The influence of rolling on the variation of unevenness parameters of the treated surface

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Abstract. The paper studies the process of changing the elements of the surface roughness by lathe work in the course of the surface plastic deformation, or rolling. The results of the work allow enhancing the treatment technology and improving the quality of the machine elements.

1. Introduction

The enhancement of the operational characteristics of work-pieces is connected with the improvement of the quality parameters of their surface, which is often achieved by means of different kinds of surface plastic deformation.

One of these kinds is burnishing. It refers to the static method of the surface plastic deformation, which allows enhancing both the strength characteristics of the surface and its wearability [1, 2]. The major parameters of the process are the contact force and the size of the working part of the indenter [2, 3].

It is known [2, 5-7] that asperities on the contact surface of the deformation zone and the tool are plastically deformed. Besides, they change their form, or move down, filling the hollows by metal (while the bottom of the hollow rises up). The change parameter of the original roughness is not usually specified and the process continues until the asperities and the bottom reach the same level. It is obvious, that there is an opportunity to enhance the process by improving the quality of the deformed surface and finding the best values of hardening and roughness for work-pieces regarding their special functions.

The aim of the paper is to study the deformation parameters of the surface elements during rolling, and to determine the conditions of getting the best value of the surface roughness after hardening. The surface plastic deformation, as a rule, occurs after the mechanical treatment by means of turning or grinding. The mechanical treatment results in the roughness of the surface which looks like a sequence of hollows and bulges, being the traces of the cutting tool. Every such surface element in section is presented in the form of a triangle, which differs in the angle \( \alpha \) and the height \( h \) (fig. 1). Two variants of the process of changing the form of the surface elements by plastic deformation are possible [3, 4, 5-7]. They are characterized by the change of the angle \( \alpha \). In case the angle flattens out (fig. 1, a), the hollows look like discontinuity, with the angle \( \alpha \) flattening out to zero. Thus, “collapsing” occurs. As a result, co-directional micro-fissures appear on the surface.
If the forming takes place with an increase of the angle $\alpha$ up to $180^\circ$ (fig. 1, b), one can observe leveling. The hollow bottom rises up, while the tops of the surface elements flatten out. The surface becomes more even, there are no traces of the original roughness left. If the forming process is not completely finished, the surface hollows will remain and serve as oilways later on.

**Figure 1.** The change of surface elements by plastic deformation: $\alpha$ – an angle; $h$ – height; $b$ – the distance between the nearby adjacent asperities; $l$ – the width of the contact surface of an asperity.

### 2. Research

The forming process is studied on two samples in the form of rectangular blocks having waviness on one of the surfaces like the one after mechanical treatment. The working assumption is that in cross section the waviness looks like a triangle (fig.2). To carry out the experiments, three types of samples are used with the angle of the surface elements $\alpha$, corresponding to: $90^\circ$, $120^\circ$, and $150^\circ$, and the intervals: 1,5 mm, 1,5 mm, and 2 mm respectively.

Later on, the samples are rolled. To do this, a cylindrical indenter 1 is fixed on the spindle of a horizontal milling machine, revolved by line feed (вращаемый посредством продольной подачи) relative to sample 2 and at angle $\beta$ relative to the longitudinal direction of the waviness (Fig. 3). The angle $\beta$ is set at the values $0.45^\circ$ and $90^\circ$.

**Figure 2.** A sample with the waviness in the form of a triangle.
Figure 3. The process of deforming a sample: a – at an angle of 0°, b – at an angle of 45°, c – at an angle of 90°.

Measuring of the height parameters of the surface elements of the deformed samples is done by a contact method with the use of a mercer clock gauge of ICh10 type, having a spear fixed in a support with an accuracy of 0.01mm. The width of the contact flattened surface of the tops of the asperities is measured by BMI microscope in reflected light with an accuracy of 0.005 mm regarding 50-fold increase.

The measurements are done in 4 cross-cut sections of the deformation zone, where the metal of the sample is re-deformed up to a certain constant value. The number of the measured elements amounts to 6-8 per each section for the sake of static processing.

It is clear that with the increase of the deformation degree the depth of the hollows decreases while the square of the flattened surface tops of the asperities increases (fig.4). The elements of the surface straighten up in the longitudinal direction of the asperity if the load is applied at an angle of $\beta = 0°$. If the load is applied at an angle of 45° or 90°, the elements of the surface are also deformed in the direction of the indenter motion, i.e. at an angle to the longitudinal direction of the waviness.

Figure 4. A re-deformed sample.

According to the measurements, we counted the aperture angles, the relative change of the depth of the surface elements and the relative width of the contact surfaces regarding the degree of plastic deformation of the surface layer of the sample.

Figure 5 presents the diagrams of the height change of the surface elements. Having analyzed these diagrams, we conclude that when rolling at 0° and 45° angles relative to the surface the difference in the height of the asperities is insignificant in comparison with the rolling at 90° angle. In case of rolling at 90° angle the bulbs of the diagrammatic curves go up, while in the case of rolling at 0° and 45° angles the decrease of the height parameter is observed on the diagrams where the bulbs of the diagrammatic curves first look down and then up. When rolling at 0° angle one can observe a sharp decrease of the height parameter in comparison with the other angles. The diagrams of the height parameters are located from low to high regarding the angle of the asperity surfaces (150°, 120°, 90°...).
respectively). It proves the preliminary data that in case of rolling at 90° angle the height of the surface elements of asperity is greater and it gives more opportunities to enlarge the height parameter.

Figure 5. The change of the height of the surface elements with respect to an indenter moving at: a) 0° angle, b) 45° angle, c) 90° angle relative to the surface while rolling.

Figure 6 presents the diagrams of the change of the aperture angle of the surface elements. Having analyzed these diagrams, we conclude that the diagrams of the aperture angles are located from low to high regarding the angle of the asperities (90°, 120°, 150° respectively). Due to the diagrams, when rolling the aperture angle increases, as a consequence, there will be no fractures on the surface. When rolling all the aperture angles increase smoothly and evenly. In case of burnishing at 45° angle all the diagrams have bulbs of diagrammatic curves first going up and then down, and in case of rolling at 0° and 90° angles the increase of the aperture angle can be observed at the diagrams at which the bulbs of the diagrammatic curves go down.

Figure 7 presents diagrams of the change of the width of the surface elements. Having analyzed these diagrams, one can conclude that they are located from low to high regarding the angle of the rolled steel section surface of 90°, 120°, and 150° respectively.

Figure 6. The change of the aperture angle of the surface elements with respect to an indenter moving at: a) 0° angle, b) 45° angle, c) 90° angle relative to the surface while rolling.

It proves the preliminary data that the distance between the surface elements of asperities (in case of 150° angle) is bigger, which means there are more opportunities to make the width parameter bigger. The diagrams show that when rolling the width parameter increases. Thus, when rolling the width increases smoothly and evenly regarding all the types of deformation. The form of the diagrams is close to the linear function.
3. Conclusion

Thus, the experiments show that collapsing is more common among the two ways of treatment of the surface elements (“burnishing” and “collapsing”). It means that regardless of the aperture angle value $\alpha$ the rough elements tend to become fractures. Rolling (relative to the asperities) should be done at $45^\circ$ angle, the aperture angle would better be over $120^\circ$. The deformation of the surface layer being at the level of 60-70 % of the height of the original roughness, rolling will allow forming a net of hollows on the surface, which will serve as oilways when the working piece is used. The relations on the diagrams allow determining the parameters of the formed oilways, the type of the finishing work and the value of the original (before the surface plastic deformation) roughness of the piece surface.

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