The results presented were achieved in the framework of the COAMWELD project, a CORNET project funded by Vlaio (Flanders Innovation & Entrepreneurship) under the Grant Agreement HBC.2020.2994

COAMWELD

Weldability Investigation of Additively Manufactured Al Alloy Parts by GMAW Welding Process: Influence of Filler Metal Quality and Laser Cleaning Prior to Welding

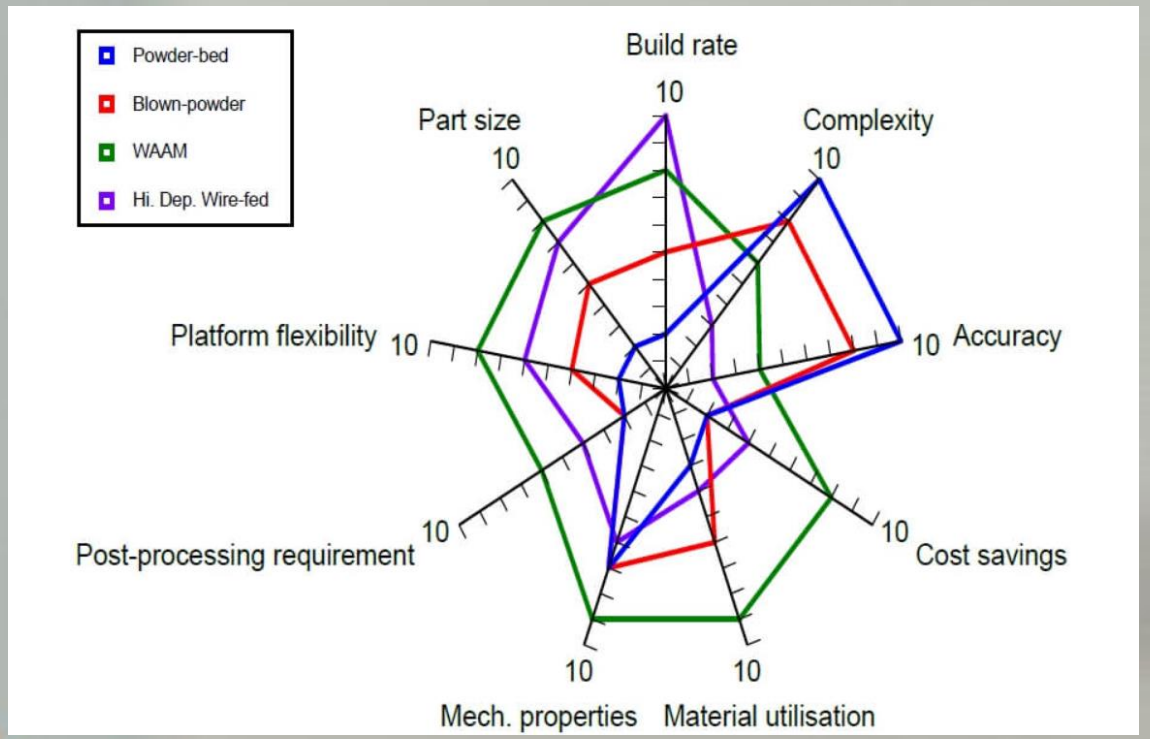
R. Nunes, K. Faes, W. Verlinde, W. De Waele, W. Sneyers, A. Simar, M. Lezaack

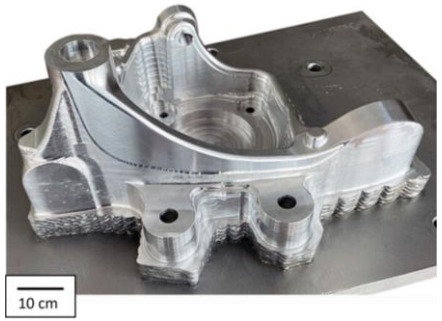
IBS research

GHENT UNIVERSITY

UCLouvain
Institute of Mechanics, Materials and Civil Engineering (iMMC)

Selection of Additive Manufacturing Process





Complexity / Resolution

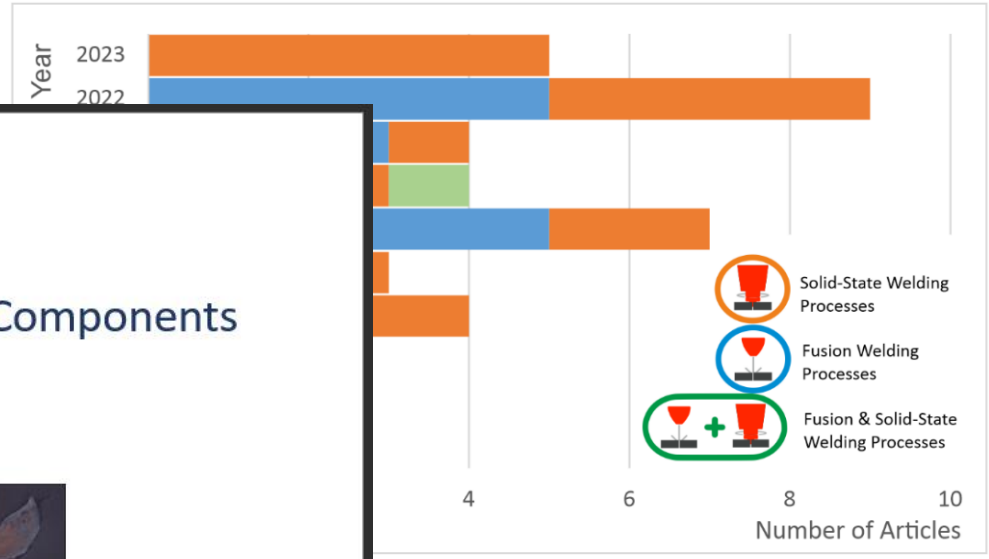
Deposition Rate

Joining your future.

UCLouvain
Institute of Mechanics, Materials and Civil Engineering (iMMC)
GHENT UNIVERSITY

Current Status of the Art | Weldability of AMed Al Alloy Parts

Only 39 published articles : in peer-reviewed journals, congresses, conferences, and technical magazines



…blication on Welding of AMed Al Alloys per Year

Are you interested in more?

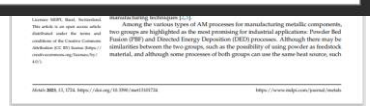
Improving the Weldability of PBF-LB Manufactured AlSi10Mg Components by Solid-State Welding Processes

- Friday 20 October 2023
- Session 7C – Additive Manufacturing II
- Room Braga II 15h00

FRW of PBF-Al Alloy Parts

Joining your future. 21/22 AJP Conference 2023 - Braga, Portugal 19/10/2023

UCLouvain Institute of Mechanics, Materials and Civil Engineering (iMMC) GHENT UNIVERSITY



1 article evaluating GTAW and FSW welding processes

R. Nunes *et al.* **A Review on the Weldability of Additively Manufactured Aluminium Parts by Fusion And Solid-State Welding Processes**. Metals. Vol 13(10), 2023. https://doi.org/10.3390/met13101724

Literature Review | Literature Gap and Research Objective

- High importance to create hybrid structures made by additive and conventional manufacturing
- BUT : Lack of literature evaluating the weldability of AMed aluminium parts
- Existing articles focus on :

  - Feasibility of using specific welding processes, without comparing them,
  - Different AM processes.

→ GMAW welding of AMed Al Alloys

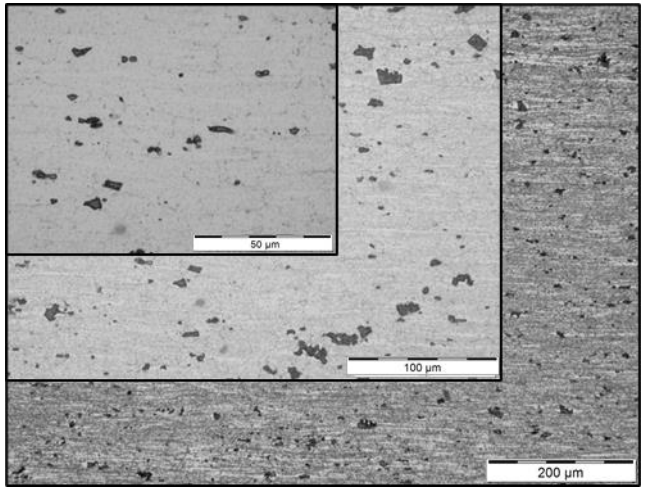
→ Weldability of DED-Arc and PBF-LB Al parts

