Tribological Characteristics of Ai-Si Alloy Coating by Supersonic Particles Deposition

S.Zhu, X.Zhang, X.M.Wang, G.F.Han, Y.Cao
National Key Laboratory for Remanufacturing, No.21 Duijukan, Beijing 100072, China

Abstract

In order to improve the surfaced mechanical property of 7A52 aluminum alloy, Ai-Si alloy coating was prepared by Supersonic Particles Deposition (SPD) processing on the surface of 7A52 aluminum alloy. The wear-resisting property and wear mechanism of the coating were researched. The results show that the hardness of coating which reached to 266 HV, is similar with that of rolled 7A52 aluminum alloy; the wear weight loss of Ai-Si alloy coating decreased 40%, compared to that of 7A52 aluminum alloy on experimental condition. The dominant wear mechanism of Ai-Si alloy coating is abrasive wear, while the wear mechanism of 7A52 aluminum alloy is micro-cutting together with oxidation-wear.

Keywords: aluminum alloy; Ai-Si alloy coating; supersonic particles deposition; tribological characteristics

1. Introduction

Supersonic particles deposition processing was a new coating preparation method. Solid particles on pure solid/thermoplastic state impact the surface of substrate with high velocity, when they went through Laval nozzle, which were carried by high pressure gas or flame flow. The solid particles with high deformation ratio deposited on surface of substrate and coating were prepared. The deposited particles using SPD processing had lower temperature and higher speed than those of other traditional spraying technology. So, on the one hand, oxidation, segregation and residual stress of deposited coating were decreased. On the other hand, some metal such as Aluminium alloy which were sensitive to temperature and oxidization was proper using SPD processing to improve the mechanical property with low content of protoxide, low internal stress, high hardness and large thickness (SHEN L et al., 2009), (Li
Compared with coating by cold spraying processing, coating prepared by SPD processing had higher bonding strength. With excellent property of specific strength, cracking toughness, and low-cycle fatigue resistance, 7A52 Aluminum alloy has been widely used in construction, aerospace vehicle, ground vehicle and other fields Changjiu et al., 2005,2003, (Zhou Yong et al., 2010), (GRUJICIC M et al., 2004), (VOYER J et al., 2003). The utility of 7A52 aluminum alloy was confined for its poor performance on wear resistance and corrosion resisting. It is possible to improve the surface property of 7A52 Aluminium alloy by SPD processing. Ai-Si alloy coating was prepared by SPD processing, and tribological characteristics under the condition of dry friction was researched in this paper.

2. Sample preparation and test methods

2.1. Test Materials

The test material was 7A52 aluminum alloy blocks (size: 20mm × 20mm × 10mm), and the spraying material was Al-Si alloy powder (size from 40um ~ 80um). The chemical compositions of substrate and spray particles were shown in Table 1.

Table 1. Chemical composition of substrate and spray particles

<table>
<thead>
<tr>
<th>Alloy code</th>
<th>Zn</th>
<th>Si</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
<th>Cr</th>
<th>Mg</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>7A52</td>
<td>4.0~4.8</td>
<td>0.25</td>
<td>0.20~0.50</td>
<td>0.30</td>
<td>0.05~0.20</td>
<td>0.15~0.25</td>
<td>2.0~2.8</td>
<td>bal</td>
</tr>
<tr>
<td>Al-Si</td>
<td>~</td>
<td>11.8</td>
<td>&lt;0.01</td>
<td>0.16</td>
<td>0.02</td>
<td>~</td>
<td>&lt;0.01</td>
<td>bal</td>
</tr>
</tbody>
</table>

2.2. Test Methods and Equipments

Firstly, the samples were treated by blast sanding to remove oxidizing layer, greasy dirt and dust on the surface of substrate, and then the coating with the thickness of 0.5mm were prepared by self-made supersonic particles deposition equipment. The spraying parameters were as follows: 24cm of spraying distance, 1.6g/s of powder feeding speed and 3000mm/s of spraying gun movement speed.

The hardness of coating was measured in TH110Leeb hardness tester, and the microstructure was observed with environmental scanning electron microscope of mode Quanta 200 made by Philips, Holland.

Abrasives resistance of coating was tested on CETR UMT-3 multifunctional friction-abrasion testing machine by way of sphere moving back and forth on plane, and the wearing piece was GCr15 steel ball (Φ4mm, hardness of 770HV). Testing conditions were: D=±2mm of reciprocating displacement amplitude and v=8mm/s of sliding speed. With reciprocal frequency of 5Hz, the normal load was chosen separately 5N, 10N, 15N and 20N, and the friction duration was 10min. Micrograph of worn coating was observed by scanning electron microscope, and the wear volume (ΔV) was measured by vertical scanning white-light interfering profile-meter, made by American ADE company.

