Hybrid laser welding of 5xxx series aluminium alloys (2)

Wim Van Haver
Research Center of the Belgian Welding Institute
Gent (B)
Overview

- Project ALUWELD
- Aluminium alloys (5xxx series)
- Experimental results
- Further research projects
- Conclusions
Project ALUWELD

- Innovative welding of high strength aluminium alloys with the Friction Stir Welding (FSW) and Hybrid Laser Welding (HLW) techniques
- 50% of fundings by IWT-Vlaanderen (IWT 30909)
- Duration: 2004-2005
- Both welding processes have in common:
  - low loss in strength
  - low deformation
  - fully automatic
- Aims:
  - Building up base knowledge about both FSW and HLW
  - Demonstrating the capabilities of FSW and HLW on relevant aluminium alloys for the industrial project members
    - HLW: 5083-H111, 5754-O, 5182-H111, 6056-T4, 6061-T6, 6082-T6, AC-46000
  - Modelling
  - Comparison with « traditional » welding processes
Aluminium alloys: subdivision

- Aluminium wrought alloys (rolled products/extrusions): « series » based on chemical composition

- Depending on the chemical composition:
  - 1xxx: Al with different degrees of purity (> 99%)
  - 2xxx: Al-Cu(Mg)
  - 3xxx: Al-Mn
  - 4xxx: Al-Si
  - 5xxx: Al-Mg
  - 6xxx: Al-MgSi
  - 7xxx: Al-ZnMg(Cu)
  - 8xxx: « specialty alloys » (e.g. Al-Sn)
Al 5xxx series: properties

- Al-Mg alloys
- Non-precipitation hardenable
- Strength increase by cold deformation only
- Important influence of Mg on strength
- Very good corrosion resistance (but ICC/SCC possible)
- Good weldable
- Typical applications of 5xxx series:
  - Welded structures, storage tanks, structural sheet…
- 5xxx Al-alloys within the project: 5083, 5754 and 5182
5xxx Al-legeringen within the project

- Supplied by industrial project members:
  - 5083-H111 sheets Al Mg4,5Mn0,7 (5-8 mm)
    - Cryogenic applications, structural applications, piping and tubing…
  - 5754-O sheets Al Mg3 (4 mm)
    - Nuclear, chemical and food industry, load floors, pressure vessels…
  - 5182-H111 sheets Al Mg4,5Mn0,4 (1,5 mm)
    - Packaging, automotive industry
HLW experimental results: 5083 (1)

- Optimization process
  - Laser-MIG distance (0 – 4 mm)
  - Welding speed (0.4 – 2.4 m/min)
  - Laser power
  - Consumable:
    - 4043 (Al Si5)
    - 5183 (Al Mg4,5Mn)
  - Shielding gas:
    - pure Ar
    - « Astec » (70% Ar – 30% He)

  lower strength
  no improvement (porosity)
HLW experimental results: 5083 (2)

- Radiography + tensile testing:

- Laser-MIG: 2 mm
  - 1.5 m/min
  - 267 MPa
  - no porosity

- Laser-MIG: 2 mm
  - 1.5 m/min
  - 269 MPa
  - 282 MPa
  - porosity

- Laser-MIG: 1 mm
  - 1.5 m/min
  - 277 MPa
  - few porosity

- Laser-MIG: 1 mm
  - 2 m/min
  - 219 MPa
  - 282 MPa
  - 288 MPa
  - porosity

Benelux Laser Event - 26/04/05-27/04/05
HLW experimental results: 5754 (1)

- Optimization process
  - Laser-MIG distance (1 – 4 mm)
  - Welding speed (1,2 – 2,7 m/min)
  - Laser power
  - Consumable:
    - 4043 (Al Si5)
    - **5183 (Al Mg4,5Mn)**
  - Shielding gas:
    - pure Ar
    - « Astec » (70% Ar – 30% He)
**HLW experimental results: 5754 (2)**

- Radiography + tensile testing:

<table>
<thead>
<tr>
<th>Material</th>
<th>Diameter</th>
<th>Speed</th>
<th>Fracture Site</th>
<th>Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser-MIG: 2 mm</td>
<td>0.5 mm</td>
<td>1.5 m/min</td>
<td>undercut of weld face</td>
<td>221 MPa</td>
</tr>
<tr>
<td>Laser-MIG: 1 mm</td>
<td>1.5 m/min</td>
<td>2 m/min</td>
<td>root, much porosity (RX)</td>
<td>230 MPa</td>
</tr>
<tr>
<td>Laser-MIG: 2 mm</td>
<td>1.5 m/min</td>
<td>2 m/min</td>
<td>HAZ</td>
<td>226 MPa</td>
</tr>
<tr>
<td>Laser-MIG: 2 mm</td>
<td>1.5 m/min</td>
<td>2 m/min</td>
<td>weld face</td>
<td>228 MPa</td>
</tr>
</tbody>
</table>
HLW experimental results: 5754 (3)

