AIDAINNOVA

Additive Manufacturing by LPBF technology

WP10 26.04.2023

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CSEM aim for AIDAINNOVA WP10

- AM metal

- Define the optimal geometrical features attainable for 3D printed ultra-thin cold plates in metal alloys

CSEM objectives for AIDAINNOVA WP10

- AM of metal alloys → AlSi12 (stiffness to weight ratio and high thermal conductivity)

- **Quality evaluation of built parts**
  - Thermal conductivity ✓
  - Long test cavity (single pipes & multi-channel) ✓
  - Inner wall roughness (single pipes & multi-microchannel)
  - Dimensional accuracy
  - Flatness (multi-microchannel)
- **Minimal wall thickness**
  - Minimum leak-tight wall thickness (single pipes & multi-microchannel) ✓
- **Powder management**
  - Minimum ratio (D/L) for single pipes (straight & 180 degree-bent geometry) ✓
  - Minimum ratio (D/L) for multi-microchannel

CSEM objectives for AIDAINNOVA WP10

- AM of metal alloys → COVAR & INVAR (low CTE)

- **Phase 1**
  - Benchmarking for AM grade powder
  - Development of process parameters
  - Best candidate (COVAR or INVAR) selection based on obtained results

- **Phase 2**
  - Same investigation as AlSi12 but on a limited number of configuration

Technical Achievements

- **Minimal wall thickness strategy**
  - AlSi12

  - Laser power tune in single track laser

  - Thickness tuned by CADs

↓ Power tuning

  - Laser power tune in double track laser

↓ Fine tuning

  - Tuning between 100 W and 110 W

- **Characterization**
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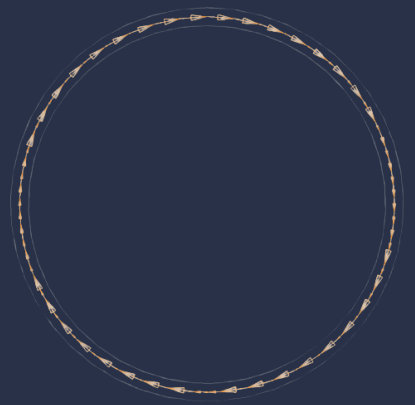