→ Filler metal quality influence

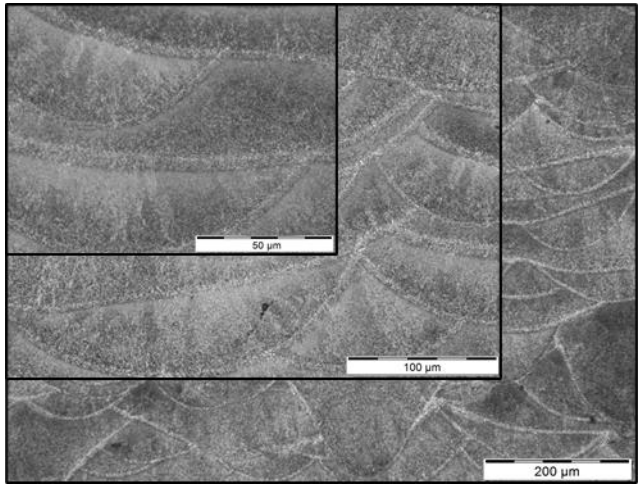
→ Laser cleaning prior to welding

Base Materials

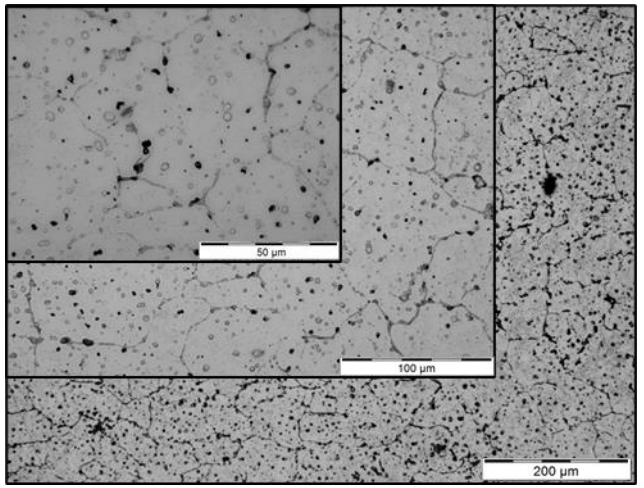
CONV 5083 Longitudinal



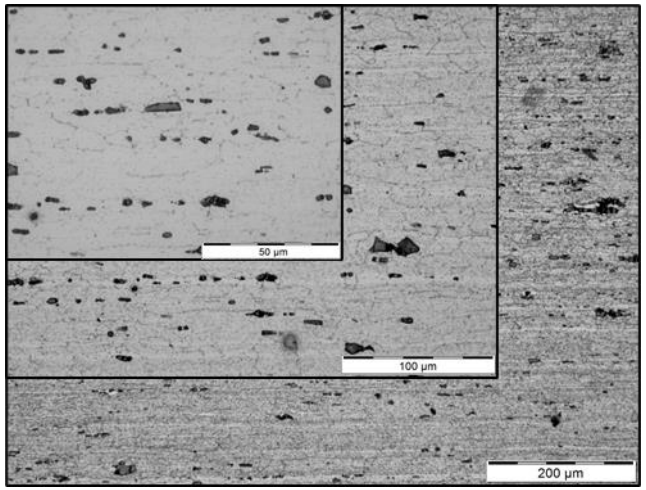
PBF-LB AlSi10Mg PBD



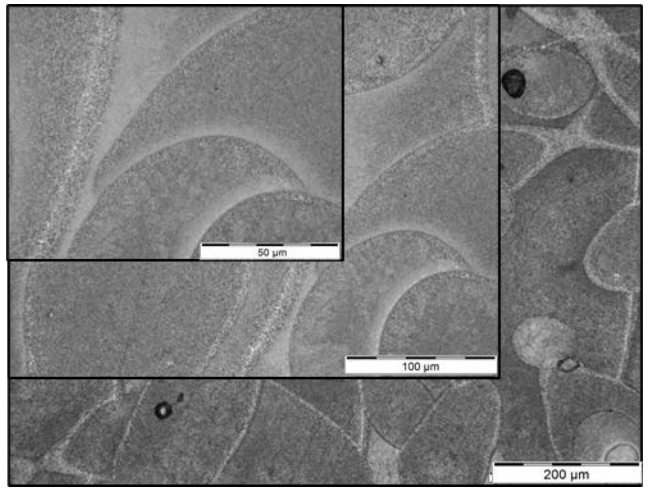
DED-Arc 5183 PBD



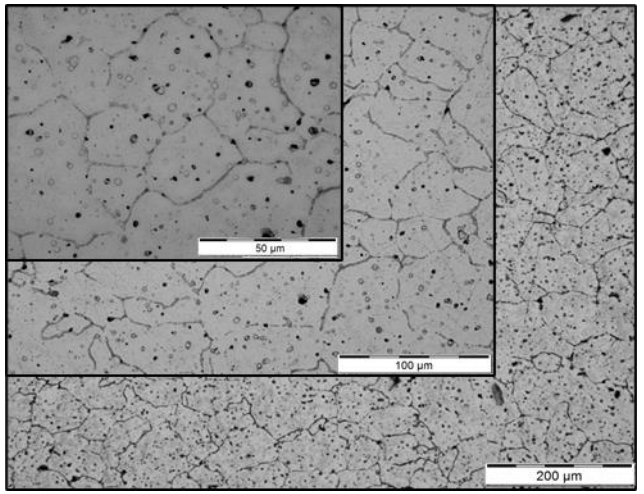
CONV 5083 Transversal



PBF-LB AlSi10Mg PDD



DED-Arc 5183 PDD



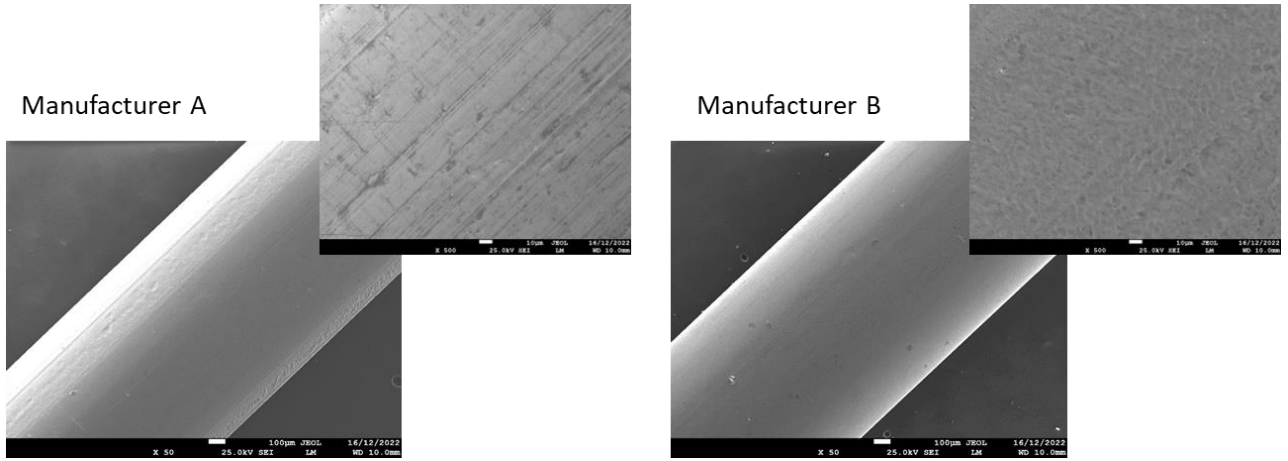
CONV UTS: 310.6 MPa

PBF-LB UTS: 435.6 MPa

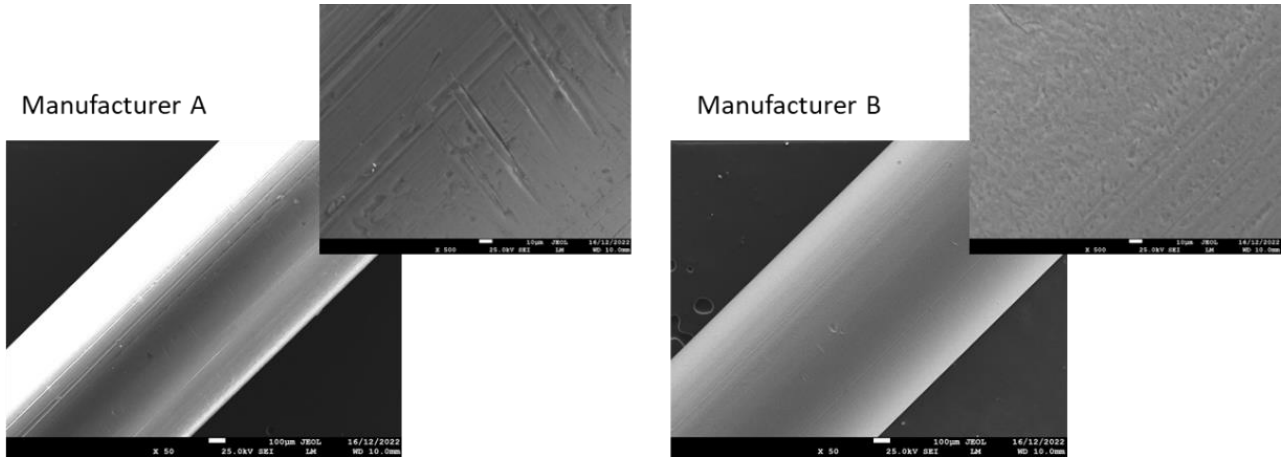
DED-Arc UTS: 288.4 MPa

- It's well described by the literature the impact of the filler metal surface quality on the porosity level and mechanical properties in joining of conventionally manufactured Al alloy parts.
- The filler metal quality (surface roughness and chemical composition) has directly influence on:
  - ➡ Oxygen and Hydrogen content in the welding
  - ➡ Lubricants appearing as contaminants in the welding

*No literature available showing the influence of filler metal in the welding of AMed Al parts



ER 5183 Provided by Manufacturer A and B (MIGAL) filler metal



ER 5356 Provided by Manufacturer A and B (MIGAL) filler metal

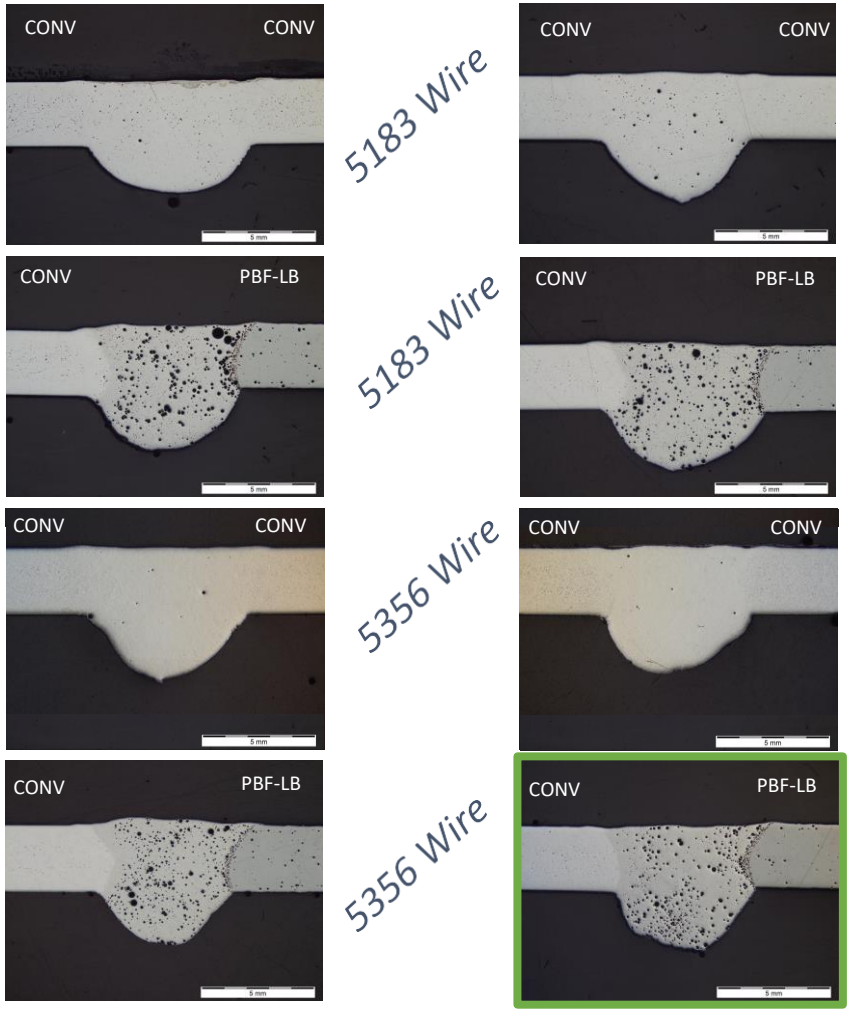
Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts

