PO4D17

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

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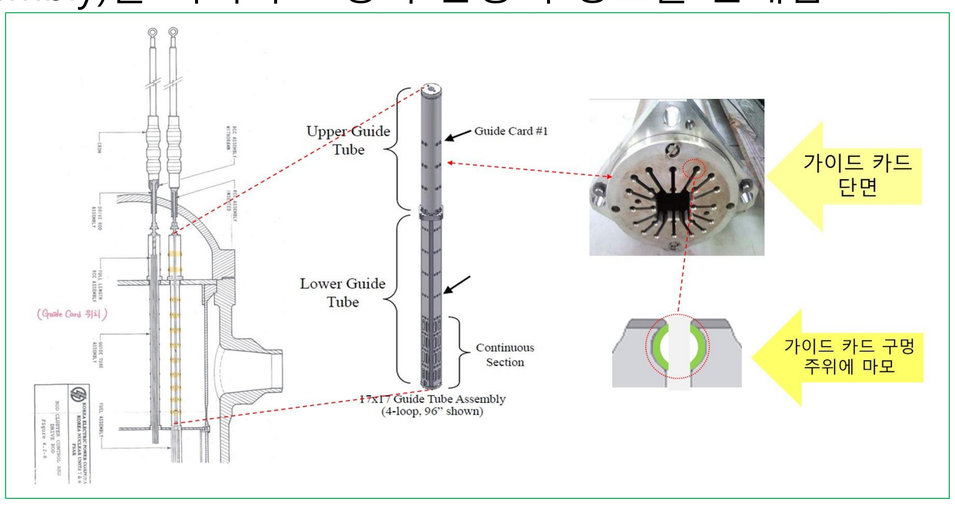
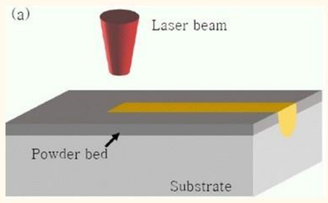
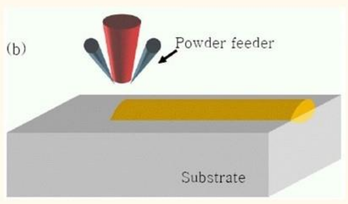
INTRODUCTION

- **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

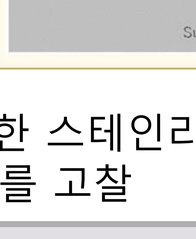
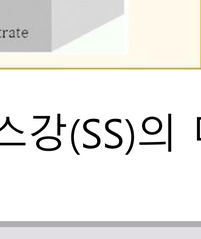
- **Metal 3D Printing (3DP) Methods – PBF | DED**
  - 금속 3DP 방법 가운데 대표적인 PBF (Powder Bed Fusion) 및 DED (Directed Energy Deposition) 특성 고찰

Powder Bed Fusion (PBF)	Directed Energy Deposition (DED)
A process in which thermal energy selectively melts metal powder spread	A process in which focused thermal energy is used to fuse materials by melting as they are being deposited
• Sophisticated metal-product forming • Possible to build up overhang structure ✓ Expensive metal powder	• Possible to repair used products • Use of common metal powder ✓ Low resolution
	

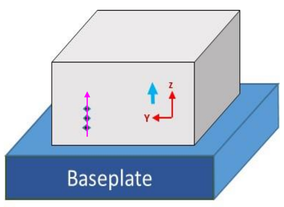
→ 3DP 및 고전적인 방법으로 제작한 스테인리스강(SS)의 마모 특성을 평가하고 그 현상에 대한 기구를 고찰

EXPERIMENTAL

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

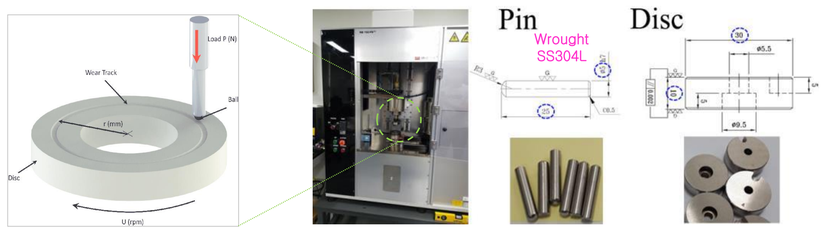
	Powder	3D Printing	3D Specimen	Appearance
PBF	Spec. / CSC (창성) Grade/Alloy: STS304L Flow rate: - Density: 3.97 g/cm³ Particle: 15-45 μm Composition: 19.4Cr-10.3Ni-0.98Mn-0.54Si-0.028C	Build Parameters Laser power: 180 W Scanning speed: 0.8 m/s Laser spot size: 50-150 μm Inert gas: Argon Layer thickness: 30 μm Island scanning		
DED	Spec. / CARPENTER Grade/Alloy: Micro-Melt 304 Flow rate: 17.0 s/50g Density: 4.34 g/cm³ Particle: 45-150 μm Composition: 18.4Cr-9.7Ni-1.4Mn-0.67Si-0.025C	Build Parameters Build rate: ~ 5.5 cm³/h Feed rate: 2.5-3.0 g/min Laser spot size: 0.8-1.0 mm Scan speed: 850 mm/min Chess board scanning		

- **Vickers Hardness Test**
  - Used micro-hardness tester (HM-122) with 1 kgf load
  - Perform hardness test along height from bottom to top ↑



EXPERIMENTAL (Cont.)

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



  - Test conditions

Humidity	Temperature	Force	Speed	Length	Time
50±5%	25±2°C/ 250±5°C	30N	0.22m/s	1.6km	2hr

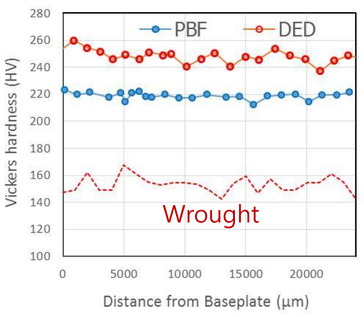
→ Measure mass loss of pin and disk separately before and after test; Convert the mass loss to volume loss/traveling distance

RESULTS

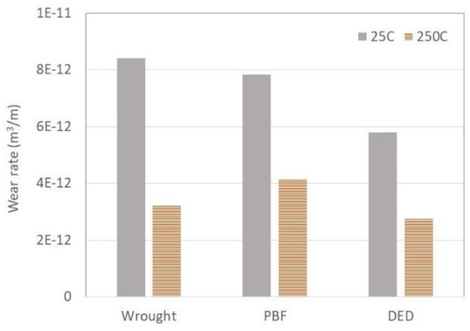
- **Hardness Measurements**

Hardness	wrought	PBF	DED
Vickers (HV)	152	218.9 ± 2.5	247.7 ± 5.3
SI unit (MPa)	1491	2147 ± 25	2430 ± 52

HV : DED > PBF > Wrought



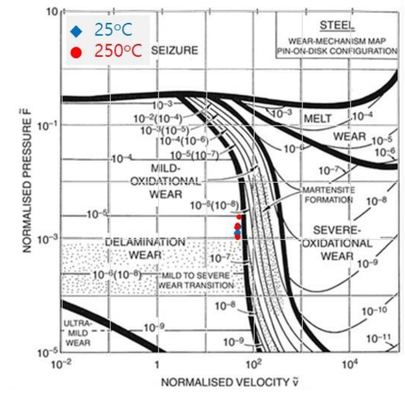
- **Unlubricated Wear Rates (@ Temperature)**



  - 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 → oxidational 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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