Topology Optimization and AM Simulation – Application at the micrometric scale

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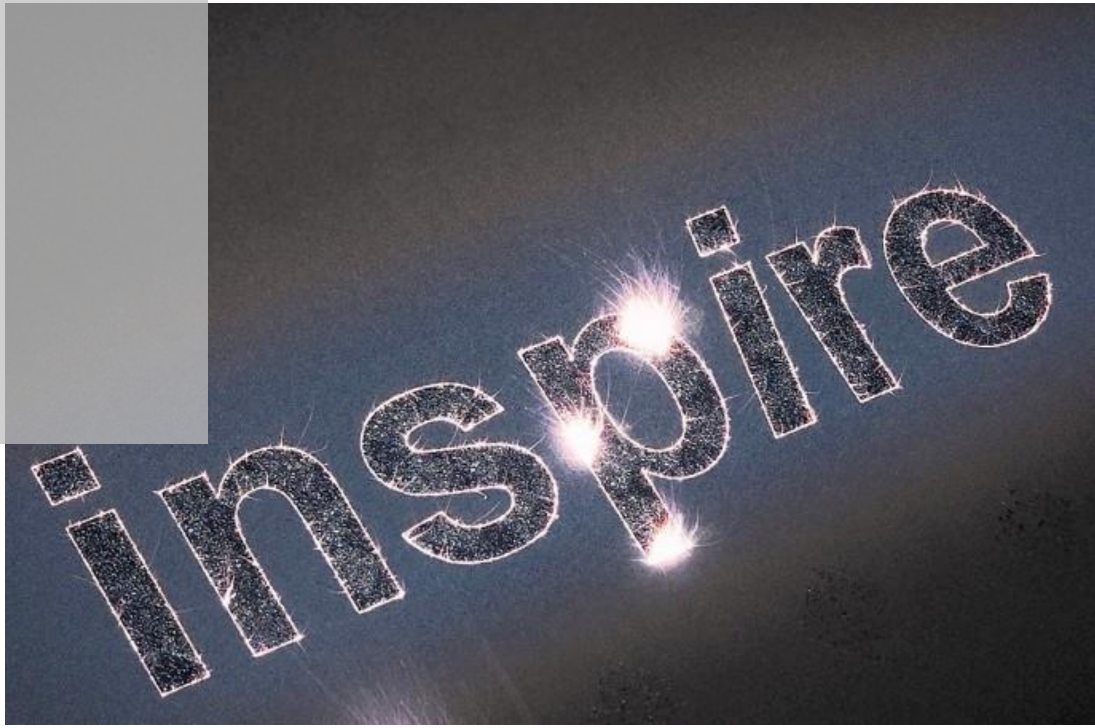

