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ANALYSIS OF BALL BURNISHING INFLUENCE ON TRIBOMECHANICAL PROPERTIES OF ALUMINUM

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Abstract: *In recent years, modern industry has been paying great attention to the environmental aspects of processing that relate to the elimination of processes requiring cooling and lubricating agents, whenever possible. Used equipment for cooling and lubrication, according to modern legal regulations, must be stored and destroyed in an appropriate manner, i.e. recycled, which increases the costs of business entities. On the other hand, the demands of the market in terms of geometric and dimensional accuracy are getting tougher, and it is therefore desirable that coarse and finishing workpieces are carried out in one clamping in order to eliminate baseline errors. To this end, a finishing tool has been developed without removing the chips from material, i.e. plastic deformation of the surface layer of the object of processing. This paper deals with the study of the influence of this type of treatment on the micro-hardness of the surface layer as well as on the wear resistance. The tests were carried out on aluminum alloy EN AW-6082 (AlMgSi1) T651.*

Keywords: *one clamping, plastic deformation, finishing, micro-hardness.*

1. INTRODUCTION

Methods of mechanical treatment are classified into two groups, to processes with chip removal, and methods without removing material. If the above division of mechanical treatment is taken into account, then the metal finishing process based on rolling a ball on the surface of the processing object can be classified into processing operations without removing excess material. The main goal of the final mechanical processing is to achieve the maximum level of processing quality. The quality of processing is a very complex indicator and the function is the quality of the construction workpiece, the quality of the processing system, the projected production process, the quality of the semi-finished products, etc. [1, 2].

"Ball burnishing" is a process in which the ball is rolling over the surface of the processing object, with high contact pressures. High contact pressures lead to plastic deformation of the surface layer of the processing object, resulting in material leakage and the uneven surfaces fill the dents of the profile of the surface to be processed. In addition to significantly reducing surface roughness, this method also leads to hardening of the surface layer due to the reinforcement effect. The depth of the reinforced layer depends on the material of the processing object and the parameters of the "ball burnishing" process. [3].

The "Burnishing" process can be applied to various types of materials such as: steel [Rao et al., 4; Bougharriou et al., 5; Ibrahima et al., 6], aluminum alloys [El-Axir, 7; Gharbi et al., 8; Travieso-Rodriguez et al., 9, Esme et al., 10; Basak and Goktas, 11], brass alloys [El-Taweel and El-Axir, 12], titanium alloys [Mohammadi, 13], etc.

El-Axir [14] examined the dependence of residual stresses and fatigue on materials depending on the parameters of the "burnishing process" (speed, force, etc.). Sayahi et al. [15] presented the 2D and 3D model of finite elements. They considered the ability of the proposed model to consider the residual stresses generated by the processing process. The results show that the 3D model provided residual stress with the information on processing parameters used. Rao et al. [16] examined the dependence of the "burnishing" parameters on the surface hardness and the strength of low-alloy steels. It has been proven that the lubricant, speed and diameter of the ball had a significant impact on the surface hardness of the workpiece. Basak and Goktas [17] considered the effect of the number of passages, forces and rpm on the surface roughness and hardness of Al 7075 T6 material. El-Taweel and El-Axir [12] applied the "Taguchi" method to determine the optimal parameters of the "burnishing" process in terms of surface roughness and microhardness. Abu Shreehah [18] compares the influence of the different method of "burnishing" the process on microhardness and surface roughness. Empirical formulas have been developed that predict surface roughness and microhardness on mesing. Babu et al. [19] evaluate the effects of the different parameters of the "burnishing" process on the characteristics of the steel and brass surface. "Taguchi" technique was used to determine the most influential parameter on surface roughness.

