METALLIC COMPLIANT STRUCTURES based on ADDITIVE MANUFACTURING (AM)

csem

Research and technology organization – CH Neuchâtel

Hervé Saudan, L. Kiener, K. Vaideeswaran, M. Dadras

3D PRECISION SA

Manufacturing of metal parts – CH Delémont

Dominique Beuchat, founder and CEO

AM PLATFORM

19th AM Platform meeting

General assembly

June 14th 2017

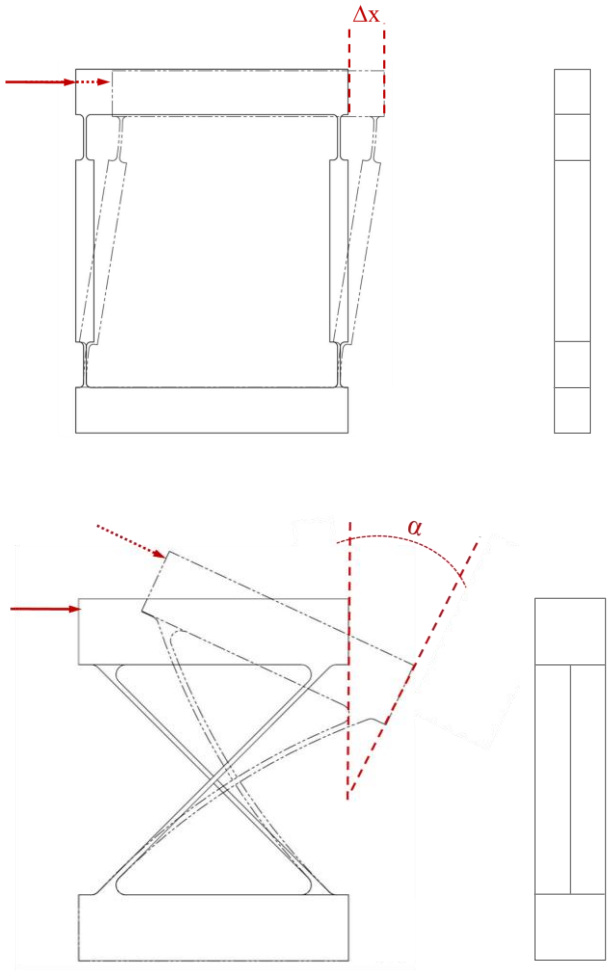
Presentation outline

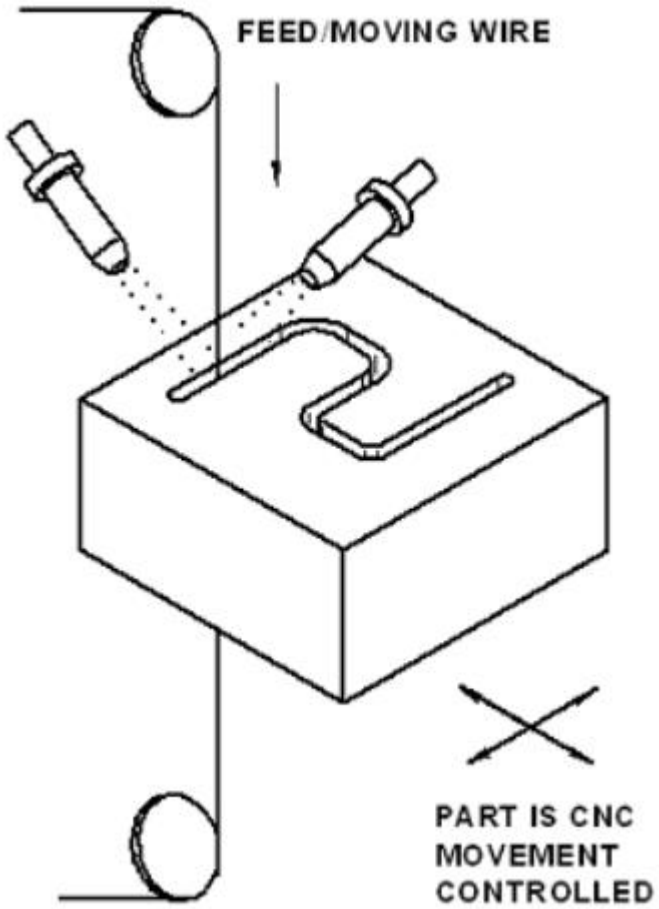
1. Why developing compliant structures based on AM?
2. How to tackle this challenge?
3. What are the most critical aspects?
4. What results were obtained?
5. What to conclude?