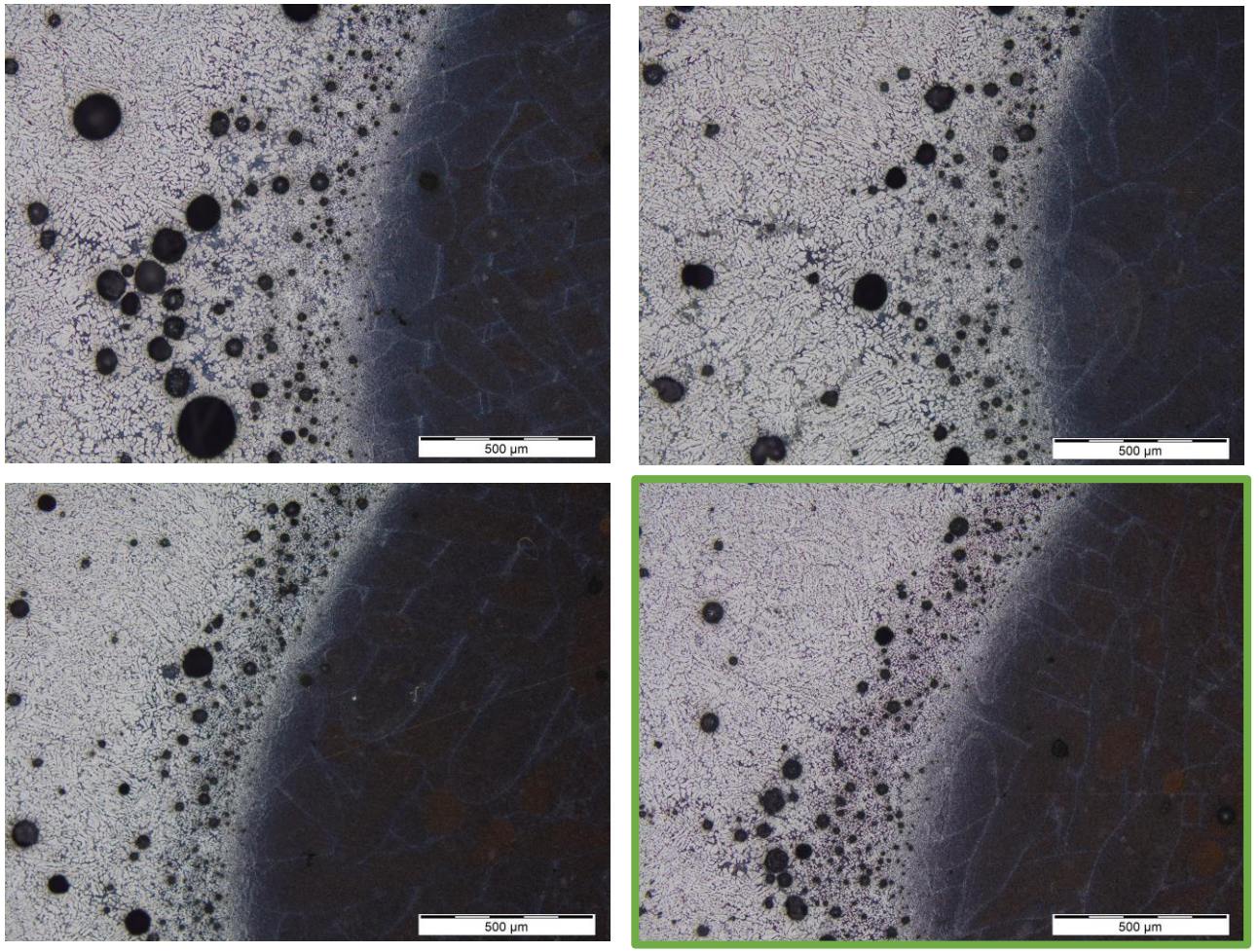
Influence of Filler Metal

Laser Cleaning

Manufacturer A

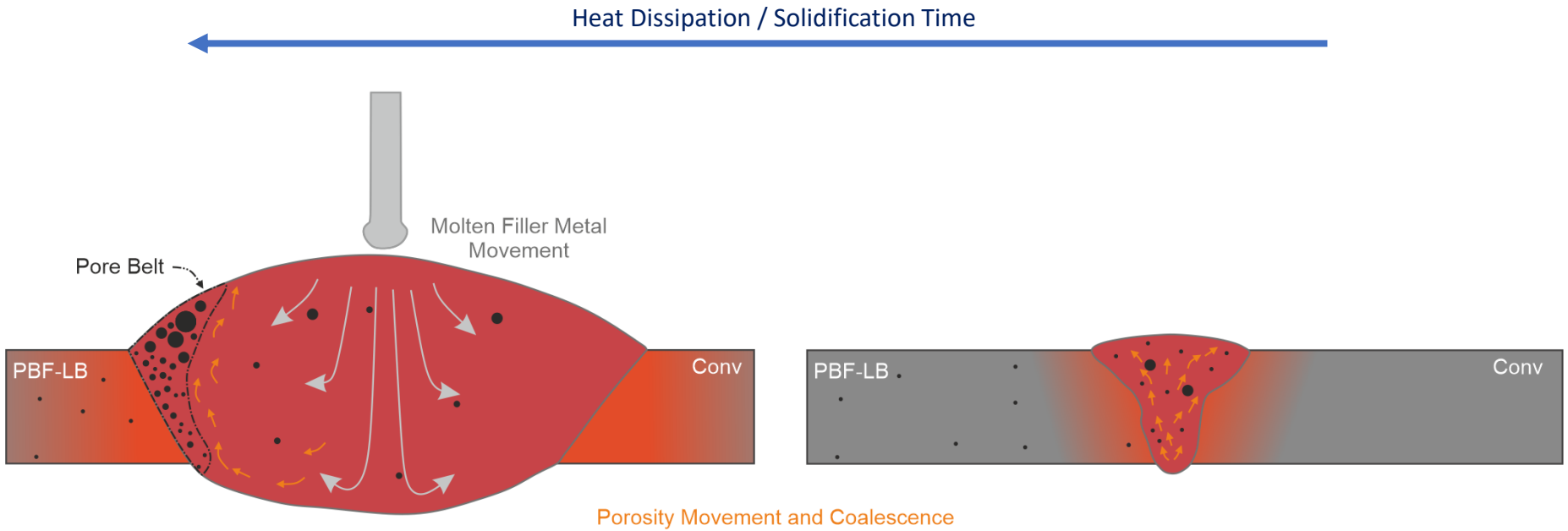
Manufacturer B
MIGAL





Porosity on Welding of PBF-LB Al Alloy Parts | Pore Belt Region

(a) Arc Welding Processes with Filler Metal Feeding

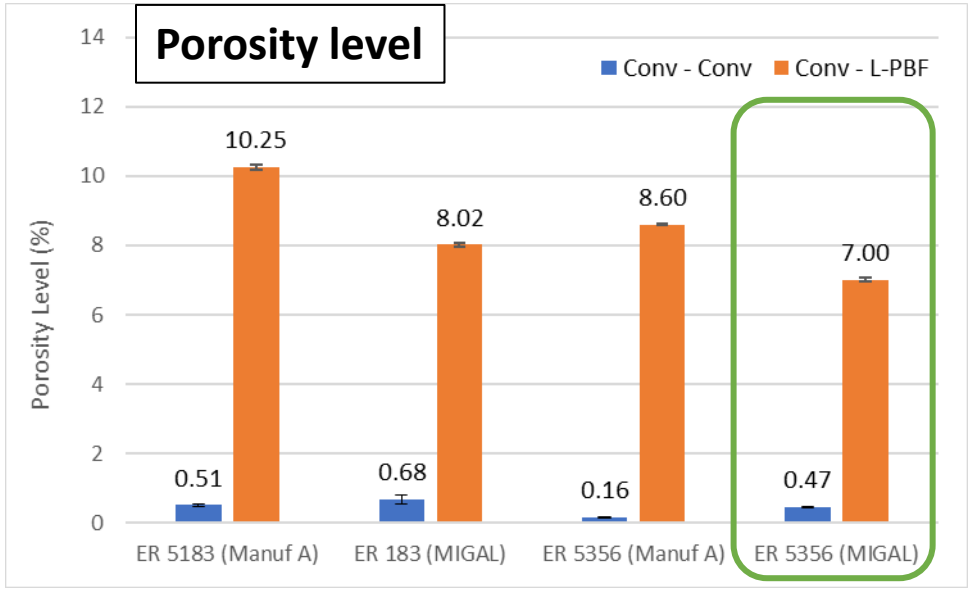


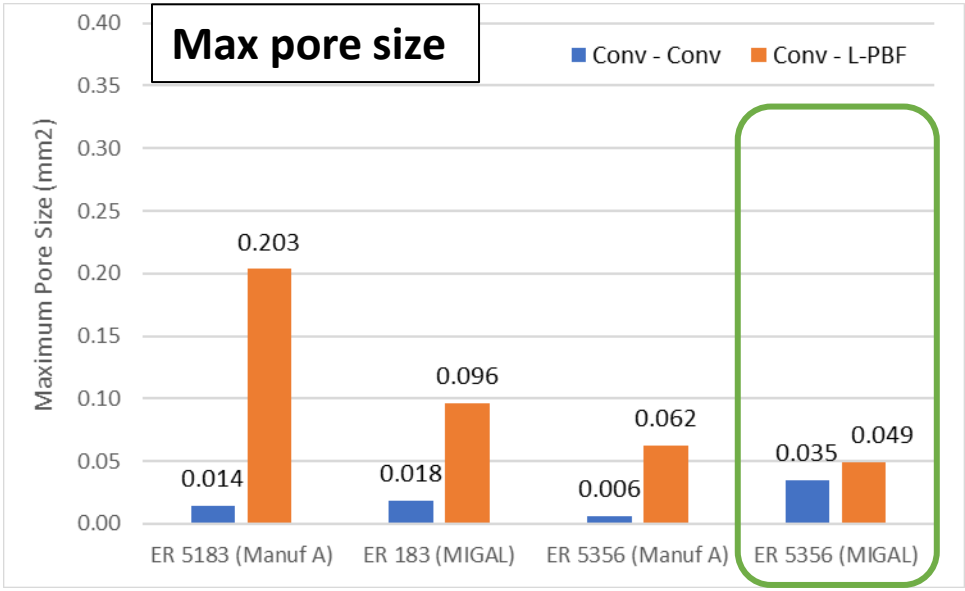
(b) Laser and Electron Beam Welding Processes without Filler Metal Feeding