3. Results and Discussions

3.1. Microstructure observation of coating

The microstructure of coating was shown in Fig. 1. Bigger grains gathered and inserted the coating and were surrounded by cracked powder grains as seen in Fig.1 (a). Some molten powder was deposited to the coating as shown in Fig.1 (b). The observation showed that bigger grains easily deposited through inserting, and some of them disintegrated during the process of depositing, meanwhile small grains easily tended to melt. Machinery bonding was dominated and metallurgical bonding was second among bonding of coating.
3.2. Test on Micro-hardness

Micro-hardness of 7A52 aluminum alloy substrate and Al-Si coating were tested respectively. The results were shown in Table 2. Because there were some pores distributed in coatings, micro-hardness of coating with the average value 266.2HV was lower than that of 7A52 aluminum alloy substrate.

Table 2. Micro-hardness test results

<table>
<thead>
<tr>
<th>Category</th>
<th>Micro-hardness (HV)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate</td>
<td>297.6 310 276.6 208.4 283.3 275.18</td>
<td></td>
</tr>
<tr>
<td>Coating</td>
<td>285.9 250.7 217 304.1 273.3 266.2</td>
<td></td>
</tr>
</tbody>
</table>

Section headings dry friction

3.3. 7A52 aluminum alloy and Al-Si coating tribological behavior under dry friction

Coefficient of friction of 7A52 aluminum alloy substrate material and Al-Si coating under different loads were shown in Fig.2. The friction coefficient of substrate and coating increased at first and then stabilized. The friction coefficient of coating was lower than that of substrate on the condition of low load, as shown in Fig.2 (a). The friction coefficient of substrate was lower than that of coating on the condition of higher load, as shown in Fig.2 (b). It could be explained as follows. On low load condition, oxidation film formed in substrate surface during experimental period had lubrication action, while greater un-melted grains of Al-Si coating had motion-impeding effect on GCr15 steel ball. So the friction coefficient of coating was higher than that of substrate on the condition of higher load.

The wear volume and wear depth of 7A52 aluminium Alloy and Al-Si alloy coating were shown in Table 3. The wear volume of 7A52 aluminium alloy and Al-Si alloy coating increased with the increase of load. Under the same...
load, the wear volume and wear depth of Ai-Si alloy coating lowered than those of 7A52 aluminium alloy. On 5N load, the wear volume of Ai-Si alloy coating was 53% of 7A52 aluminium Alloy.

Table 3. Wear volume of the test results

<table>
<thead>
<tr>
<th>Load/N</th>
<th>Wear volume/μm³</th>
<th>Depth of the wear scar/μm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Substrate</td>
<td>Coating</td>
</tr>
<tr>
<td>5</td>
<td>3.2×10⁷</td>
<td>1.5×10⁷</td>
</tr>
<tr>
<td>10</td>
<td>6.4×10⁷</td>
<td>3.6×10⁷</td>
</tr>
<tr>
<td>15</td>
<td>7.5×10⁷</td>
<td>4.1×10⁷</td>
</tr>
<tr>
<td>20</td>
<td>9.1×10⁷</td>
<td>5.3×10⁷</td>
</tr>
</tbody>
</table>

3.4. Analysis on wear mechanism

SEM morphologies of worn scar of 7A52 aluminum alloy and Ai-Si alloy coating were presented in Fig.3. It showed that the worn surface of Ai-Si alloy coating was much smoother than that of aluminum alloy. From Fig.3 (a), we also saw that, there were furrows and adhesive phenomenon on the surface of 7A52 aluminum alloy, and furrows were not distributed evenly, besides, some of them were very deep. Meanwhile, much abrasive dust had come out and gathered on the surface. From Fig.3 (b), we saw that there were obvious tear and scratches, even crimp on the surface of abrasive coating. In Fig.3 (b), it showed that smooth bearing surface from plastic deformation and furrows existed alternately, so we could take the conclusion that wear mechanism of Ai-Si coating is fatigue wear, while that of 7A52 aluminum alloy is micro cutting.

![Fig.3. SEM morphologies of worn scar of 7A52 aluminum alloy (a) and Ai-Si alloy coating (b)](image)

4. Conclusions

(1) The connection between Ai-Si alloy protective coating prepared by SPD processing and 7A52 aluminium alloy are machinery bonding and metallurgical bonding.

(2) Micro-hardness of Ai-Si alloy coating reaches to 266HV, similar with that of rolled 7A52 aluminum alloy substrate (275HV). On experimental condition of dry friction, the wear weight loss of Ai- Si alloy coating decreased 40%, compared to that of 7A52 aluminum alloy.

(3) The dominant wear mechanism of Ai-Si alloy coating is abrasive wear, while the wear mechanism of 7A52 aluminum alloy is micro-cutting together with oxidation-wear.

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References


