SLIDING WEAR BEHAVIOR OF PLASMA SPRAYED ZIRCONIA
CERAMIC COATING UNDER DIFFERENT CONDITIONS

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ABSTRACT

The sliding wear behavior of ZrO 2-22wt%MgO (MZ) and ZrO 2-8wt%Y 2O 3 (YZ) deposited on a cast aluminum alloy with bond layer (NiCrCoAlY) by plasma spray against a SiC ball was investigated under dry and lubrication conditions at room temperature. At all load conditions, the wear mechanisms of the MZ and YZ coatings were almost the same. The wear mechanism involved material transfer and pullout under dry condition, but micro-fractures and spallation under lubrication condition. When oil was used for lubrication, the friction coefficient of the sliding pairs and the wear loss of the ceramics were reduced. The wear loss of the MZ coating was less than that of the YZ coating under dry test, but more than that of the YZ coating under lubrication test. The test conditions and the mechanical properties of the ceramic coatings were correlated to the wear performance.

Key words: Plasma spray, Wear, Zirconia coating.

1. INTRODUCTION

The wear behavior of zirconia ceramics seemed to be very sensitive to the structure of the material, and to test parameters such as temperature, environment, and sliding speed [1]. Some studies have revealed that microstructure and mechanical properties, such as grain size [2] and fracture toughness [3,4], hardness and elastic modulus [5] had a strong dependence on temperature [6]. A predominantly tribochemical wear mechanism for zirconia sliding [7,8]. The material transfer occurs during sliding test, so the final wear loss can be reduced [2-4,7,8,11,13-15]. The oxidized layer forms on to worn surface [8,9]. Under lubrication test, the effect of lubricants on the friction and wear of ceramic such as forming protective film [10], graphite film [11,12], carbon films [13], and reducing interfacial temperature [5,11-13]. Although a number of researchers have investigated the factors influencing the wear of zirconia ceramics [1-4,6-8,10,14-16]. However, the tribological behavior of zirconia ceramics has not been well understood. The goal of the current study was to investigate the wear behavior of plasma-sprayed ZrO 2-22wt%MgO and ZrO 2-8wt% Y 2O 3 coatings under dry and lubrication conditions.

2. EXPERIMENTAL PROCEDURES

The thickness of the top coatings was 350µm. The NiCrCoAlY layer was applied as a bond coating with thickness of 150µm. The wear test was carried out on the ball-on-disk test rig at room temperature under dry and lubrication (SAE 40W15) conditions. The loads used were 30N, 50N, and 80N and the sliding speed was 100 mm/s.

Table 1. Mechanical properties of these coatings

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness (MPa)</th>
<th>Elastic modulus (GPa)</th>
<th>Fracture toughness (MPa.m1/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZrO 2-22%MgO</td>
<td>3400 ± 100</td>
<td>28</td>
<td>2.5</td>
</tr>
<tr>
<td>ZrO 2-8%Y 2O 3</td>
<td>5000 ± 125</td>
<td>47</td>
<td>1.7</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

3.1. FRICTION BEHAVIOR

The friction coefficients of the MZ and YZ coatings were about 0.45-0.6 under dry test and about 0.1-0.15 under lubrication test. With an increase of load from 30N to 80N, the friction coefficient of the coatings slightly decreased.

3.2. WEAR BEHAVIOR

The wear volume of the MZ coating was much less than that of the YZ coating under dry condition (Fig. 1a) but more than that of the YZ coating under lubrication test (Fig. 1b), and both of them increased with an increase in normal load.

Figure 1. The variation of the wear volume vs normal load
(a) Under dry condition after 720 (m)
(b) Under lubricated condition after 7000 (m)

EDX spot analyses at the smooth regions of the worn surfaces detected the present Si and C elements beside Zr, Y, Mg, and oxygen. A smooth wear track was very important for wear resistance [1-4,11,14-15], the material transfer played
an important role in the wear resistance of zirconia ceramics [2-4,7,8,14,15] and since the oxidized transferred layer strongly adhered to the coating surface, the wear rate was reduced [3,9]. The smooth area of the MZ worn surface was larger than that of the YZ worn surface. The wear rate of the ceramics was improved by an increase of fracture toughness [3,4,13]. As a result, the fracture toughness of the MZ coating is higher than that of the YZ coating (Tab.1). The tougher the material was, the smoother the worn surface [4]. That is why the wear loss of the MZ coating was less than that of the YZ coating. It was suggested that material transfer on the worn surfaces plays an important role in the wear resistance of these coatings.

Under lubrication condition, the worn surfaces of the MZ and YZ coatings at 50N are shown in Fig 4. The wear mechanism is micro-factures and spallation. The smooth region is not evident on the worn surfaces. The friction coefficient and wear loss reduce because of the lubricating and cooling effects of the lubricant oil. The high interfacial temperature can be reduced. As result, the thermal stresses in the subsurface area are reduced or event avoid [16]. The lubricant reduces the adhesive wear and the higher porosity of ceramic can serve as an oil reservoir to lubricate the pair during testing. Therefore, wear loss reduced [10]. The pre-existing cracks, elastic modulus [17] had a significant influence on the wear performance. With a fracture dominated wear process, a decrease in the indentation hardness reduces the wear resistance [5]. On the other hand, elastic modulus and the hardness of the YZ coating were higher than those of the MZ coating. That is why the wear loss of the MZ coating is more than that of the YZ coating under lubrication condition.

5. CONCLUSIONS.

(1) The friction coefficients of MZ and YZ were almost the same under these test conditions. With an increase of load from 30N to 80N, coating exhibited a slightly decreased trend in friction coefficients.

(2) The wear mechanisms of the coatings were almost the same under the different load conditions. The wear mechanisms were material transfer and pull-out under dry condition, but micro-fracture and spallation under lubrication condition.

(3) The wear resistance of the MZ coating was higher than that of the YZ coating under dry condition, but lower than that of the YZ coating under lubrication condition.

REFERENCES