Why developing compliant mechanisms based on AM?

Main drawbacks of CMs

- Limited stroke
- Susceptibility to vibrations/shocks
- **WEDM process**
  - **design forced to pseudo 3D shapes**
  - **monolithic approach not straightforward**



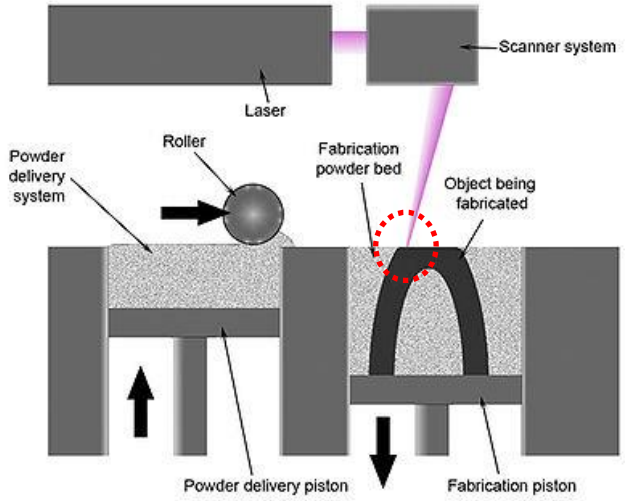


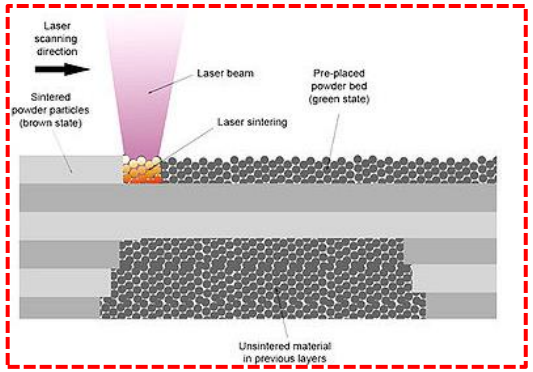
pictures source: http://www.engineersedge.com

What can we hope from CMs based on AM?

- **Increased design freedom**
  - ➢ Novel kinematic topologies
- **Optimized mass/stiffness**
  - ➢ Improved performances
- **Monolithic designs**
  - ➢ Reduced complexity, better reliability

