ITA
October 2006
ATI 425™ Titanium
ATI 425™ Titanium

Today

– What is ATI 425™ Titanium
– A Few Facts
– Features, Advantages, Benefits
– Applications
– Development Status
• Do you use a hot process to fabricate titanium into products?
• Does the hot manufacturing process add to the cost of doing business?
• If you had a sheet, strip or coil titanium product that is “cold workable”, would that add value
  – To your business?
  – To your customer?
ATI 425™ Titanium
What is it?
An Alpha – Beta Alloy
Nominal Chemistry

• 4% Aluminum
• 2.5% Vanadium
• 1.5% Iron
• 0.25% Oxygen
• Balance Titanium
ATI 425™ Titanium Alloy

Patents
U.S. Patent No. 5,980,655, and pending
U.S. and foreign patent applications
ATI 425™ Titanium

• **Physical Properties**
  
  – Density 0.162 lbs/in³
  – MP ~2950°F.
  – Hardness 32-36RC
  – Beta Transus 1765 - 1785 °F.
Typical Tensile Strength

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<th>Ti - 12</th>
<th>Ti - 9</th>
<th>ATI 425™</th>
<th>Ti - 5</th>
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(Ti-3 Al-2.5V) (Ti-6 Al-4 V)
Typical Yield Strength

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(Ti-3 Al-2.5V)

(Ti-6 Al-4V)
Typical % Elongation

- Ti - 2: 26.2
- Ti - 12: 22
- Ti - 9 (Ti-3 Al-2.5 V): 15.2
- ATI 425™ (Ti-6 Al-4 V): 15
- Ti - 5 (Ti-6 Al-4 V): 11
ATI 425™ Titanium

Cold Workable
ATI 425™ Titanium

Features

• Cold Workable
• High Strength
• Weldable - Ductile welds
• Machinable - Faster than Ti-64
• Super Plastic Formable - Like Ti-64
• Corrosion Resistant - Like Ti-64 & Ti-325
ATI 425™ Titanium Advantages

• Better Yield
• Smaller Bend Radii
• Cold Rolled Finish
• Better Gauge Control
• Coil Lengths
ATI 425™ Titanium Benefits

• Better Yield Means
  • Plant Efficiencies Improve

• Better Finish Quality Means
  • Less Processing Time

• Lower Converting Cost Means
  • Better Profitability
ATI 425™ Titanium Applications

- Aircraft Panels
- Formed Structural Panels, Honeycomb, Face-sheet
- Roll-Formed Structural Components
- Cold Formed, Stamped & Coined parts
- Fasteners
- Super-Plastic Formed Parts
- Aircraft Tubing
- Oil Field Tubing
- Structural & Recreational Uses
- Pressure Vessels
ATI 425™ Coil
0.125” T x 26” Hot Band

ATI 425™ SPF
Cover Sheet
Trial Parts
General Development Status

- Production to Date = 72,000 lb
- Mill Products Manufactured
  - Cold Rolled - Sheet, Strip, Foil
  - Cold Reduced Seamless Tubing
  - Hot Forged - Billet, Bar, Rod
  - Hot Rolled - Plate, Strip (Coil)
  - Hot Tubular Extrusion
  - Weld Wire

ATI 425™
0.085” Sheet ~ 500x
ATI 425TM Titanium
Certifications to Date

- ASTM Grade 38
- UNS #54250, UNS #54250-1
- ASME Boiler Code Case 2532
- Other certifications in process
  - AMS - #6946 in ballot, moving to Aerospace Council
  - AWS
ATI 425™ Titanium Tubing
## Comparison Tubing Properties

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<th>Yield (KSI)</th>
<th>Ultimate (KSI)</th>
<th>Elongation (%)</th>
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<td>• Ti-3Al-2.5V</td>
<td>73 – 115</td>
<td>90 – 140</td>
<td>16 – 20</td>
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<td>• Ti-6Al-4V ELI</td>
<td>105 – 133</td>
<td>125 – 150</td>
<td>7 – 17</td>
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<td>• ATI 425™ Titanium CWSR</td>
<td>130</td>
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<td>Annealed</td>
<td>116 – 122</td>
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 ATI 425™ Titanium

Cold Workable
Thank You

Questions?

john.seton@wahchang.com
## ATI 425™ Titanium Mechanical Properties

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<td>CW</td>
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1. All Products includes: HR plate; Wrought Bar & Billet; CR Sheet & strip; Hot Extrusion; Tube
Machining Comparison

Comparison Cutting forces at Baseline feeds & Speeds

ATI 425™ Titanium can be machined 15% faster than 6Al-4V

Courtesy Boeing M&PT Machining Lab
Uniaxial Tensile Tests of Titanium Sheet under SPF Conditions
Comparison of Ti-425 to conventional T-6Al-4V at 900°C and 3x10^-4/sec

