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

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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) en 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
    - FSW: 2024-T3, 5754-O, 5182-H111, 5083-H111, 6056-T4, 6061-T6, 7475, AC-46000
    - 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

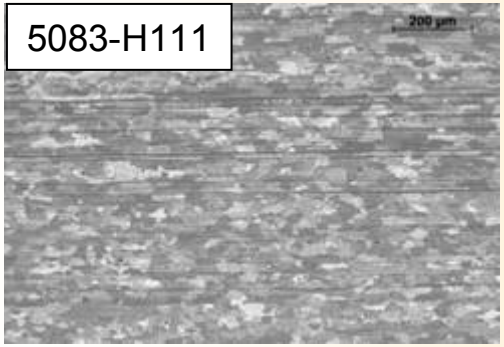
5083

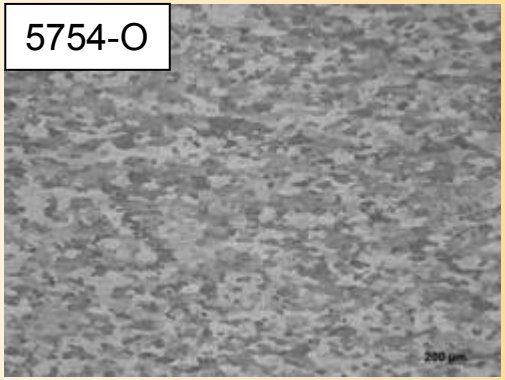
5754

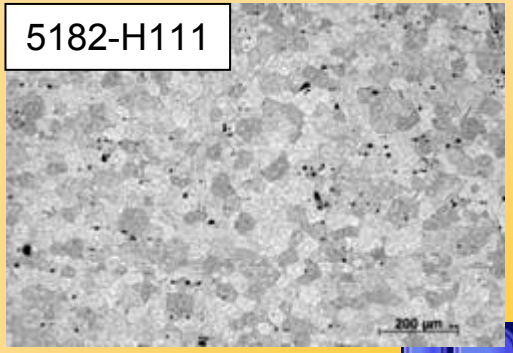
5182

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







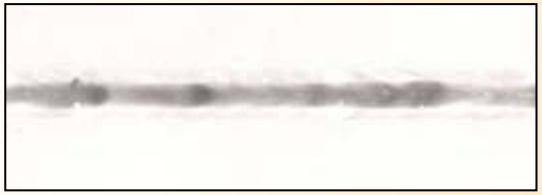
HLW experimental results: 5083 (1)

- Optimization process
  - Laser-MIG distance (0 – 4 mm)
  - Welding speed (0,4 – 2,4 m/min)
  - Laser power
  - Consumable:
    - 4043 (Al Si5) → lower strength
    - 5183 (Al Mg4,5Mn)
  - Shielding gas:
    - pure Ar
    - « Astec » (70% Ar – 30% He) → no improvement (porosity)

HLW experimental results: 5083 (2)

- Radiography + tensile testing:

269 MPa
no porosity



Laser-MIG: 2 mm
1,5 m/min

267 MPa
porosity

Laser-MIG: 2 mm
2 m/min

283 MPa
277 MPa
few porosity

Laser-MIG: 1 mm
1,5 m/min

219 MPa
288 MPa
282 MPa
porosity

Laser-MIG: 1 mm
2 m/min

HLW experimental results: 5754 (1)

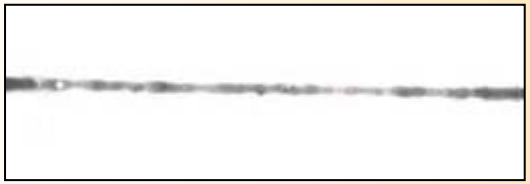
- Optimization process
  - Laser-MIG distance (1 – 4 mm)
  - Welding speed (1,2 – 2,7 m/min)
  - Laser power
  - Consumable:
    - 4043 (Al Si5)
    - 5183 (Al Mg4,5Mn)

    → lower strength
  - Shielding gas:
    - pure Ar
    - « Astec » (70% Ar – 30% He)

    → based on 5083 results

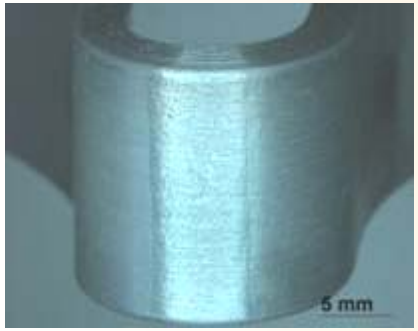
HLW experimental results: 5754 (2)

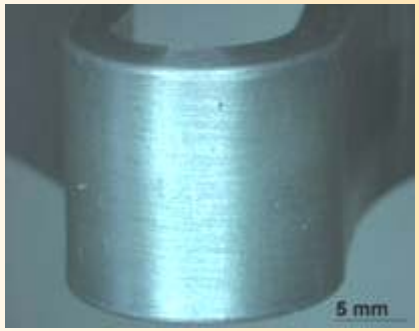
- Radiography + tensile testing:

