Near Net Manufacturing Using Thin Gage Friction Stir Welding

AeroMat 2006
Seattle, Washington

Jennifer Takeshita
David Potter  Michael Holguin
Lockheed Martin
- Background
- Objective
- Approach
- Results
- Acknowledgements
Background

Work done for NASA’s H&RT BAA

- Objective of BAA
  » Increase the technology level over 4 years
  » Provide technology that is affordable, multi-purpose

- Focus of this BAA
  » Friction stir welding on thin gage alloys
  » Near net manufacturing methods
  » Mass efficient pressure vessels

Today’s Topic
Near-Net Spin Forming

- Spin form a near-net dome using friction stir welded material
  
  - Technology Development
    - Epoxy tool for spin forming
    - Near net spin forming
  
  - Advantages:
    - Materials more affordable
    - Less material to remove if near net
    - Tooling approach lightweight
    - Technology is independent of size

Michael Holquin, 303-971-2312
Jennifer Takeshita, 504-257-0250
David Potter, 303-971-2647
Alloy Selection

• **Select alloys**
  - **Criteria**
    » Readily available in gages near 0.125”
    » Good mechanical properties
    » Good material properties
      - i.e. corrosion resistance, density

• **Alloys selected**
  - 2024
  - 2219
  - 7075
Weld Equipment

- MTS Universal Weld System
Weld Set-Up

- Same fixture for all welding
  - Finger clamping
  - Minimal heat sink

- Retractable pin tool used for all alloys
Weld Development

- Each alloy was bounded
- Bounds were used to run simulated DOE

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ultimate Tensile Strength</th>
<th>Yield Strength</th>
<th>% Elongation (1&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent Metal</td>
<td>64 ksi</td>
<td>47 ksi</td>
<td>12</td>
</tr>
<tr>
<td>Weld Ave</td>
<td>65.5 ksi</td>
<td>47.5 ksi</td>
<td>13.8 ksi</td>
</tr>
<tr>
<td>St Dev</td>
<td>1.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>2219</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent Metal</td>
<td>63 ksi</td>
<td>51 ksi</td>
<td>5</td>
</tr>
<tr>
<td>Weld Ave</td>
<td>48.7 ksi</td>
<td>28.5 ksi</td>
<td>5.3</td>
</tr>
<tr>
<td>St Dev</td>
<td>1.95</td>
<td>1.31</td>
<td>0.58</td>
</tr>
<tr>
<td>7075</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent Metal</td>
<td>78 ksi</td>
<td>70 ksi</td>
<td>8</td>
</tr>
<tr>
<td>Weld Ave</td>
<td>75.1 ksi</td>
<td>52.9 ksi</td>
<td>7.9</td>
</tr>
<tr>
<td>St Dev</td>
<td>0.76</td>
<td>1.32</td>
<td>0.68</td>
</tr>
</tbody>
</table>

18 Welded Panels

Typical Ranges:
- 200 RPM
- 4 IPM
- 400 lbf
Fabrication of Dome Blanks

- Deliverable:
  - Three (3) dome blanks
    » One per alloy (7075, 2219, 2024)
    » Final dimensions: 4’ x 4’

- Process

Use schedule proven on confidence panels

<table>
<thead>
<tr>
<th>Weld</th>
<th>NDE</th>
<th>Trim to size</th>
<th>Anneal</th>
<th>Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>7075</td>
<td>Pass</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2219</td>
<td>Pass</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>Pass</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Panels remediated after Hurricane Katrina
Fabrication of Dome Blanks

Making the first weld

Pin Tool
Surface Screw Clamps
Side Clamping

Making the second weld

Steel Anvil

Surface Screw Clamps
Side Clamping

Pin Tool

Michael Holguin, 303-971-2312
Jennifer Takeshita, 504-257-0250
David Potter, 303-971-2647
Spin Forming the Dome Blanks

- Used female mandrel rather than male
  - Potential to reduce cost of tooling at large scale
    - At large-scale, multiple breakdown tools required
  - Potential to improve control for tolerances and contour
    - Further enhancing near-net forming capability
  - Used an epoxy tool with metal ring
    - Scale up would cause tool to be too heavy if all metal
FSW Dome Spinning Process

1. Install the dome blank

2. Spin form the blank

3. Check thickness
2024 Dome Results

- Material was formed ~ 10-11” inboard prior to cracking
  - Noticeable stress risers on the surface where the crack started
    » Appears due to hand sanding with 180 grit
  - Material thinned down to ~0.070” near crack initiation
  - Cracking appears to be a brittle failure from being cold worked
2219 Dome Results

- Heat applied
  - Monitored via IR gun

- Material formed ~10-11” inboard prior to cracking
  - Forming operation was manually controlled
  - Material thinned to ~0.029” near crack initiation
  - Rest of material was ~0.070” thick
FSW 7075 Blank Spinning

- Heat applied
  - Monitored via IR gun

- 7075 Dome Blank:
  - Material was formed ~10-11” inboard
  - Small tear formed in FSW joint
Approach – Round Two (Female)

Used 2024 only

Heat applied

Fully formed dome almost accomplished
Approach – Round Two (Male)

- Used 2024
- Heat Applied

Full dome accomplished
Summary of Results

- Use of female dome
  » More stretch accomplished
  » Complicated by use of epoxy die with metal
  » Higher risk method

- Use of male dome
  » Less stretch accomplished
Recommendations

- Find a better way to put fasteners into epoxy die

- Use dome blanks that are one temper
  » Anneal welds and parent metal prior to spinning
Acknowledgements

• Hi – Temp – David Lind, provided spin forming

• NASA
  – Contract officer Louis Lollar
  – Technical counterparts Carolyn Russell
  – Program Managers: Chris Moore and Judith Watson

• Lockheed Martin
  – Bob Anderson
  – Duy Pham
Thank You!