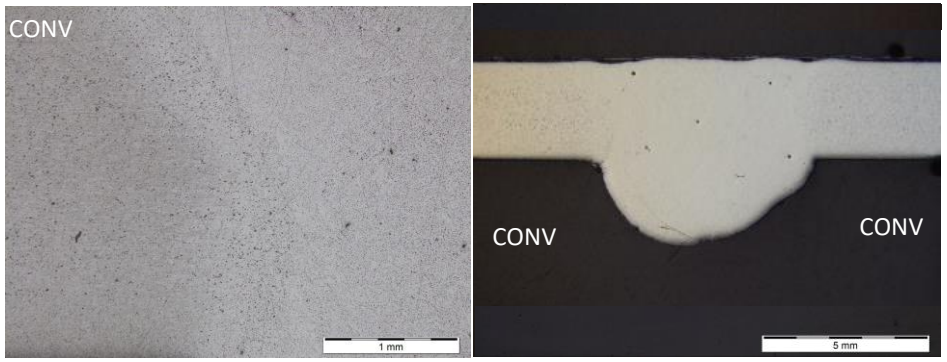
Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts

Influence of Filler Metal

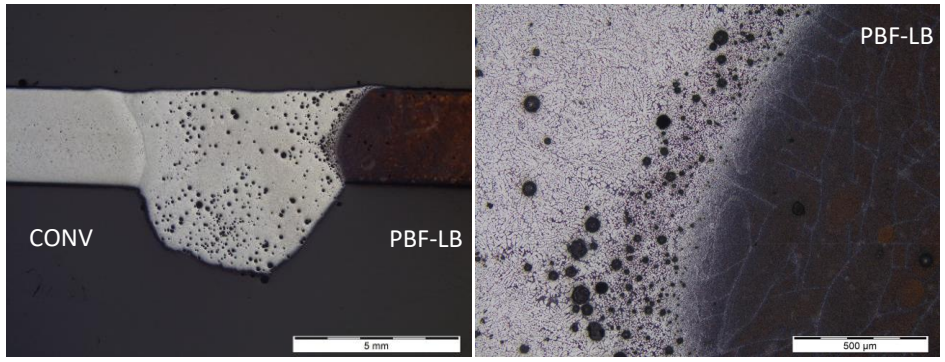
Laser Cleaning





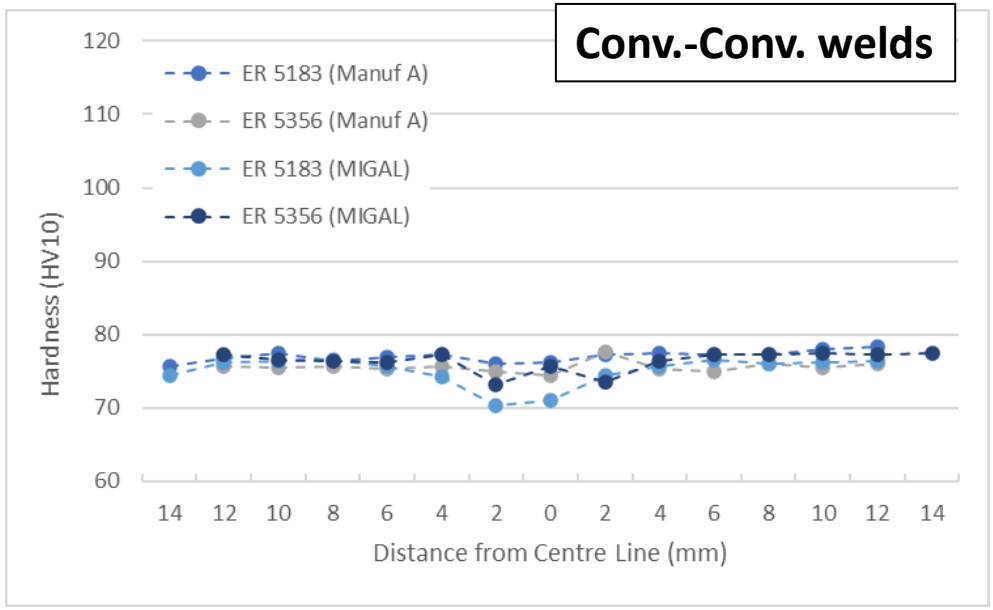


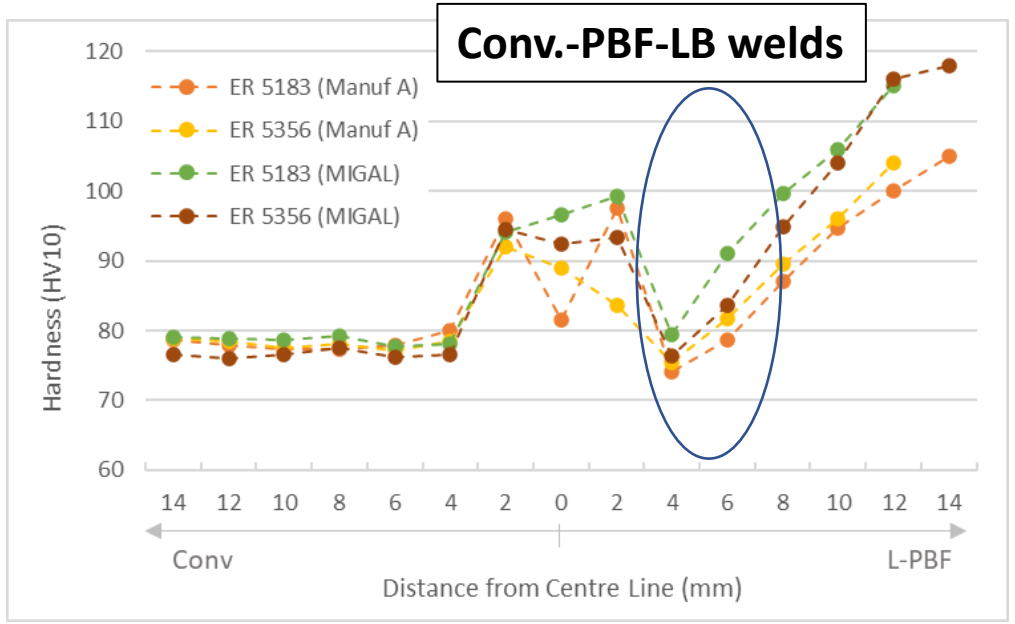
Cross-section of a Conv-Conv weld using ER 5356 (MIGAL)



Cross-section of a Conv-PBF-LB weld using ER 5356 (MIGAL)

Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts



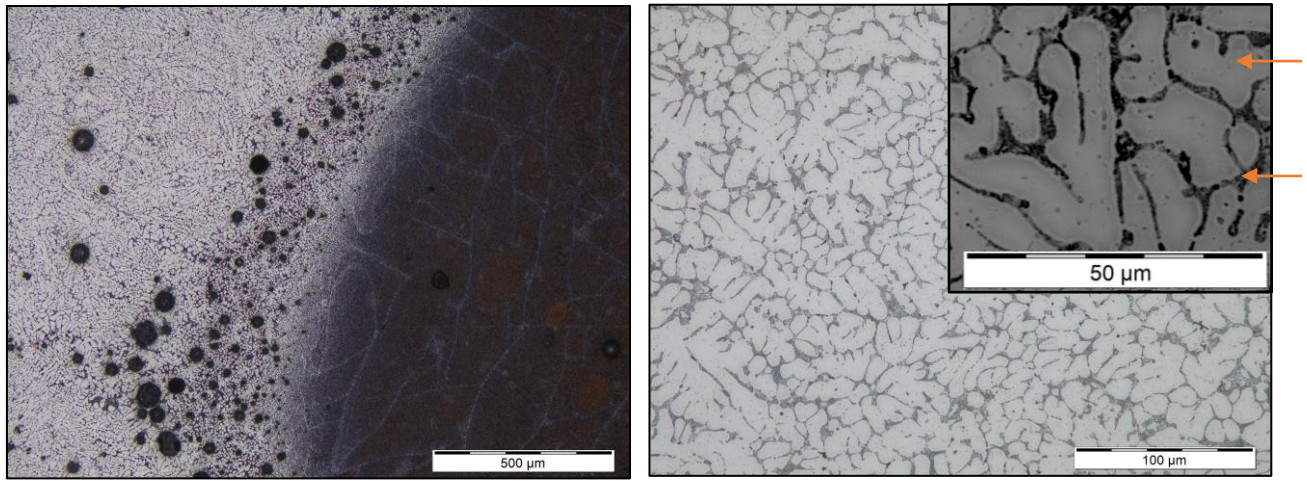


<u>Hardening</u> in WZ in the Conv-PBF-LB welds :

- α-Al cells surrounded by Si-rich eutectic phases

<u>Softening</u> in HAZ of Conv-PBF-LB welds :