Tadić et al. [20] examined the impact of the "burnishing" process on the roughness of the surface. The processing was done using a specially designed high-stiff tool. The authors have proven that the high rigidity of the tools increases the quality of the processing. El-Tayeb et al. [21] designed a tool with which carried out the burnishing process on aluminum 6061 workpieces with different processing parameters. The experiment was carried out with the aim of determining the optimal processing parameters for the tribological properties of the surface. The aim of this paper is to examine the influence of surface treatment by "Ball Burnishing" on the mechanical and tribological characteristics of aluminum. To determine these characteristics of the tested surfaces, the Scratch Test was selected due to the concept of the test procedure as well as counter body, which is a Rockwell diamond cup with a radius at the top of 120 °. These tests were preceded by tests on the Nanotribometer, which indicated the tendency of aluminum to be transferred to the surface of the counter body [22], with the tribological parameters of the contact being drastically changed after the material transfer occurred. Accordingly, the scretch test proved to be a very reliable way of characterizing tribological characteristics of aluminum.

2. MATERIAL

The experiment was carried out on a plate 62x62x25 mm from the aluminum alloy EN AW-6082 (AlMgSi1) T651. The processing was carried out with a ball diameter of 7 mm from A 295 52100 (USA/ASTM).

The machining of the "ball burnishing" was preceded by the preparation of the surface by milling with a 20 mm diameter milling cutter. The rolling treatment is carried out in a field of 10x10 mm, with the feed f = 0.2 mm / min and the speed v = 2000 mm / min. The depth of the ball piercing in the material of the processing object was δ = 2 µm. Figure 1 shows the tool in the procedure during the experiment.

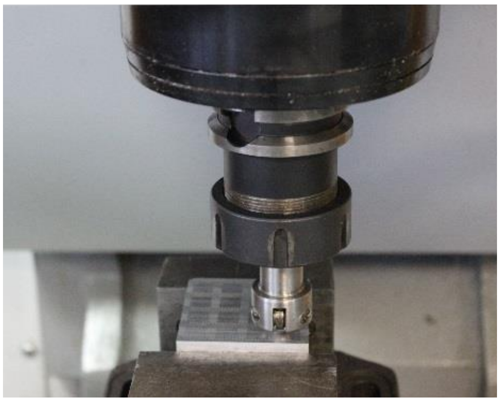


Figure 1. Displays the tools in the procedure

The "ball burnishing" procedure was performed on a single-spindle vertical milling machine HAAS Toolroom Mill TM-1HE.

A solid surface treatment tool with "ball burnishing" was used to perform the experiment.

The rigidity of the tool is very high and is determined by the size of the deformations that occur in the contact of the ball and the three radial bearings that are arranged under a spatial angle of 120º in relation to the direction of penetration of the ball into the material of the object of the treatment. With this concept of the tool with the reliance of the ball around the three points, it is ensured that the ball is completely rolling at the level of processing.

2.1 Experiment

The tribomechanical characterization of the prepared samples was carried out using the CSM (Anton Paar) Scratch tester (Figure 2) using a progressively increasing normal load, from a starting value of 0.01 N to a maximum value of 5 N. The length of the slip route was 2.5 mm, with a slip speed of 0.5 mm /min, i.e. a normal power increment was 1 N/min. On both surfaces, the previously milled surface and the surface area processed by Ball Burnishing, 5 tests were performed with identical values of the starting parameters. Accordingly, the values shown represent the midlle value of all five examinations of the obtained surfaces.

The Scratch test is performed in three phases. The first phase involves the analysis of the investigated surface with a minimum force of 0.01N, in order to determine the roughness profile of the surface, based on which the values of the depth of penetration of the impeller (Rockwell Coupe) are determined at the next stage. The first phase is called Pre-scan. The next phase, represents the scratch test during which penetration of the impellers in the examined surface layer occurs in accordance with the predetermined parameters. The second phase result is the penetration depth of the impeller as well as the friction coefficient value. The final, third phase or post-scan is also performed using a minimum load of 0.01 N in order to determine the value of the elastic relaxation of the material, that is, the residual depth values.

