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Evaluation of microgeometry of cylindrical parts after cross-rolling in smooth plates

Alexander Metel¹, Semen Zaides², Nikolaj Bobrovskij³, Fam Dak Fong², Olesja Levitskih⁴, Le Hong Quang² and Aleksey Lukyanov⁴

¹ Moscow State Technological University Stankin, Moscow, Russian Federation

² Irkutsk National Research Technical University, Irkutsk, Russian Federation

³ Togliatti State University, Togliatti, Russian Federation

⁴ Samara Scientific Center of Russian Academy of Science, Samara, Russian Federation

E-mail: zsa@istu.edu

Abstract. Hardening and finishing processing of cylindrical parts by transverse rolling in smooth plates was studied. The effect of the relative deformation and rotational speed of the workpiece on the main quality characteristics of the surface layer of hardened parts, such as diameter accuracy, roughness and ripples of the surface layer was determined experimentally. The results of the work offer a means for adopting the described method of cross-rolling for manufacturing of machine parts. The process in question can be implemented without the use of environmentally hazardous lubricating cooling technological means, which makes it possible to attribute it in the future to one of the types of green mechanical processing technologies.

1. Introduction

The reliability and service life of machine parts is largely determined by the qualitative state of their surface layer [1]. The required parameters of surface quality and practically all the most important operational properties of machine parts can be provided by hardening by the method of surface plastic deformation (PPD). The widespread industrial use of PPD is explained by its high efficiency combined with high productivity and cost effectiveness. The hardening by the method of PPD leads to an increase in surface hardness, the formation of residual compressive stresses in the surface layers of parts and a favorable change in surface microgeometry. As a result, depending on the functional purpose and conditions of operation of parts, their fatigue and contact strength, wear resistance, corrosion resistance, and ability to retain lubricant increase [2, 3].

Cross running by flat plates is a promising technology of finishing finishing-hardening metal forming, allowing to process parts like discs, thin short axes and rollers [4]. A distinctive feature of hardening processing on smooth plates are: high processing performance, the ability to automate the process, eliminating the need to fix the part before processing, the absence of center holes, the availability of complete processing of the cylindrical surface without re-installing the part, the exception bending of the workpiece during hardening details.

The process of cross-rolling with flat plates is similar to the process of cross-wedge rolling [6, 7, 8]. The main parameters of cross-wedge rolling are the degree of compression and the geometry of the tool. In the process of cross running, the tool has the appearance of a smooth plate with a small angle of the



inlet part α_1 (figure 1). A small angle α_2 in the output part of the tool serves to reduce the stress concentration when the part leaves the machining area. Therefore, for the process of cross running, the main parameter of the treatment mode is the degree of relative compression Q [9, 10].

$$Q = \frac{F_n - F_{np}}{F_{np}} = \left(1 - \frac{d^2}{D^2}\right) \cdot 100\%, \quad (1)$$

where F_n - the area of the initial section of the workpiece; F_{np} - the cross-sectional area of the workpiece after running, D - the original diameter of the workpiece; d - diameter of the workpiece after running.

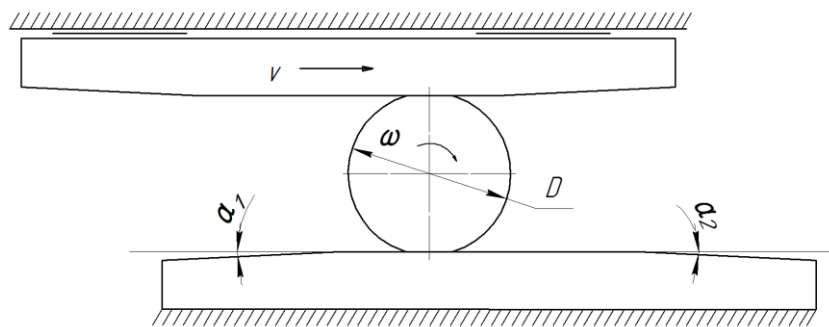


Figure 1. Scheme of the process of cross running smooth plates.

The kinematics of the process of cross-rolling with smooth plates and processing modes are described in [11, 12]. The considered process of finishing and hardening by running with smooth plates is a new type of surface plastic deformation [13, 14]. Therefore, the condition of the surface layer and parts in general is important for the implementation of this processing scheme in the technology of manufacturing machine parts [15]. The purpose of this work is to assess the quality of cylindrical parts, strengthened by running in smooth plates.