- Pore belt region formation decreasing the hardness and strength *

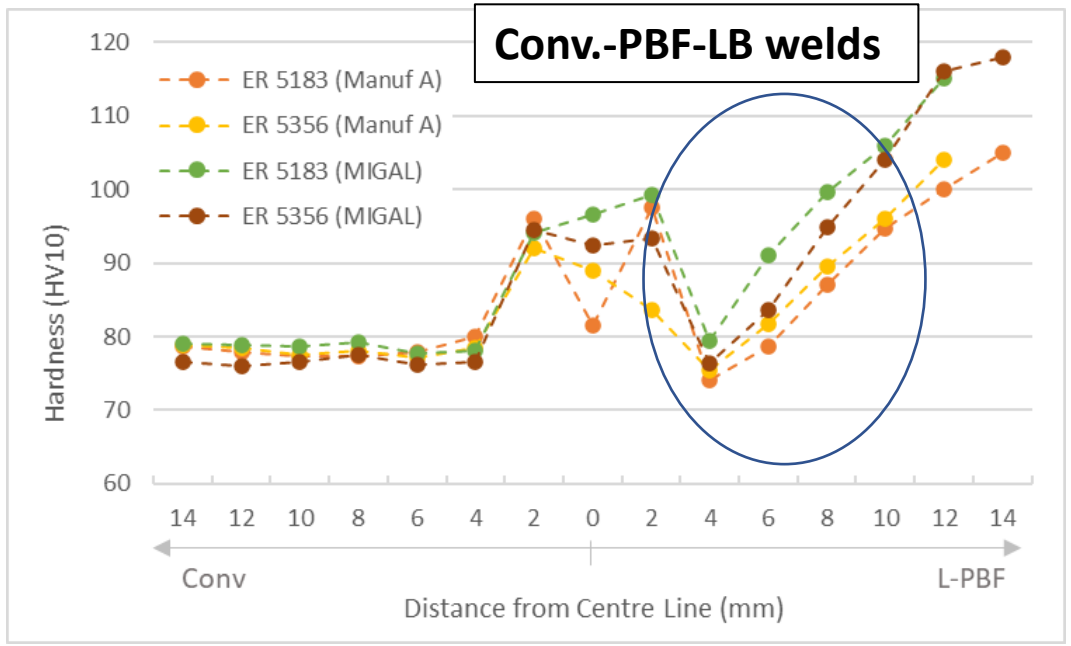


HAZ and WM of a Conv-PBF-LB weld, evidencing the presence of equiaxed α-Al cells surrounded by Si-rich eutectic phases

Spheroidization of the silicon in the base material:

- Si structure subjected to high heat input without reaching melting point
  - Breaking of the eutectic structure and the silicon starts to spheroidize
  - Decrease in the hardness

- The lack of Si structure in the conventionally manufactured AA 5083 material explains why this phenomenon is not noticed at CONV side of the weld



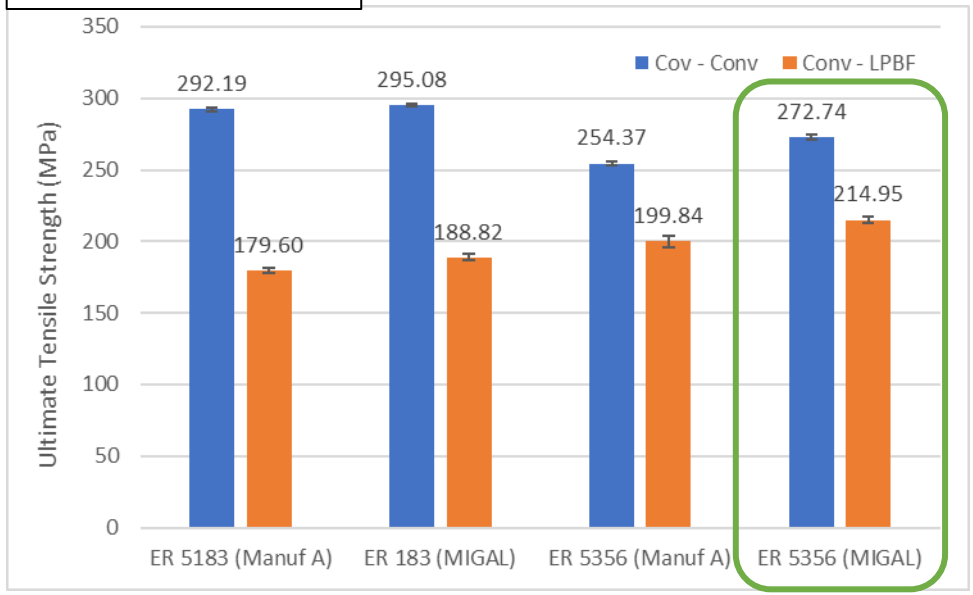
- All joints between Conv – PBF-LB were **not approved***
- All joints between Conv. – Conv. were **approved***

Based on the filler metal quality and observed results :

ER 5356 MIGAL

Filler Metal	Material Combination	Ultimate Tensile Strength AVG (MPa)	Bend Testing Results
ER 5183 (Manuf A)	Conv - Conv	292.19	Approved
	Conv - L-PBF	179.60	Not Approved
ER 5356 (Manuf A)	Conv - Conv	295.08	Approved
	Conv - L-PBF	188.82	Not Approved
ER 5183 (MIGAL)	Conv - Conv	254.37	Approved
	Conv - L-PBF	199.84	Not Approved
ER 5356 (MIGAL)	Conv - Conv	272.74	Approved
	Conv - L-PBF	195.12	Not Approved

Tensile strength

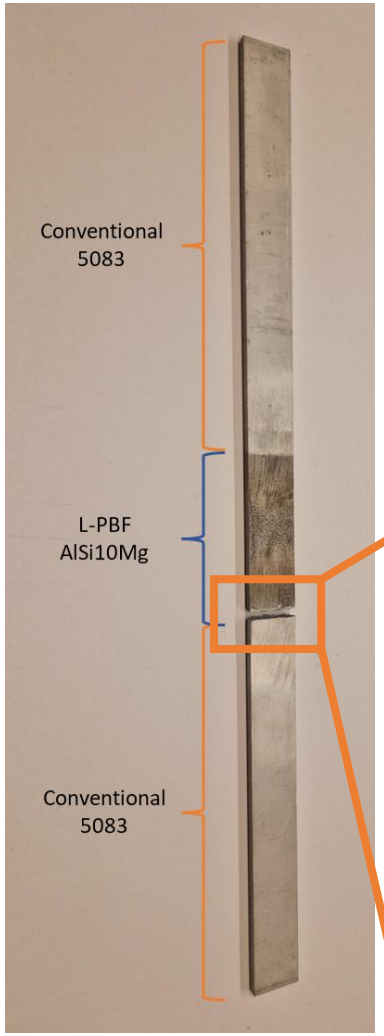


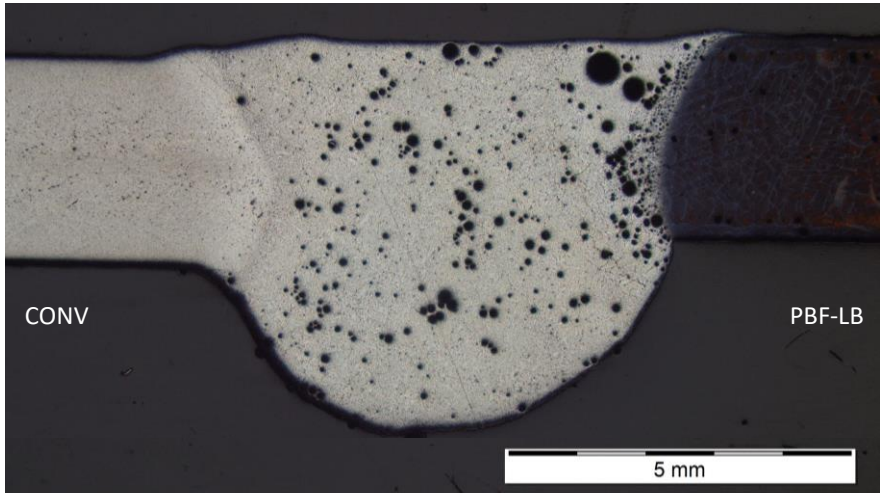
*EN ISO 15614-1

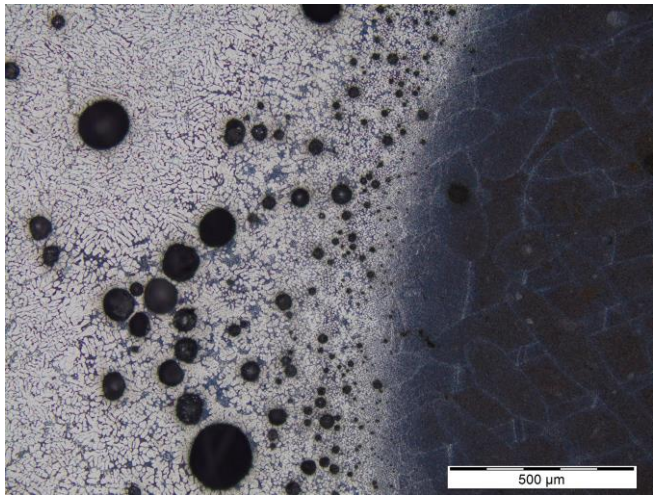
Techniques to Improve the Welding Quality of AMed Al Alloy Parts

