AACHEN CENTER FOR ADDITIVE MANUFACTURING

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Additive Manufacturing - Innovation with Future

Weldability of Al components produced by L-PBF

Alexander Schwarz | 28.09.2022

Weldability of Al components produced by LPBF
Agenda

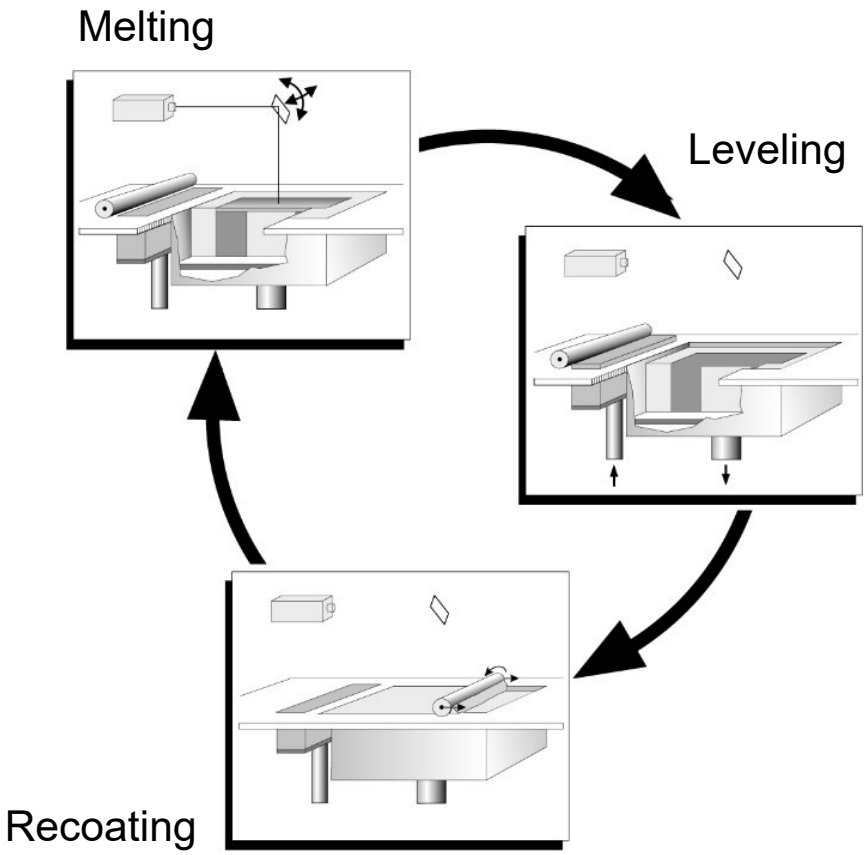
- Laser powder bed fusion (L-PBF)
- Challenges
- Laser welding in vacuum
  - First test series
  - Second test series
- Conclusion

Weldability of Al components produced by LPBF
Laser powder bed fusion (L-PBF)

Principle of the laser powder bed fusion (L-PBF) process

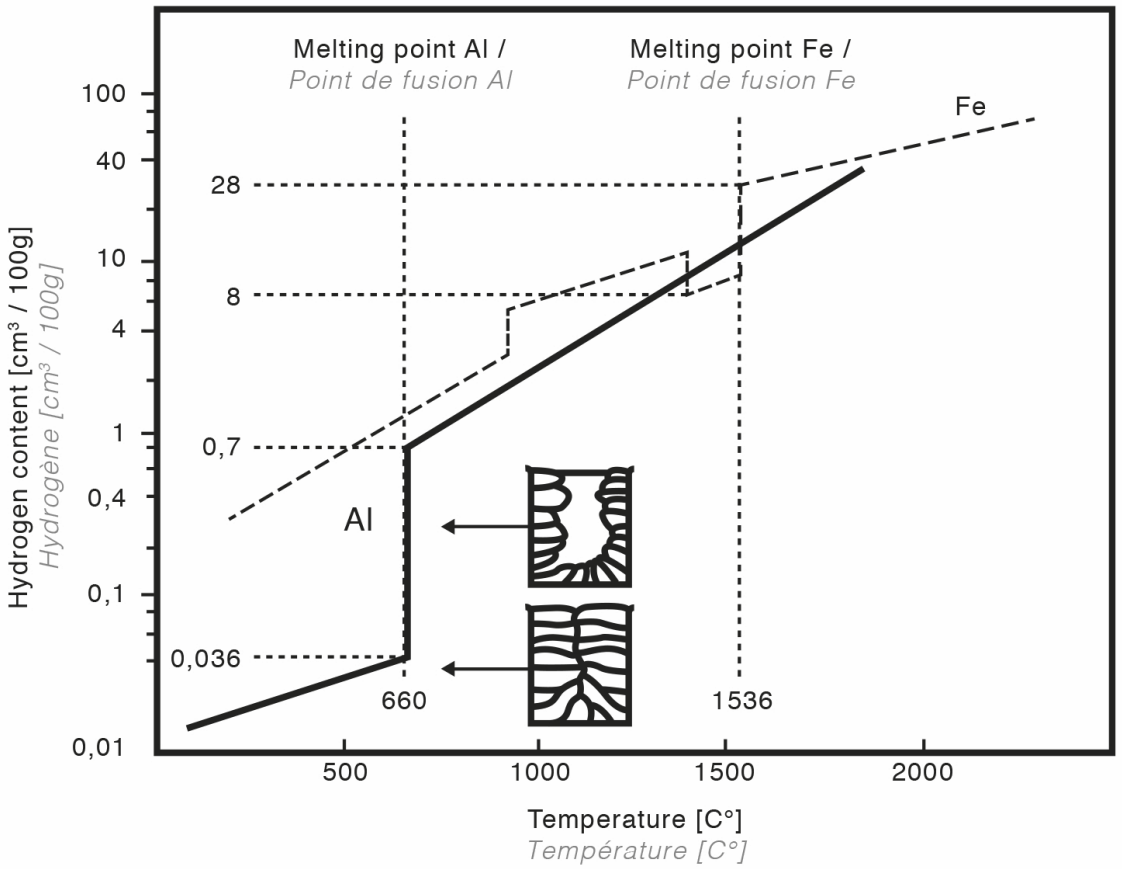
- Absorption of the laser radiation on metal surface
- Heat conduction into the material leads to complete melting of the powder material