2. Experimental Procedure

To determine the influence of the degree of relative compression on the quality of the surface layer, an experiment was conducted with statistical processing of the results obtained. The main parameter of the experiment, affecting the quality of the surface layer, adopted the degree of relative compression. As indicators of the quality of hardening considered: deviation from roundness, roughness parameter (R_a), and waviness (W_a).

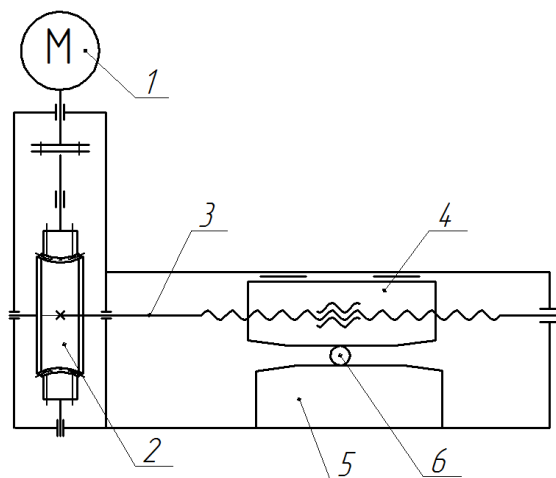


Figure 2. Scheme of the rolling machine.

1 - electric motor, 2 - worm gear, 3 - working screw, 4 - movable plate, 5 - fixed plate, 6 - work piece.

The experiments were performed on a flat-boring machine (figure 2), which works as follows: rotation from the shaft of the electric motor 1 is transmitted through the worm gear reducer 2 to the working screw 3. Using a threaded hole in the movable plate 4, the rotation of the screw 3 is converted into translational motion of the plate 4 which moves from left to right and realizes cross running of part 6. The reverse movement of the movable plate 4 to the initial position is carried out by reversing the rotation of the electric motor 1.

3. The effect of the degree of relative compression on the quality of hardened parts

Twelve cylindrical specimens with a diameter of 8 and a length of 65 mm from structural carbon steel 45 were used as the investigated parts. Each group, consisting of three parts, is machined on a rolling machine with an absolute reduction value of 0.1; 0.2; 0.3; 0.4 mm. These values consistently correspond to the degrees of relative reduction (Q) of 0.8%; 1.3%; 1.8% and 2.4%. All parts were tested for four full turns before leaving the treatment area.

3.1 Estimation of the diameter

After cross-rolling, the change in the diameter of the parts is determined by a micrometer with an accuracy of 0.01 mm. The measurement results are shown in figure 3. Diameter changes are in the range of 24-32% of the absolute compression. This is due to the elastic deformation of the workpiece and the deformation of the device itself. The increase in the relative compression increases the change in the diameter of the parts almost linearly.

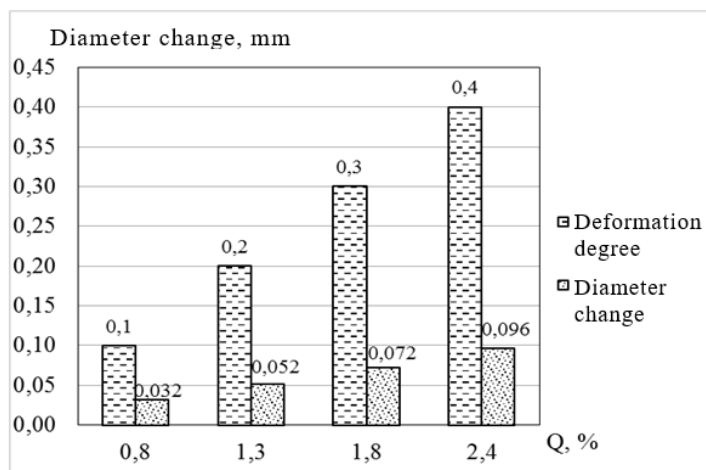


Figure 3. The effect of relative compression on the change of the diameter of the workpiece.

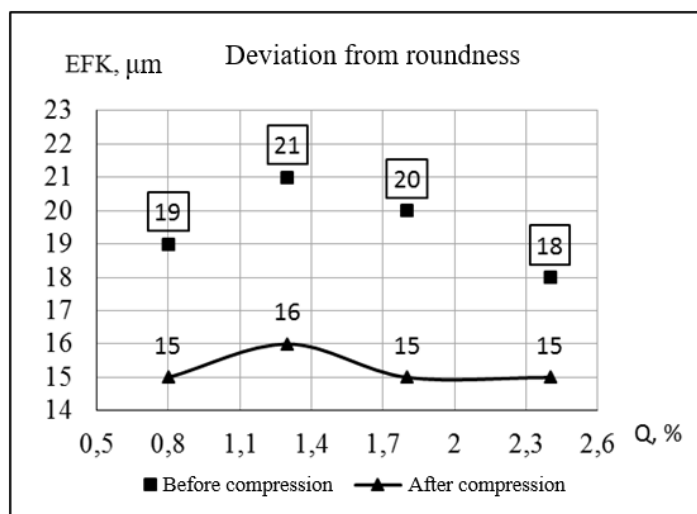


Figure 4. The dependence of the deviation from roundness on the magnitude of the relative compression.

