



ADDITIVE MANUFACTURING OF COMBUSTION PARTS AT SAFRAN HE

September, 28th 2017



Summary

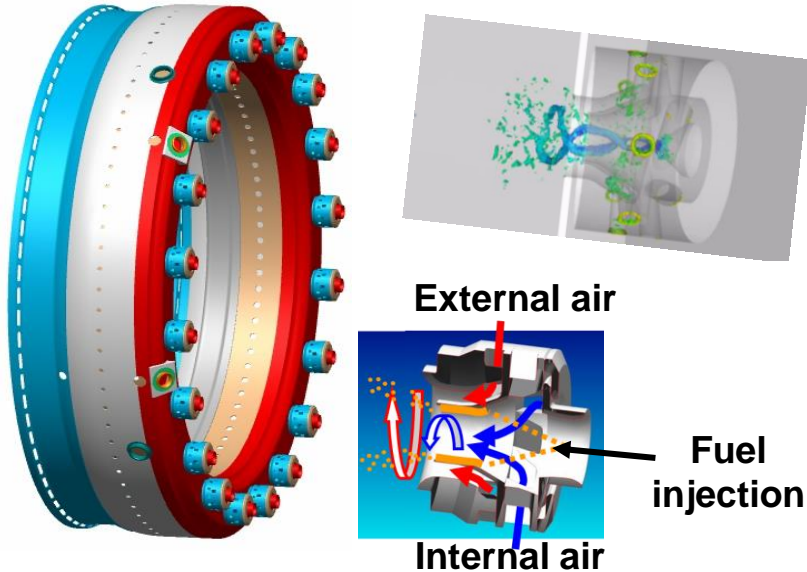
- 1. Presentation of AM combustion parts**
- 2. MASTERING the quality of SLM parts**
- 3. Conclusions**



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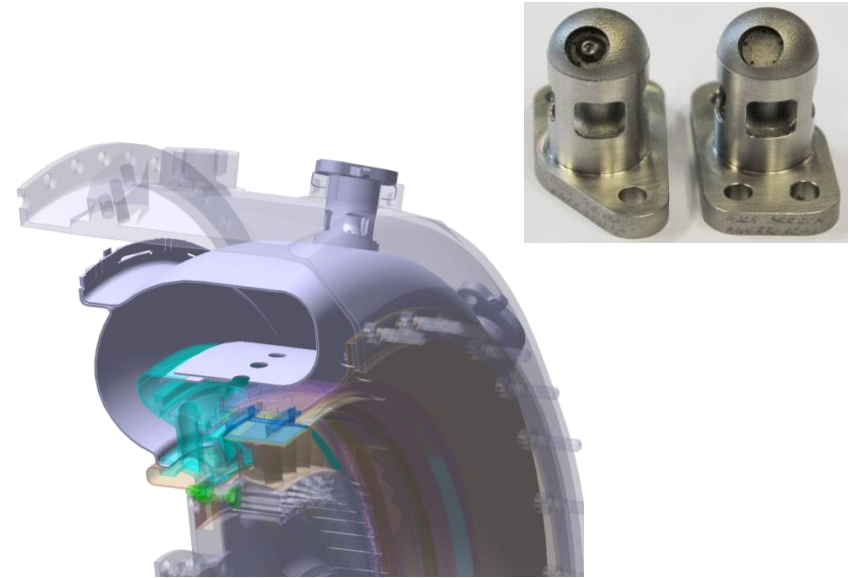
PRESENTATION OF AM COMBUSTION PARTS

AM Combustions parts – Low stresses, Low criticality in the sense of AMC E510



Ardiden swirlers

- Simplification of the design
- Reduction of the number of assemblies
- Better repeatability of the flow section



Arrano Fuel injectors

- Improvement of the design
- This part can only be manufactured with AM



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MASTERING THE QUALITY OF SLM PARTS