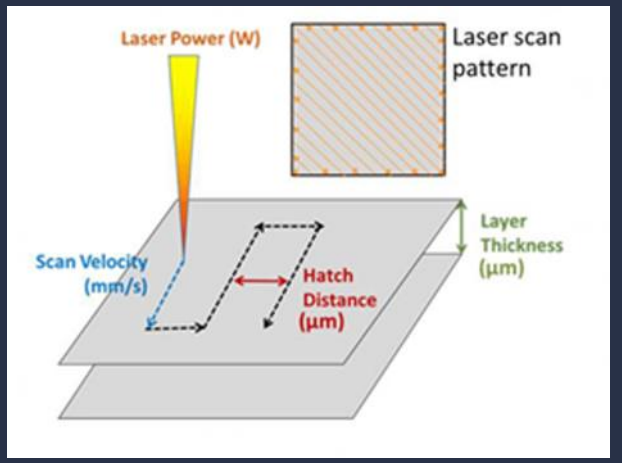

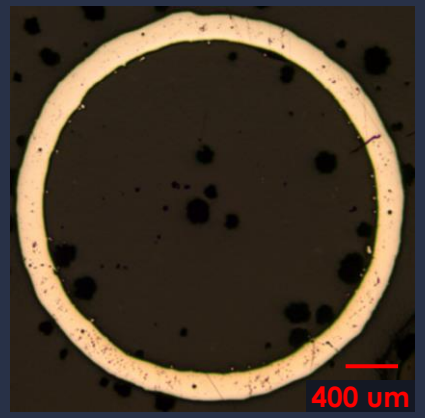

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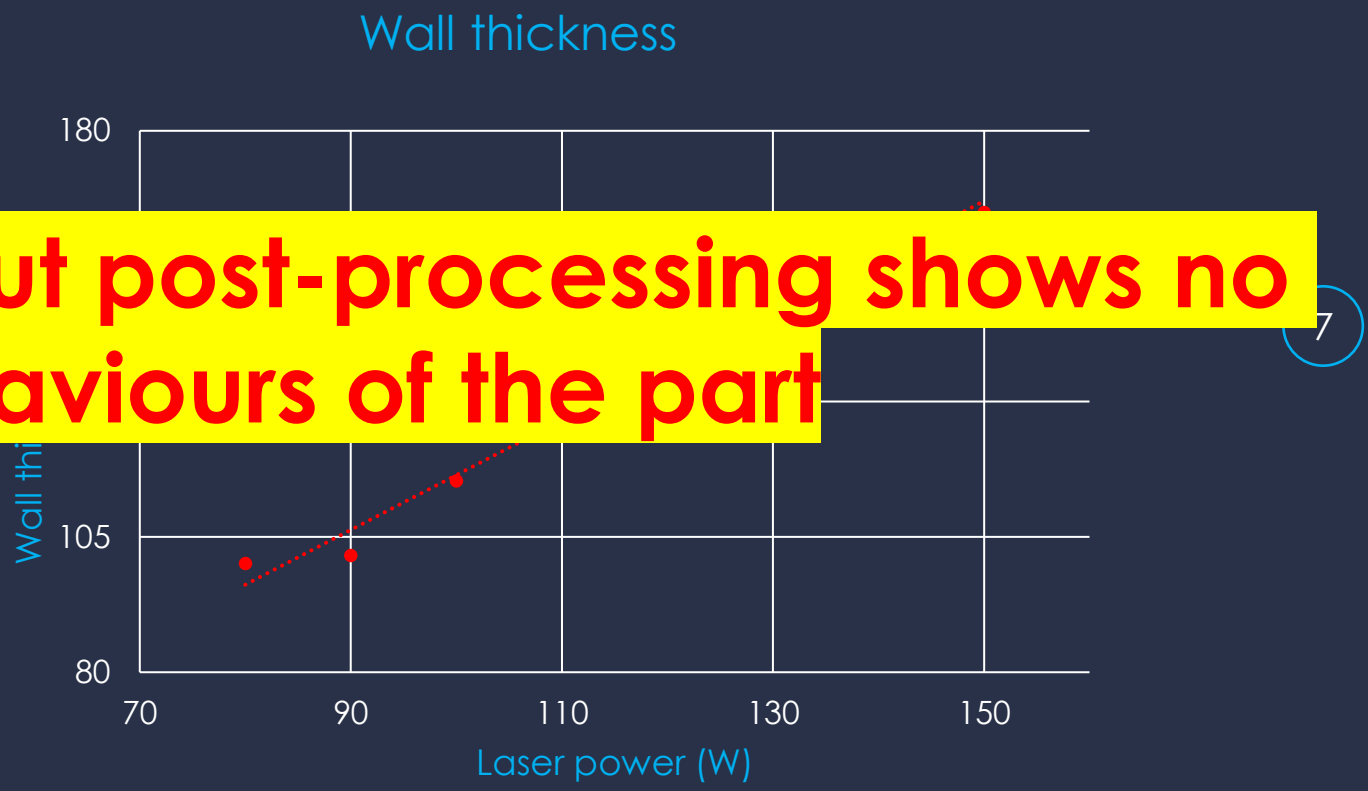
- **Minimal wall thickness strategy**
  - AlSi12 → **1) Laser power tune on single-line (SL)** ✗

Single line printing without post-processing shows no leak-tight behaviours of the part

    - Change
    optimize
  - Results:
    - **ok but not leak-tight**



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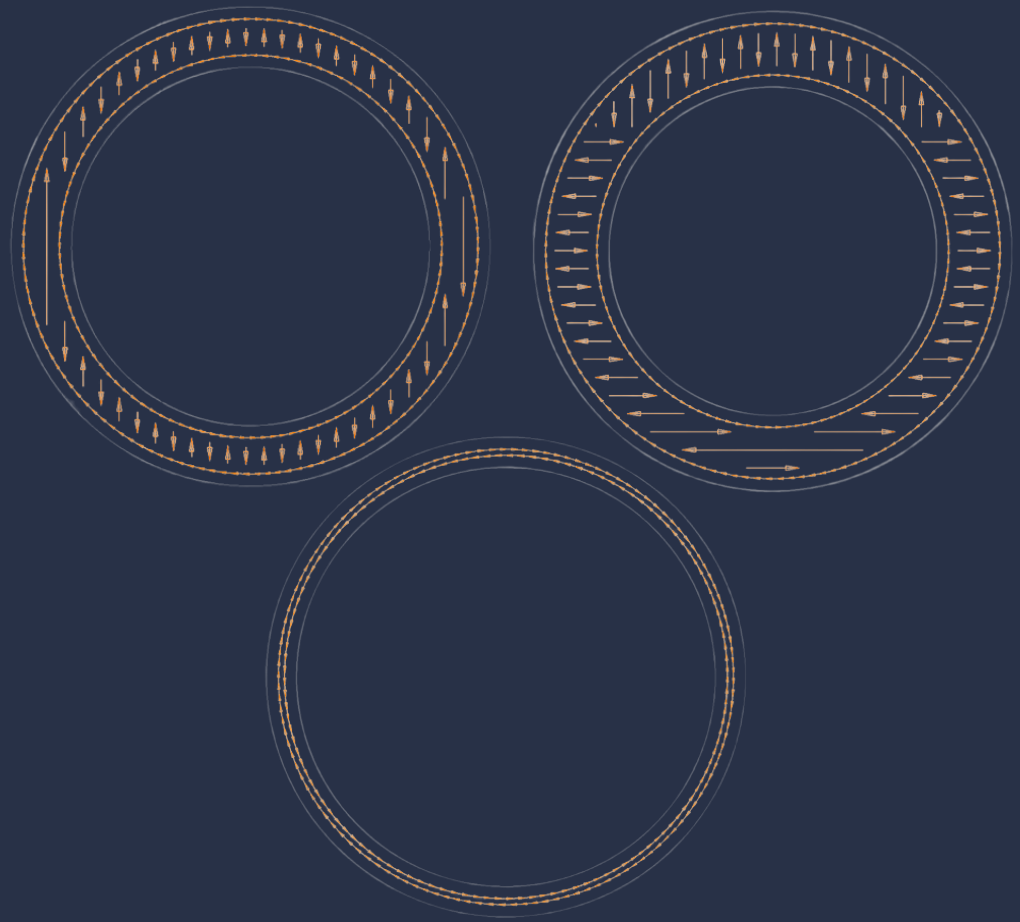