The deviation from the roundness of the parts was measured with a portal coordinate measuring machine (CMM) CONTURA G2 with a scale value of 1 μm . In figure 4 shows the deviation from the roundness of the samples before and after running. The initial degree of accuracy of a batch of parts is the tenth. After cross running, the accuracy of the part shape is increased by one degree. The value of the absolute compression does not have a significant impact on the accuracy of the hardened parts.

3.2. Evaluation of roughness and waviness of the rolled surface

After running in the blank, the measurement of roughness and waviness parameters was performed on a Taylor Hobson Form Talysurf i200 computer-controlled profilometer. For each part, the initial and the resulting roughness are measured at three different places around the circumference. The average values of the three measurements obtained are shown in figure 5. The initial surface roughness of the parts, obtained after semi-turning, reaches the fifth class (R_a 2.5 ... 5.0 μm). After cross-rolling, the roughness class rises to the eighth

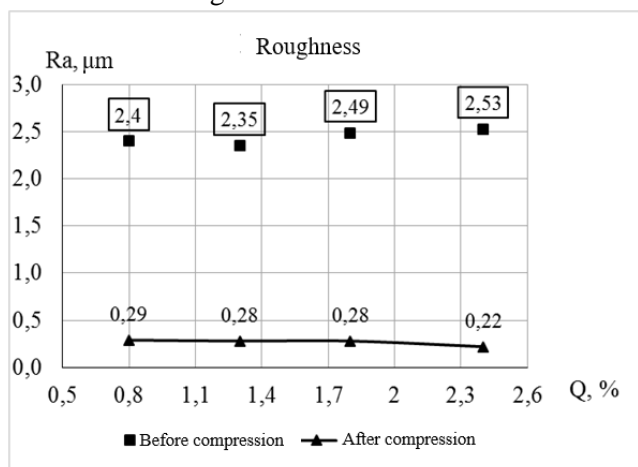


Figure 5. The dependence of the roughness of the rolled surface on the degree of relative compression.

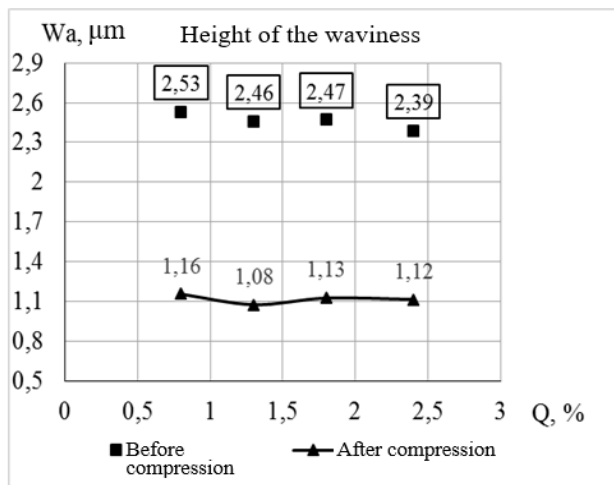


Figure 6. The dependence of the height of the waviness of the rolled surface on the value of the relative compression.

Cross rolling can significantly reduce the surface roughness of the parts. This is explained by the fact that in casting from local hardening methods during cross-rolling, the deformation zone is extended to the entire length of the cylinder forming line. This gives a more favorable condition for smoothing asperities in the direction of the axis of the cylinder. With an increase in the relative compression, the clamping force of the tools on the surface to be treated increases. At a small amount of reduction, incomplete smoothing of irregularities occurs, since a small specific pressure does not allow to completely deform the surface asperity. Similarly, there is also a sharp decrease in the height of the waviness (more than twice) after running (figure 6).

4. The effect of the number of revolutions of the workpiece on the quality of hardened parts

The experiments were performed to study the effect of the number of revolutions of the workpiece on the quality of the hardened layer and parts in general. For these experiments, a batch of twelve cylindrical samples with a diameter of 16 and a length of 65 mm from structural carbon steel St45 was used. Each group, consisting of three parts, is machined on a rolling machine with an absolute reduction of 0.2 mm. All parts were run-in, respectively, for 2, 4, 6, 8, 10 full turns before leaving the treatment area.