- The process consists of three basic steps
  1. Application of a defined powder layer (Recoating)
  2. Melting of the powder according to the CAD model
  3. Lowering of the build platform by a layer thickness (Leveling)



Weldability of Al components produced by LPBF
Challenges

- <u>Inconsistent solubility of aluminum for hydrogen</u>
  The jump in solubility for hydrogen leads to pore formation during welding



Weldability of Al components produced by LPBF
Challenges

- Inconsistent solubility of aluminum for hydrogen
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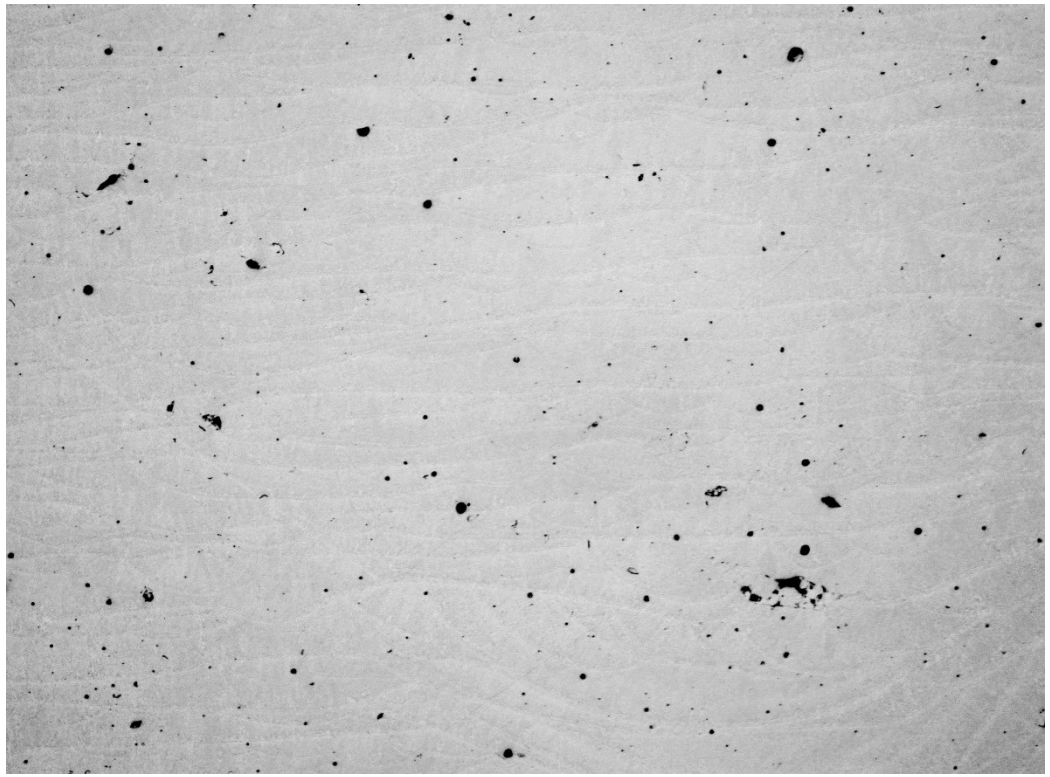
- Porosity of the base material
  The pores in the base material include gases and loose powder, which influences the welding process