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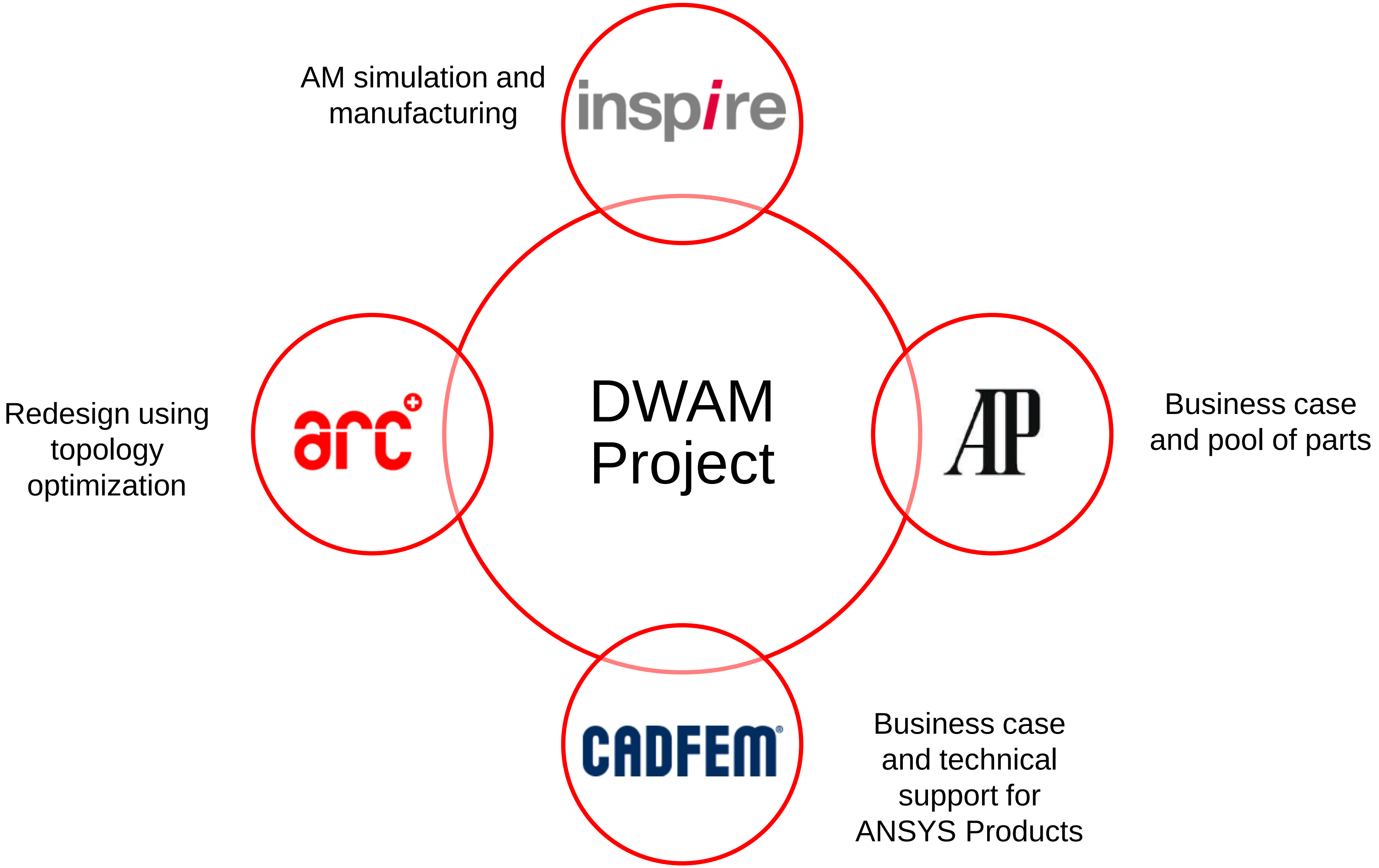
Agenda

- DWAM Project Consortium
- Goals of the project
- Processing conditions for Ti6Al4V for fine layers
- Topology Optimization approach using Ansys
- Conclusion and outlook