4.1 Estimation of the diameter

At different speeds of the workpiece, the decrease in the diameter of the cylinder after running in is almost the same and was 0.05 mm. This means that the number of revolutions slightly influences the final size of the parts. In figure 7 shows that increasing the number of revolutions of the workpiece has a positive effect on the accuracy of the rolled parts.

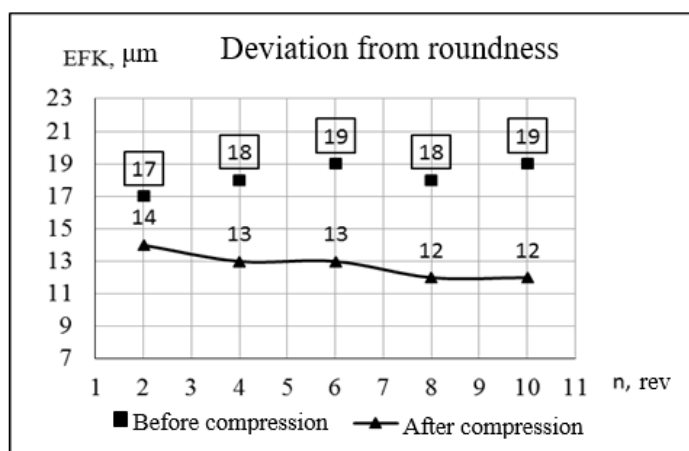
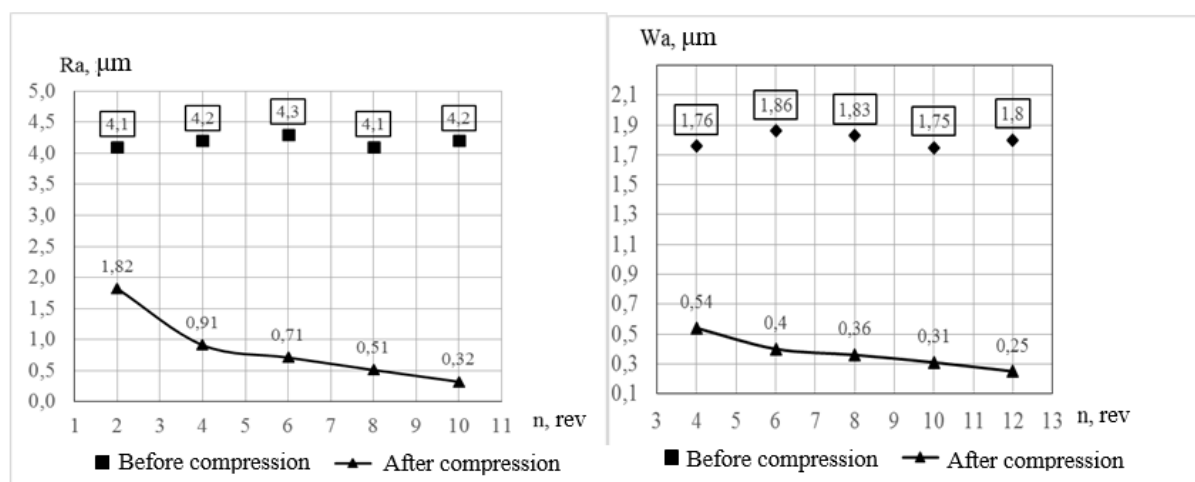


Figure 7. The dependence of the deviation from roundness on the number of revolutions of the workpiece.

4.2. Evaluation of roughness and waviness of the rolled surface

Figure 8 illustrates that the roughness improves dramatically with an increase in the number of revolutions from two to four and further, the roughness also decreases, but with less intensity. A similar pattern is obtained for the height of the waviness. This circumstance suggests that an increase in the number of revolutions of the workpiece during running-in significantly affects the quality of smoothing the surface asperities.



a)

b)

Figure 8. Dependence of roughness (a) and waviness (c) of the rolled surface on the number of revolutions of the workpiece.

5. Conclusions

Experimental studies to assess the quality of parts after surface plastic deformation by cross-rolling with smooth plates showed the following favorable changes in the surface layer of samples: a sharp decrease in the initial roughness, ensuring high accuracy of the processed part in size and shape. When cross-rolling, depending on the amount of compression and the number of revolutions of the workpiece, the surface quality increases by 1-2 classes. The results obtained allow us to state that for strengthening processing of a certain group of parts (short shafts, rollers, axles, bushings, pins) it is advisable to use the proposed method of cross running with smooth plates, which allows to obtain high quality parts.

Acknowledgments

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