Weldability of Al components produced by LPBF
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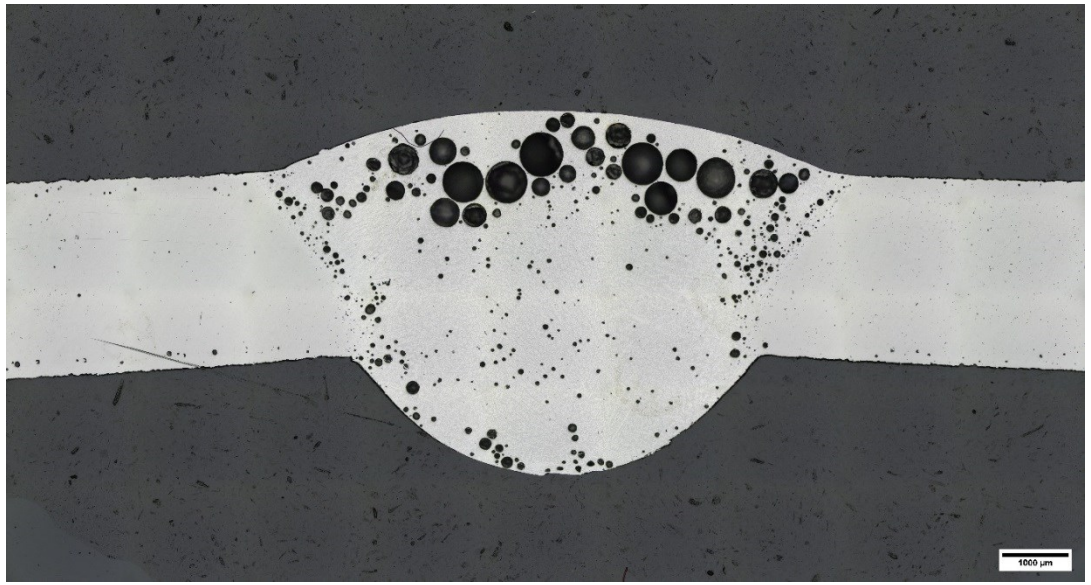
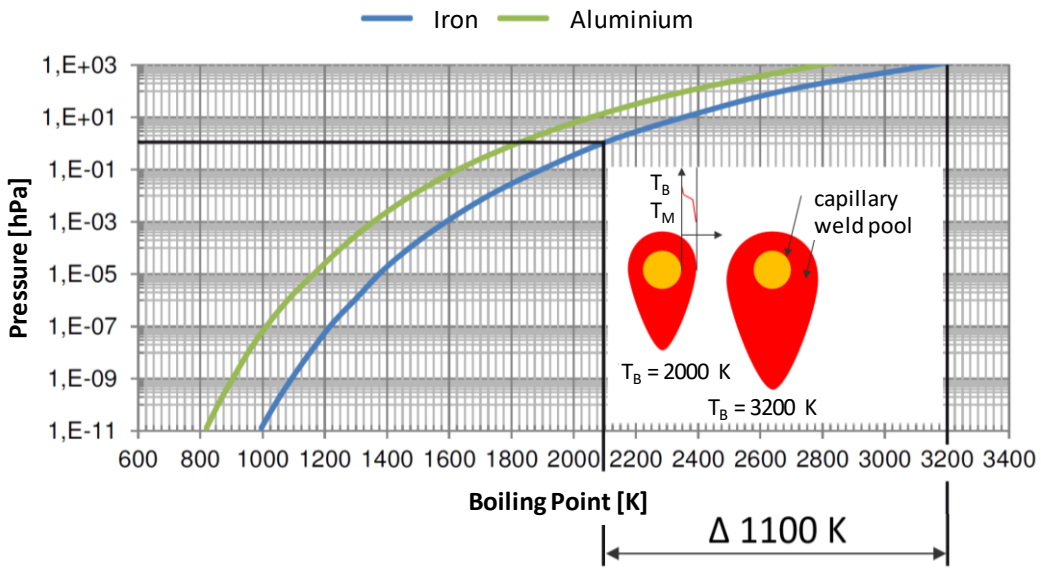
  → Tungsten Inert Gas (TIG)-Welding of the additive manufactured AlSi10Mg results in weld seams with a high porosity