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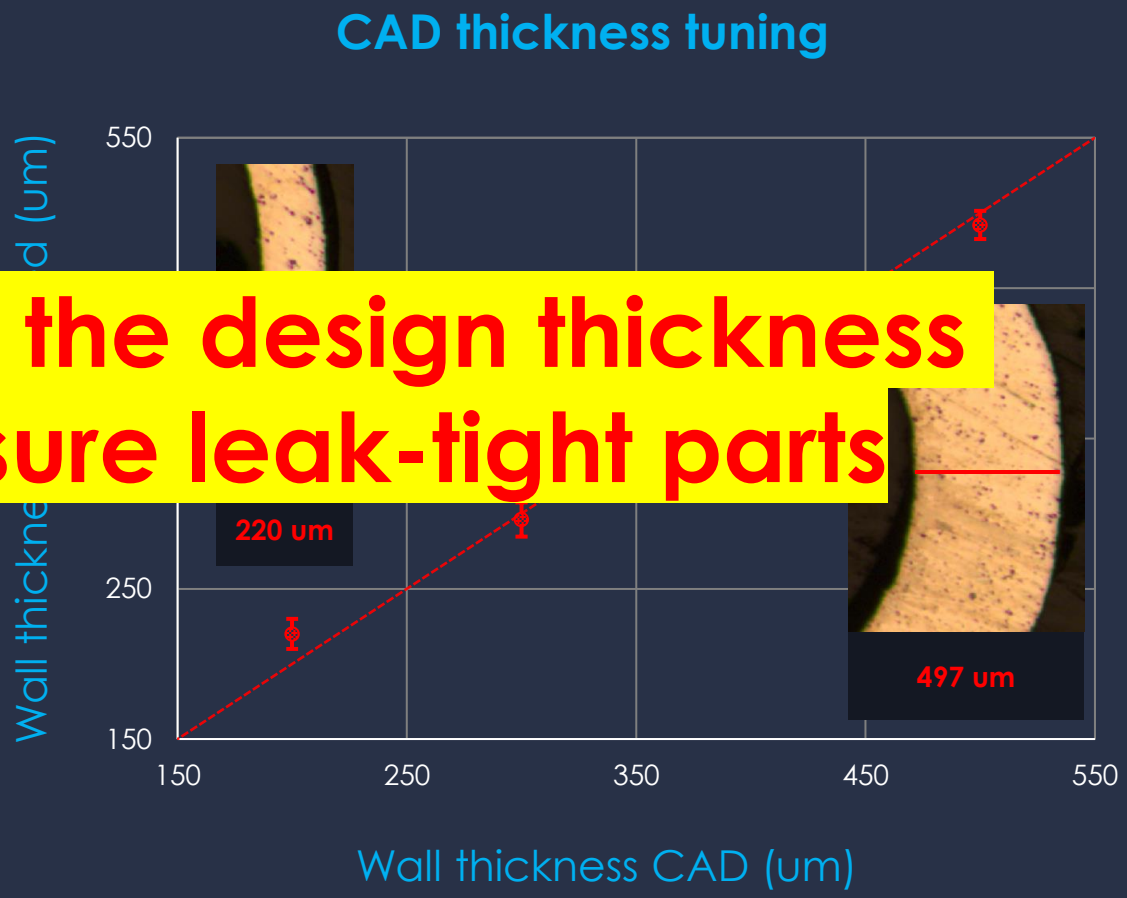
- **Minimal wall thickness strategy**
  - AlSi12 → **2) Thickness tuned by CAD**

- Method:
  - Ch… on…
- Results:
  - Except some defects parts, **all printed parts are leak-tight**

Results by tuning the design thickness lead high pressure leak-tight parts



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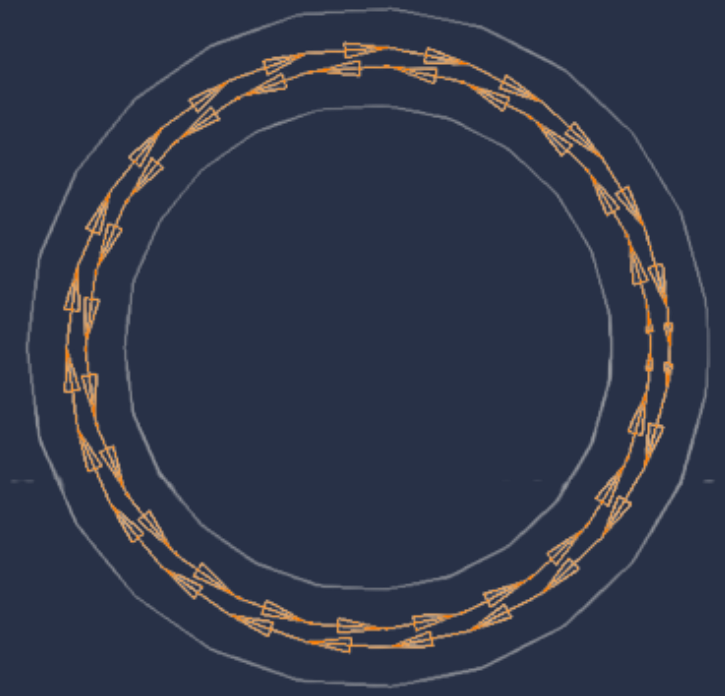