DWAM Project Consortium

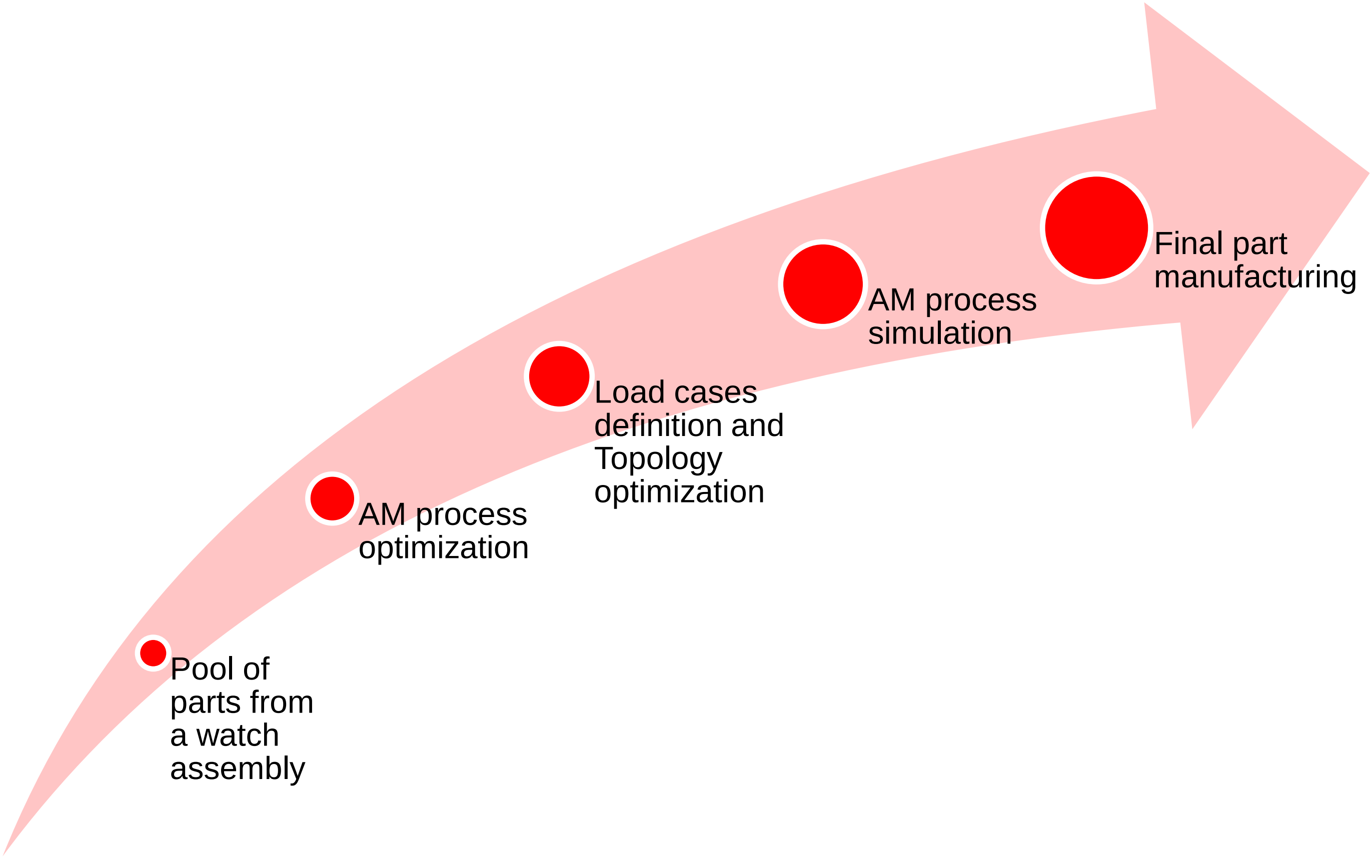


Goals of the project

- Improve processing conditions for fine details of Ti6Al4V
- Redesign micro-scaled components using topology optimization and the advantages of AM
- Lead AM process simulation at for micro scaled components and correct for in process / after process deformation
- Manufacture final components
- Implement a repeatable workflow for Audemars Piguet's daily use in new design development

