Improvements in Oxidation Resistance
A New Titanium Alloy for Aerospace Applications

Arconic Engineered Structures – Niles, OH

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Acknowledgements

- Arconic Team Members
- US Air Force Metals Affordability Initiative
- Boeing Team Members
- Honeywell Team Members
Challenge: Critical Need for High Temperature Titanium Alloys

Fuel efficient jet engines provide enabling capabilities
- Higher efficiency and reduced fuel burn

Hotter engines present structural challenge to adjacent systems
- Pylons, Nacelles, Heat shields, Plugs, and Nozzles

Temperature requirements exceeding the current capabilities of Ti
- Inevitable use of high density materials (Ni, Steels, CMCs)

Weight and cost penalties
Titanium Oxidation Issue

Ti-6Al-2Sn-4Zr-2Mo Sheet

- Surface discoloration
- Oxide scale buildup & flaking
- Oxygen ingress (alpha case)
- Thermal stability

Exposed Air/1200°F (649°C)/ 2 Days

**State-of-the-Art in High-Temperature Ti Alloys**

Temperature requirements of NG engines exceeding the current capabilities of Ti

- **Ti 6-4**: Ti 6Al-4V
- **Ti 8-1-1**: Ti 8Al-1Mo-1V
- **Ti 6-2-4-6**: Ti 6Al-2Sn-4Zr-6Mo
- **Ti 17**: Ti-5Al-2Sn-2Zr-4Cr-4Mo
- **Ti 6-2-4-2**: Ti 6Al-2Sn-4Zr-2Mo-0.1Si
- **Ti 834**: Ti 5.8Al-4Sn-3.5Zr-0.5Mo-0.7Nb-0.3Si
- **Ti 1100**: Ti 6Al-2.7Sn-4Zr-0.4Mo-0.45Si
- **Ti 21S**: Ti 15Mo-3Nb-3Al-0.2Si
Alloy Development Challenge

Superior Oxidation Resistance Ti Alloy Attributes

Chemistry + Processing balancing to achieve desired performance without compromises in producibility, fabricability, and affordability
Arconic Innovation

- 5× Reduction in Weight Gain compared to Ti 6-2-4-2
- Stable surface condition, absence of flaking, high thermal stability
Oxidation of Ti Alloys at 1382°F (750°C)/208h

Dense surface scale for ARCONIC-THOR™; porous surface scale for Ti6242 & Beta21s

5x reduction in weight gain compared to Ti-6242
Improvement in Post-Thermal Exposure Fatigue Life

Double-hole Fatigue 0.080" sheet
Thermal exposure at 1292°F/100 h
RT, R = 0.06, 30 Hz, Sine wave
Integrated Product Development

Focused Maturation of ARCONIC-THOR™

- USAF Metals Affordability Initiative Project
- Arconic-Boeing-Honeywell Collaborative Team
- Manufactured full-scale Cast and Wrought products
- Demonstrated product readiness from R&D to production floor
- ICME approach to model and predict post-thermal exposure life

**Benefits:**
- Exhaust systems exposed to as much as 200°F above the state-of-the-art Ti alloys
- Significantly reduced weight and improved system performance

**Castin**
Courtesy: Honeywell

**Seamless Ring**
Courtesy: Honeywell

**Closed-die Forging**
 Courtesy: Honeywell

**Sheet Formed Part**
Courtesy: Boeing

**Foil**
Courtesy: Ulbrich Stainless
ARCONIC-THOR™ Sheet Specification

Tensile properties equivalent to Ti-6242 sheet (AMS4919™) w/ Superior oxidation resistance up to 1200°F

Room Temperature Tensile S-basis

<table>
<thead>
<tr>
<th>Nominal Thickness</th>
<th>Tensile Strength ksi</th>
<th>Yield Strength at 0.2% Offset ksi</th>
<th>Elongation in 2 inches or 4D %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.020 to 0.1874, incl</td>
<td>135</td>
<td>125</td>
<td>8</td>
</tr>
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<td>0.020 to 0.1874, incl</td>
<td>135</td>
<td>125</td>
<td>8</td>
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</tbody>
</table>

Room Temperature Bend

<table>
<thead>
<tr>
<th>Nominal Thickness Inch</th>
<th>Nominal Thickness Millimeters</th>
<th>Specimen Orientation</th>
<th>Bend Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.020 to 0.070, incl</td>
<td>0.51 to 1.78, incl</td>
<td>L and LT</td>
<td>4.5</td>
</tr>
<tr>
<td>Over 0.070 to 0.1874, incl</td>
<td>Over 1.76 to 4.760, incl</td>
<td>L and LT</td>
<td>5</td>
</tr>
</tbody>
</table>
Takeaways

- ARCONIC-THOR™ is a ~50% lighter conventional titanium alternative to nickel superalloys for the next generation aerospace systems providing significant cost savings and fuel efficiency.

- Superior oxidation resistant properties enable ARCONIC-THOR™ to operate at service temperatures 200°F higher than the state-of-the-art Ti alloys.

- Arconic has completed successful development projects with commercial aerospace and defense customers, including the U.S. Air Force, Boeing and Honeywell.

- AMS6953™ for sheet enables designers to incorporate ARCONIC-THOR™ into aerospace applications.