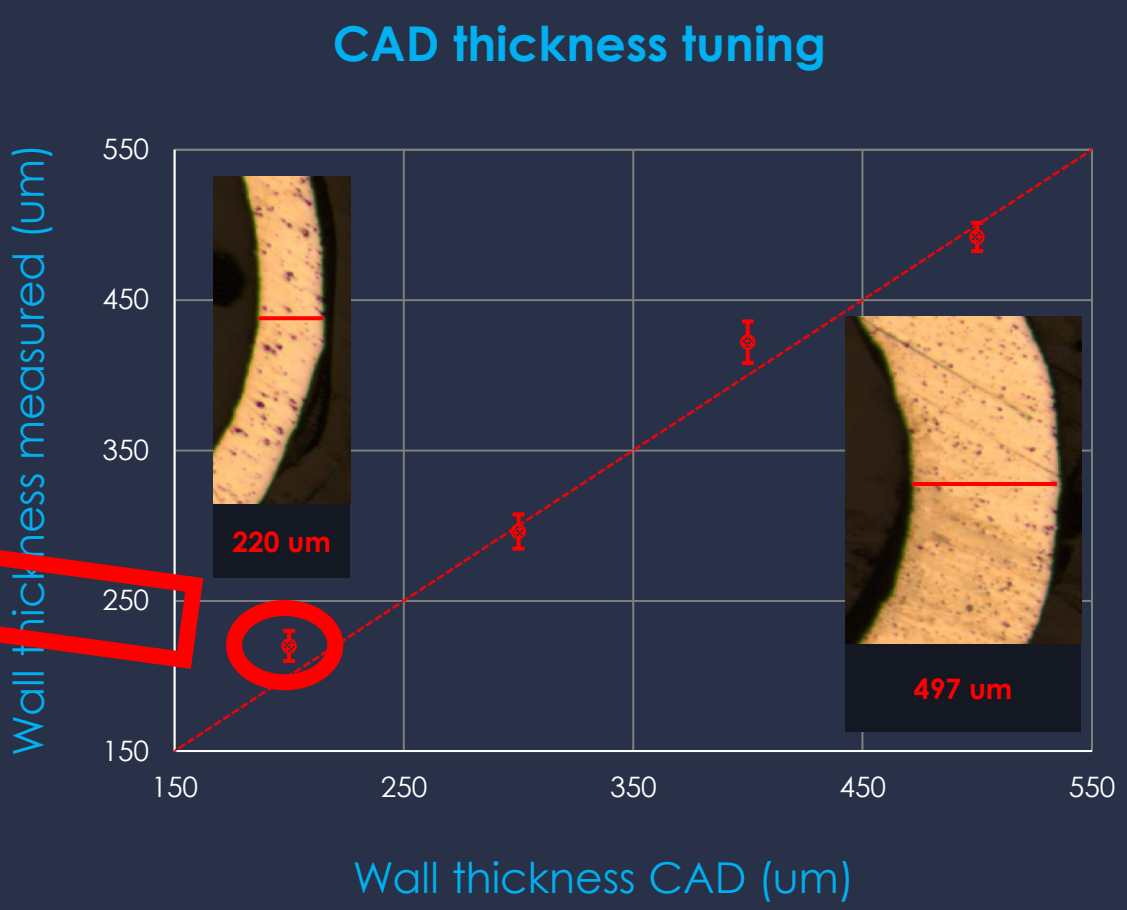

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• Minimal wall thickness strategy

- AlSi12

✗ Laser power tune in single track laser

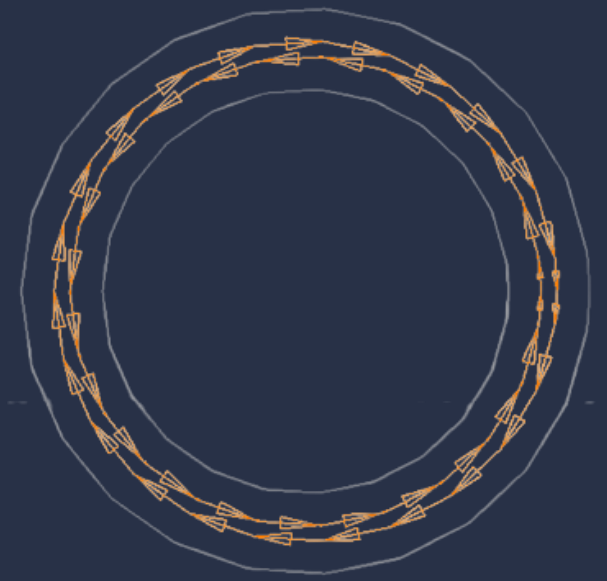
✓ Thickness tuned by CADs

↓ Power tuning

- Laser power tune in double track laser

↓ Fine tuning

- Tuning between 100 W and 110 W



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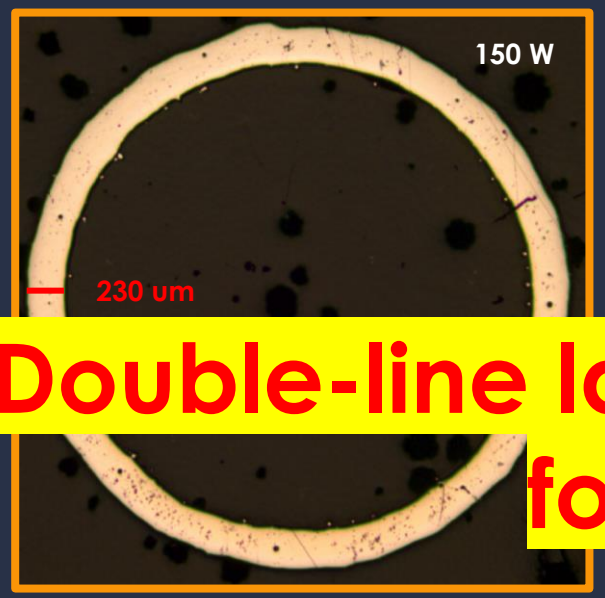
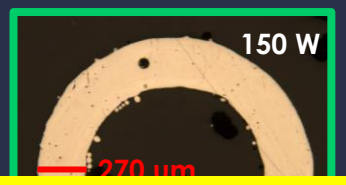
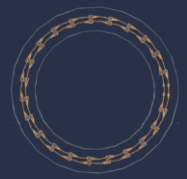
- **Minimal wall thickness strategy**
  - AlSi12 → **3) Laser power tuning on double-line (DL)** ✓