Goals of the project

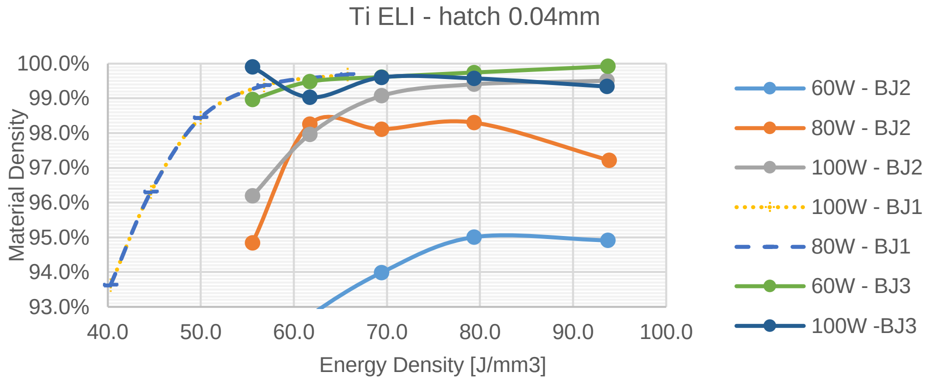
- Workflow idea



Processing conditions for Ti6Al4V

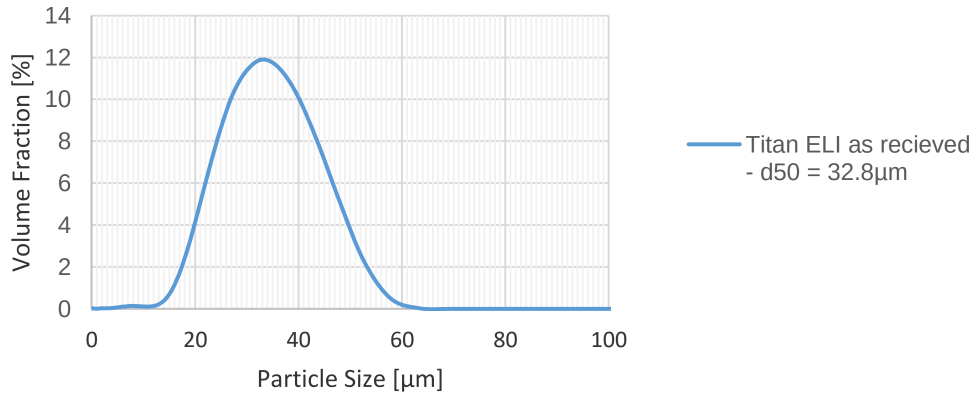
- Fixed inputs:
  - Fine layers = 20µm
  - Small laser spot 1/e2 = 56µm
  - Processing under Argon

- With off-the-shelf powder:



Energy density:

