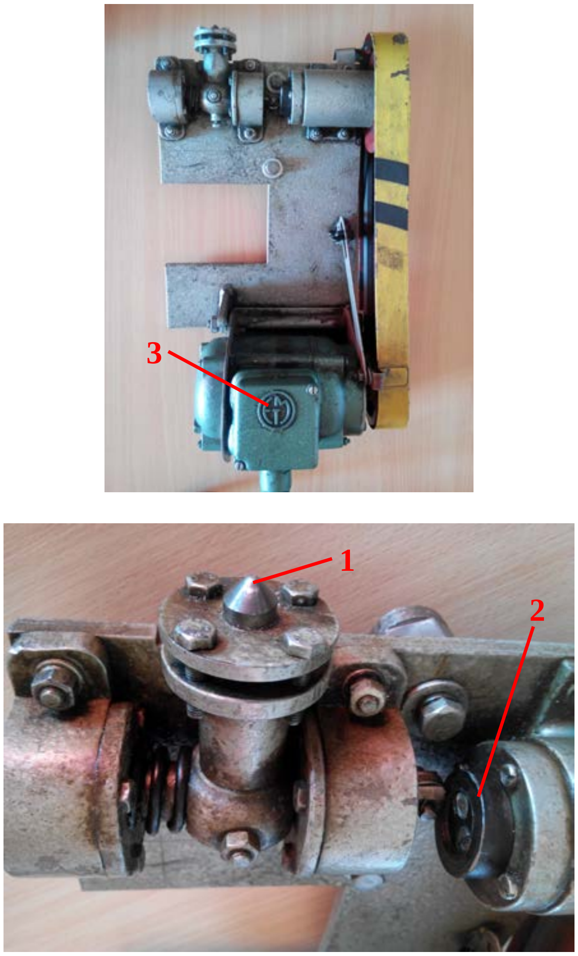

Fig. 2 Device for vibromechanical finishing

The device [6] (Fig. 2) uses for printing the deforming tool's traces, as a result of the vibratory motion, a spherical tip – **1**, made from tungsten carbide having r_{sf} = 2 mm. The vibratory motion is achieved by means of the front cam – **2**, whose raising ensures the vibration amplitude, 2e = 2 mm. The tool's vibrations frequency is a direct function of the rotation speed of electric motor – **3**, n_M = 2000 [rev/min]. So, n_L = 2000 [number of double strokes/min]. Pressure force P is given by a helical compression spring, which provides a maximum force of 37.5 daN. It works with a medium force of 25 daN.

3. Simulated Shapes of the Resulting Microrelief

The microrelief aspect is different depending on the technological parameters, namely the fractional part {i} of the value representing the report between n_L/n. So, {i} = 0 for MR I, {i} = 0.5 for MR II and {i} ≠ 0.5 for MR III. The maximum feed rate is established as a function of r_{sf}, t (the working depth, ~ 0.03 ... 0.06 mm, considering the previous maximum heigth of the surface's irregularities), e and {i}. Usualy, s_{max} can varies between 0.02 ... 3 mm/rev.

Shapes of the deforming tool traces remaining on the part, for all types of MR, are given in Fig. 3 – Fig. 6. They have been calculated with the following equation, set for our device and working conditions (Excel program was used to plot the graphs of simulation):

$$d = s\frac{\varphi}{360} + e \cdot \cos\left[\frac{\pi}{180}\left(\frac{n_L}{n}\varphi + \Phi_i\right)\right] \qquad (1)$$

where:
d [mm] – displacement of the deforming tool;
φ [º] – angle of rotation of the part;
Φ_i [º] – initial phase, the difference between the rotation angle of cam and the rotation angle of part, respectively.