Double-line laser power tuning shows good trend for the pressure thightness

- Method:
  - Change laser power on an optimized recipe always keeping two laser tracks
- Results:
  - **≥ 110 W → Leak-tight (180 um)**
  - **< 110 W → Not leak-tight (170 um)**

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- **Minimal wall thickness strategy**
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✗ Laser power tune in single track laser

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✓ Laser power tune in double track laser

↓ Fine tuning

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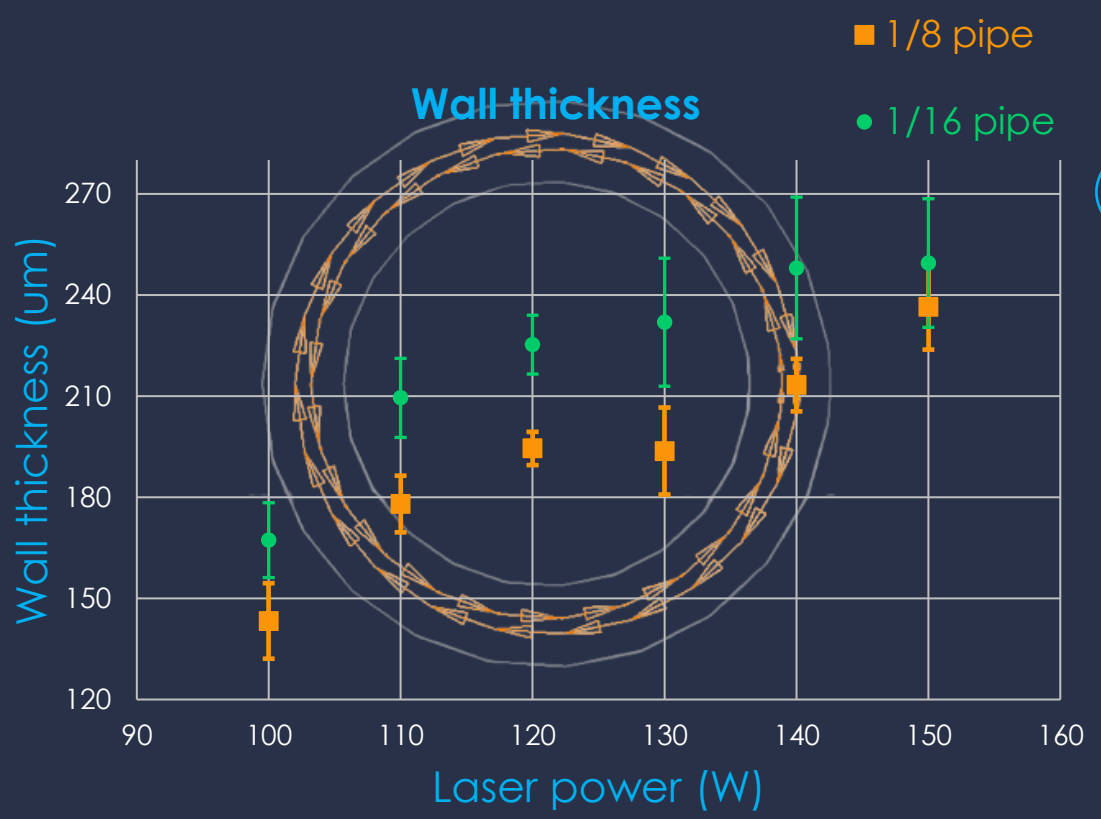

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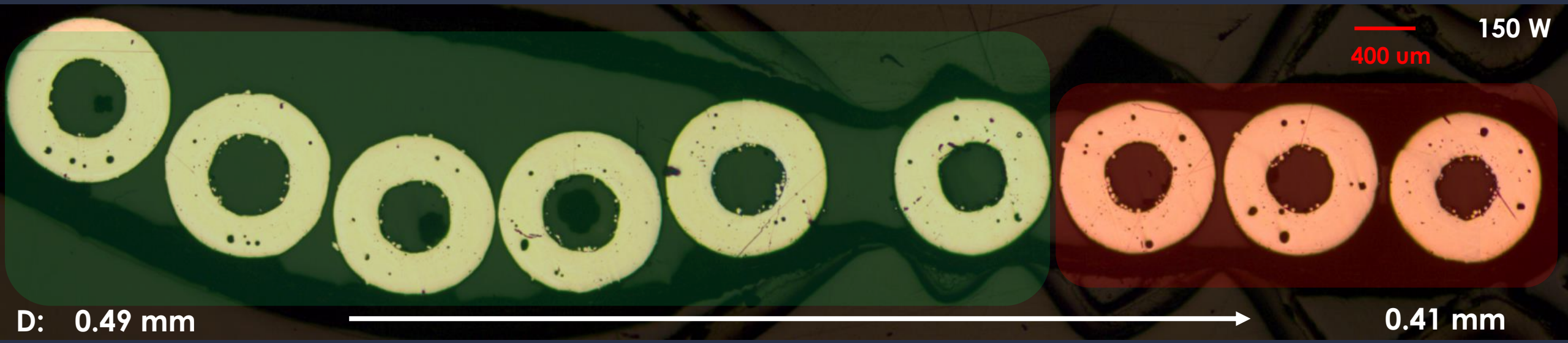
• Powder management

- AlSi12 → straight pipe
  - Minimum hole diameter to length ratio for single straight pipe
    - Method:
      - Print maximal length possible (85 mm) & change hole size.
    - Results:
      - **150W → D: 0.44 mm, L: 85 mm**