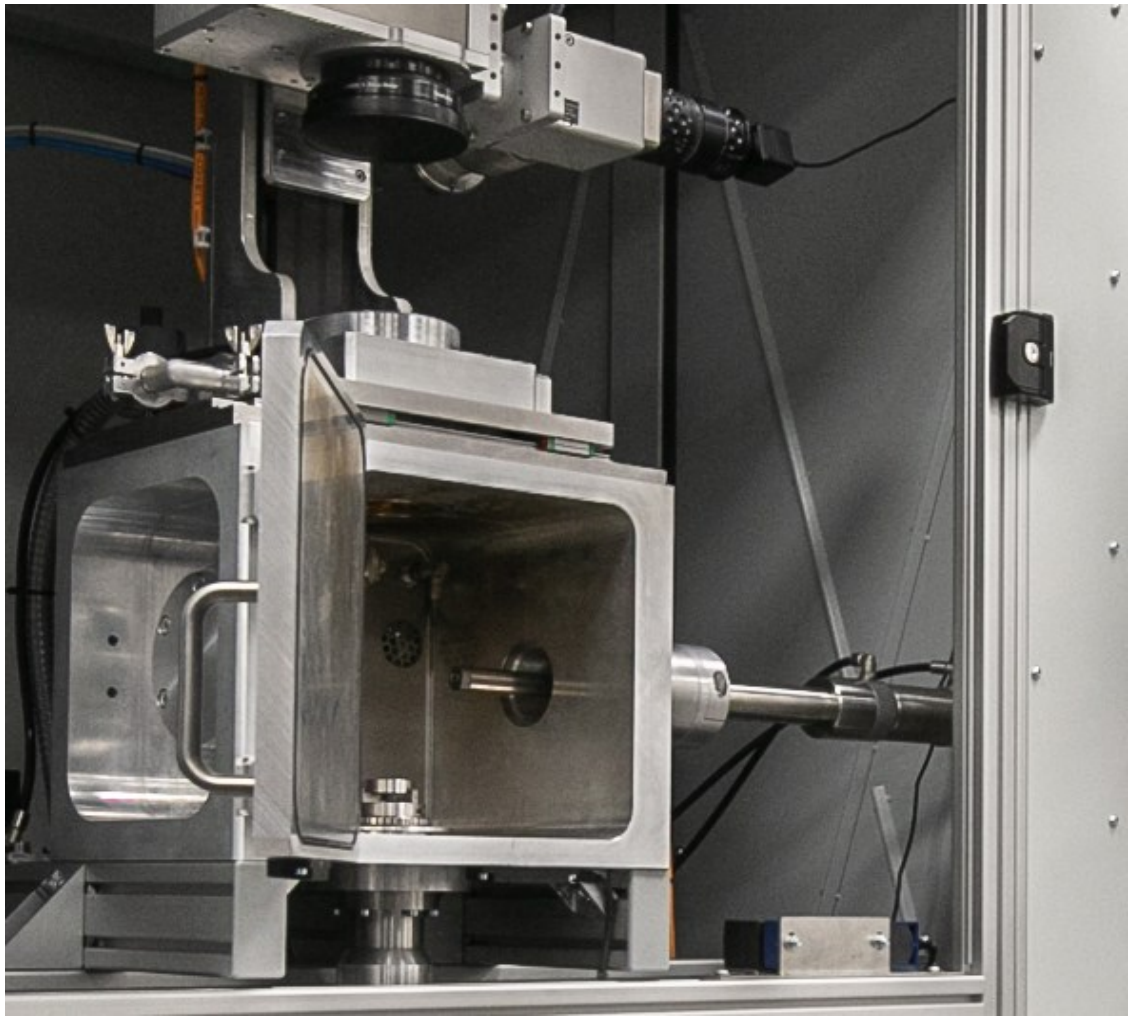


Weldability of Al components produced by LPBF
Laser welding under Vacuum

Advantages of the vacuum

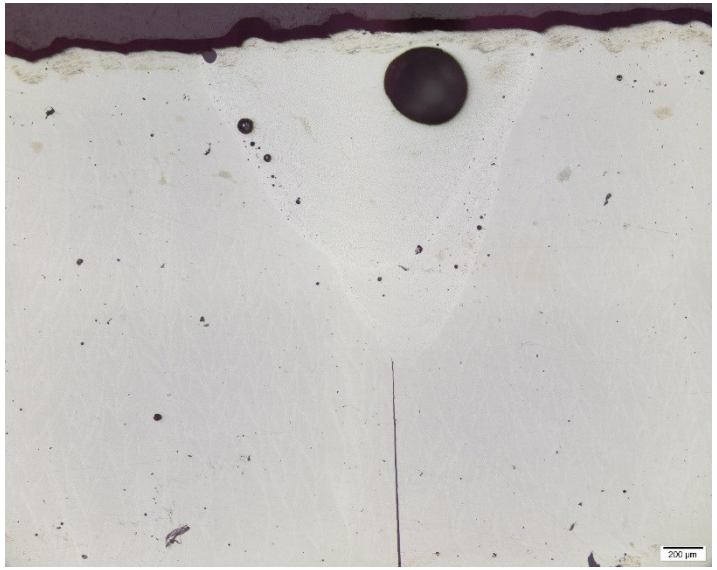
- Reduction of the temperature of the boiling point
- Lower temperature of the vapour cavity reduces the amount of molten base material
- Fewer impurities in the weld pool





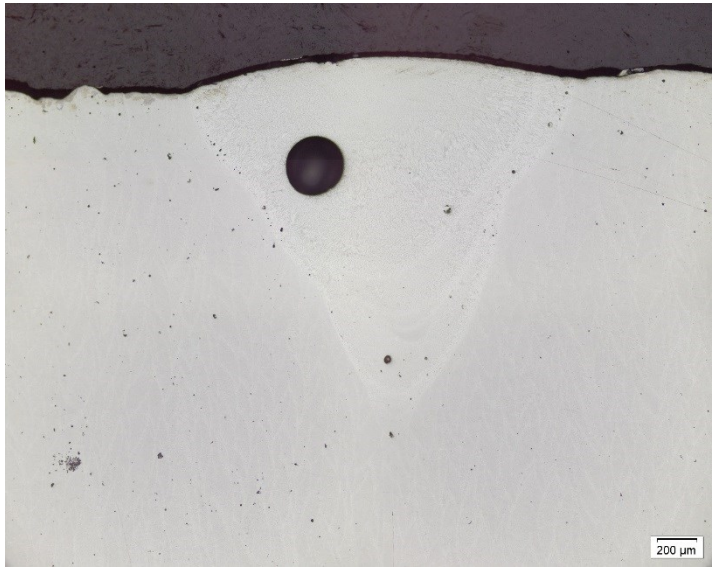
Weldability of Al components produced by LPBF
Laser welding under Vacuum – First test series

Pressure [mbar]	Laser power [W]	Welding velocity [mm/s]	Shielding gas [l/min]
15,5	500	10	5