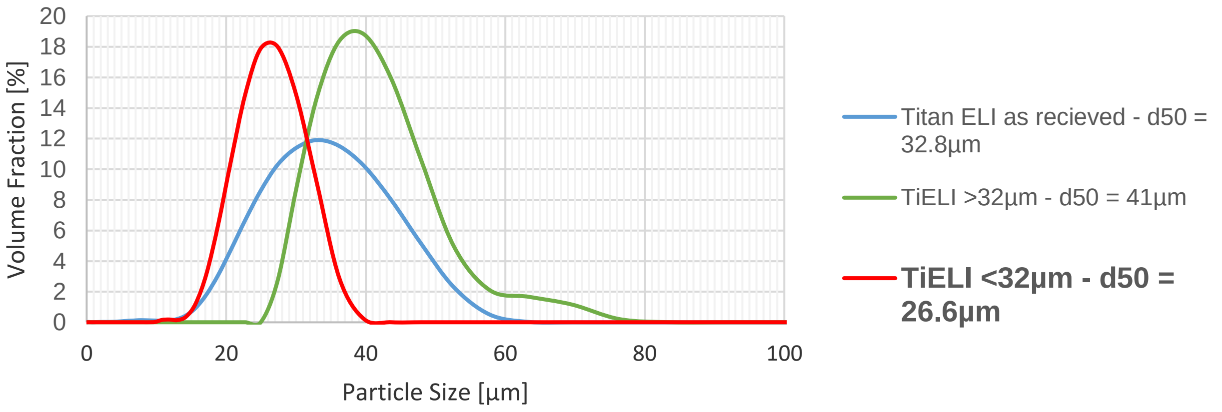
$$e_d = \frac{P}{L * h * v}$$



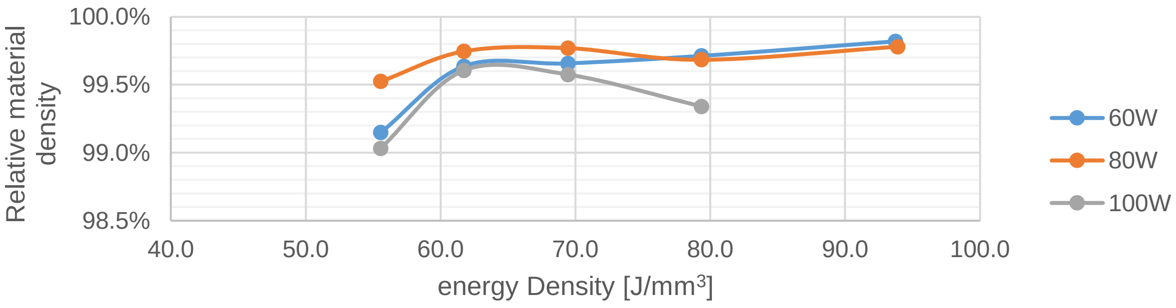
- Difficulty in stabilizing the processing conditions:
  - Layer to fine vs. mean particle diameter
  - Meltpool too small vs. biggest particles

Processing conditions for Ti6Al4V

- Reduction of the powder fraction



- Density results and first fine details



Single track
0.12mm thick

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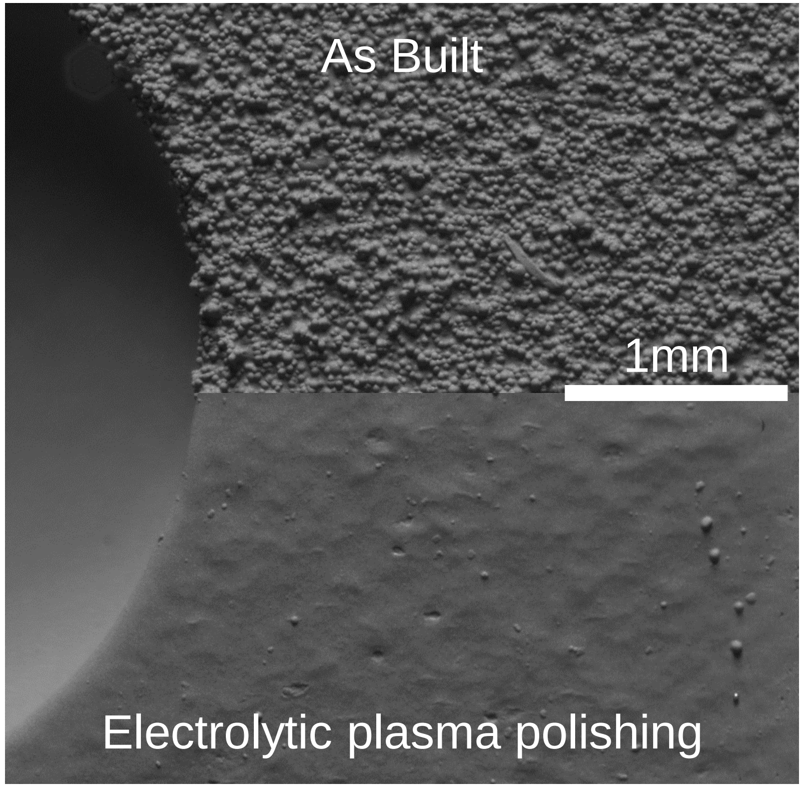
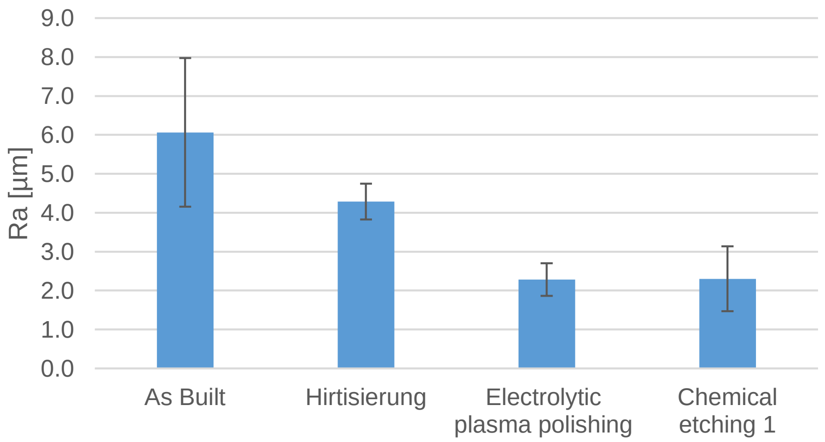
Processing conditions for Ti6Al4V