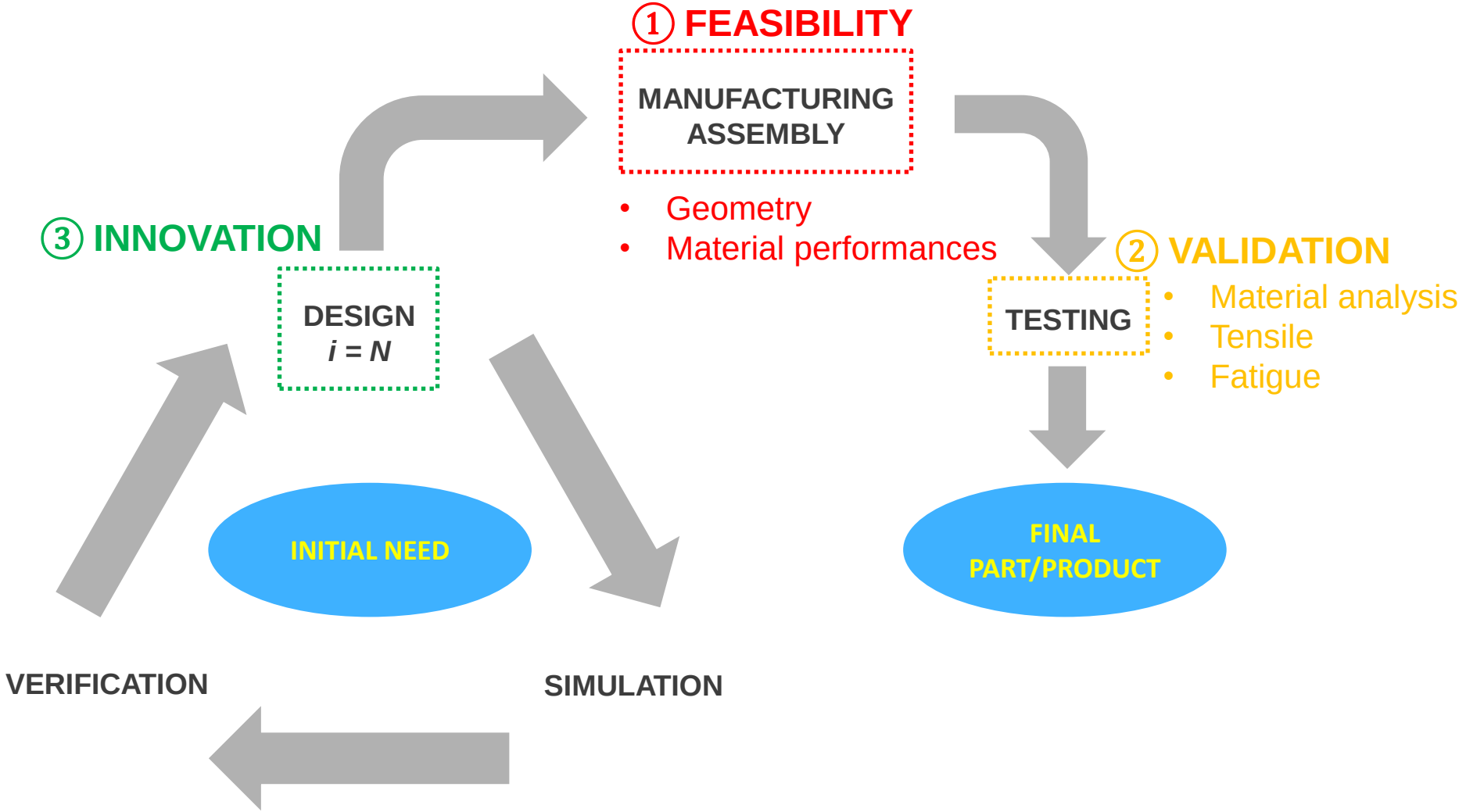
Selective **L**aser **M**elting (SLM)





schematic pictures source: Wikimedia

How to tackle this challenge?

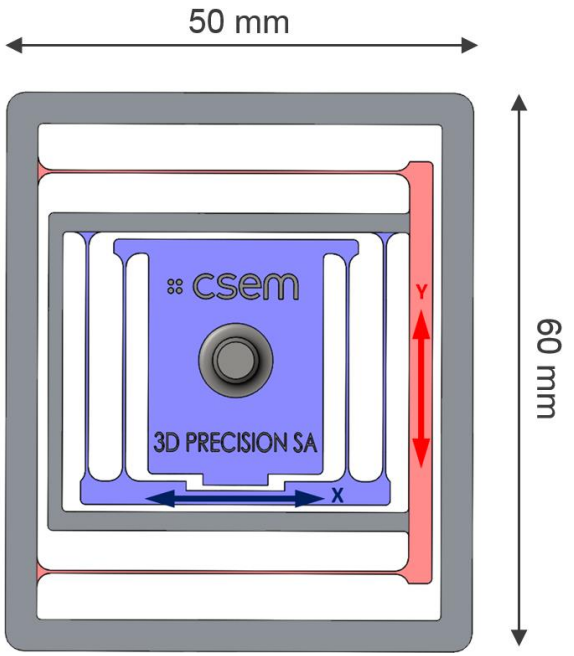


What are the most critical aspects?

- Identify the best alloy for application(s) foreseen
  - ➢ 17-4PH stainless steel equivalent

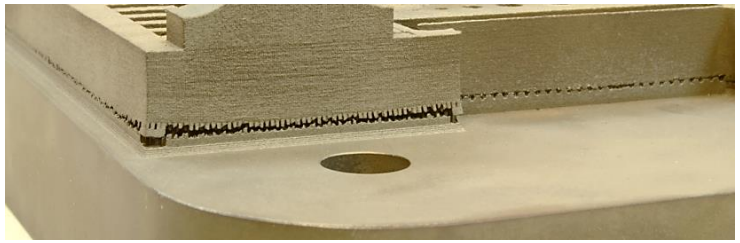
- Determine SLM parameters adapted to:
  - **Structure** segments in the centimeter range
  - **Flexure** segments thinner than 0.35 mm