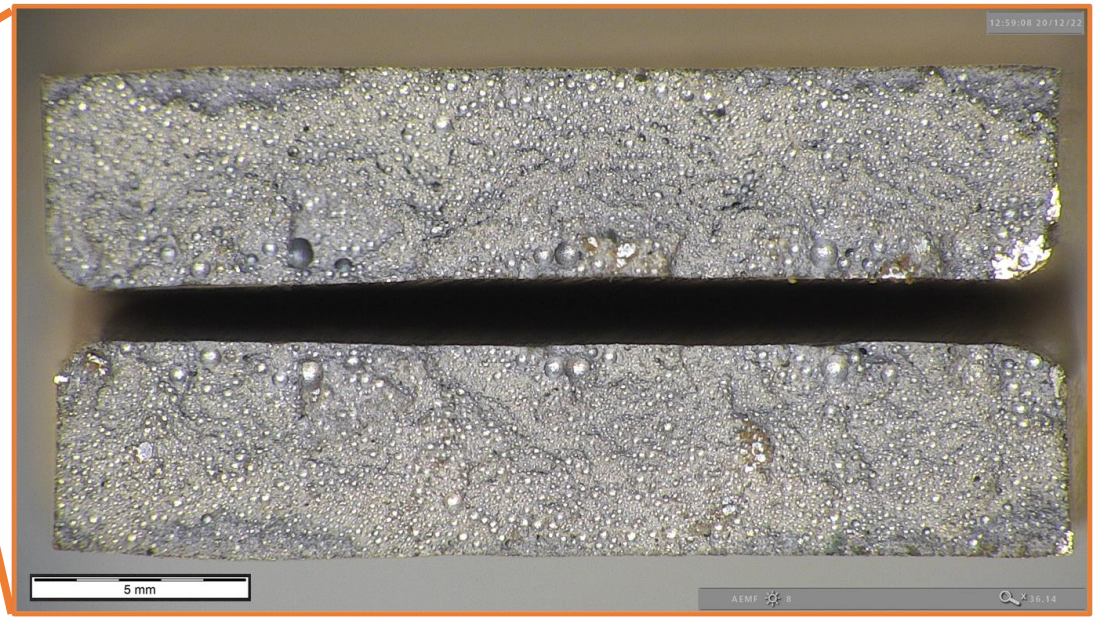
Influence of Filler Metal

Laser Cleaning







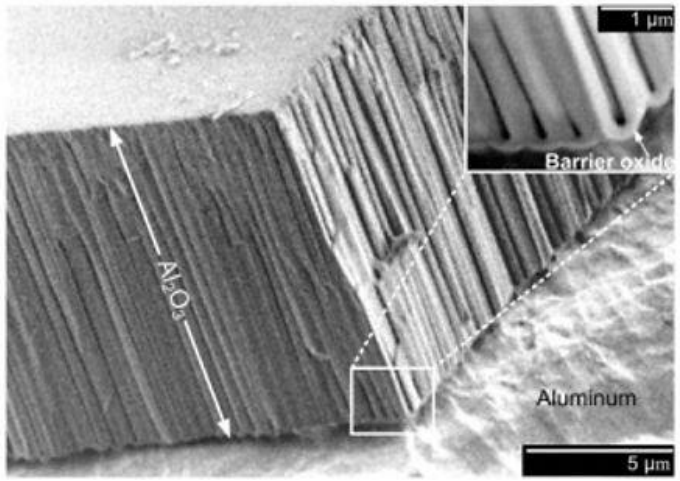


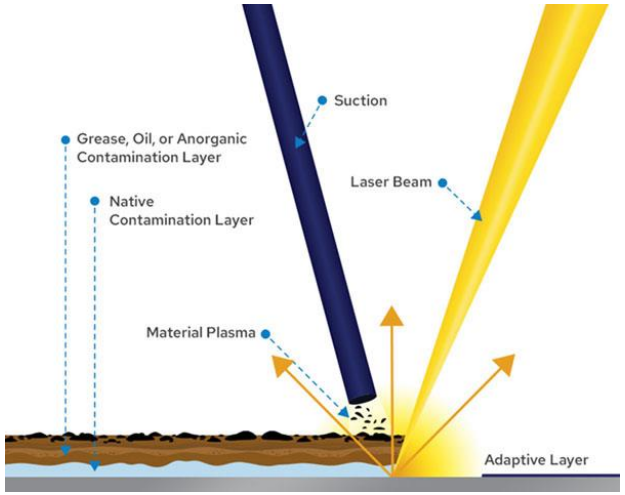
Main factor for strength reduction:

High porosity level in HAZ near the PBF-LB part (Pore Belt Region)

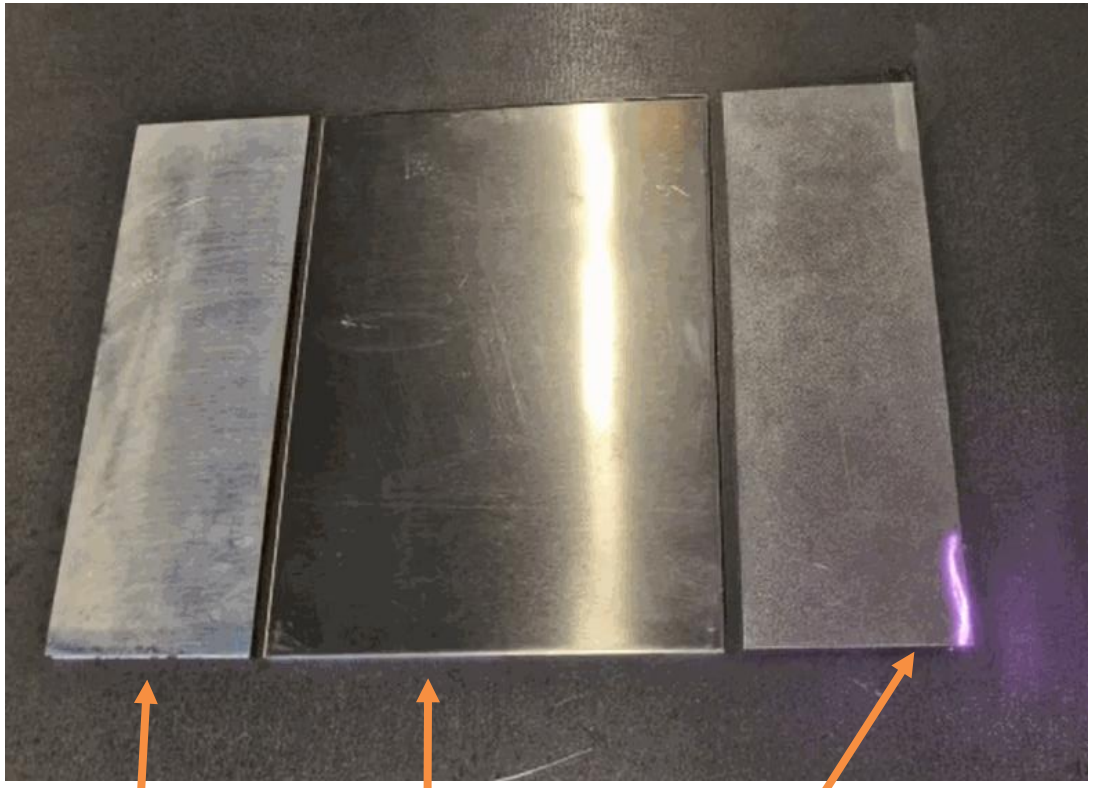
Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts

Al2O3 Oxide Layer (MP 2072 °C)





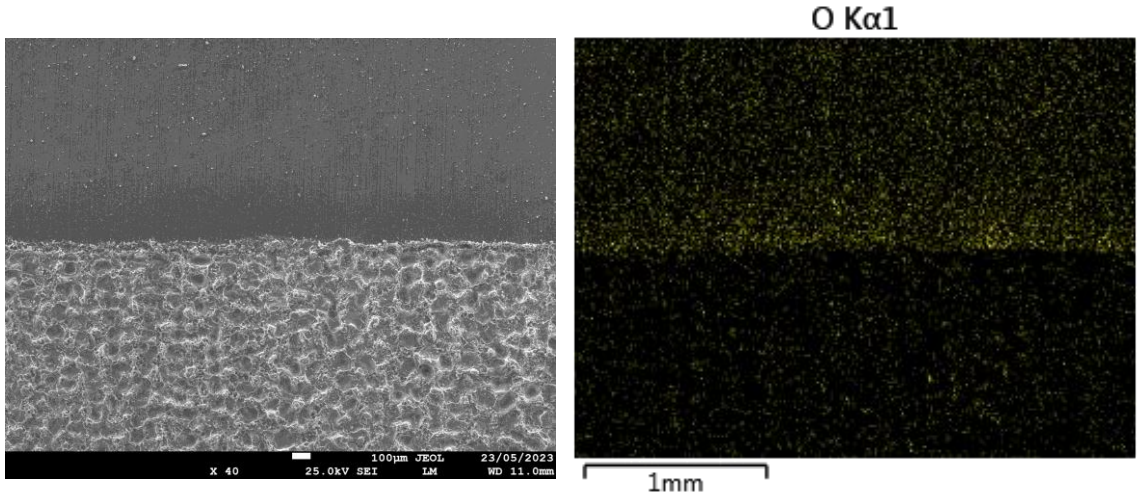
Used for efficient rust, oil or grease removal from metallic componenets; restoration of paintings, sculptures



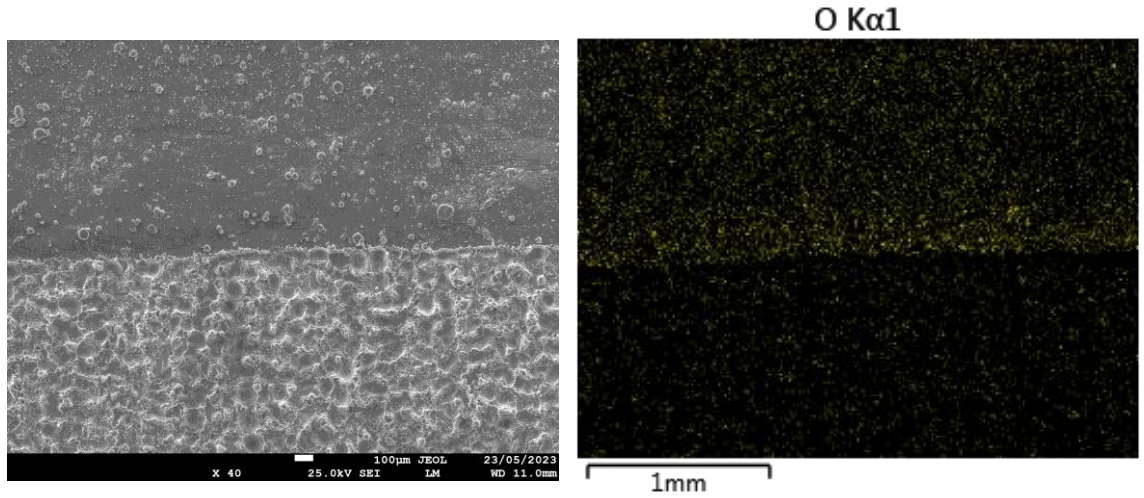
DED-Arc 5183 Conv 5083 PBF-LB AlSi10Mg

*No literature available showing the use of laser cleaning prior to the welding of AMed Al parts