- Post processing
  - Improve surface quality
  - Reduce minimal feature size (to be fed in the topology optimization)

- Demonstrator part:
  - Wall thickness 0.2 and 0.4mm
  - Holes 4 and 2 mm



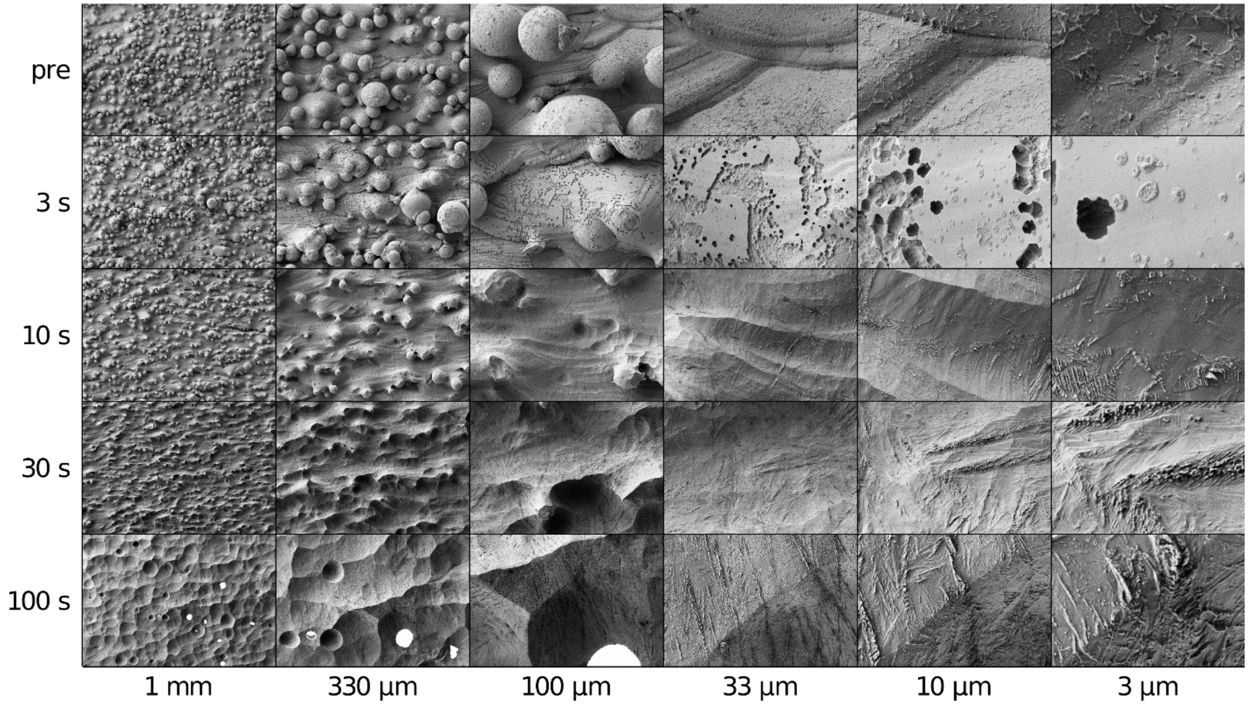
- Results



Processing conditions for Ti6Al4V

- Chemical etching at ETHZ
  - Etching using 40 wt.% Hydrofluoric acid (HF)

  $2Ti + 6HF \rightarrow 2TiF_3 + 3H_2(g)$



Acknowledgment for these results:
Jona Engel
laboratory for nanometallurgy

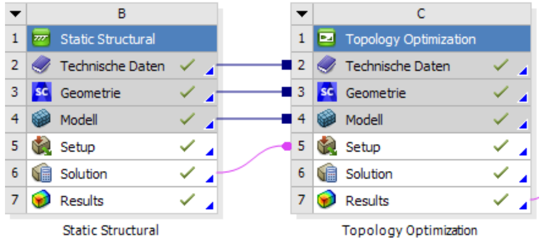
  - Longer etching tend to heat up the bath and increase the corrosive effect → need a temperature control for such reactions.