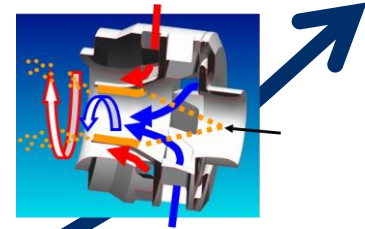
Part validation process



Material Evaluation

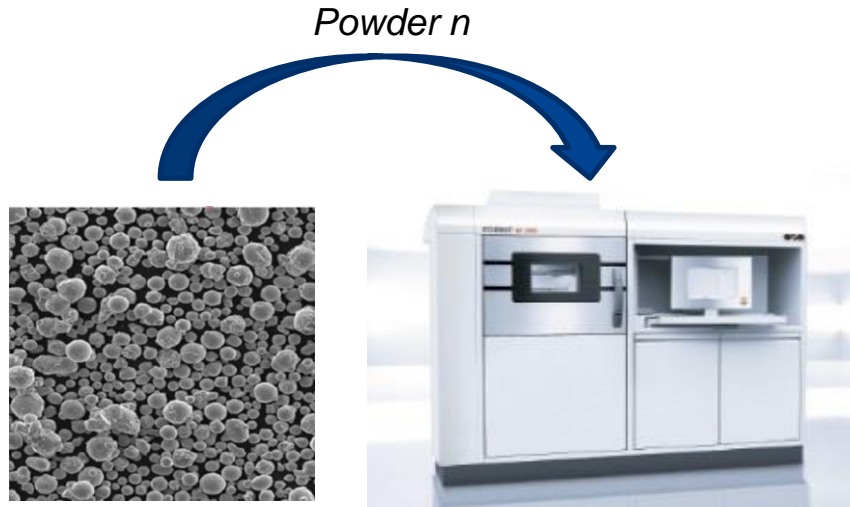


Machine / process Qualification



Part Validation

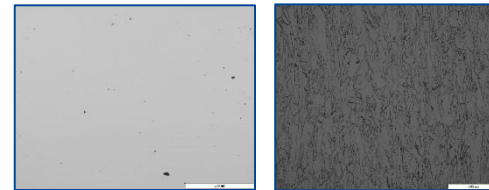
Material evaluation



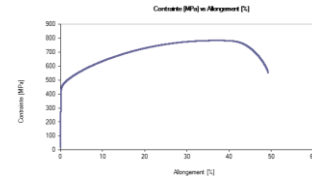
Parameters frozen



Samples : Mechanical and metallurgical evaluation

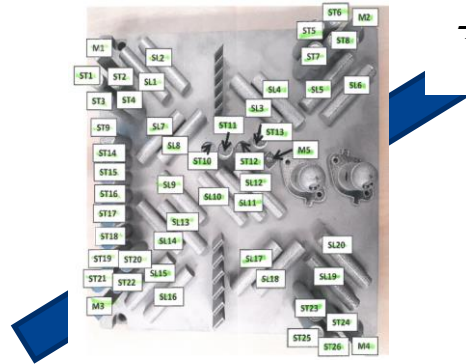
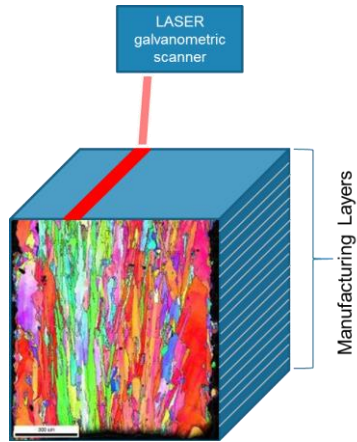


Metallurgical evaluation



Mechanical characterization

Material evaluation – Strategy

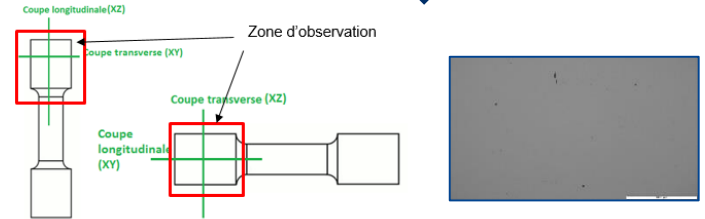


Example of manufacturing plate with mechanical and metallurgical test samples

Heat treatment
→ reduce / remove anisotropy



Mechanical tests performed on horizontal and vertical samples



To ensure correlation between metallographic criteria and mechanical properties, analyses performed in the heads of each mechanical sample

