Friction Stir Welding of AA 6016-T4 thin sheets

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Outline

• Introduction
• Base Material
• Welding Procedure
• Microstructural analysis of the welds
• Mechanical testing
  – Hardness results
  – Tensile Test results
  – Forming Results
• Conclusions
Introduction

Previous works:

- AA 6061
- AA 6082
- AA 6063
- AA 6056
- AA 6022
- AA 6005
- AA 6013

- Artificially aged temper condition (T5, T6 and T651)
- Plates thicker than 3 mm

Friction Stir Welding of AA 6016-T4 thin sheets
Influence of process parameters
Base Material

- AA 6016 aluminium alloy
- 1.0 mm thick rolled plates
- heat-treated and naturally aged

- good hemming properties
- good weldability
- very good corrosion resistance
- very good formability
- no stretcher strain marks

Nominal chemical composition of the AA 6016 alloy (wt-%)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA 6016-T4</td>
<td>1.0–1.5</td>
<td>&lt; 0.5</td>
<td>&lt; 0.2</td>
<td>&lt; 0.2</td>
<td>0.25–0.6</td>
<td>&lt; 0.1</td>
<td>&lt; 0.2</td>
<td>&lt; 0.15</td>
</tr>
</tbody>
</table>

Mean grain size: 23 µm
### Welding Procedure

#### Conical shoulder

- **Shoulder:** 8° inclination cavity
  - 10 mm in diameter

- **Pin:**
  - Cylindrical threaded
  - 3 mm in diameter
  - 1 mm long

#### Scrolled Shoulder

- **Shoulder:** Helical flutes
  - 14 mm in diameter

- **Pin:**
  - Cylindrical threaded
  - 3 mm in diameter
  - 0.85 mm long

<table>
<thead>
<tr>
<th>Welding speed ((v))</th>
<th>Rotation speed ((\omega))</th>
<th>Tool tilt angle</th>
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</thead>
<tbody>
<tr>
<td><strong>Tool 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conical shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tool 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrolled Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hot Welds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cold Welds</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12-07-2008

IIW 2008
Macrostructural analysis of the welds

Hot Welds

Cold Welds

Thickness undermatch

No thickness undermatch
Microstructural analysis of the welds

**Hot Weld**

AA 5182-H111

AA 6016-T4

**Cold Weld**

AA 5182-H111

AA 6016-T4
Microstructural analysis of the welds

Hot Weld
Mean grain size: 7 \( \mu m \)

Cold Weld
Mean grain size: 2 \( \mu m \)
Hardness Profile

Distance from weld center line (mm)

Hardness (HV 0.1)

Advancing Side

Retreating Side

Hot Weld

Cold Weld
Tensile test results

Engineering Strain

Engineering Stress (MPa)

Cold Weld

Hot Weld

AA 6016-T4

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Formability results

punch speed - 100 mm/min
clamping force - 8 kN

Punch Displacement (mm)
Punch Force (kN)

- Hot Weld
- Cold Weld
- AA6016-T4

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Formability results

Cold Weld

Hot Weld
Conclusions

- Defect free welds were obtained for both tool geometries and welding parameters
- **Hot welds** were in evenmatch relative to the base material
- **Cold welds** were in undermatch relative to the base material
- Both welds had lower ductility than the base material
- Cold welding improved the formability of the TWB