Effect of Temperature on Unlubricated Sliding Wear of Additively Manufactured Stainless Steels

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INTRODUCTION

- Tribological Problems in Nuclear Power Plants
  - 웨스팅하우스 가압경수로 가이드 카드 부품에서 비정상적 마모 현상 발생
  - 가이드 카드 기능, 제어봉 집합체 (Rod Control Cluster Assembly)를 지지하고 상하 운동시 경로를 안내함

  ➤ 가이드 카드 마모에 따른 대체부품 부재시 3D 프린팅을 이용한 부품 제작 가능성 고려

- Metal 3D Printing (3DP) Methods – PBF | DED
  - 금속 3DP 방법 가운데 대표적인 PBF (Powder Bed Fusion) 및 DED (Directed Energy Deposition) 특성 고찰

  ➤ 3DP 및 고전적인 방법으로 제작한 스테인리스강 (SS)의 마모 특성을 평가하고 그 현상에 대한 기구를 고찰

EXPERIMENTAL

- Sample Preparation
  - SS 304L samples made by PBF and DED with following process conditions

<table>
<thead>
<tr>
<th>Sample</th>
<th>P</th>
<th>B</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec.</td>
<td>Gra/Size</td>
<td>Micro-Met/304</td>
<td>Density</td>
<td>Particle</td>
</tr>
<tr>
<td>Vickers Hardness Test</td>
<td>Used micro-hardness tester (HM-122) with 1 kgf load</td>
<td>Perform hardness test along height from bottom to top</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPERIMENTAL (Cont.)

- Wear Testing with Pin-on-Disk (ASTM G99)
  - Pin-on-disk wear test performed with SS304L disks (PBF, DED, wrought)

  ➤ Measure mass loss of pin and disk separately before and after test; Convert the mass loss to volume loss/traveling distance

RESULTS

- Hardness Measurements

<table>
<thead>
<tr>
<th>Hardness</th>
<th>wrought</th>
<th>PBF</th>
<th>DED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vickers (HV)</td>
<td>152</td>
<td>218.9 ± 2.5</td>
<td>247.7 ± 5.3</td>
</tr>
<tr>
<td>SI unit (MPa)</td>
<td>1491</td>
<td>2147 ± 25</td>
<td>2430 ± 52</td>
</tr>
</tbody>
</table>

  ➤ HV : DED > PBF > Wrought

- Unlubricated Wear Rates (@ Temperature)

  - At room temperature, DED sample shows the lowest wear rate > highest wear resistance
  - At high T (250°C), the wear rates of all samples drop significantly > changes in wear mechanism
  - Observed wear surface of disk samples (upper Right)
  - Low T; bright metallic surface
  - High T; thins layer of dark oxide

DISCUSSION

- At room temperature;
  - DED sample with highest hardness shows strong wear resistance, following Archard's law (wear rate ∝ hardness−1)
  - Bright metallic surface → plasticity-dominated wear

- At high temperature;
  - Dark oxide films on the wear surface → oxidative wear
  - High temperature causes oxidation
  - Wear rates decreased due to the formation of oxide film

Mechanism from Wear-Mode Map
  - Shift from plasticity-dominated to mild oxidation-wear resulting from temperature change

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