TITLE:

B218 Weld Filler Wire Characterization for Al-Li Alloy 2195

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ABSTRACT:

NASA Marshall Space Flight Center, Lockheed Martin Space Systems- Michoud Operations, and McCook Metals have developed an aluminum-copper weld filler wire for fusion welding aluminum lithium alloy 2195. The aluminum-copper based weld filler wire has been identified as B218, a McCook Metals designation. B218 is the result of six years of weld filler wire development funded by NASA, Lockheed Martin, and McCook Metals. The filler wire chemistry was developed to produce enhanced 2195 weld and repair weld mechanical properties over the 4043 aluminum-silicon weld filler wire, which is currently used to weld 2195 on the Super Lightweight External Tank for the NASA Space Shuttle Program. An initial characterization was performed consisting of a repair weld evaluation using B218 and 4043 weld filler wires. The testing involved room temperature and cryogenic repair weld tensile testing along with fracture toughness testing. From the testing, B218 weld filler wire produce enhanced repair weld tensile strength, ductility, and fracture properties over 4043. B218 weld filler wire has proved to be a superior weld filler wire for welding aluminum lithium alloy 2195 over 4043.
B218 Weld Filler Wire Characterization
For Al-Li Alloy 2195

AEROMAT 2000
Seattle, WA

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B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

Background

- Welding 2195 Aluminum Lithium for the Space Shuttle
  Super Lightweight External Tank

NASA Space Shuttle

Variable Polarity Plasma Arc Welding
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

Background

1993
- FILLER WIRE DEVELOPMENT FOR 2195 ALUMINUM-LITHIUM LMSS/MSFC/RMC (14) AL-CU BASED FILLER WIRES

1995
- PART II FILLER WIRE DEVELOPMENT FOR 2195 ALUMINUM-LITHIUM LMSS/MSFC/RMC (4) AL-CU BASED FILLER WIRES

1998
- SDS 3750 ALUMINUM-LITHIUM WELD PROCESSES AND EQUIPMENT DEVELOPMENT LMSS/MSFC B218 FILLER WIRE QUICK LOOK
- C458 AIR FORCE AL-LI ALLOY WELD AND REPAIR EVALUATION MSFC CHEMISTRY #16 FILLER WIRE

1999
- SDS 3763 LMSS/MSFC B218 REPAIR WELD EVALUATION
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

2195T8M4 VPPA Weld Ultimate Tensile Strength

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Material</th>
<th>Ultimate Tensile Strength (ksi)</th>
<th>SHAVED</th>
<th>AS-WELDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.200&quot;t</td>
<td>4043</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.200&quot;t</td>
<td>B218</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.320&quot;t</td>
<td>4043</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.320&quot;t</td>
<td>B218</td>
<td>50</td>
<td></td>
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</tbody>
</table>
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

2195T8M4 VPPA Weld Tensile Elongation

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Material</th>
<th>Tensile Elongation (% gage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.200&quot; t</td>
<td>4043</td>
<td>SHAVED</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

VPPA Weld Grain Structure Comparison

0.320t 2195 PLATE TO 2195 PLATE VPPAW

4043 WELD FILLER WIRE

10X Original Magnification

B218 WELD FILLER WIRE

10X Original Magnification
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

B218 VPPA Weld Grain Structure

0.200t 2195 PLATE TO 2195 PLATE VPPAW

10X Original Magnification

10X Original Magnification
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

B218 GTA Repair Weld Grain Structure

R1 GTA Repair 0.200t 2195 PLATE TO 2195 PLATE VPPAW

10X Original Magnification
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

2195 Repair Weld Residual Stresses
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

2195 Repair Weld Residual Stresses

Distance From Repair Weld Midlength - Inches

- Unplanished
- Planished 70%
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

2195 Repair Weld Residual Stresses

R5 GTA Repair 0.200t 2195 PLATE TO 2195 PLATE VPPAW

Photostress of Unplanished Repair Weld

Photostress of Planished Repair Weld
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

Objective

• Assess B218 weld filler wire for Super Lightweight External Tank production, which could improve current production welding and repair productivity.

Approach

• Perform a repair weld quick look evaluation between 4043/B218 and B218/B218 weld filler wire combinations. Evaluate tensile properties for planished and unplanished conditions.