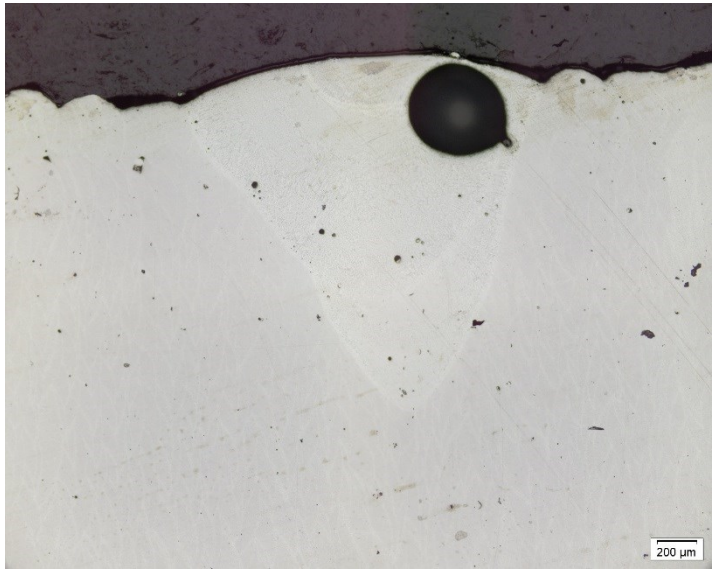
2 Passes

Penetration depth: 1,68 mm
Porosity: 3,308 %
Ø largest pore: 0,16 mm



4 Passes

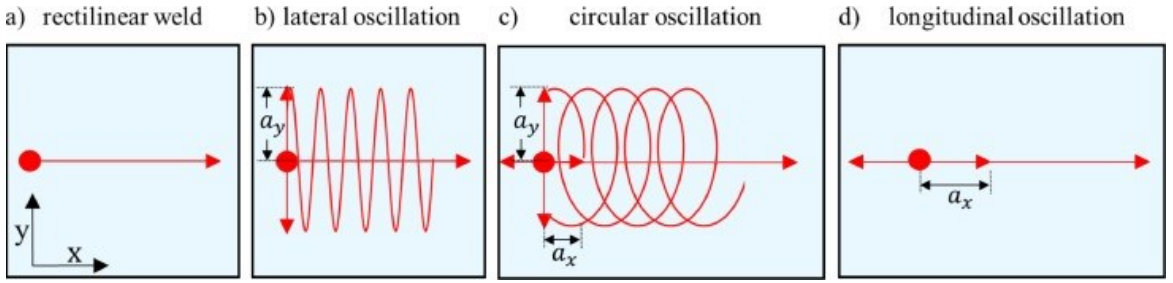
Penetration depth: 1,68 mm
Porosity: 2,17 %
Ø largest pore: 0,12 mm



6 Passes

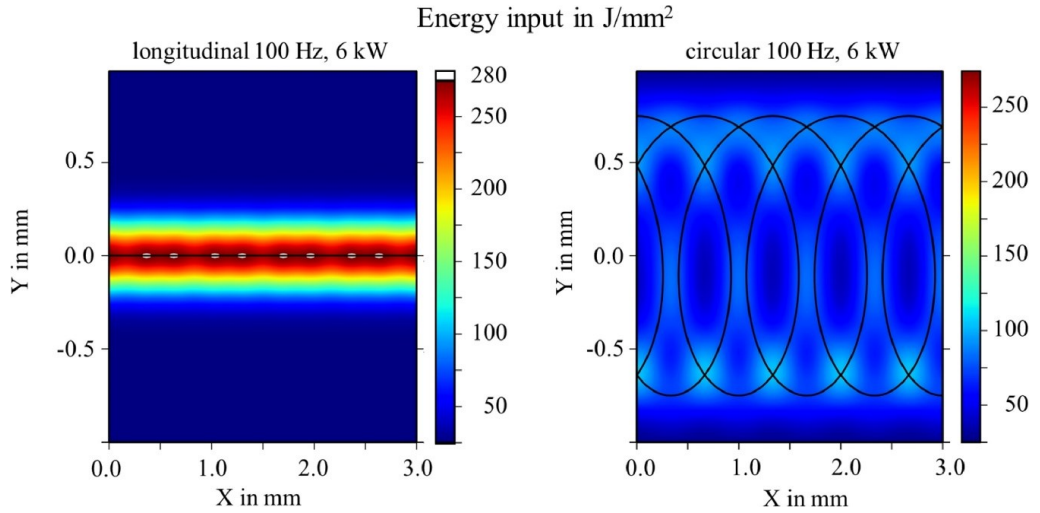
Penetration depth: 1,62 mm
Porosity: 4,179 %
Ø largest pore: 0,19 mm

Weldability of Al components produced by LPBF
Laser welding under Vacuum – Beam oscillation figures



Results first test series

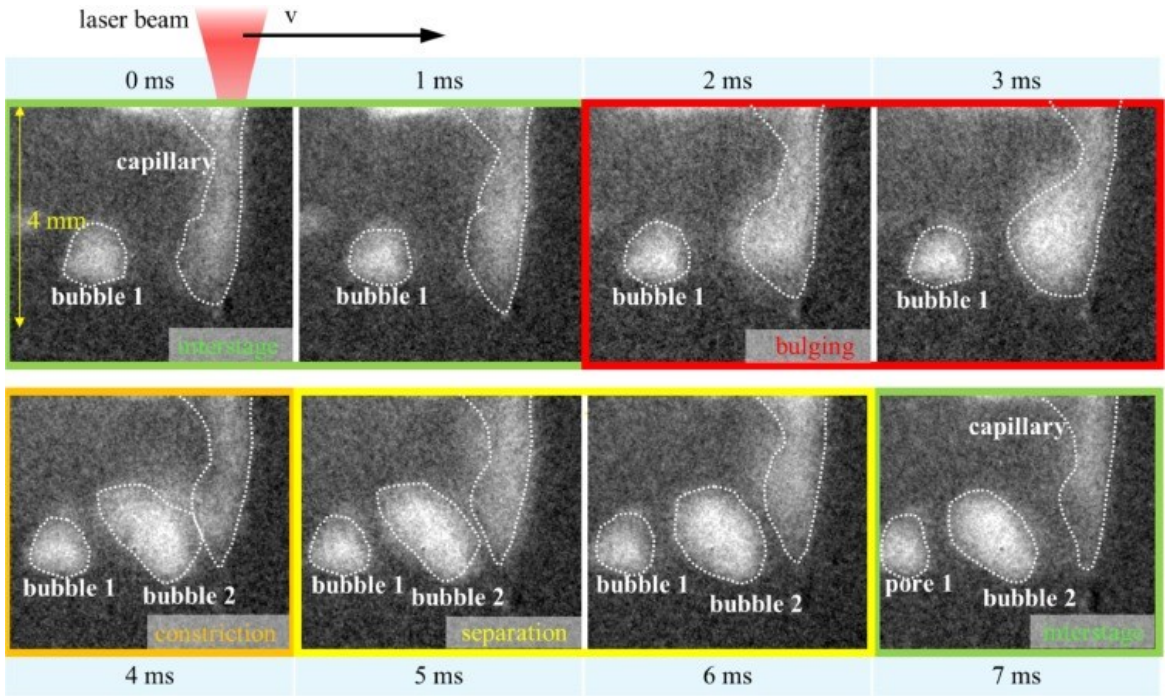
- The first test series shows a reduction in porosity
- There are still pores left in the weld seam
- A Solution can be a change in the beam oscillation figure, known from conventional welding