As for other elaboration process, anisotropy could be induced by SLM process

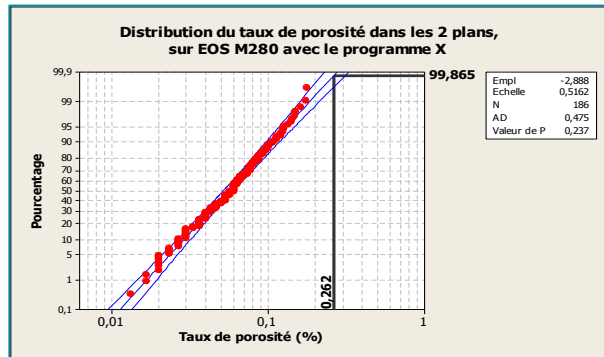
Material evaluation – Metallurgical results



Example of metallography on Hx SLM

Analyses performed on samples all over the manufacturing plate

Porosity rates, size of linear and spherical indications were evaluated through image analysis of metallographic samples.

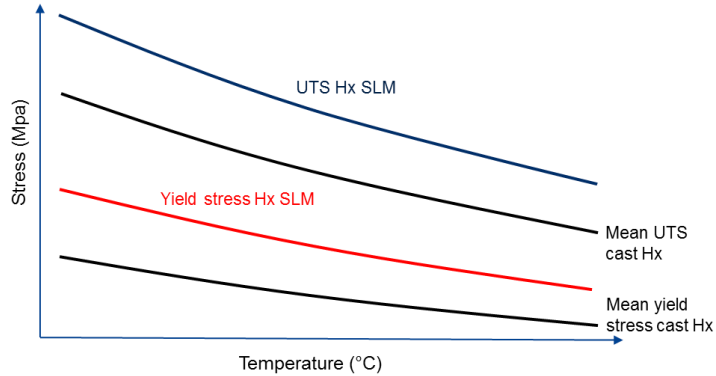


Example of normal distribution evaluated for porosity rates

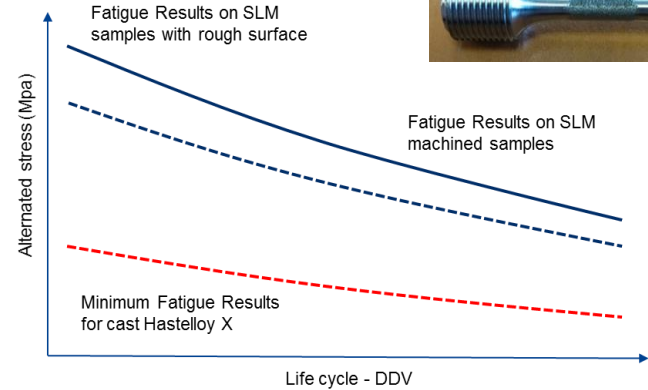
These analysis allow to determine maximum size and amount of indications that are statistically representative of the metallurgical soundness :

- ◆ Spherical pores < 50µm
- ◆ Linear indications < 100µm
- ◆ Porosity rates < 0,25%

Material evaluation – Mechanical results



Tensile properties

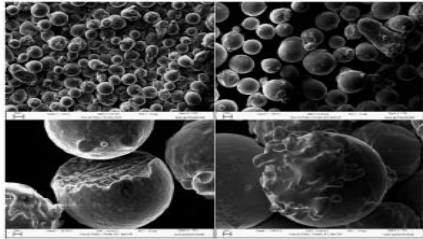
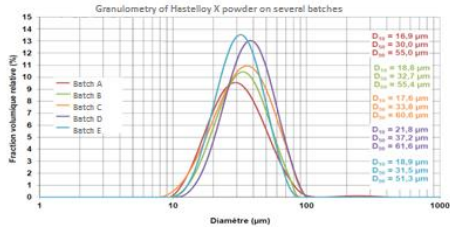


Fatigue properties on Machined and rough Hx SLM samples

Mechanical tests performed to evaluate :