Explorative part

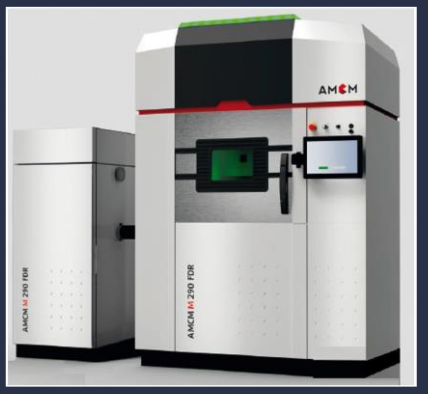
Idea & Perspectives

- AlSi12

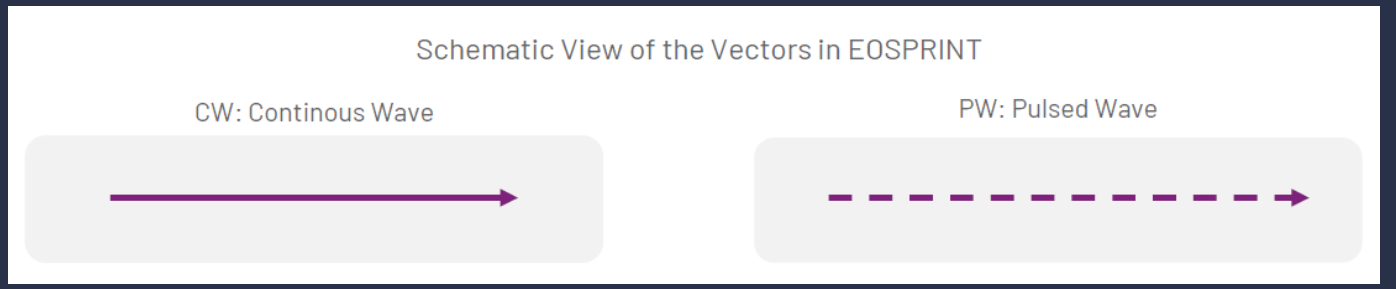
- **Pulsed laser**
- **HIP post-process**
- **Boost the process limit of AM**
- **Diamond composite**

Idea & Perspectives

- AlSi12 → Pulsed laser



Better control of introduced heat compared to a continuous wave



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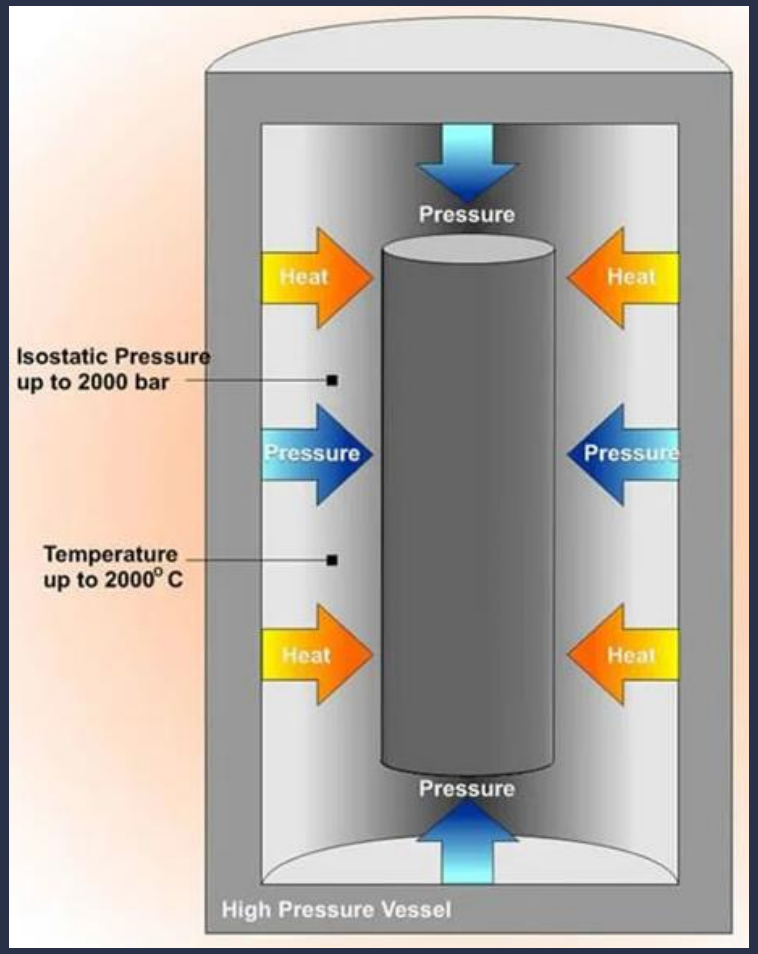
Idea & Perspectives