- Determine post-process (thermal, mechanical)

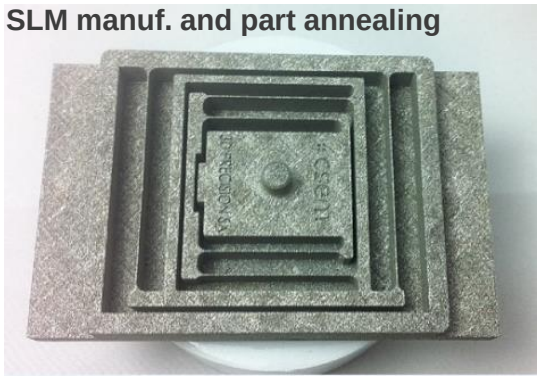


Lessons learned during feasibility

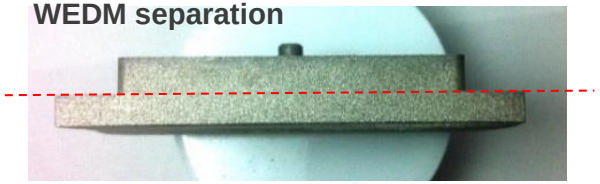
- SLM process induces thermal stress
  - Manufacture on a stiff substrate
  - Perform Stress relief annealing
- SLM parameters highly critical