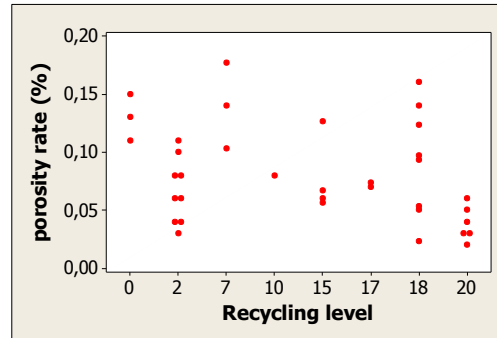
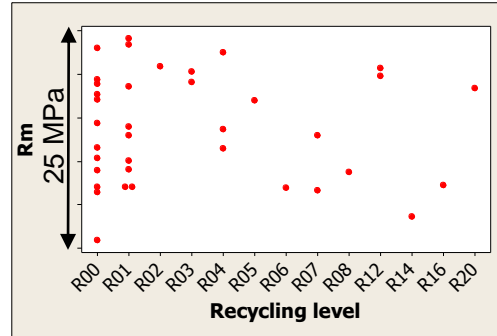
- Tensile properties
- Fatigue properties including with higher surface roughness

Material evaluation – Recycling and powder characterization



Manufacturing of samples

Powder characterization at different recycling levels (Granulometry, Chemical composition, Morphology, ...)



- Parameters frozen
- Powder from different batches, recycling levels
- ➔ No impact on metallurgical and mechanical properties

These analyses also allow to validate :

- A set of manufacturing parameters

That allow to obtain

- Robust and repeatable mechanical properties
- Robust and repeatable metallurgical properties

Powder and SLM material specifications have been written to ensure this robustness