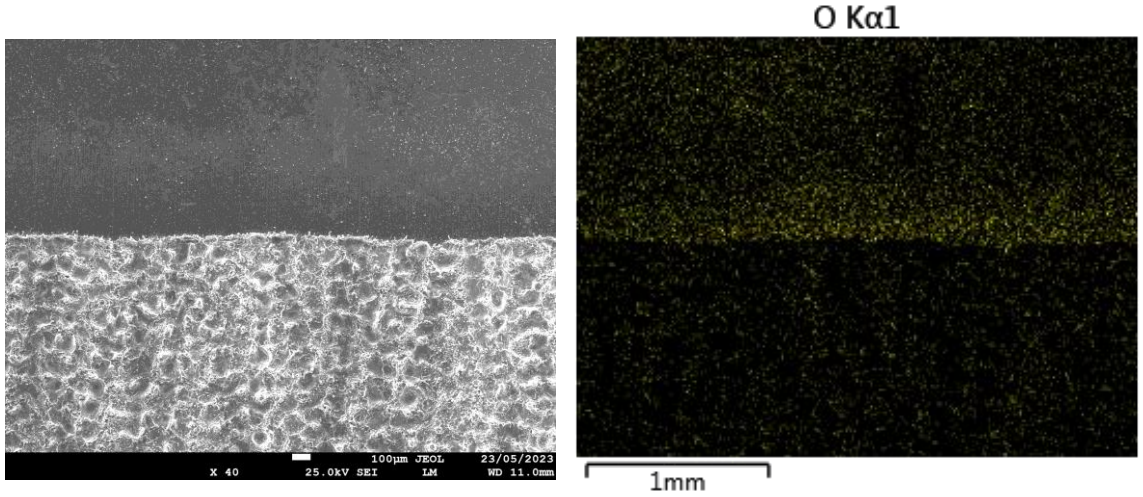
→ Siginificant reduction in the Oxygen Content (Al_2O_3 Oxyde Layer) in the 3 base materials:



Conv 5083



PBF-LB AlSi10Mg



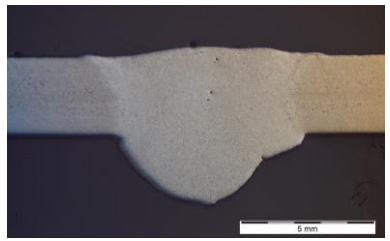
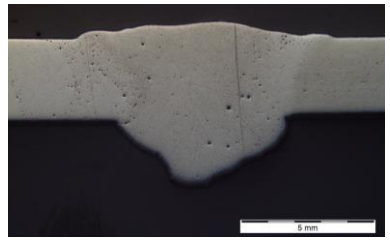
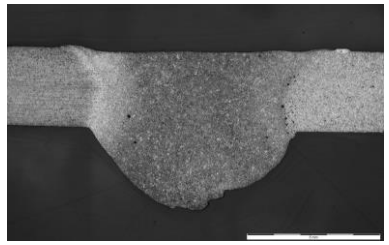
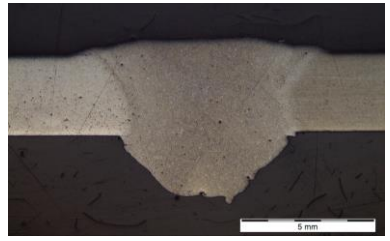
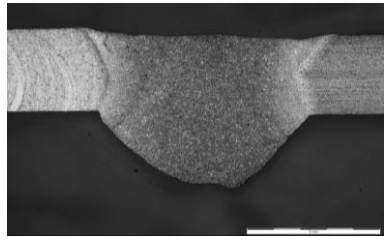
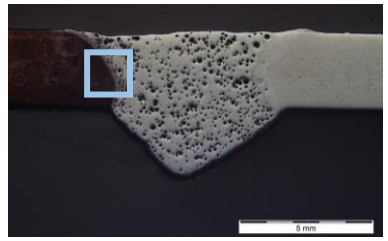
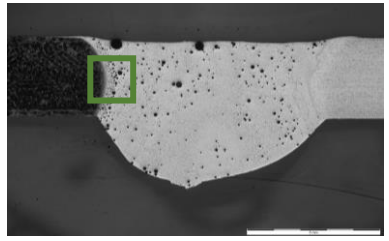
DED-Arc 5183

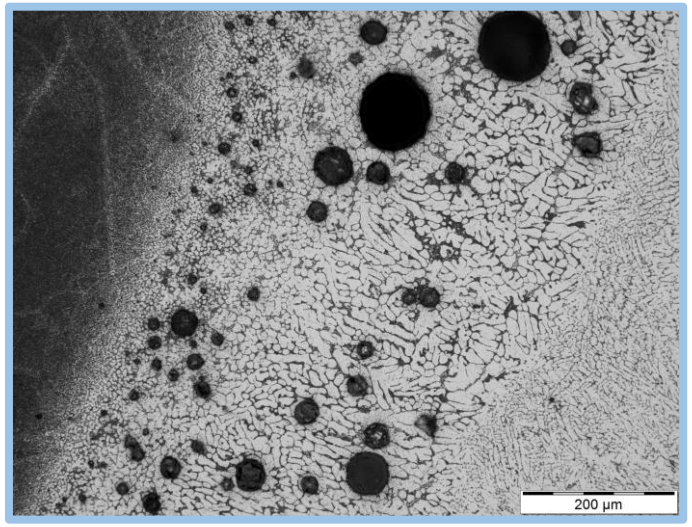
*SEM analysis performed 1 day after the Laser cleaning

Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts

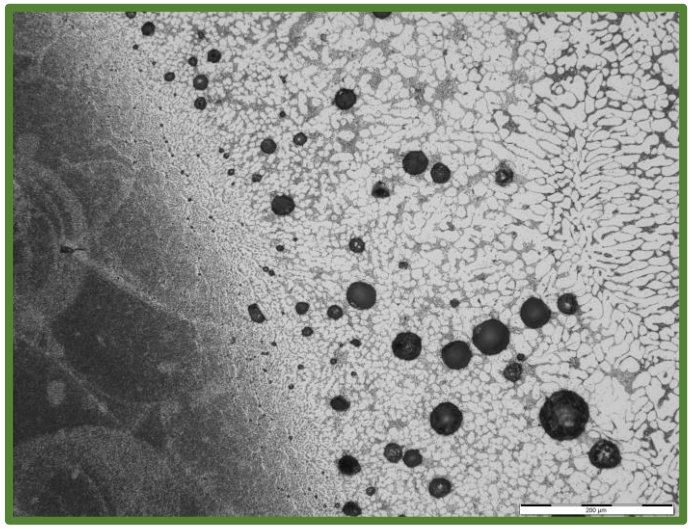
Influence of Filler Metal

Laser Cleaning

	Without Laser Cleaning	With Laser Cleaning
Conv 5083 Conv 5083		
Conv 5083 DED-Arc PDD		
Conv 5083 DED-Arc PBD		
Conv 5083 PBF-LB AlSi10Mg		