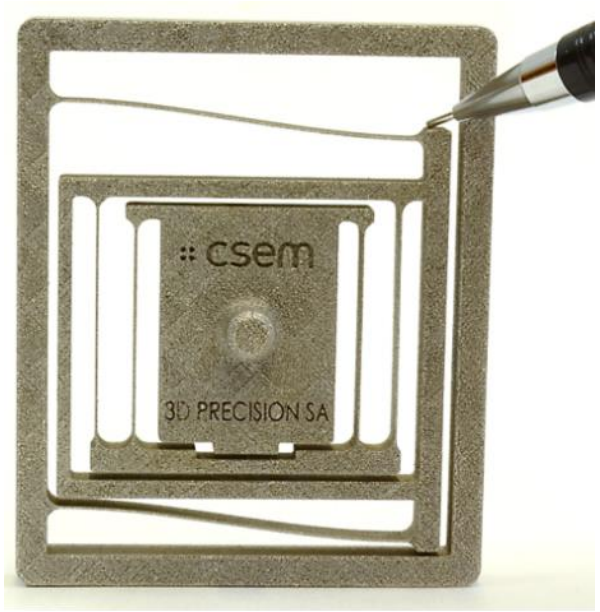


SLM manuf. and part annealing



WEDM separation

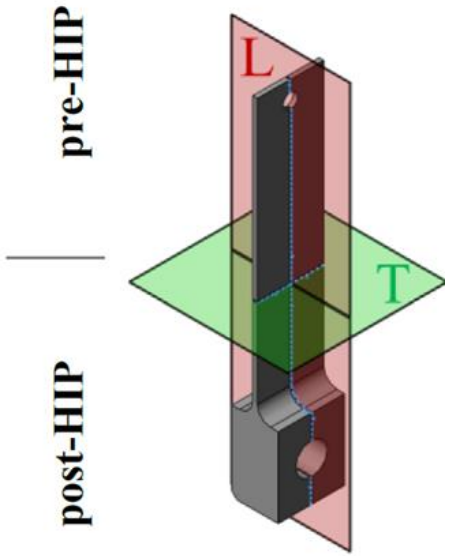


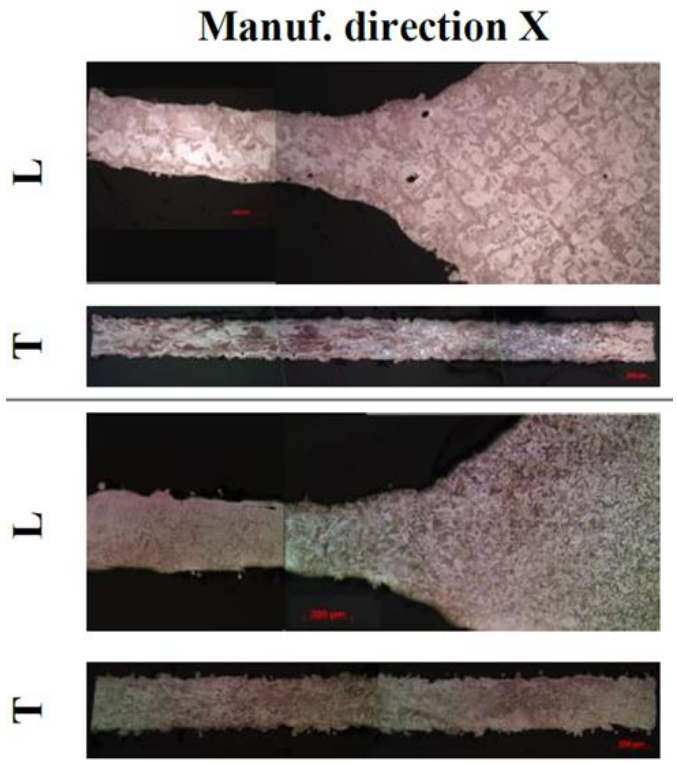


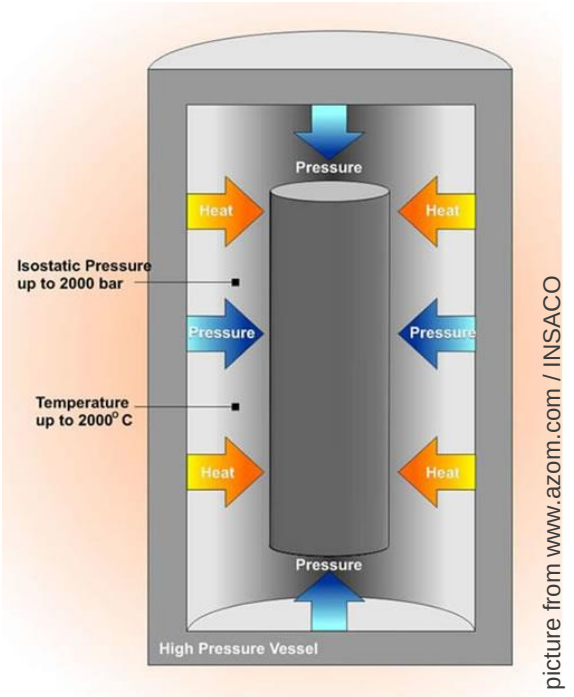
Lessons learned during feasibility

- **Laser pattern strategy =** main success maker
- Laser focus + power + scan speed also precisely tuned
- Residual porosity → requires **HIPing post process**