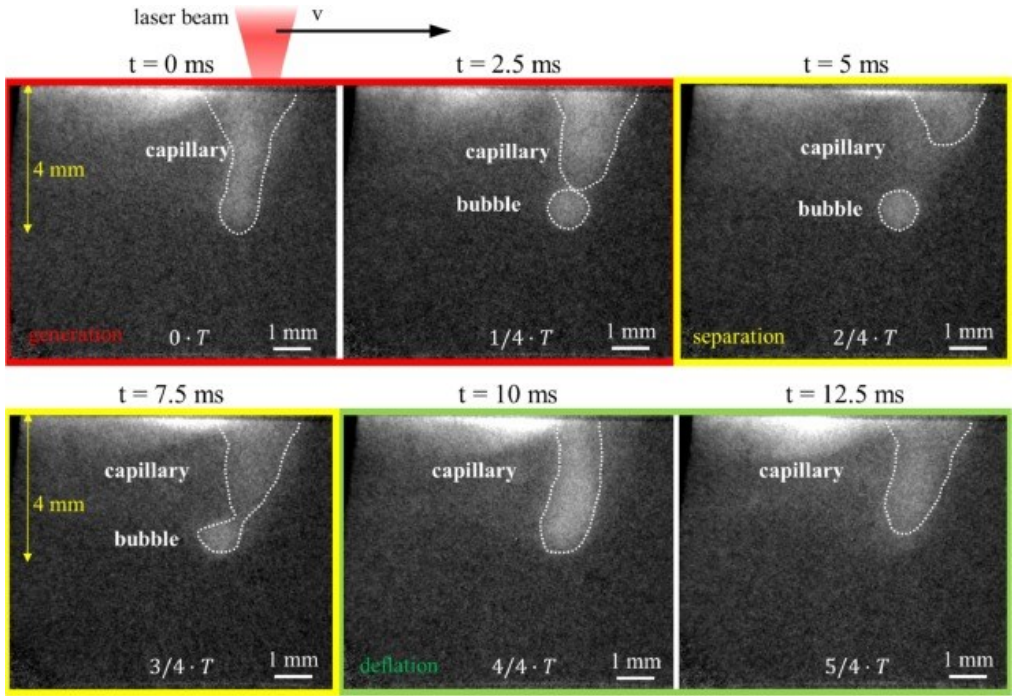


Advantages of the beam oscillation

- Multiple interactions between the beam and the weld pool
- The time for the outgassing is extended

Weldability of Al components produced by LPBF
Laser welding under Vacuum – Beam oscillation figures





Pore formation without beam oscillation

Oscillation figure:	none
Amplitude:	-
P =	4 kW
v =	4 m/min
d_f =	560 µm

Pore formation with beam oscillation

Oscillation figure:	Circular, 100 Hz
Amplitude:	0,75 mm
P =	4 kW
v =	4 m/min
d_f =	560 µm

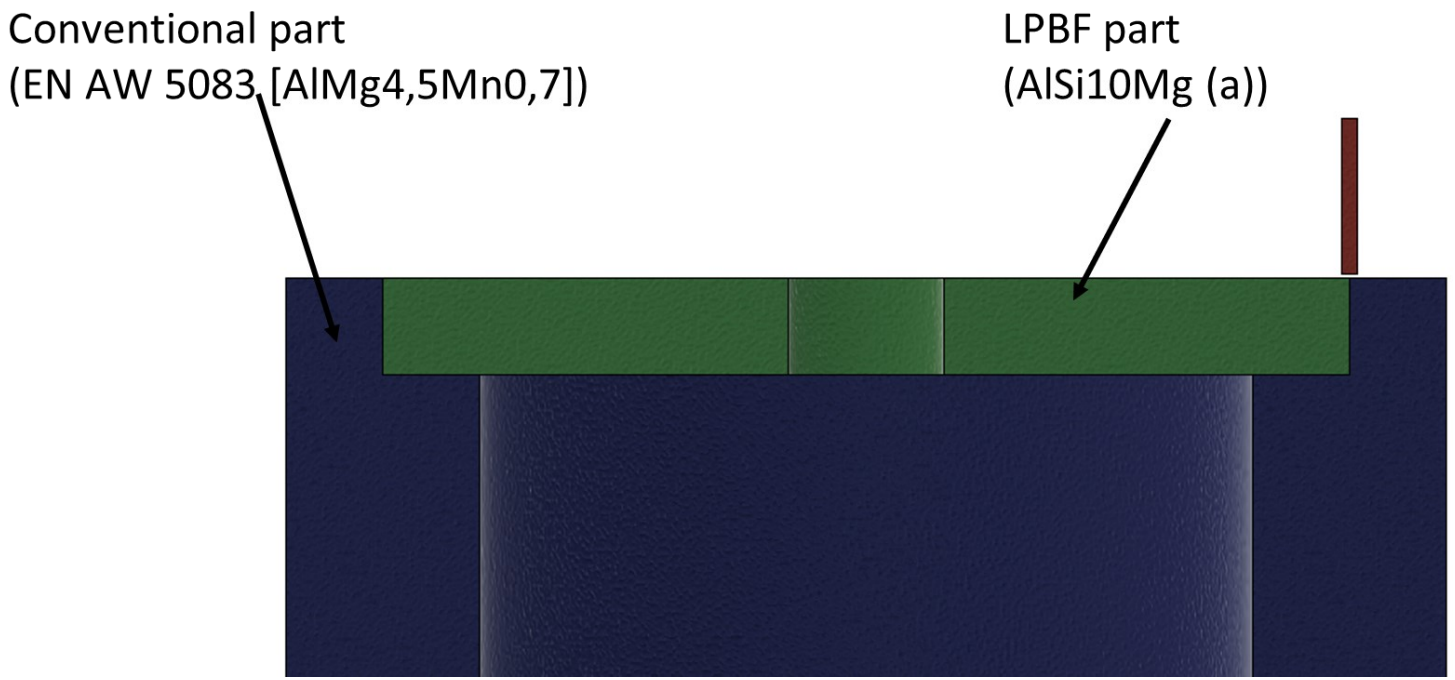
Source: Fetzer, Florian; Sommer, Martin; Weber, Rudolf; Weberpals, Jan-Philipp; Graf, Thomas (2018): Reduction of pores by means of laser beam oscillation during remote welding of AlMgSi. In: *Optics and Lasers in Engineering* 108, S. 68–77. DOI: 10.1016/j.optlaseng.2018.04.012.

