A STUDY INTO THE PARAMETERS AFFECTING NICKEL OXIDE GLAZE FORMATION

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ABSTRACT
At elevated temperatures Nickel Alloys have the ability of forming a ‘glaze’ layer. If the test conditions are favourable, this layer can protect components from subsequent wear and fretting damage. This phenomenon has been previously shown by several researching bodies. Unfavourable conditions, on the other hand, can either delay or prevent its formation, rendering a component susceptible to further damage. This study investigates the effect that various test parameters have on the formation of these glaze layers, and how this may impact the fretting fatigue life. Parameters investigated include normal load and cycle frequency. Tests were carried out at two temperatures: 20°C was used as the control group, and 680°C as the experimental ‘glaze’ group. Experimental results are provided, and explained in terms of wear rate and frictional effect.

1. INTRODUCTION
It has been widely reported that under certain conditions Nickel alloys produce a thin surface film, known as a ‘glaze’. It is also well documented that this glaze layer can protect the surface from subsequent wear, reduce the surface friction and significantly reduce the effect of fretting on fatigue life.

Glaze layers are formed via the breakdown of large oxidized debris particles that become embedded into their originating wear tracks, once they are below a critical particle size. These agglomerated particles aid a system by separating the two mating metal substrates, and subsequently reducing the wear rate. As such, it is said that the system undergoes a ‘Severe-to-Mild Wear Transition’. At temperatures above 250°C the oxide particles closest to the surface are subsequently softened and sintered, allowing the formation of a thin, relatively stable, homogenous glaze layer.

At temperatures above 400°C the glaze is thought to become self-healing, such that its stability is further enhanced. However, even at these temperatures unfavourable parameters will delay the Wear Transition, and wear volumes will increase as a result. This study aims to investigate the effect that load, and frequency has on glaze production.

2. METHODOLOGY
The Nickel alloys investigated were commercially available, and are commonly known as Udimet 720 and CMSX4. The nominal composition for Udimet 720 was 16%Cr, 8.5%Co, 3.5%Al and 3.5%Ti. And for CMSX4 it was 9.6%Co, 6.5%Cr, 6.5%Ta and 6.4%W.

The two alloys were reciprocated against each other in a standard displacement-controlled wear rig with a sphere-on-flat (button-on-plate) type contact. Displacement was controlled to 2.54mm peak-to-peak sliding. Temperature, normal load and sliding frequency were varied systematically, whilst the tangential load was measured in order to calculate the coefficient of friction. A list of the test parameters is provided in Fig. 1.

Following the completion of 10,000 cycles, a plot of the coefficient of friction over time was produced, as well as total wear volumes, and correlation analyses.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Normal Load (N)</th>
<th>Frequency (Hz)</th>
<th>Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10</td>
<td>0.3</td>
<td>10,000</td>
</tr>
<tr>
<td>680</td>
<td>50</td>
<td>1.0</td>
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<td></td>
<td>100</td>
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Fig. 1. Test parameters.

3. RESULTS AND DISCUSSION

3.1. Metallography
An example of a resultant wear patch is provided in Fig. 2.
This particular example was carried out at 680°C, 1Hz frequency and 100N normal load. The raised area of glaze is relatively homogeneous, apart from a central section where glaze breakdown has become evident. An unglazed wear patch at 20°C, carried out at identical load and frequency is provided in Fig. 3.

Although there is some evidence of isolated patches of glaze, it is thought that these are unstable and are therefore discounted as a true glaze layer.

At each frequency, evidence of glaze breakdown was observed at 50 and 100N. The severity of breakdown was positively correlated to both frequency and load (low at the lower frequency and load, high at the higher frequency and load). At 10N load, however, a relatively homogeneous glaze layer was produced across the entire wear scar. Jiang et al\(^3\) reported that the size of wear debris particles increases with increased normal load due to cracks propagating deeper into the surface. As a result, wear particles find it more difficult to become embedded into the wear tracks, and so the formation of a glaze layer is hindered. This metallographic inspection suggests that 10N was sufficiently low to prevent this phenomenon.

3.2. Wear Rates

The wear volume produced during each test was also dependant on both load and frequency. The glazed specimens consistently produced a much lower amount of wear than unglazed, supporting the evidence that a glaze layer protects the surface from further damage. Wear volume increased with both load and frequency, although load appeared far more influential. These results are illustrated in Figs. 4 and 5.

As discussed previously, an increase in load increases the size of wear debris particles. This in turn leads to a delay in the Severe-to-Mild Wear Transition, and a resultant increase in the total wear volume. Frequency had a similar effect on wear volume, but in this instance the effect was due a reduction in sintering time. Glaze production is a time-dependant process, relying on time at pressure and temperature in order to become established. Despite the increase in frictional heating that should have assisted glaze production, the increase in frequency reduces this dwell time and hinders glaze formation as a result.

3.3. Friction

In general, the friction of an unglazed surface (at 20°C) was calculated at about 0.45 to 0.85. For a glazed surface (at 680°C), it was calculated at about 0.3-0.4. These results are illustrated in Figs. 6 and 7.

For the parameters involved in these tests, there appears to be no apparent wear transition, associated with the formation of a glaze layer. However, it is believed that the parameters involved caused an almost immediate reaction, such that the coefficient of friction appears constant throughout the test.
2. An increase in load and frequency led to an increase in friction at 20°C. At 680°C the presence of a glaze effectively protected the contact from this effect.

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REFERENCES