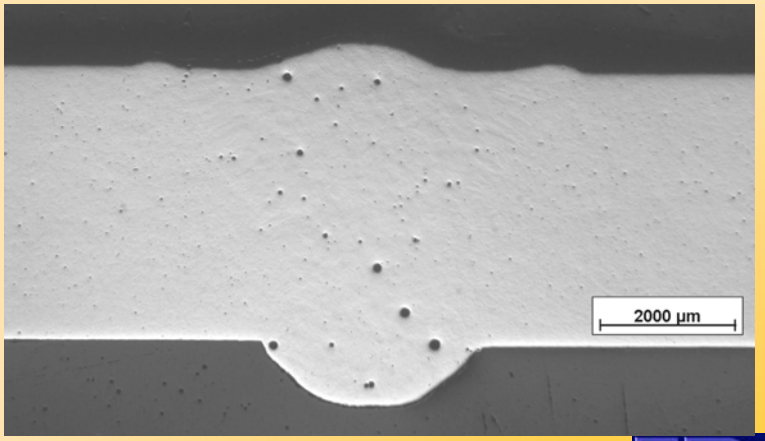
226 MPa fracture initiation on undercut of weld face		Laser-MIG: 2 mm 1,5 m/min
221 MPa 2 porosities of 0,5 mm diameter		Laser-MIG: 2 mm 2 m/min
228 MPa fractured in HAZ		Laser-MIG: 1 mm 1,5 m/min
230 MPa fracture initiation on root, much porosity (RX)		Laser-MIG: 1 mm 2 m/min

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)

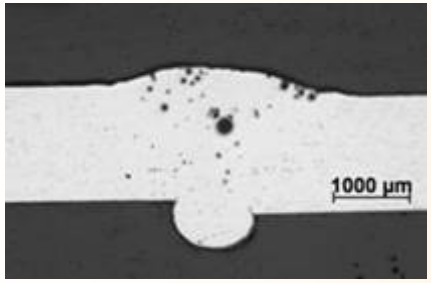
- Laser beam welding alone:
  - Welding speeds up to 8,4 m/min
  - Strength increases with higher welding speed

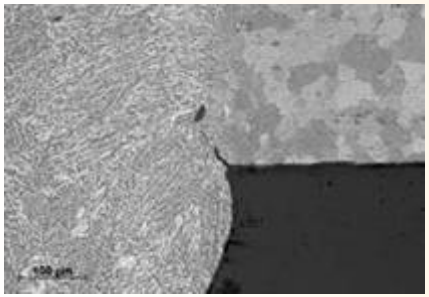
Consumable	none	none	none
Welding speed (mm/min)	3600	6000	8400
Laser power (W)	2200	2400	3000
Tensile strength 1 (MPa)	252	258	270
Tensile strength 2 (MPa)	253	253	271

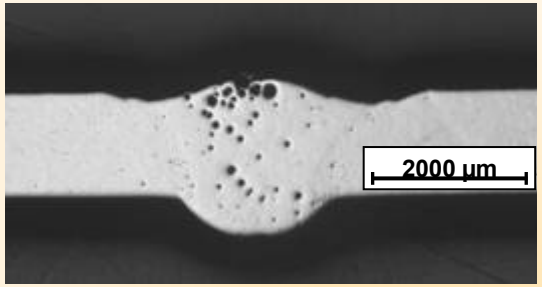
- Hybrid laser welding:
  - Welding speed: 3,6 m/min up to 8,4 m/min, laser-MIG = 4 mm
  - Tensile strength too low at highest welding speeds

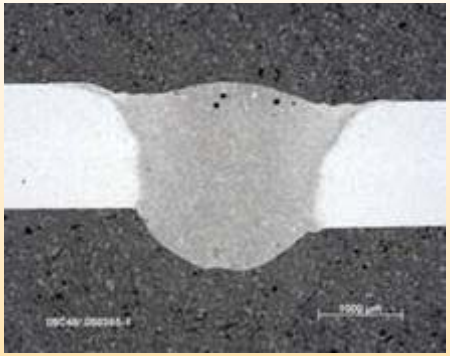
Consumable	5183	5183	5183	5183	5183	5183
Welding speed (mm/min)	3600	4200	4800	6000	7200	8400
Distance laser-MIG (mm)	4	4	4	4	4	4
Type of shielding gas	Ar	Ar	Ar	Ar	Ar	Ar
Laser power (W)	2200	2300	2300	2400	2600	3000
Tensile strength 1 (MPa)	258	279	255	246	260	201
Tensile strength 2 (MPa)	262	260	270	252	250	207

HLW experimental results: 5182 (2)









Consumable	5183
Welding speed (mm/min)	6000
Distance laser-MIG (mm)	4
Type of shielding gas	Ar
Laser power (W)	2400

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

Consumable	5183
Welding speed (mm/min)	6000
Distance laser-MIG (mm)	3
Type of shielding gas	Ar
Laser power (W)	2500

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

Consumable	5183
Welding speed (mm/min)	3600
Distance laser-MIG (mm)	3
Type of shielding gas	Ar
Laser power (W)	2300

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:
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  - **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.