- AlSi12

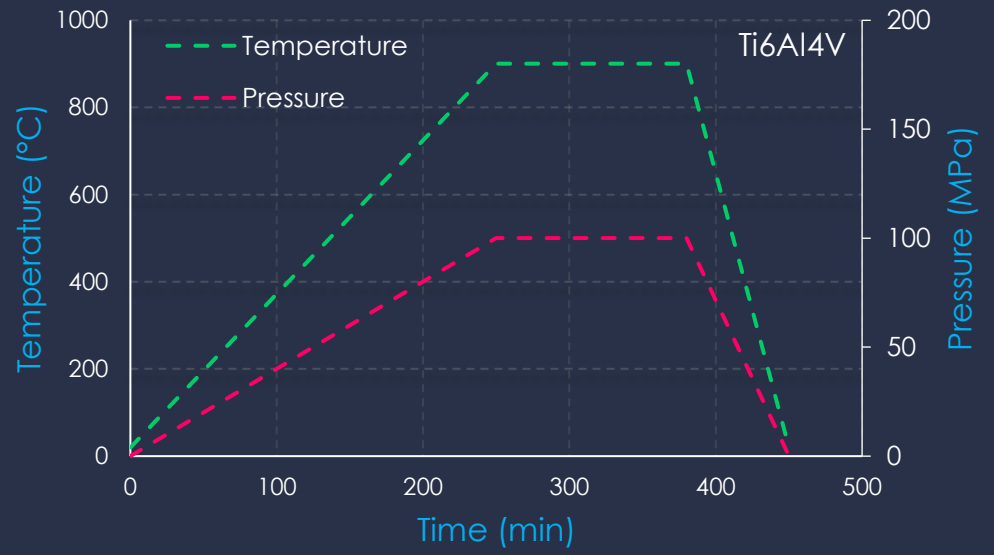
- Pulsed laser
- **HIP post-process**
- Boost the process limit of AM
- Diamond composite

Idea & Perspectives

- AlSi12 → HIP post-process

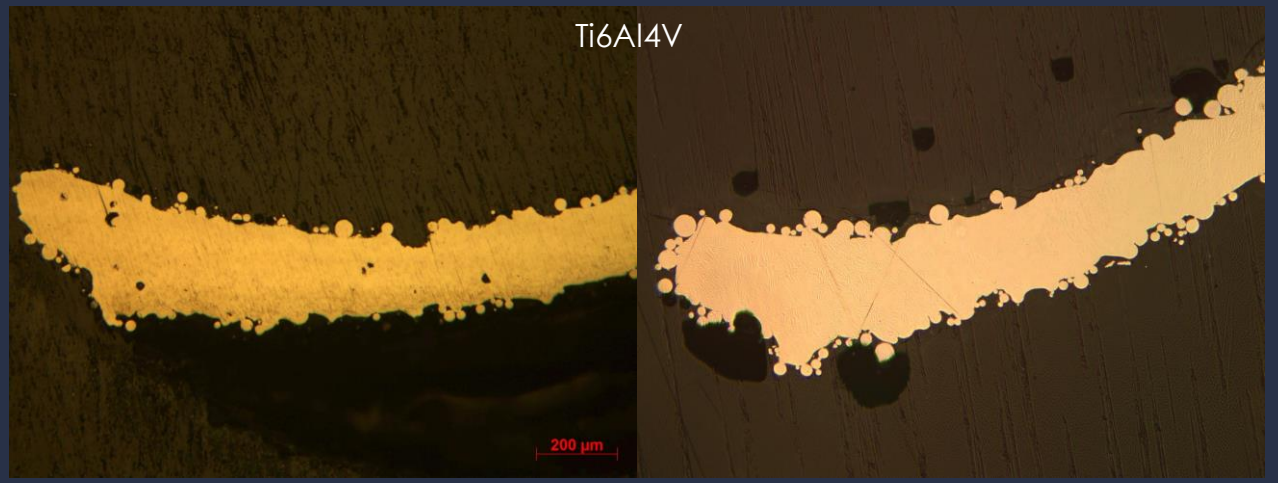


Schematic of the Hot Isostatic Pressing Process
*Azo material



Pre-HIP

Post-HIP



Porosity decreasing

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Idea & Perspectives

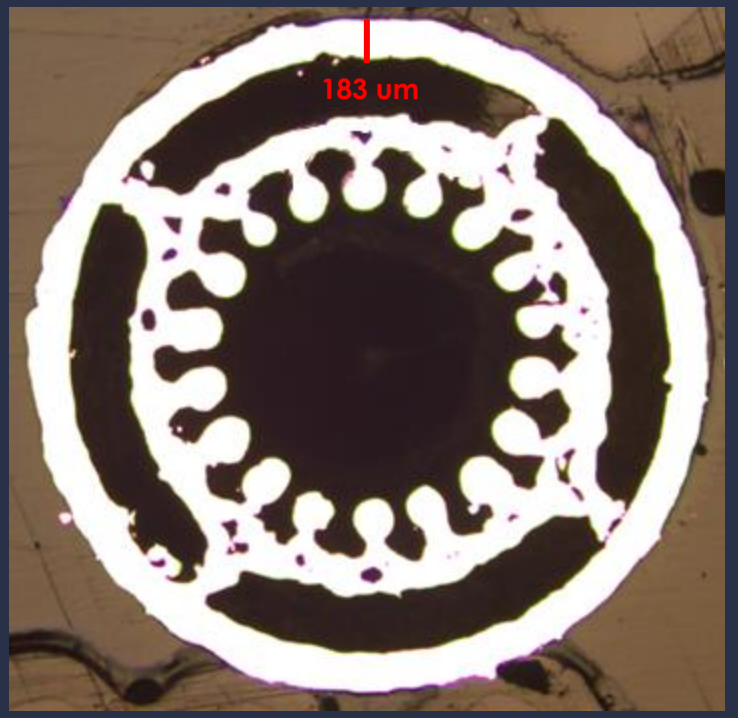
- AlSi12

- Pulsed laser
- HIP post-process
- **Boost the process limit of AM**
- Diamond composite

Idea & Perspectives

- AlSi12 → Boost the process limit of AM

- Different roughness in the same part (fluid dynamics)
- Internal pipe structurization (induce phase transition)
- Exploit design freedom – internal porous pipe and external tight pipe (improve phase transition)