Weldability of Al components produced by LPBF
Laser welding under Vacuum – Second test series

Parameter first pass

- Pressure: 7 mbar
- Laser power: 500 W
- Welding velocity: 10 mm/s
- Shielding gas: 5 l/min
- Oscillation figure: Circle
- Amplitude: 0,2 mm

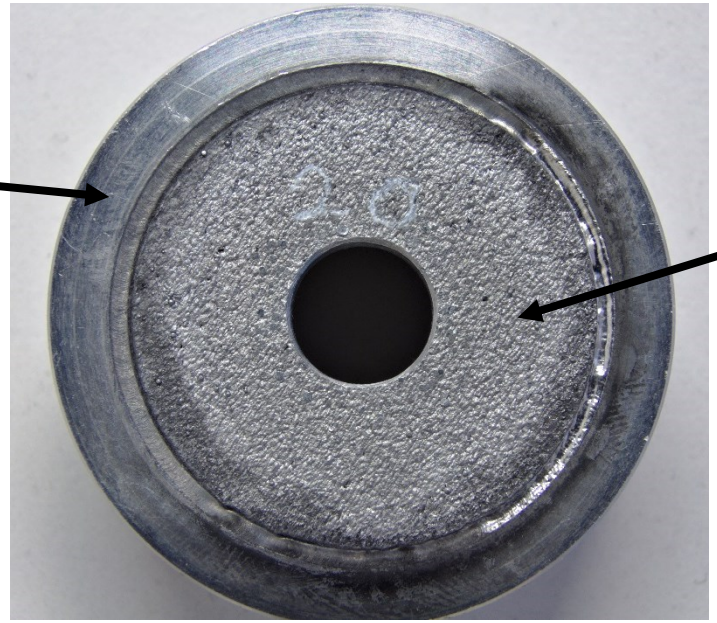
- Parameter for second weld seam
- Oscillation figure: Circle
- Amplitude: 0,5 mm



Weldability of Al components produced by LPBF
Laser welding under Vacuum – Second test series

Pressure [mbar]	Laserpower [W]	Welding velocity [mm/s]	Shielding gas flow [l/min]	Oscillation figure	Amplitude [mm]
7	500	10	5	Circular	0,2
7	500	10	5	Circular	0,5

Conventional part
(EN AW 5083 [AlMg4,5Mn0,7])