• Perform repair weld evaluation on structural simulation panel using 4043/B218 and B218/B218 weld filler wire combinations. Evaluate tensile and simulated service fracture properties for planished and unplanished conditions.
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

VPPA/GTA Repair Weld Quick Look

- 14” X 24” Standard Repair Weld Panel

Manual GTA Repair Welding
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200”t 2195T8M4 Repair Weld Ultimate Tensile Strength -Coupon Level

VPPA INITIAL WELD
MANUAL GTA R5 FUSION LINE REPAIR

0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

REPAIR ULTIMATE TENSILE STRENGTH (ksi)

4043/B218 0% PLAN.
4043/B218 70% PLAN.
B218/B218 0% PLAN.
B218/B218 70% PLAN.
4043/4043 70% PLAN.

△ RT
× LHe
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200"t 2195T8M4 Repair Weld Ultimate Tensile Elongation - Coupon Level

Diagram showing tensile elongation data for different conditions and materials.
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200t 2195T8M4 VPPA/ GTA Repair Weld Metallography

- 4043/B218 0% Planished

C008-RT02
RT Tensile Test
36.2 ksi / 2.74% El. 1” gage

C009-CT01
LH2 Tensile Test
62.5 ksi / 3.4% El. 1” gage
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200t 2195T8M4 VPPA/ GTA Repair Weld Metallography

- B218/B218 0% Planished

C080-RT01
RT Tensile Test
45.2 ksi / 9.75% El. 1” gage

C080-CT01
LH2 Tensile Test
68.1 ksi / 7.40% El. 1” gage
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

VPPA/ GTA Repair Weld Structural Simulation Panel Evaluation

- 19” X 48” Repair Weld Wide Panel
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200t 2195T8M4 Structural Simulation Panel Weld Tensile Strength (-423°F)
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.320t 2195T8M4 Structural Simulation Panel Weld Tensile Strength (-423°F)
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.200t 2195T8M4 VPPA/GTA Repair Weld Simulated Service Fracture Toughness

![Graph showing crack length vs. gross fracture stress for different conditions.](image-url)

- ▲ a/2c=0.5, -320 F, 4043/B218 0%P
- △ a/2c=0.5, -320 F, B218/B218 0%P
- ● a/2c=0.5, -423 F, 4043/B218 0%P
- ○ a/2c=0.5, -423 F, B218/B218 0%P
- × a/2c=0.2, -320 F, B218/B218 0%P
- ■ a/2c=0.2, -423 F, 4043/B218 0%P
- □ a/2c=0.2, -423 F, B218/B218 0%P
- ○ a/2c=0.5, -423 F, 4043/B218 70%P
- ● a/2c=0.5, -423 F, B218/B218 70%P
- ▲ a/2c=0.5, -423 F, B218/B218 70%P

- Initial weld RT lower bound
B218 Weld Filler Wire Characterization For Al-Li Alloy 2195

0.320t 2195T8M4 VPPA/GTA Repair Weld Simulated Service Fracture Toughness

![Graph showing fracture toughness data for B218 repairs.](image)

- **B218 repair**
  - $t=0.320''$
  - -423°F test temperature

- **Initial weld RT lower bound**

- **Data Points**
  - $a/2c=0.5$, 4043/4043 0%P
  - $a/2c=0.5$, B218/B218 0%P
  - $a/2c=0.2$, 4043/B218 0%P
  - $a/2c=0.2$, B218/B218 0%P
  - $a/2c=0.5$, 4043/B218 70%P
  - $a/2c=0.2$, 4043/B218 70%P
  - $a/2c=0.5$, B218/B218 70%P
  - $a/2c=0.2$, B218/B218 70%P

- **Graph Axes**
  - **Y-axis**: Gross Fracture Stress, PSI
  - **X-axis**: Crack Length ($2c$), IN.
Conclusions

- B218 weld filler wire displayed higher repair weld tensile strength and ductility compared to 4043.

- Unplanished and planished B218 repair welds exceeded the current SLWT 4043 repair weld tensile strength requirement.

- B218 repair weld simulated service results surpassed 4043 repair welds and were comparable to 2195 initial welds made with 4043.

- B218 displays a high potential for improving SLWT production through increased repair weldability and the reduction/elimination of planishing for the removal of repair weld residual stresses.