TRIBOLOGICAL PROPERTIES OF (EN AW-ALCU4MGSI(A)) ALUMINIUM ALLOY SURFACE LAYER AFTER BALL BURNISHING


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Abstract: EN AW-AlCu4MgSi(A) aluminium alloy is widely used as a structural material in aerospace and automotive applications. We have subjected it to grinding, polishing and ball burnishing. We have performed ball-on-disk tribological tests. We have also determined normalized 3D roughness parameters. High surface smoothness turns out to be obtainable. Favorable effect of the ball burnishing on the tribological properties of the alloy are seen. Results will be presented at the Conference.

Keywords: ball burnishing, grinding, polishing, tribological properties, surface roughness

1. INTRODUCTION

One of the principal attributes of technological quality of machine parts is their wear resistance-dependent on mechanical working processes, often preceded by thermal and sometimes thermo-chemical treatment. Wear is related to the surface roughness and to the hardness of the surface layer.

Burnishing enables improvement of surface properties [1, 2]. It relies on local cold plastic deformation of the object by the force and kinetic co-operation of tool and the worked surface. We have applied it to an aluminium alloy.

2. EXPERIMENTAL

Our workpiece material was a EN AW-AlCu4MgSi(A) aluminium alloy in the hardened T451 state. Tables 1 and 2 specify its chemical composition and the mechanical properties.

Table 1. Chemical composition of EN AW-AlCu4MgSi(A) alloy.

<table>
<thead>
<tr>
<th></th>
<th>Ti</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti+Zr</th>
<th>other</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06</td>
<td>0.64</td>
<td>0.04</td>
<td>4.2</td>
<td>0.95</td>
<td>0.76</td>
<td>0.04</td>
<td>0.17</td>
<td>0.06</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mechanical properties of EN AW-AlCu4MgSi(A) alloy.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate tensile strength Rm [MPa]</td>
<td>445</td>
</tr>
<tr>
<td>Yield stress Rp0.2 [MPa]</td>
<td>292</td>
</tr>
<tr>
<td>Elongation A5[%]</td>
<td>17</td>
</tr>
<tr>
<td>Hardness [HB]</td>
<td>110</td>
</tr>
<tr>
<td>Density [g/cm³]</td>
<td>2.80</td>
</tr>
</tbody>
</table>

We have applied grinding, polishing and ball burnishing. The abrasive wear resistance was determined by the “ball-on-disc” method with a T-01M mechanical tester (Fig. 1). Standards ASTM G 99-05 and ISO 20808:2004 were applied. In the ball-on-disc method, sliding contact is brought about by pushing a ball specimen onto a rotating disc specimen under a constant load. A controlled load $F_n$ is applied to

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the ball holder and the friction force measured continuously during the test with an extensometer. For each test, a new ball was used or the ball was rotated so that a new surface was in contact with the disc. The ball and disc samples were previously washed in ethyl alcohol and dried. The following test conditions were applied: ball diameter = 6 mm, applied load = 0.25 N, rotation speed = 120 min⁻¹, radius of the sliding circle = 3 mm, number of cycles = 2000. The tests were carried out without a lubricant at room temperature at 60 % relative humidity.

Dynamic friction $\mu$ was calculated as:

$$\mu = \frac{F_t}{F_n}$$  \hspace{1cm} (1)

where $F_t$ is the measured friction force and $F_n$ is the applied normal force. The cross-sectional profile of the wear track was measured at four places at intervals of 90° using a contact stylus Micro-Combi-Tester and the average cross-sectional area of the track calculated. The specific wear rate $W_s$ is calculated from:

$$W_s = \frac{V}{F_n \cdot L}$$  \hspace{1cm} (2)

where $V$ is the volume of the removed material and $L$ is the sliding distance.

Surface topographies resulting from grinding, polishing and burnishing were recorded and 3D roughness parameters (ISO 25178 and EUR 1517 EN) were estimated using a TOPO-01P profilometer with a diamond stylus radius of 2.0 µm.

3. RESULTS

The roughness parameters obtained are listed in Table 3 of the tested surface before wear test was dependent on what type of surface treatment was used (Table 3).

<table>
<thead>
<tr>
<th>Surface treatment</th>
<th>Sa</th>
<th>Sz</th>
<th>Sk</th>
<th>Spk</th>
<th>SvK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding</td>
<td>0.270</td>
<td>4.978</td>
<td>0.818</td>
<td>0.267</td>
<td>0.463</td>
</tr>
<tr>
<td>Polishing</td>
<td>0.108</td>
<td>4.685</td>
<td>0.260</td>
<td>0.336</td>
<td>0.085</td>
</tr>
<tr>
<td>Burnishing</td>
<td>0.028</td>
<td>0.329</td>
<td>0.088</td>
<td>0.035</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Surface profiles obtained for different machining conditions are presented in Fig. 2. As shown in Fig. 2 all sharp peaks profile after burnishing are completely deformed by the ball and a very smooth profile is generated.
Figure 2. Examples of surface profiles produced in machining operations: grinding, polishing and ball burnishing.

Results of dynamic friction $\mu$ determination are displayed in Fig. 3.

Figure 3. Dynamic friction values for various surface treatments.

Wear rates calculated as described above are presented in Fig. 4. Significant differences dependent on the surface treatment applied are seen.
Figure 4. Results of wear rate after various surface treatment processes.

Lower roughness influence on less dynamic friction and lower abrasive wear corresponds to better smoothness of the machined surfaces.

4. CONCLUSIONS

An aluminium alloy machined is distinctly deformed during ball burnishing. As a result, the surfaces are smoothed and optical quality sculptured surfaces are produced. Ball burnishing allows to obtain a surface with low roughness and increases wear resistance. Depending on the type of surface treatment mean friction coefficients are 0.45 after grinding, 0.34 after polishing and 0.32 after ball burnishing. Compared to grinding and polishing after ball burnishing about two times lower rate of wear was obtained.

REFERENCES