Inconel 718 is a nickel-based super alloy widely used in aerospace applications due to its strength at high temperatures, weldability, and resistance to creep. Applications of the alloy extend to gas turbines, jet engine components, structural materials, and cryogenic storage tanks. Cryogenic fatigue data for Inconel 718 exists but primarily in its age hardened condition. This study aims to provide cryogenic fatigue data for Inconel 718, in its solution annealed state, and shed light on a potential ductile to brittle transition present in the alloy. High cycle fatigue characteristics of commercially available Inconel 718 in the solution annealed and age hardened condition were investigated at 77 K.

**MATERIAL**

Table 1 shows the chemical composition of alloy 718 as received from the manufacturer. Inconel 718 is a precipitation-strengthened material with the formation of body-centered tetragonal (BCT) \( \gamma ^{''} \), Ni$_3$Nb, and face-centered cubic (FCC) \( \gamma ^{'} \), precipitates in the \( \gamma \) matrix.

<table>
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<tr>
<th></th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Nb</th>
<th>Al</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconel 718</td>
<td>0.02</td>
<td>0.06</td>
<td>0.09</td>
<td>0.009</td>
<td>0.001</td>
<td>17.79</td>
<td>54.02</td>
<td>2.3</td>
<td>3.07</td>
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<tr>
<td></td>
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<td>0.21</td>
<td>0.041</td>
<td>0.004</td>
<td>0.004</td>
<td>18.29</td>
<td>5.07</td>
<td>0.07</td>
<td>0.98</td>
<td></td>
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</tr>
</tbody>
</table>

Table 1. Inconel 718 material certification sheet chemical composition

The heat treatment for the alloy per manufacturer recommendation: 990 K for 8 hours, 895 K for 8 hours, air cooled. Age hardening was performed prior to sample machining in a computer programmable 3-zone furnace with an inert sample environment, Argon. Samples were extracted from original forging via wire EDM and machined to drawing specifications (Figure 1).

**RESULTS AND DISCUSSION**

Inconel 718 microstructure post heat treatment. Nominal grain size of 5-25 microns. Secondary phase precipitates can be seen forming in and between grain boundaries. Small grain sizes and twinning contribute to higher tensile strengths.

Tensile and fatigue testing was performed under testing standards, ASTM E8 and ASTM E466 respectively. All testing was done on a servo-hydraulic MTS test machine equipped with a cryostat. For tensile testing, strain was measured using three one-inch extensometers and force was recorded using a 250 kN load cell. Tension-tension fatigue test were run on a 100 kN capacity load cell at 10 Hz in load control, constant load amplitude (R=0.1). Fatigue specimens were designed to a constant radius geometry.

Fatigue life of INC718 in the solution annealed condition was reported in this study. Fig. 4. shows the results in comparison with previous published data in the age hardened condition and solution annealed. Fracture surface of Inconel 718, Figure 5. In the top right corner a “thumbnail” fatigue crack transitions to a ductile tear. Fatigue cracks initiate on the surface and travel across the cross section until reduction of area causes tensile failure.

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