EFFECT OF THE SUBSTRATE ON THE FRETTING WEAR OF SPUTTERED W-Si-N COATINGS AGAINST STEEL

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ABSTRACT
Fretting tests of sputtered W-Si-N amorphous coatings were performed on both cemented tungsten carbide with 6wt.% of Co and AISI 310 steel substrates against spherical AISI 52100 steel counterbodies. The normal load and the amplitude of relative displacement were varied. The evolution of the tangential force during the test was recorded. At the end of each test, the volume and the surface morphology of the wear scars were measured and analyzed. The relationship between the dissipated frictional energy and the wear volume was calculated. The results allowed plotting fretting maps identifying the occurrence of different fretting regimes.

INTRODUCTION
Fretting wear is a surface damage phenomenon occurring when contacting surfaces are submitted to vibrations. Surface engineering has been used to improve the behavior of mechanical components working under fretting contact conditions. Especially thin coatings deposited by PVD have already demonstrated good performances in fretting contacts [1-2]. The coating integrity is very important on the contact behavior and the substrate is a key factor for the integrity of the coating under load bearing conditions. The ability of W-Si-N sputtered coatings to protect materials in fretting contacts has been studied [3-4]. However, the effect of the substrate on the fretting behavior has not been investigated yet.

EXPERIMENTAL
The fretting tests were carried out using a ball-on-flat geometry under the conditions given in Table 1. The spherical counterbodies (AISI 52100 steel) were forced against two types of W-Si-N coated substrates: cemented tungsten carbide with 6wt.% of Co (from here on designated as WC6Co) and AISI 310 steel. The diameter of the cylindrical coated specimens was 30mm, while that of the spherical counterbodies was 10mm. The wear scars were assessed using 2D and 3D profilometry to evaluate the removed volume while the morphology of the resulting wear scars was analyzed using optical and scanning electron microscopes. The wear volume of the removed material was calculated by averaging the area of the wear scar cross section and multiplying it by the average stroke length [5].

Table 1: Fretting tests conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Load</td>
<td>5 to 30 N</td>
</tr>
<tr>
<td>Fretting Stroke</td>
<td>1 to 10 µm</td>
</tr>
<tr>
<td>Frequency</td>
<td>40 Hz</td>
</tr>
<tr>
<td>Test Duration</td>
<td>1.5 ×10⁵ cycles</td>
</tr>
<tr>
<td>Temperature</td>
<td>22 ± 3°C</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Laboratory air</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>50 ±5%</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION
The values of the friction force and the relative displacement were acquired during the fretting tests. Figure 1 illustrates, for both types of substrate, the typical variation of displacement vs. friction force, corresponding to each of the three main fretting regimes. It can also be observed that when the W-Si-N films are sputtered on a WC6Co substrate, the friction coefficient is lower than for the AISI 310 steel in similar fretting conditions.

Figure 1: Fretting loops corresponding to the three main fretting regimes for both WC6Co and 310 steel substrates.
For the stick regime, no apparent damage was observed. Figures 2 and 3 illustrate the characteristic topography and morphology of the fretting wear scars for the other fretting regimes: partial slip and gross slip.

The energy dissipated in the contact can be calculated as the work of the friction force. Therefore, the sum of the areas of the friction force vs. displacement loops (Fig. 1) during a fretting test corresponds to the total energy dissipated in the test. This energy can be correlated with the quantity of worn material. Thus, its analysis allows comparing quantitatively the wear behavior of materials submitted to fretting. Figure 4 shows the evolution of the wear volume as a function of the cumulated dissipated energy for both types of substrate fretting tests.

For the tested conditions, it can be observed that the volume wear losses increased proportionally to the energy values, being those of the WC6Co substrate lower than that of the 310 steel substrate. It can be concluded that, for the same wear values, the fretting tests performed on the coated WC6Co substrate must have larger displacement amplitudes than for the coated 310 steel. This is explained by the lower friction coefficient values occurring for the coated WC6Co substrate (Fig. 1).

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