FSU PC NASA USLI Team

Inconel 718 Mechanical Properties Testing

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Abstract

Six additively manufactured Inconel 718 samples provided through Astro-America and Maritech were tested in torsion and analyzed through fracture surface examination. The samples were divided into two groups: un-heat-treated (UHT) and heat-treated (HT). The goal of this study was to determine how the additive manufacturing process and heat treatment affect the mechanical properties and failure behavior of IN718.
Originally, tensile testing was planned to evaluate the material properties; however, due to a faulty tension tester, tensile data could not be obtained. As a result, torsional testing was used as the primary method of mechanical evaluation.
Torsional testing was used to determine ultimate shear strength, yield strength, shear modulus, and modulus of elasticity. Fracture surface analysis was used to relate failure behavior to microstructure.

Test Samples

Samples:
- 6 total samples tested
- 3 Un-Heat-Treated (UHT)
- 3 Heat-Treated (HT)
- All samples: L-PBF Inconel 718
- Dogbone geometry per ASTM E8 sample size 3

Identification:
- UHT – silver color in the as-built condition.
- HT - darker due to the heat treatment process.
- All samples built in vertical orientation

Equipment and Procedure

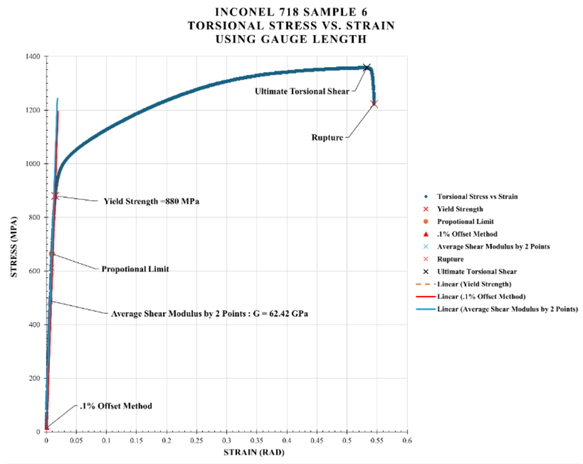
Equipment Used:
- Torsion tester (Tinius Olsen)
- Metallurgical microscope and stereoscope
- Digital caliper
- PC software for test control

Procedure:
1. Measure sample dimensions
2. Mark gauge length and straight line for twist visualization
3. Mount sample in torsion tester
4. Apply torsional load until failure
5. Record torque and angle of twist
6. Analyze fracture surfaces after testing

Testing Results

Un-heat-treated NI718 Sample #6 Stress -Strain Curve with Data to Failure

- Lower torsional strength
- Higher angle of twist
- High variability due to a variety of microstructure defects in the as-built condition.

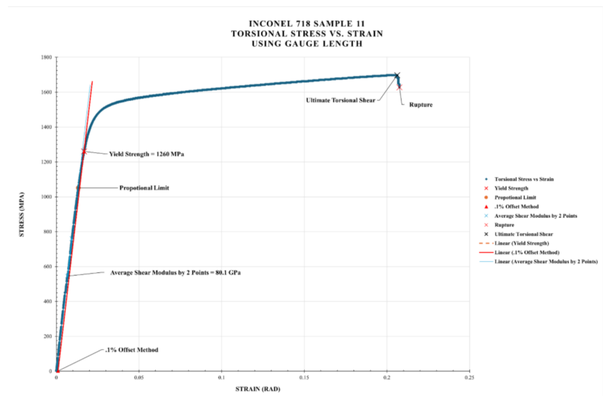


Sample #6 Mechanical Properties in Torsion

Sample Number	$\tau_{ultimate}$	G_{small}	G_{2point}	E_{small}	P	at Failure
1359 *MPa*	880 *MPa*	132 *GPa*	63.1 *GPa*	345 *GPa*	665 *MPa*	440°

Heat-treated NI718 Sample #11 Stress -Strain Curve with Data to Failure

- Higher torsional strength
- More consistent behavior between heat-treated samples due to a more homogeneous crystalline structure.
- Most samples failed around ~180° twist (~0.5 revolution)

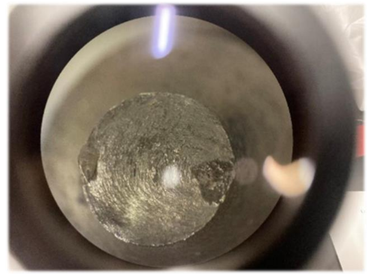


Sample #11 Mechanical Properties in Torsion

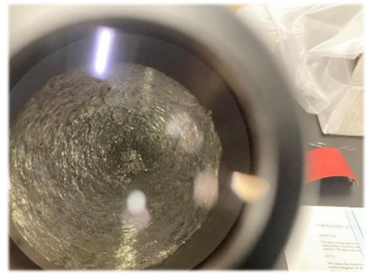
Sample Number	$\tau_{ultimate}$	G_{small}	G_{2point}	E_{small}	P	at Failure
1698 *MPa*	1260 *MPa*	85.4 *GPa*	80.1 *GPa*	220 *GPa*	1052 *MPa*	168°

Fracture Surface Examination

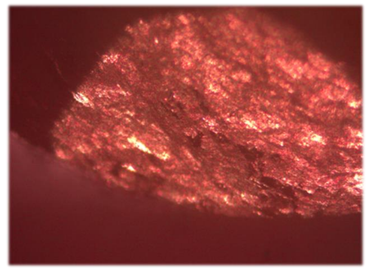
UHT Samples	HT Samples
• Large internal tearing • Clear crack initiation point • High porosity • High internal stress-concentration areas	• Uniform deformation across cross-section • More even load distribution across cross-sectional area • No obvious failure start point • Reduced porosity



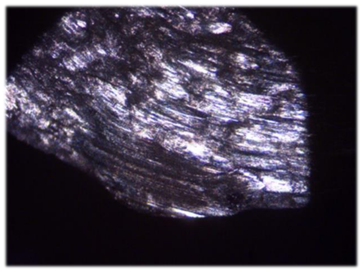
1x Un-heat-treated Inconel 718



1x Heat-treated Inconel 718



5x Un-heat-treated Inconel 718



5x Heat-treated Inconel 718

Additional Usage of Research

- Demonstrates importance of heat treatment in IN718
- Shows direct link between microstructure and mechanical performance
- Highlights a variety of parameters that could affect the build quality of the specimens
- Supports potential improvement in mechanical properties through optimized annealing (1160 °C for 4 hours), as suggested by other sources, which promotes more effective dissolution of Laves phases.