Without Laser Cleaning



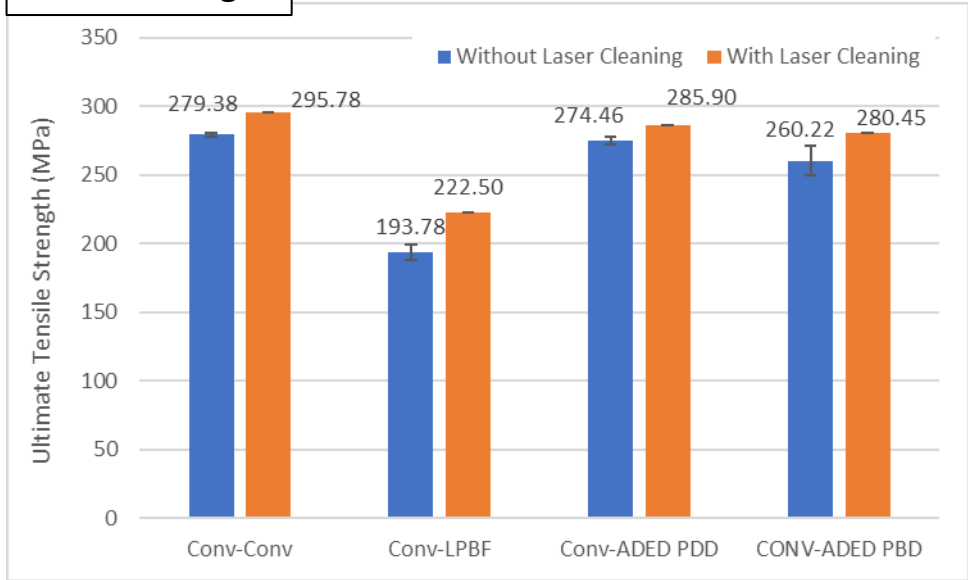
With Laser Cleaning

Techniques to Improve the GMAW Welding Quality of AMed Al Alloy Parts

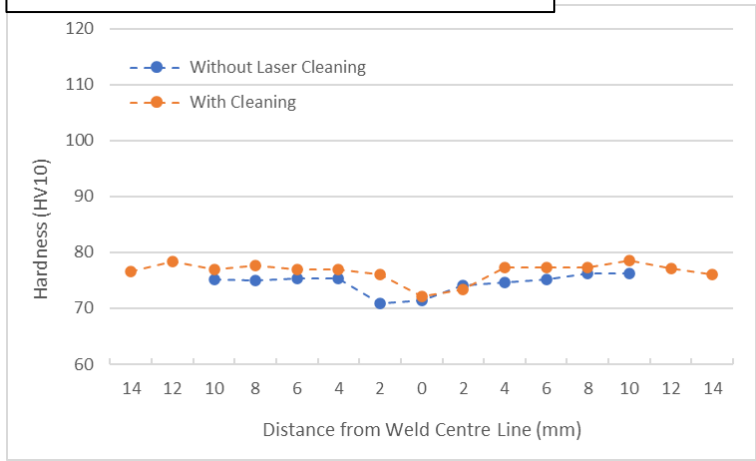
Influence of Filler Metal

Laser Cleaning

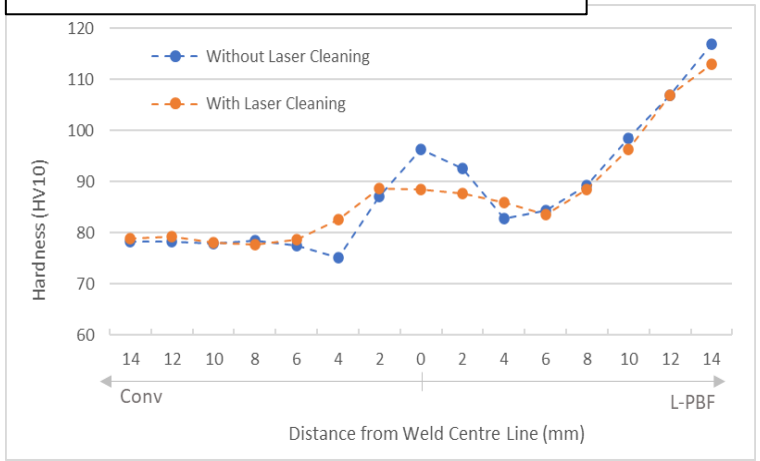
Tensile strength



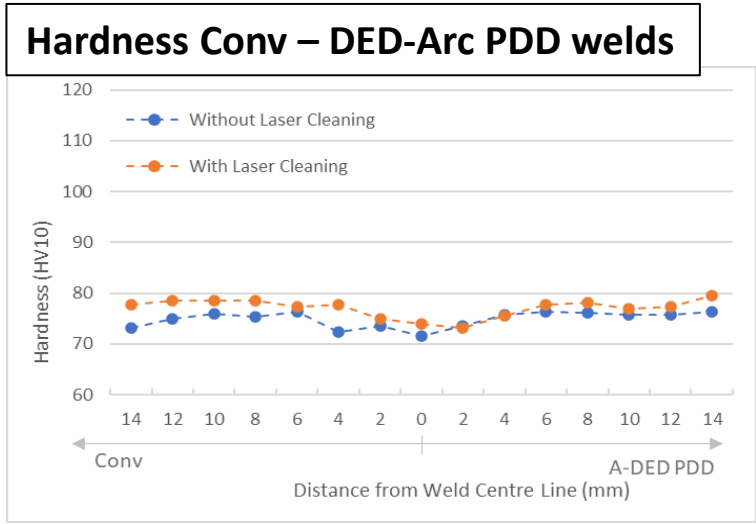
Hardness Conv – Conv welds



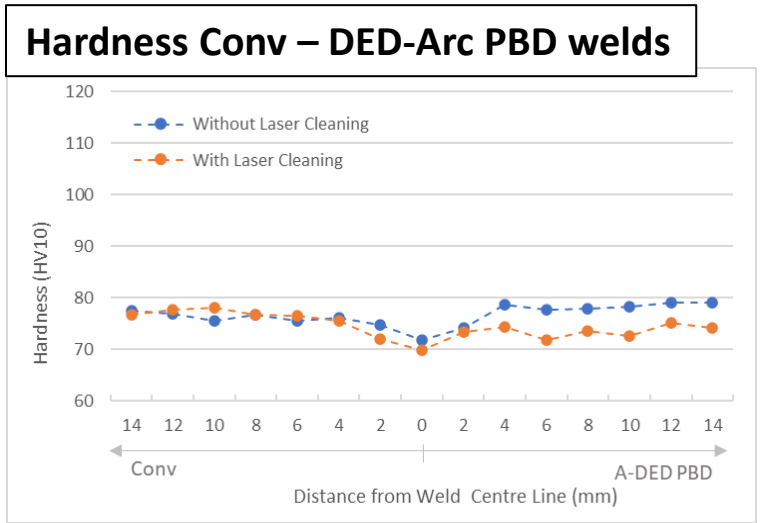
Hardness Conv – PBF-LB welds



Hardness Conv – DED-Arc PDD welds



Hardness Conv – DED-Arc PBD welds



Using Laser Cleaning prior to the Welding:

- Decrease of hardening behaviour on the WZ of Conv-PBFLB weld
- Increase of UTS in all welding conditions
- Extreme high repeatability of UTS values

Conclusion and Final Remarks

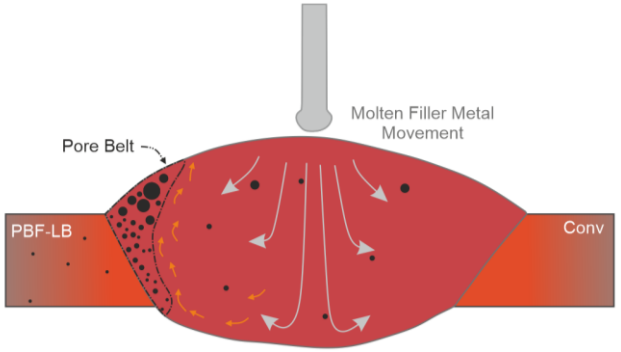
Even considering materials with very similar chemical composition, weldability is strongly affected by the manufacturing process used in the fabrication:

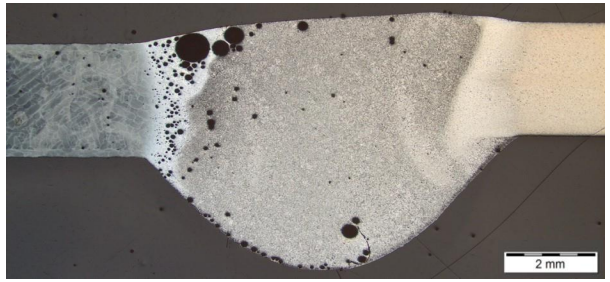
- → Different thermal cycles
- → Different filler material form (wire/powder)
- → Different microstructure
- → Different mechanical (material) properties

Due to the lack of available information, it is still not possible to have a complete overview on the weldability of AMed Al alloys

GMAW Welding of AMed Al Alloys:

- High weldability of WAAMed Al alloy parts
- Extremely low weldability of PBF-LB Al alloy parts (Pore Belt Region Formation)
- Both filler metal quality and (laser) cleaning prior to welding present very promising results in achieving lower porosity level and higher mechanical properties





Are you interested in more?

Improving the Weldability of PBF-LB Manufactured AlSi10Mg Components by Solid-State Welding Processes

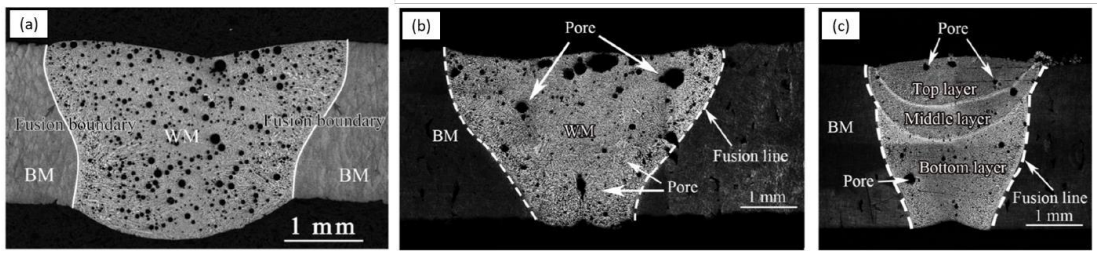
- Friday 20 October 2023
- Session 7C – Additive Manufacturing II
- Room Braga II 15h00

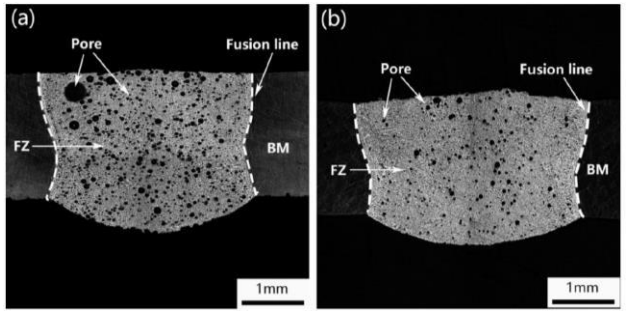
FRW of PBF-Al Alloy Parts

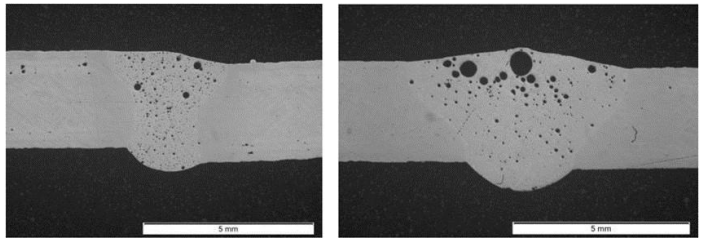
MSc.-ing Rafael Nunes
Project Engineer
T +32 (0)9 292 14 13
rafael.nunes@bil-ibs.be

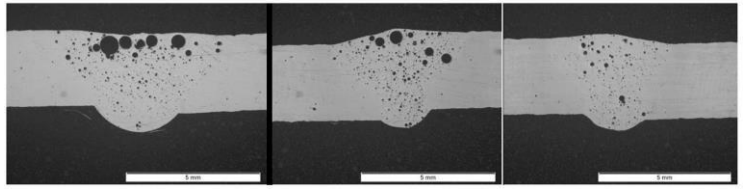
Belgisch Instituut voor Lastechniek vzw
Technologiepark-Zwijnaarde 48, B-9052 Zwijnaarde (Gent)
BTW BE 0406.606.875 info@bil-ibs.be www.bil-ibs.be

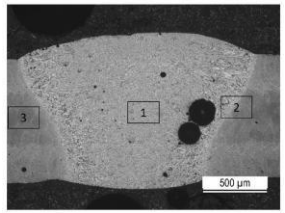
Current Status of the Art | Weldability of AMed Al Alloy Parts

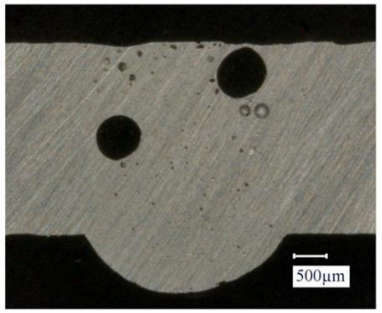


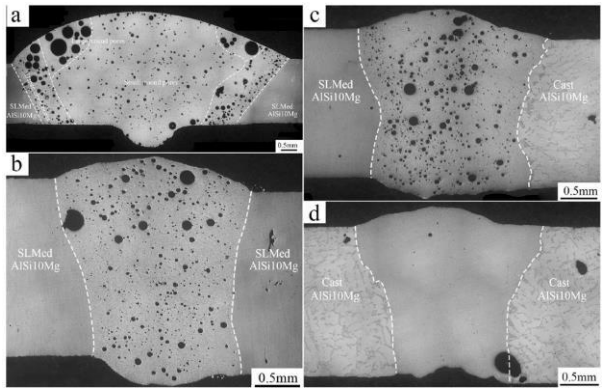












Unlikely the porosity can be entirely avoided by optimization of welding parameters,
Other fusion welding processes are likely to suffer from porosity issues.

Theory of several authors :
High porosity level in L-PBF joints are formed due to the porosity in the L-PBF base material.

→ Higher surface area to volume ratio compared to wire filler material,

→ Common to recycle powder in PBF-LB process.