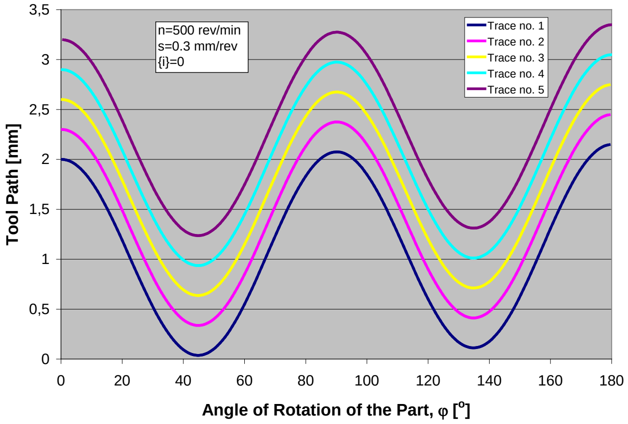

Fig. 3 Microrelief of type I - {i} = 0

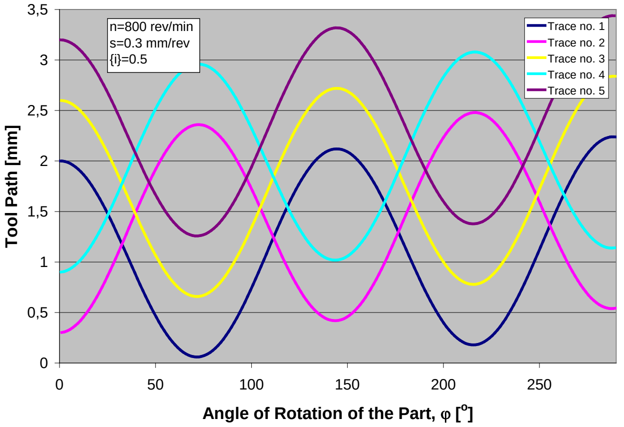

Fig. 4 Microrelief of type II - {i} = 0.5

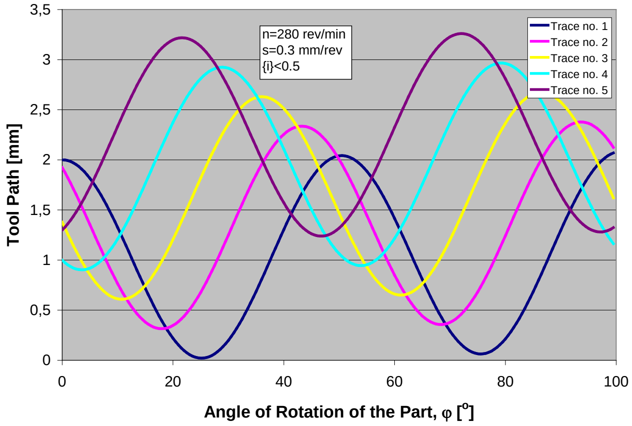

Fig. 5 Microrelief of type III - {i} < 0.5

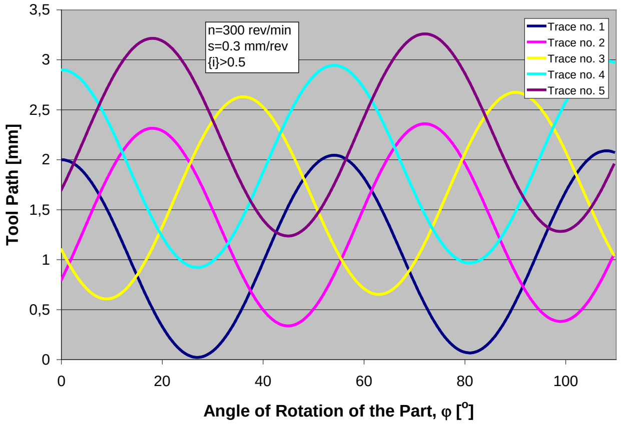

Fig. 6 Microrelief of type III - {i} > 0.5

4. Experimentation Conditions

Our tests focused on determining the dependence between technological parameters for vibromechanical finishing (rotation speed, feed rate) and characteristic features for the obtained surfaces (MR type, R_{max}). The experiments have been performed on three materials, such as: aluminium, brass and carbon steel. The conventional (manual) SN 380 lathe was used, choosing values of rotation speed (n = 71; 280; 800 rev/min) and feed rate (s = 0.008; 0.012; 0.016 mm/rev) specific to precision machining. The initial roughness of turning machined surfaces was $R_{max,\ i}$ = 4.39 µm (aluminium); 5.26 µm (brass); 5.79 µm (carbon steel). The double microscope Linnik-Schmaltz and light section method have been employed to measure the roughness parameter R_{max}, before (initial) and after (final) the vibromechanical processing.

5. Experimental Results and Discussion

The obtained results have been summarized in the graphs given in Fig. 7 – Fig. 9 (the roughness dependence on feed rate and rotation speed for each material), and Fig. 10 – Fig. 12 (the roughness dependence on feed rate, comparatively for the studied materials, for each rotation speed). The resulted types of microrelief was MR III – {i} < 0.5 for 71 and 280 rev/min, and MR II – {i} = 0.5 for 800 rev/min.