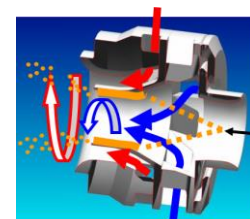
Part validation process



Material
Evaluation

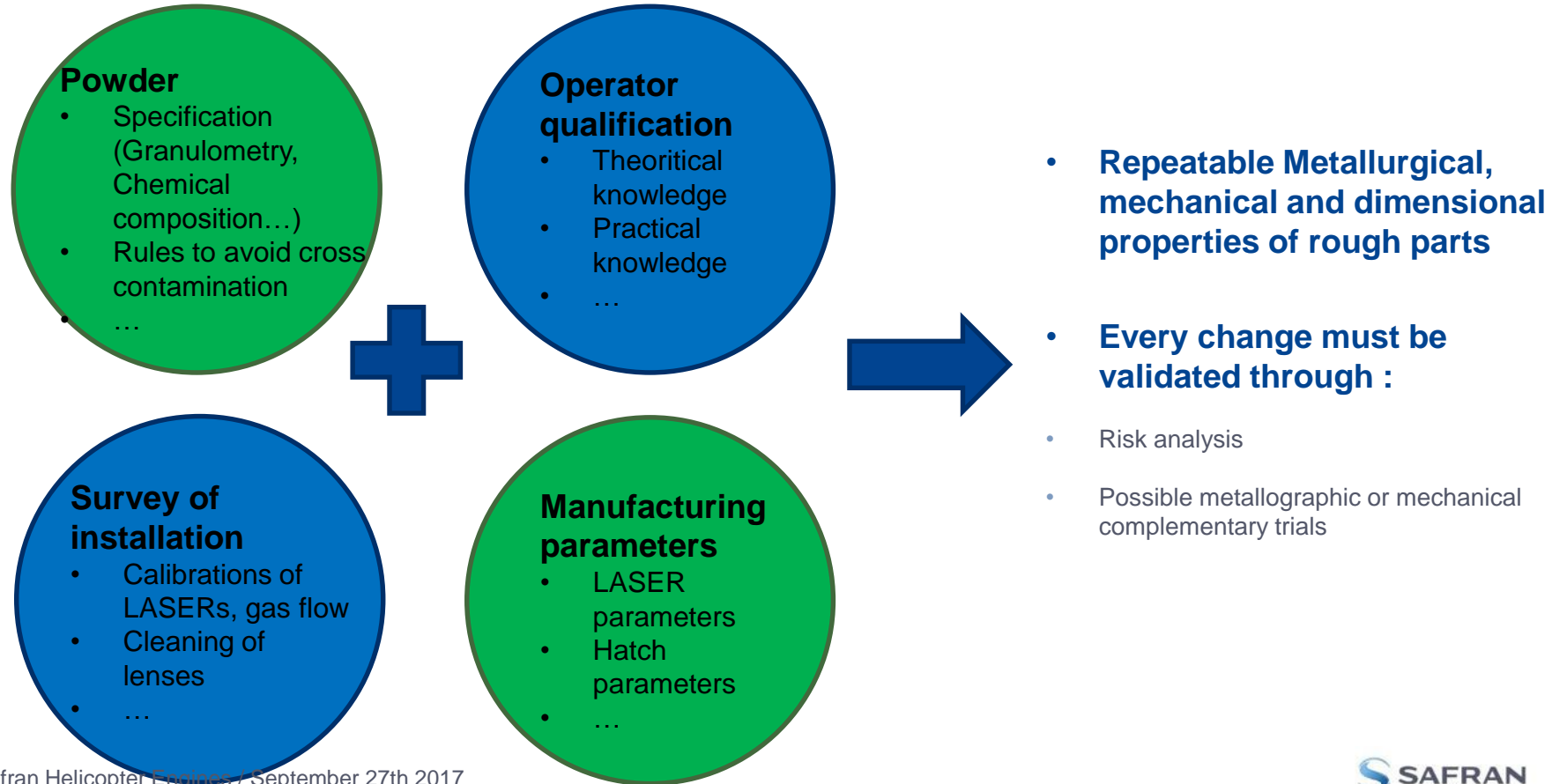


Machine / process
Qualification



Part
Validation

MACHINE / PROCESS QUALIFICATION



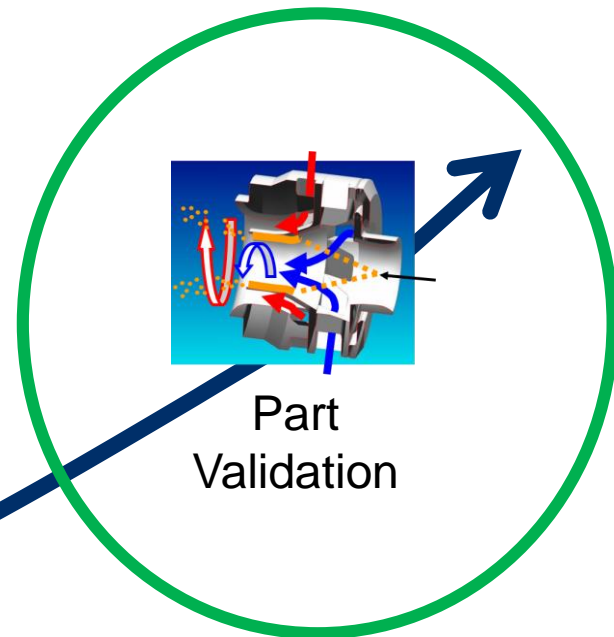
Part validation process



Material
Evaluation



Machine / process
Qualification



Part
Validation

Going to serial production – How to ensure the quality of the parts ?

- **Using parameters and environment validated and qualified**

- Installation and operators qualified
- Powder validated
- Frozen manufacturing parameters

- **First part validation**

- Appropriate NDT
- Metallurgical analysis on part cuts
- Dimensional analysis
- NDT

- **Serial inspections to detect every deviation**

- NDT
- Dimensional analysis
- Metallurgical inspection of coupons
- Tensile tests



Example of the manufacturing plate for Injectors. The position of parts is frozen

SLM IS A SPECIAL PROCESS and is validated accordingly



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CONCLUSIONS

Conclusions

In the context of the certification memo CM-S-008, as required by the EASA, two kind of part using additive manufacturing is today certificated within SAFRAN HELICOPTER ENGINES:

- ◆ On ARDIDEN 1H1 and ARDIDEN 3G engine (engine already certificated) : Swirlers
- ◆ On ARRIEL 2 engines series (all variants - engine already certificated) cooling inserts in gas generator nozzle guide vanes

The following parts will be also developed in the frame of current engine development:

- ◆ On ARRANO 1A engine (to be certificated by end 2018): Combustion chamber fuel aerodynamic injectors, and cooling inserts in gas generator NGV

All those parts are made of Hastelloy X



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