Transforming the inferior metal alloy by electroless Ni-P/SiC deposit

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1. Introduction

Surface modification by metal deposition onto inferior material is of paramount importance for many engineering applications. A type of metal coating by electroless technique is versatile owing to its promising material properties and characteristics. Heat treatment of electroless coating is important owing to the properties enhancement such as increase in microhardness, tribology and phase transformation [1].

1.1 What is the purpose?

For automotive and aerospace industries light weight aluminium alloy are the back bone for any great designs and structure. But these alloys are vulnerable to wear, corrosion etc. Electroless nickel coating reinforced with hard particles can transform the surface behavior of the substrate. With optimal heat treatment the coating properties can further be enhanced.

1.2 Research state

The present work aims to develop and understand the composite coating Ni-P/SiC by electroless technique. The characterization such as phase structure, morphology and properties like microhardness, friction and wear are investigated systematically.

Aluminium alloy LM6 (Al-6%Si-0.5%Cu) alloy was used as substrate. It underwent pre-treatment as shown in Table 1. Each step was followed by tap water washing and distilled water rinsing. The composite coating process parameters are shown in Table 2. The hard particles were introduced and stirred for 30 minutes prior to the plating process started. Upward and downward of the pH adjustment was done using ~50 % NH4OH and ~10 % H2SO4, respectively.

Heat treatment was done in furnace and for vacuum all the samples were sealed in glass before placing in the furnace. XRD analysis on coated samples was carried out at room temperature using PANalytical X-ray diffractometer applying CuKα radiation. The step-size of scans was 0.2°. Energy dispersive X-ray (EDX) setup by Aztec version 2.0 software was used for chemical composition analysis. Microhardness by microhardness tester using load of 100 gf. Tribology behaviour was tested using wear tester with load.

Table 1. Pre-treatment conditions and parameters [2]

<table>
<thead>
<tr>
<th>Process</th>
<th>Chemicals</th>
<th>Temperature</th>
<th>Time</th>
<th>Degree of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degreasing</td>
<td>NaOH</td>
<td>80-90°C</td>
<td>~5</td>
<td>30 min</td>
</tr>
<tr>
<td>Cleaning</td>
<td>5.75 g Na2S2O3</td>
<td>60-65°C</td>
<td>~5</td>
<td>15 min</td>
</tr>
<tr>
<td>Cleaning</td>
<td>15 % (vol.) H2SO4 (reactive time: 245 s)</td>
<td></td>
<td>15</td>
<td>30 min</td>
</tr>
<tr>
<td>Cleaning</td>
<td>180 g/l NaOH</td>
<td>Room</td>
<td>~30</td>
<td>15 min</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Magnetic wire along with sample</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Plating process parameters [2]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temperature</th>
<th>Time</th>
<th>Degree of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>465°C</td>
<td>60 s</td>
<td>80%</td>
</tr>
<tr>
<td>Time</td>
<td>80 s</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Film Composition</td>
<td>5-18 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution</td>
<td>Magnetic wire along with sample</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The coating uniformity and the distribution of the reinforcing particles are shown in Fig. 1. The particles are evenly distributed in the coating which also follows the contour of the substrate [2].

2. Results and discussion

2.1 Phase structure

The best track for the as-deposited state (AD) of the coating shows the amorphous structure for all the samples. The heat treated state both in atmospheric (AD) and vacuum (HT) conditions show well defined sharp peaks mainly from the crystalline Ni and SiC peak for composite coatings. Oxide peaks are not observed for the two types of heat treated samples.

Fig. 2. XRD patterns for samples A, B, C and F

2.2 Microhardness

Significant increase in microhardness post coating as compared to the bare Al substrate (Fig. 3) is observed. Upon heat treatment the microhardness further increases. Reference grey cast iron was taken as it is the conventional material for cylinder liner in engine system.

Fig. 3. Microhardness for bare aluminium, grey cast iron and coated samples (heat treated in light grey colour)

2.3 Friction

There are substantial fluctuations in the friction graph especially in the early stage of the wearing time and then the friction becomes stable and smooth after this period of wearing time for atmospheric conditions. Large significant difference is exhibited before and after a threshold. Such observations do not occur in the friction graph for the samples heat treated in vacuum condition (Fig. 4). However, some inequalities of friction are seen which gradually fade away as the wearing proceeds. The main differences in the friction behavior obtained with different heat treatment conditions could be due to the considerable layer of oxide formation. The blush appearance (visual inspection) on the surface of sample heat treated in atmospheric condition which is not seen for vacuum heat treated samples is the indication of the oxide formation. In-situ engine simulation (200°C) friction response suggest the coated samples exhibit lower friction as compared to grey cast iron as shown in Fig. 5.

Fig. 4. Friction responses over sliding time

2.4 Wear

Wear characteristics of the bare aluminium and the coatings in terms of wear rate is tabulated in Table 3. Wear rate is lower after the coating. Wear resistance is improved on heat treatment as compared to as-deposited state.

Fig. 5. In-situ friction responses at high-temperatures

3. Tribology data from wear testing

Table 3. Tribology data from wear testing

<table>
<thead>
<tr>
<th>Sample</th>
<th>Condition</th>
<th>Wear rate (mm²/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-deposited</td>
<td>0.06-0.10</td>
<td></td>
</tr>
<tr>
<td>B-deposited</td>
<td>0.06-0.10</td>
<td></td>
</tr>
<tr>
<td>A-heat treated</td>
<td>0.03-0.04</td>
<td></td>
</tr>
<tr>
<td>B-heat treated</td>
<td>0.01-0.02</td>
<td></td>
</tr>
<tr>
<td>A-vacuum treated</td>
<td>0.01-0.02</td>
<td></td>
</tr>
<tr>
<td>B-vacuum treated</td>
<td>0.01-0.02</td>
<td></td>
</tr>
</tbody>
</table>

4. Concluding remarks

- Deposition of composite Ni-P/SiC onto aluminium alloy shows uniform coating and even distribution of reinforcing particles. SiC content increases on increasing Ni-P/SiC concentration in the plating solution.
- XRD profile shows crystalline peaks from Ni and SiC and P/SiC peak for composite samples in heat treated conditions and amorphous phase in as-deposited state.
- Microhardness increase after coating as compared to uncoated aluminium. Heat treatment further enhances the microhardness.
- Instability of the friction during the early stage of sliding is noticeable for atmospheric environment samples of electroless nickel coating. No abrupt changes in the friction are found for vacuum heat treated samples.
- High-temperature friction of near engine environment shows lower friction for coated samples as compared to grey cast iron.
- Wear performance is better for coated samples in terms of lower wear rate. Heat treated samples exhibit better wear resistance as compared to as-deposited state.

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References