The best machining precision and, also, the largest coverage of surface with traces of the tool were obtained for the smallest feed rate (0.008 mm/rev), at the smallest rotation speed (71 rev/min).

For example, in case of aluminium sample (Fig. 13), the initial diameter was 29.07 mm, and after vibromechanical processing: 29.04 mm for s_1 = 0.008 mm/rev (lower with 0.03 mm); 29.09 mm for s_2 = 0.012 mm/rev (higher with 0.02 mm); 29.16 mm for s_3 = 0.016 mm/rev (higher with 0.09 mm). In all cases, the working depth (t) was 0.025 ~ 0.03 mm.

The material hardness and its behavior to deforming are important, too. From this point of view, the carbon steel, the hardest material, in correlation with the highest rotation speed, offers the best results. Brass' ductility is very helpful in making textures at the part surface. Aluminium, the softest material is the most easily deformable.

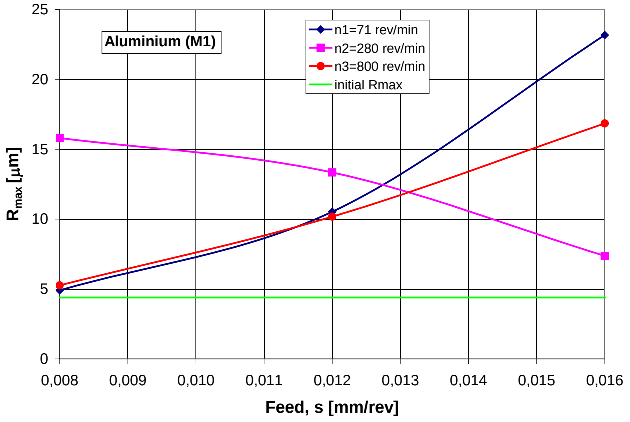

Fig. 7 Dependence of maximum roughness on technological parameters at vibromechanical finishing of aluminum

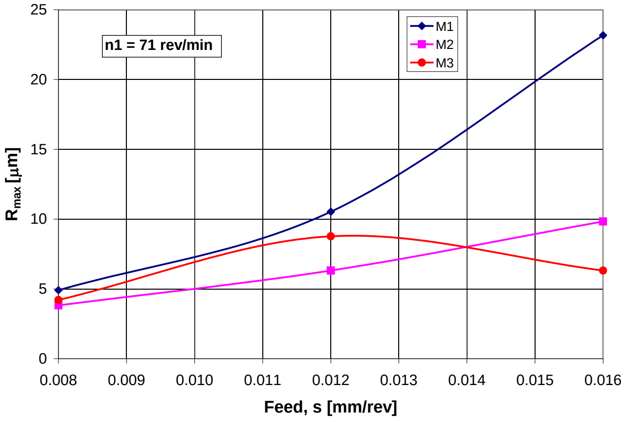

Fig. 10 Dependence of maximum roughness on feed rate at vibromechanical finishing, for all the three materials and n_1 = 71 rev/min

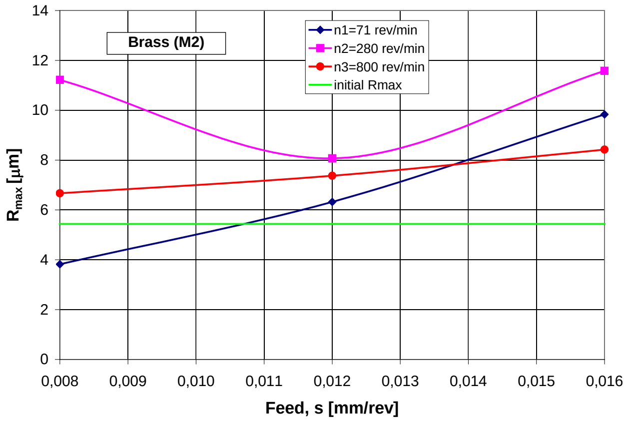

Fig. 8 Dependence of maximum roughness on technological parameters at vibromechanical finishing of brass