Topology Optimization using ANSYS

- **Topology optimization :** numerical method that leads to a material distribution maximizing the performance of the system for given loading scenarios.

Original geometry

- Considered loading scenarios :
  - Assembly of the component in a bigger mechanism
  - Normal use
  - Extreme use (3 directional shocks, relevant for a watch application)



- Constraint for optimization
  - Mass 35% to be left
  - Convergence : 0.10% (appeared to be the most successful vs. time)
  - Keep the functional areas unchanged (holes)

Max design space

- Optimization goal
  - Maximize stiffness
- Process:
  1. Clean up the part: from a complex design to a “maximal allowable design space”
  2. Define load cases (loading areas, shocks in all 3 directions, etc)
  3. Define additional geometrical constraints (ex : min. member size, regions to be left unmodified, mass to be retained, etc)

Optimized geometry

Key learning on Topology optimization

- Smallest detail of your manufacturing process is not necessarily the smallest detail of your optimization
  In this case: smallest for topology: 0.6mm

- Defining your manufacturing strategy before optimization helps
  In this case: A flat surface is always saved as contact with the build plate and EDM cut-off. Ensuring a good surface finish for further processing (milling)

- Use topology optimization options to fit manufacturing constraints and to enhance aesthetics (Fig. 1)
  In this case: the use of symmetry and “pull-out direction” in parts achieved more satisfactory results in terms of aesthetics design

- Implement extra dummy loadings to improve the obtained geometries (Fig. 2)
  In this case: A detail was not properly defined due to no solicitation, it was corrected with an extra load

- Topology optimization delivers solutions physically based on the considered load cases but can as well be used as a **design generator.**