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Idea & Perspectives

- AlSi12

- Pulsed laser
- HIP post-process
- Boost the process limit of AM
- **Diamond composite printing**

Idea & Perspectives

- AlSi12 → diamond composite (C – SiC)

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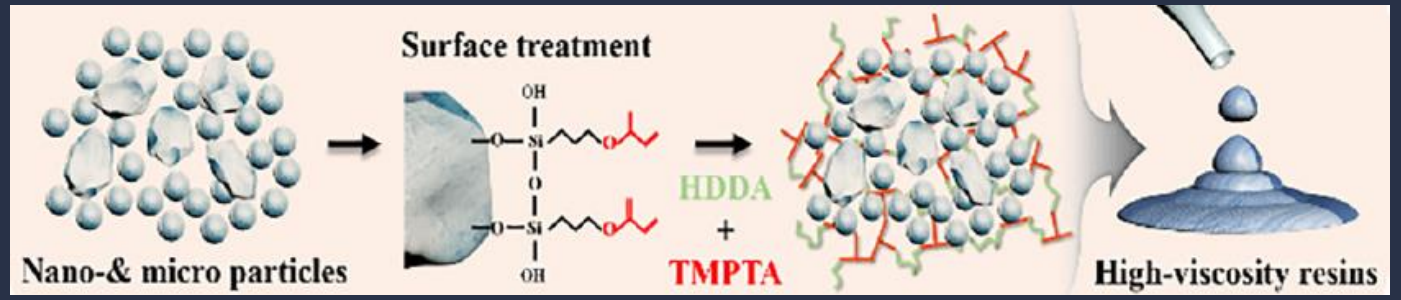
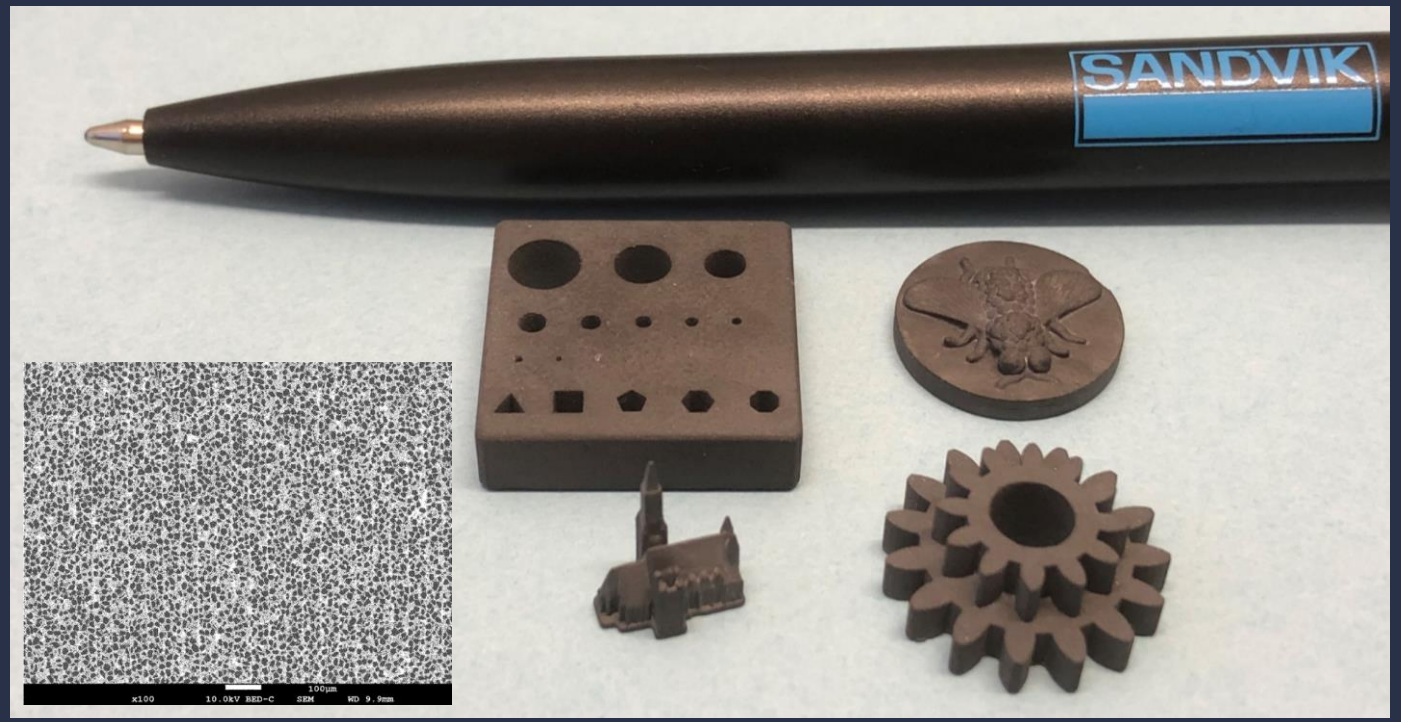


- High features definition
- Low CTE (?)
- Th. cond. ~400 W/(m * K)
- High MP (?)



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Conclusion

- A first investigation to find the minimal wall thickness was successful. Further development can be achieved by pulsed laser, which allows better control of the wall thickness, as well as HIP post-processing.

- Minimal hole diameter is more challenging to establish for LPBF process as it depends on materials (flowability, particles size) and final proprieties (roughness). For AlSi12, a D/L ratio of 0.44/85 is found. Reproducibility still needs to be investigated.

- Perspectives on new technological approaches, such as structured pipes and diamond printing, need to be analysed.