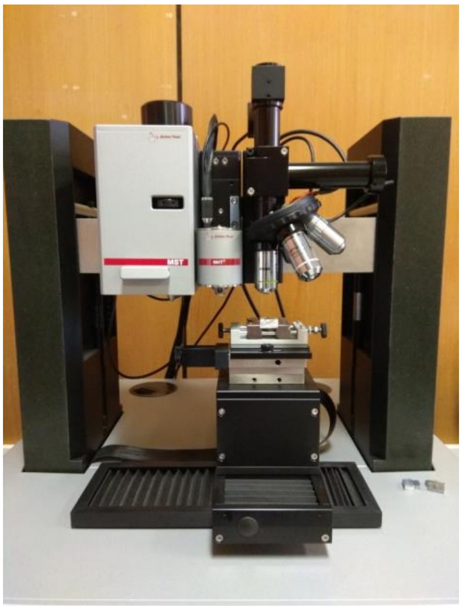
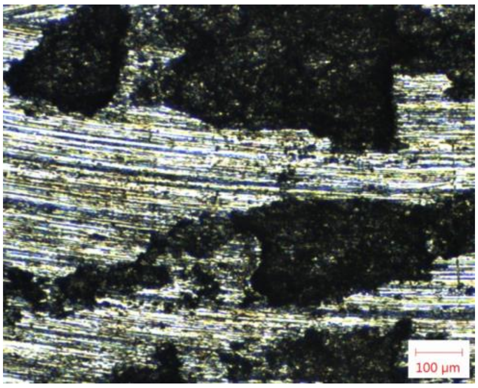


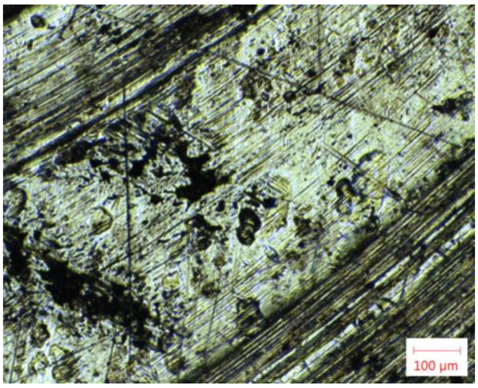
Figure 2. CSM (Anton Paar) Micro Scratch Tester (MST)

2.2 Results and Discussion

The tests themselves were preceded by an analysis of the examined surfaces by the use of an optical microscope, so in Figures 3a and 3b, the appearance of the surfaces obtained by milling and the application of a ball burnishing process with a penetration depth of 2 µm can be seen. On the surface obtained by pre-treatment milling, in addition to the traces of the rotary movement of the tool, there are also visible surface damage, which partly arises from the selection of the parameters of the technological process, and partly from the transfer of materials to the tool. In the area obtained by "ball burnishing" there are also traces of the previous processing of the milling machine, which leads to the conclusion that with the penetration depth of 2 µm, the traces of the previous processing have not been completely removed, that is, the processing of the peaks of the roughness has occurred. Also, it is noticeable that the surface damage is largely eliminated, but not completely, which probably requires greater penetration depth in the "ball burnishing" process.



a)



b)

Figure 3. The area of the examined methods of milling and "ball burnishing"

That this conclusion is justified is shown in Figure 4, which shows the profiles of the roughness of the investigated surfaces. From these diagrams it can be concluded that the surface roughness profile obtained by treating milling oscillates in a much larger range than the roughness profile obtained by the "ball burning" process. The ball burnishing process corrected the roughness profile and removed the surface damage. This is what is based on the assumption that the compression of the material in the surface layer led to improvements tribomechanical material characteristics.

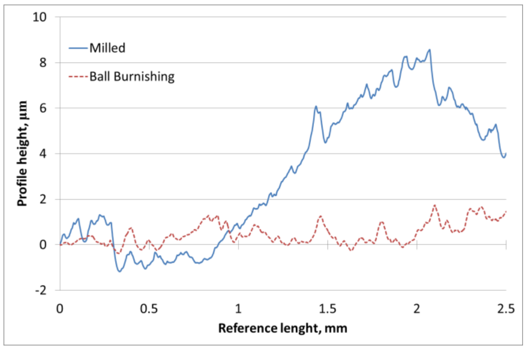


Figure 4. Profiles of roughness of examined surfaces, obtained by milling and "ball burnishing".