- Optimized welds:
  - Tensile testing: fractured in base material
  - Passed both root and face bend test (3*t) over 180°
  - Low degree of porosity
  - No softening in HAZ
HLW experimental results: 5182 (1)

- Laser beam welding alone:
  - Welding speeds up to 8.4 m/min
  - Strength increases with higher welding speed

- Hybrid laser welding:
  - Welding speed: 3.6 m/min up to 8.4 m/min, laser-MIG = 4 mm
  - Tensile strength too low at highest welding speeds

<table>
<thead>
<tr>
<th>Consumable</th>
<th>none</th>
<th>none</th>
<th>none</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Welding speed (m m / m in)</th>
<th>3600</th>
<th>6000</th>
<th>8400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laserpower (W)</td>
<td>2200</td>
<td>2400</td>
<td>3000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tensile strength 1 (MPa)</th>
<th>252</th>
<th>258</th>
<th>270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength 2 (MPa)</td>
<td>253</td>
<td>253</td>
<td>271</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumable</th>
<th>5183</th>
<th>5183</th>
<th>5183</th>
<th>5183</th>
<th>5183</th>
<th>5183</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding speed (m m / m in)</td>
<td>3600</td>
<td>4200</td>
<td>4800</td>
<td>6000</td>
<td>7200</td>
<td>8400</td>
</tr>
<tr>
<td>Distance laser-MIG (mm)</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Type of shielding gas</td>
<td>Ar</td>
<td>Ar</td>
<td>Ar</td>
<td>Ar</td>
<td>Ar</td>
<td>Ar</td>
</tr>
<tr>
<td>Laserpower (W)</td>
<td>2200</td>
<td>2300</td>
<td>2300</td>
<td>2400</td>
<td>2600</td>
<td>3000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tensile strength 1 (MPa)</th>
<th>258</th>
<th>279</th>
<th>255</th>
<th>246</th>
<th>260</th>
<th>201</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength 2 (MPa)</td>
<td>262</td>
<td>260</td>
<td>270</td>
<td>252</td>
<td>255</td>
<td>207</td>
</tr>
</tbody>
</table>
HLW experimental results: 5182 (2)

<table>
<thead>
<tr>
<th>Consumable</th>
<th>5183</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding speed (mm/min)</td>
<td>6000</td>
</tr>
<tr>
<td>Distance laser-MIG (mm)</td>
<td>4</td>
</tr>
<tr>
<td>Type of shielding gas</td>
<td>Ar</td>
</tr>
<tr>
<td>Laser power (W)</td>
<td>2400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumable</th>
<th>5183</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding speed (mm/min)</td>
<td>6000</td>
</tr>
<tr>
<td>Distance laser-MIG (mm)</td>
<td>3</td>
</tr>
<tr>
<td>Type of shielding gas</td>
<td>Ar</td>
</tr>
<tr>
<td>Laser power (W)</td>
<td>2500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumable</th>
<th>5183</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding speed (mm/min)</td>
<td>3600</td>
</tr>
<tr>
<td>Distance laser-MIG (mm)</td>
<td>3</td>
</tr>
<tr>
<td>Type of shielding gas</td>
<td>Ar</td>
</tr>
<tr>
<td>Laser power (W)</td>
<td>2300</td>
</tr>
</tbody>
</table>

TS: 246 MPa, 252 MPa
Bend tests ok
Problems on root side

TS: 269 MPa, 270 MPa
Failed root bend test
Porosity

TS: 285 MPa, 289 MPa
Bend tests ok
Misalignment
Project proposals 2006-2007

• « ALUWELD II » (BWI, VITO, UCL-PRM, Cenaero...)
  ➢ FSW and HLW
  ➢ Modelling
  ➢ Other materials: other Al-alloys, Mg, Ti, Cu, thermoplastics, steel…
  ➢ Dissimilar joints (e.g. Al to Mg)
  ➢ Other weld geometries, application-based

• « HYLAS » (BWI, VITO...)
  ➢ Hybrid laser welding of steel
  ➢ Comparison with laser welding and arc welding
  ➢ Steels: C-Mn, stainless steels, Zn-coated steel…

• Relatively limited input from your company!

• Contacts:
  ➢ Wim Van Haver, BWI (wim.vanhaver@soete.UGent.be)
  ➢ Jo Verwimp, LCV-VITO (jo.verwimp@vito.be)
Conclusions

• Very promising results for 5xxx series:
  ➢ High productivity (welding speed > 1 m/min)
  ➢ Good weld quality (strength, porosity)
• Further research is being carried out within project ALUWELD (2004-2005)
• 2 BWI project proposals (in cooperation with Laser Center Flanders) for 2006-2007 concerning HLW:
  ➢ ALUWELD II (FSW & HLW)
  ➢ Hybrid Laser Welding of steel
Thank you for your attention.