HIP post processing results







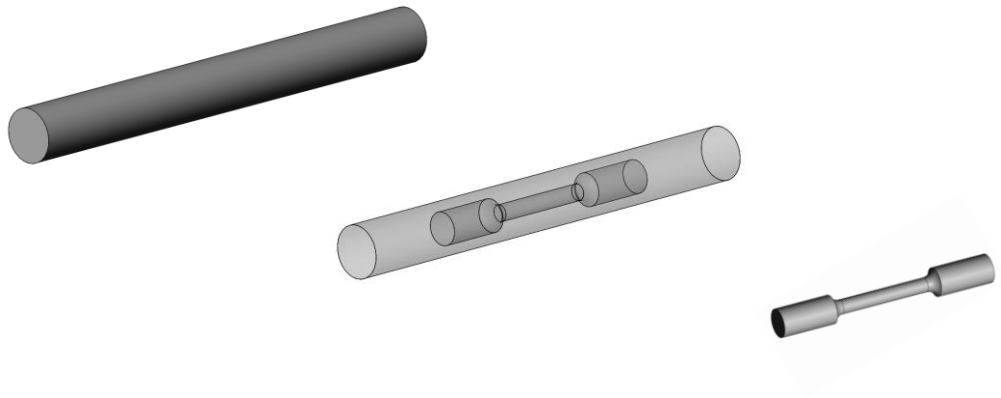
✓ Residual porosity removed

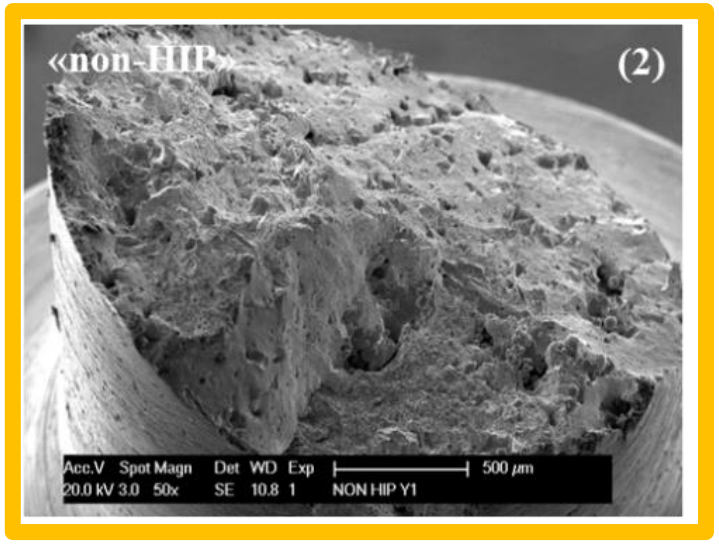
✓ Improved micro-structure

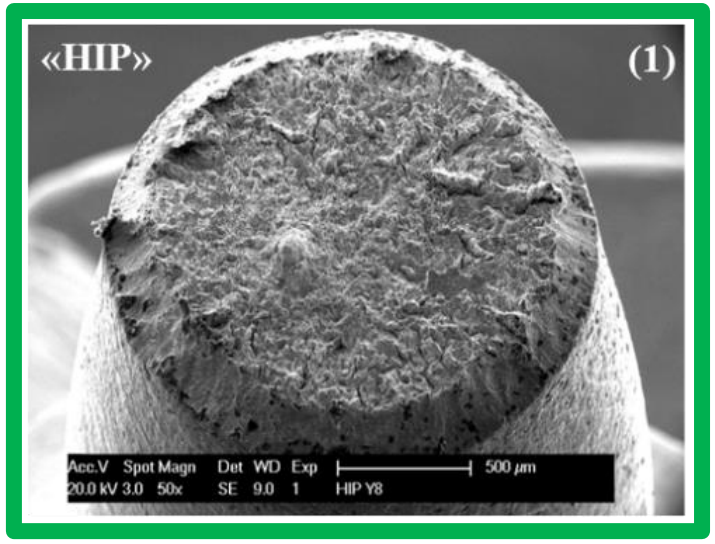
😐 Warpage observed on larger samples (plates)

Tensile tests results

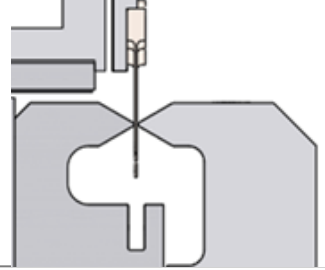
TENSILE TESTS RESULTS			17-4PH Böhler	CL92PH X-Y-Z mean values ±1σ	
Material heat condition - Solution Annealed (*SA*) - Age Hardened (*AH*)			*SA / AH*	**NO HIP**	**HIP**
UTS	Rm	N/mm^2	1170	1412±32	1415±18
Yield strength	*Rp0.2*	N/mm^2	1070	1034±43	1335±21
Elongation	A_5	%	8	3.1	9