The basic tribological phenomena are friction and wear. The friction in this case is expressed through a friction coefficient, and the diagrams of this size for both tested surfaces are shown in FIG. 5.

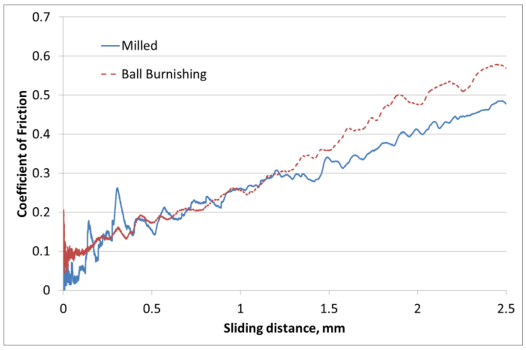


Figure 5. Coefficient of friction of surfaces obtained by milling and "ball burnishing"

From the picture, it is noticeable that the friction coefficient for the surface obtained by "ball burnishing" in the initial moments almost overlaps with the values of the coefficient of friction of surfaces obtained by milling. In the areas obtained by milling the oscillations in the values of the friction coefficient, they are significantly higher in the initial phase than the friction coefficient of the surfaces obtained by "ball burnishing", which is due to the application of small load values as well as the expressed surface roughness. In the second half of the slip time, the situation is reversed, since the effect of surface roughness ceases and the value of the friction coefficient depends solely on the characteristics of the surface layer through which the indenter slides. As the surfaces obtained by "ball burnishing“ make this surface layer more compact, the resistance of penetration and movement through such a surface layer is greater, so the value of the friction coefficient is higher.

As an indication of the resistance to wear of the examined surfaces, the depth of penetration of the indenter by pirlic sliding is taken, and in addition to the value of the depth of the trace of wear, after the elastic relaxation of the material (Figure 6). The penetration depth of indenter thru surfaces obtained by “ball burnishing“ is smaller compared to the surfaces obtained by milling. A small difference and the measured values of this parameter is due to the fact that in the case of “ball burnishing“ with a penetration depth of 2 μm, the entire surface is not fully processed, which can be clearly seen in Figure 3b. Also, the degree of elastic relaxation of the material is more pronounced in the milled surfaces, since the material in the surface layer in “ball burnishing“ is further deformed by the movement of the ball.

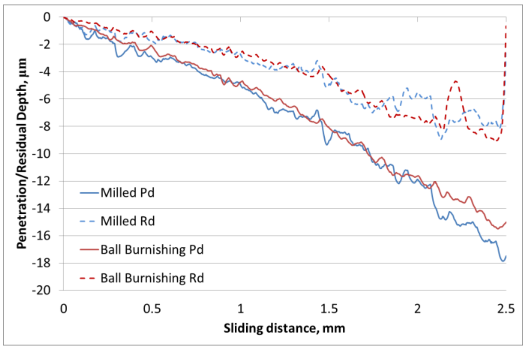


Figure 6. Penetration and residual depth of surfaces obtained by milling and “ball burnishing“.

3. CONCLUSION

Based on the experimental results, the following conclusions were drawn:

Surface machining with “ball burnishing“ positively influences the quality of treated surfaces and in this way it is possible to eliminate traces and defects that occur on surfaces after conventional material processing. The results of the study showed that the roughness of the surfaces significantly improved, which also affects the visual or decorative aspect of the treated surfaces. By applying “ball burnishing“, a greater compactness of the contact surface layer is achieved.

The sliding friction coefficient on surfaces treated with “ball burnishing“ is greater than the friction coefficient of surfaces obtained by milling, as a result of increased resistance of penetration and slip through the material of higher density.

From the abrasion resistance, the obtained penetration depth results indicate increased resistance to penetration and wear of surfaces obtained by “ball burnishing“, while the degree of elastic relaxation is lower in relation to surfaces obtained by milling.

The application of “ball burnishing“ with a penetration depth of 2μm has shown that with the application of this technique with significantly greater depths of penetration, it is possible to achieve significant improvements in the surface layer of the material both in the decorative and in the sense of improving the tribomechanical characteristics.

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