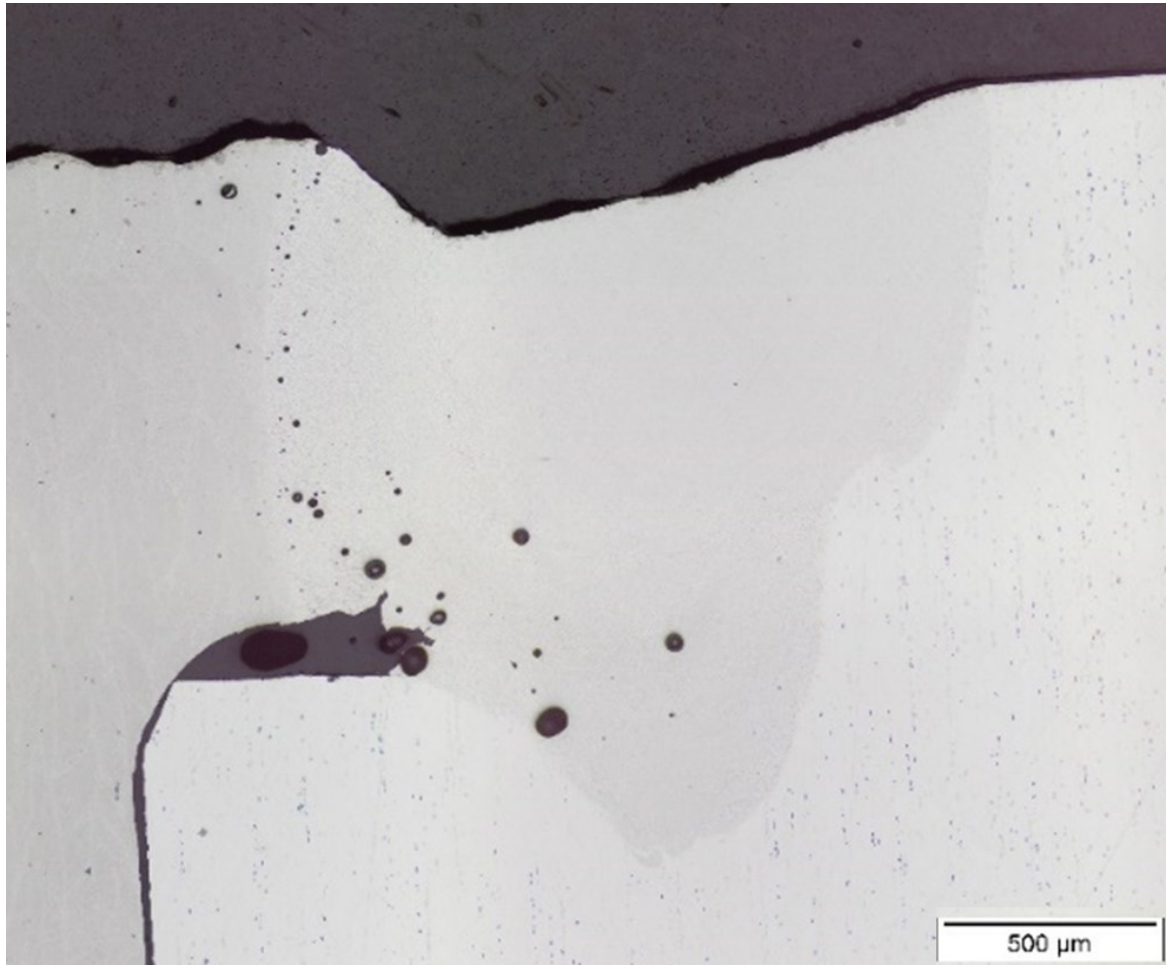


L-PBF-part
(AlSi10Mg)

Weldability of Al components produced by LPBF
Laser welding under Vacuum – Second test series

First Pass

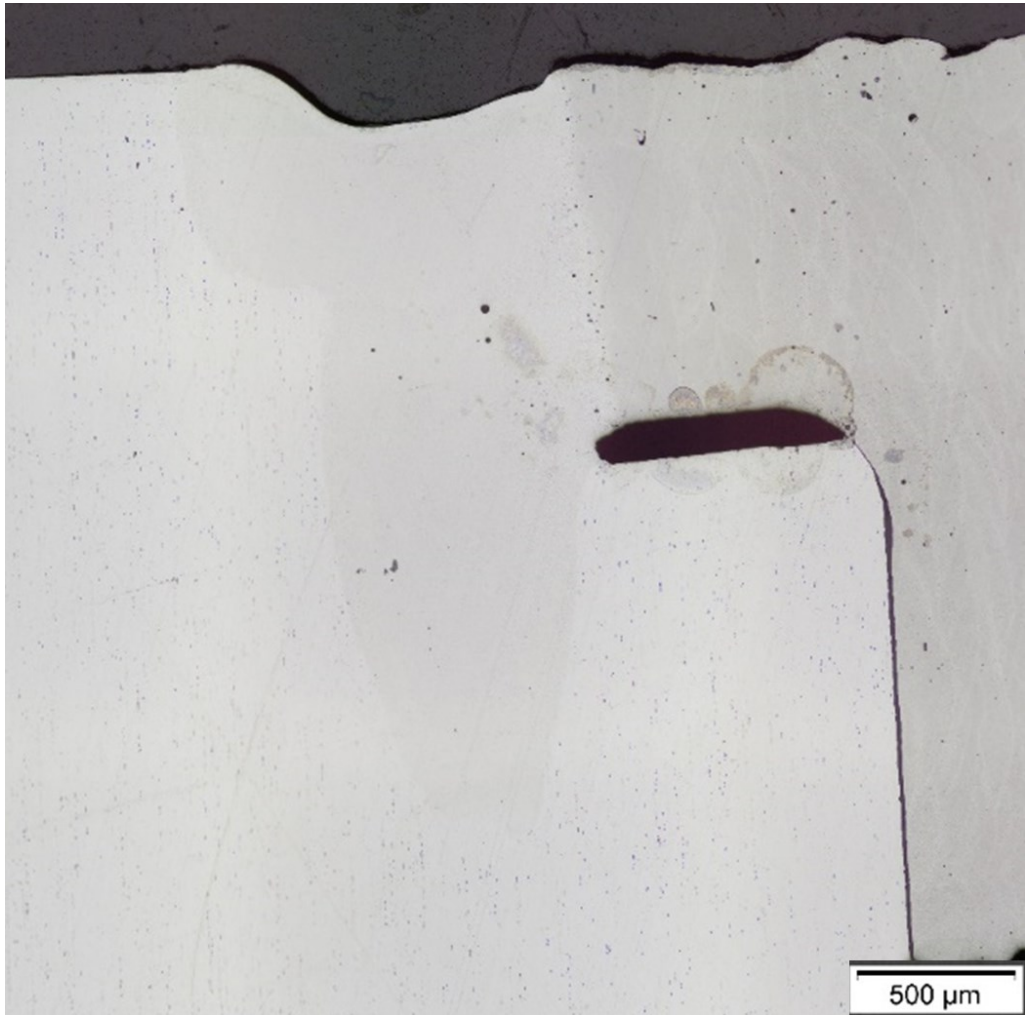
- Porosity is already reduced in contrast to the conventional manufacturing
- Still some pores left on the transition between the AM part and the weld
- No pores on the transition between the weld and the conventional material



Weldability of Al components produced by LPBF
Laser welding under Vacuum – Second test series

Second Pass

- Porosity is below 0.5 %
- The second pass has multiple influences
  - Further reduction of the porosity
  - Increase of the penetration depth from 1.6 mm to 2.3 mm



Weldability of Al components produced by LPBF
Conclusion

- Conventional welding of LPBF manufactured aluminum parts is hardly possible
- Different variables from the manufacturing process are influencing the welding process
- Laser welding under vacuum has been proofed as a sufficient solution
- But only with correctly chosen parameters a pore-free welding is possible
  - This includes the laser parameters as well as the movement of the beam
- Some limitations of the process are left:
  - Need for a vacuum
  - Limited build chamber
  - Automated process, only partly suitable for AM

Your contact

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