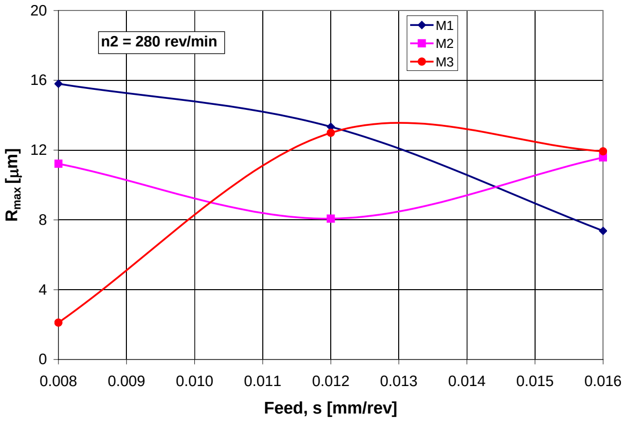

Fig. 11 Dependence of maximum roughness on feed rate at vibro-mechanical finishing, for all the three materials and n_2 = 280 rev/min

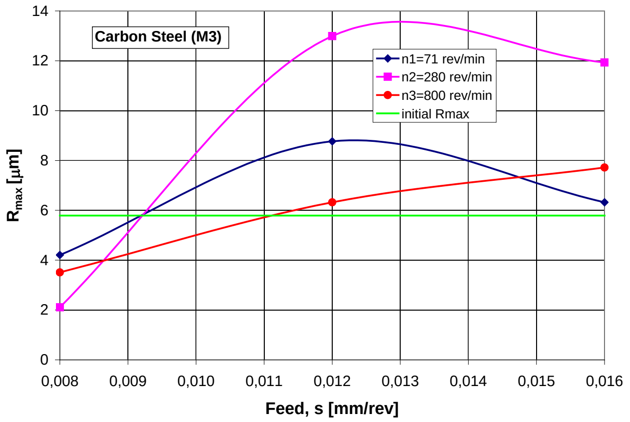

Fig. 9 Dependence of maximum roughness on technological parameters at vibromechanical finishing of carbon steel

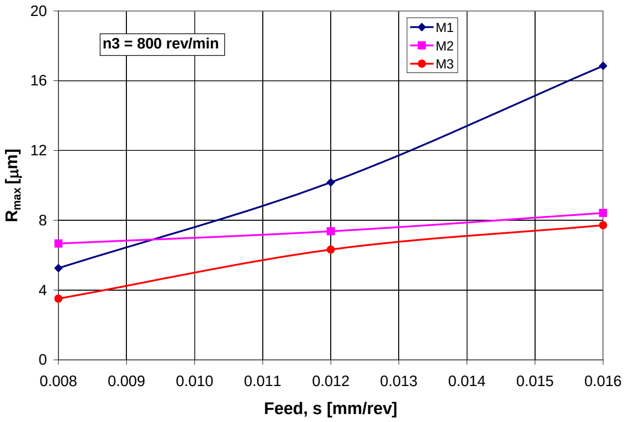

Fig. 12 Dependence of maximum roughness on feed rate at vibro-mechanical finishing, for all the three materials and n_3 = 800 rev/min

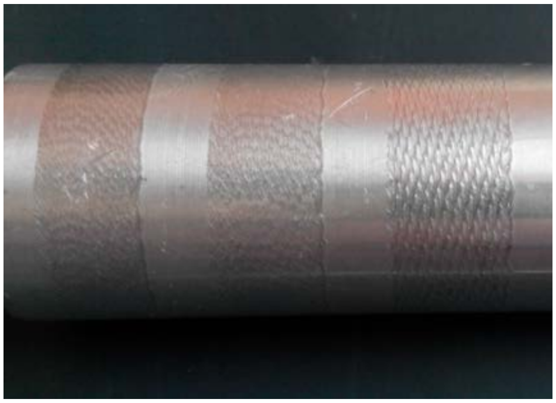

Fig. 13 The aluminium sample, processed by vibromechanical finishing with feed rates of 0.008, 0.012 and 0.016 mm/rev (from left to right), at a rotation speed of 71 rev/min

6. Conclusions

In this paper, a research of the influence of technological parameters on performance of vibromechanical finishing method has been made, with interesting results of the investigated materials for features such as increasing the wear resiatance, reducing the friction coefficients, decreasing the surface roughness, reducing the dimensional tolerances and hardening of surfaces, in applications of constructive elements from precision mechanics, as well as for decorative applications. The method has several potential advantages including: ease of adaptability to current manufacturing processes, relatively low equipment cost, and fast process time.

Study can be continued as regards the automation of working process and the microgeometries of texturization for components in tribological applications.

Acknowledgments

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