True Stress (psi)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

m-value

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

True Strain

0 0.5 1 1.5 2 2.5

T-425

Ti-6Al-4V

Super Plastic Forming Capability

Graphs courtesy Battelle NW
ASME Design Allowable Stresses for Ti Alloys

Max Allowable Stress (ksi)

Temperature (F)

ATI 425™

Ti - 9

Ti - 12

Ti - 2
Super Plastic Forming Capability

- SPF panels of welded ATI 425™ Titanium 0.100” cold-rolled sheet
- Hi-Tech Welding, El Cajon, CA
- Army Research Lab Trailer Project
Corrosion Properties

- In between Ti 6Al-4V and Ti-3Al-2.5V
- Evaluated in following media:
  - 40% Nitric 105°C.
  - 10% Hydrochloric 100°C.
  - 100% Acetic 118°C.
  - 100% Sulfuric 103°C.
  - 100% Seawater 100°C.
  - U-Bend Stress Corrosion Cracking

ATI 425™ Titanium Sheet
Coupons (U-Bend)
Mining Liquor Test
Electrical Resistivity*

- **ATI 425™ Titanium** 154 $\mu$-ohm
- **CP** 56 $\mu$-ohm
- **Ti64** 170 $\mu$-ohm
  - *courtesy Hamilton Precision*
Characterization of Titanium ATI 425™ Titanium Alloy sheet under SPF Conditions

PNWD-3500 Battelle Northwest Laboratories

• “The Ti-425 alloy exhibited flow stress, elongations, and strain rate sensitivities that are suitable for commercial SPF applications."

• “The conventional Ti-6Al-4V sheet materials are often formed at a temperature of 900°C. in commercial practice, and it appears that the Ti-425 sheet will have similar performance during SPF at these conventional forming rates and temperatures”

• Characterization of Titanium Ti-425 Alloy Sheet under SPF Conditions

• Technical Report Prepared for Wah Chang
**ATI 425™ Titanium Rammed Graphite Casting**

Gun Pod Elevation Arm Stryker Vehicle

33” L X 7” X 7.5”  167#

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Cast Plate

120  135  15(“L” & “T”)

Cast Plate ~ 100X
Mechanical Properties

Small Bar

Test Temperature deg. F.

Strength (KSI)

-100  -50  0  25  50  75  100  125  150  175  200

0  20  40  60  80  100  120  140  160  180

ATI 425™ Titanium

Ultimate  Yield  Elongation  Reduction Area
## ATI 425™ Titanium Compressive Yield Data *(Stavely)*

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<td>142.8</td>
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### ATI 425™ Titanium

Creep Rupture Data ½” Plate Heat 797Y

Westmoreland

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<th>Test Temp. (°F)</th>
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<th>Hours</th>
<th>Elongation (%)</th>
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## ATI 425™ Titanium

**Erichsen Cup Test per DIN 50 101 (RT)**

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<td><strong>Average</strong></td>
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**ATI 425™ Titanium**

**Compressive Yield Data (Staveley)**

![Graph showing compressive yield data for different types of ATI 425™ Titanium](image)

- **Yield Strength (ksi):**
  - Ti 6-4: 143, 1600
  - ATI 425™: 138, 135, 147, 140, 147, 140
  - ATI 425™: 135, 130
  - ATI 425™: 175, 155, 170
  - ATI 425™: 170, 150

- **Oxygen Content (ppm):**
  - Ti 6-4: 500
  - ATI 425™: 2400, 2900
  - ATI 425™: 2900
  - ATI 425™: 2900
  - ATI 425™: 2900
ATI 425™ Titanium
Creep Rupture Data ½” Plate Heat 797Y Westmoreland
ATI 425™ Titanium
Pin Bearing Test ASTM E238
Westmoreland
6 Lots, duplicate L & T coupons, 3 heats
Cold Rolled Sheet 6 gauges from 0.038” to 0.102”

<table>
<thead>
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<th>Pin Bearing</th>
<th>Yield (KSI)</th>
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<th>Tensile Ultimate (KSI)</th>
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<td>310.4</td>
<td>156.5</td>
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<td>8.6</td>
<td>6.6</td>
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<tr>
<td>Trans SDEV</td>
<td>18.2</td>
<td>6.1</td>
<td>9.9</td>
</tr>
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Specific Heat of Ti-4Al-2.5V-1.5Fe-O Alloy

Temperature, C

Specific Heat, J/kg-K
Thermal Expansion of Ti-4Al-2.5V-1.5Fe-O Alloy
Thermal Conductivity of Ti-4Al-2.5V-1.5Fe-O Alloy

- Temperature, °C
- Thermal Conductivity, W/m·°K