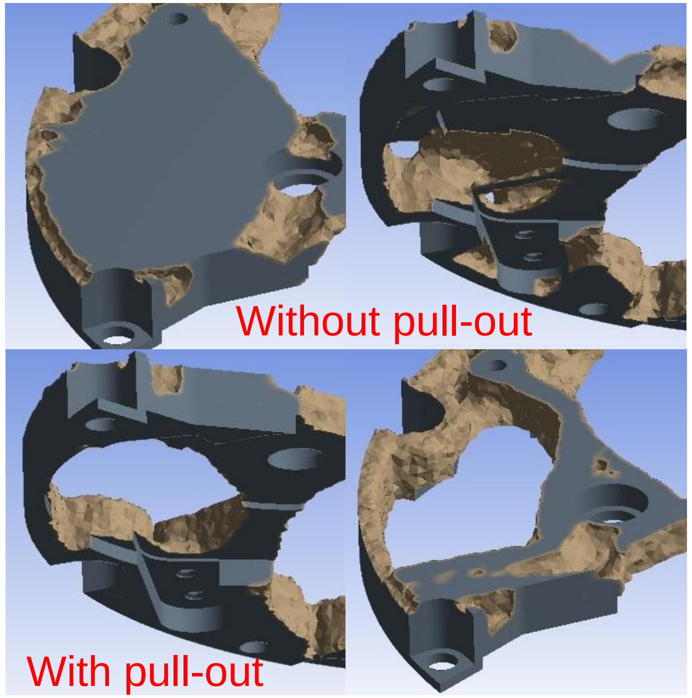


Fig. 1 : Pull-out direction

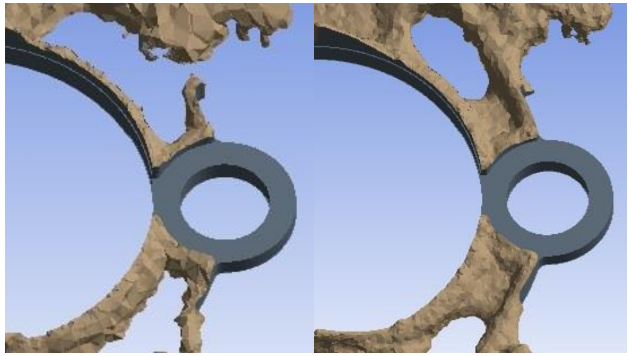
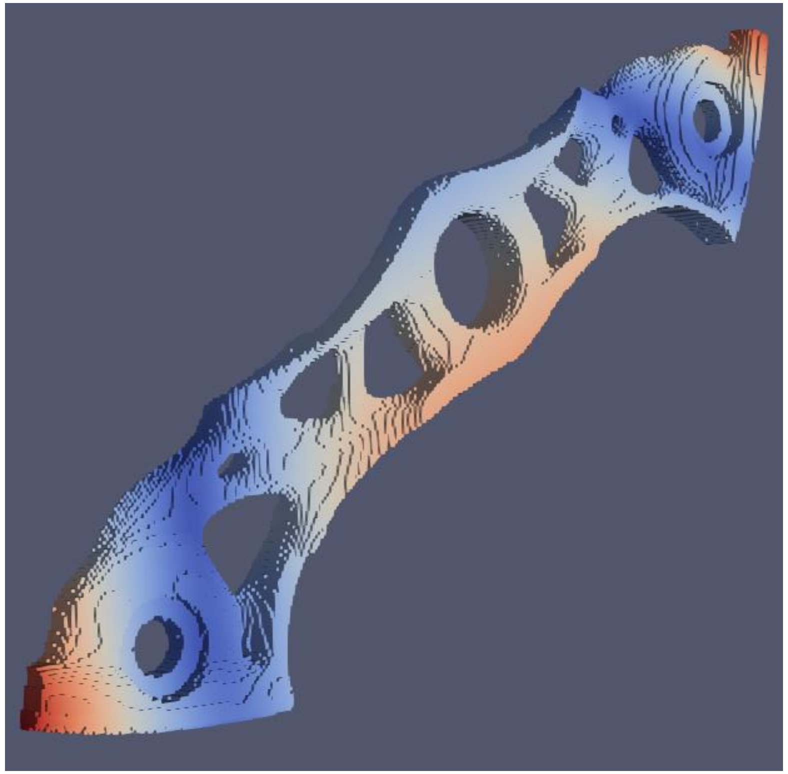


Fig. 2 : Geometry improvement thanks to additional mechanical loads

Additive Print with Ansys

- **Ansys Additive Print :** Powder Bed Fusion manufacturing simulation
  - Simulate the thermally induced distortions
  - Compensate for these distortions
  - Simulate different support strategies
  - Predict potential blade crash

- **Learnings :**
  - Even distortion patterns for microscale parts can be predicted
  - Order of magnitude of distortions for these parts is small
  - Predicting the effect of different support strategies can help with optimizing print setup
  - For decent detail resolution, longer calculation times (hours to days) need to be accounted for



Process simulation

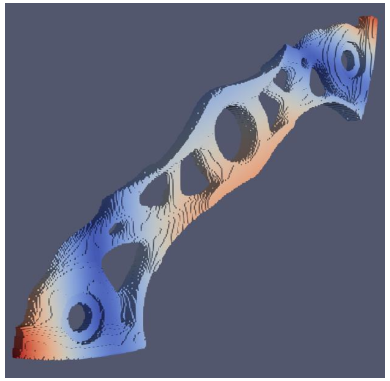
Demonstrator for topology optimization

Original geometry

Max design space

Optimized geometry

Smoothed geometry



Process simulation

Conclusion and Outlook

- Micro-scaled components have been redesigned using topology optimization and manufactured using SLM Process
- Remaining main challenges in SLM : surface roughness, part release, small details manufacturing
- Topology optimization is a great tool to achieve new design, even in less mechanically loaded parts
- The print process simulation can predict distortion patterns even at a microscale, but for a decent detail resolution a longer calculation time (hours to days) needs to be accounted for
- A good consortium is key: from software to final application – our consortium support all steps and aspects of the project.
- Further work necessary in the post processing side to achieve better surface finishing for such components

Thank you for your attention

Interested in such topics ? Get in touch !

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