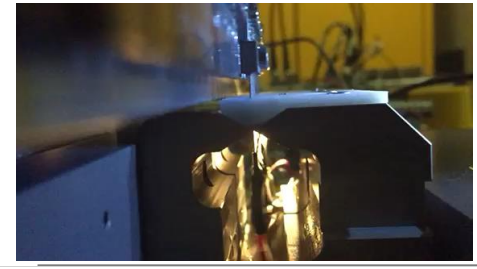


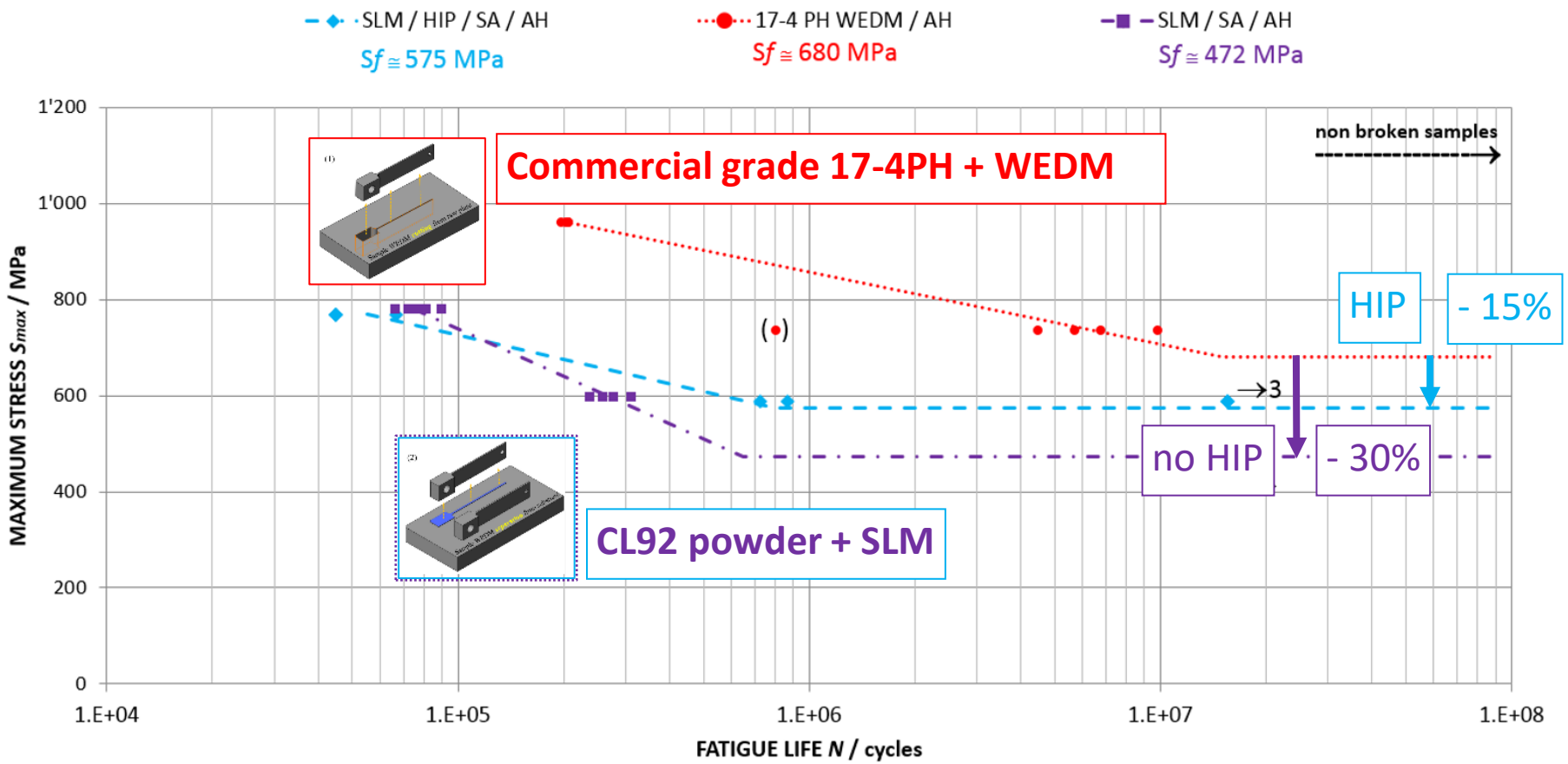


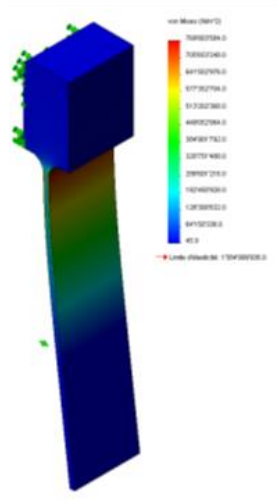


Fatigue test results – S-N curves estimates









What to conclude?

- Feasibility successfully proven
- Material performances validated, ok for most applications
- SLM-induced thermal stress to be addressed
- HIP treatment improves material performances
- HIP induce warpage for “large” parts
- **Study to be continued (accuracy, cases, …)**

THANK YOU FOR YOUR ATTENTION

csem

3D PRECISION SA