HELICOPTER ENGINES

ADDITIVE MANUFACTURING OF COMBUSTION PARTS AT SAFRAN HE

September, 28th 2017

SAFRAN

Summary

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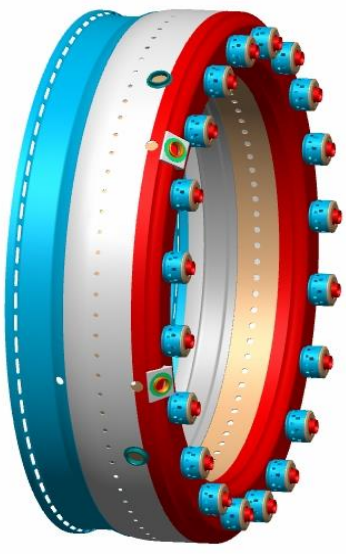
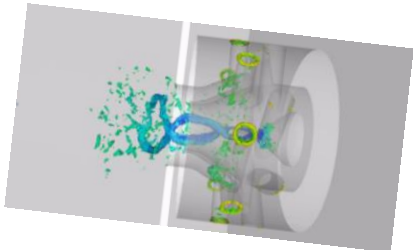
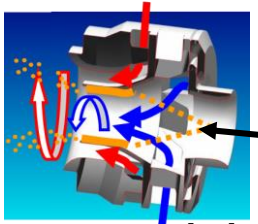
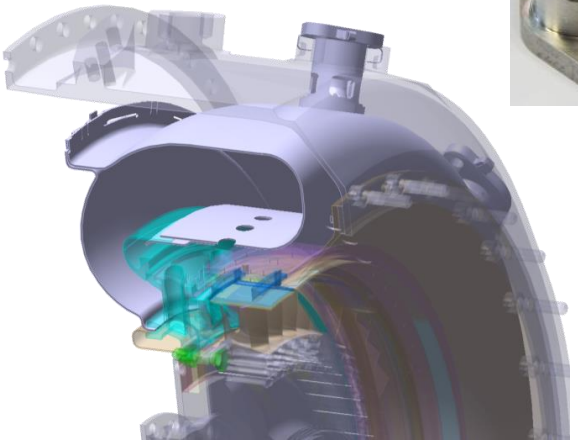
PRESENTATION OF AM COMBUSTION PARTS

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









Ardiden swirlers

- Simplification of the design
- Reduction of the number os assemblies
- Better repeatitivity of the flow section

Arrano Fuel injectors

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

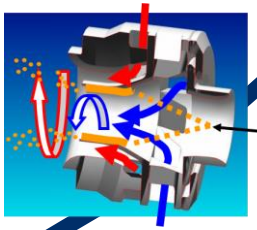
2

MASTERING THE QUALITY OF SLM PARTS

Part validation process

Material
Evaluation

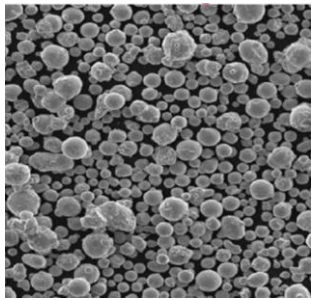
Machine / process
Qualification



Part
Validation

Material evaluation

Powder n

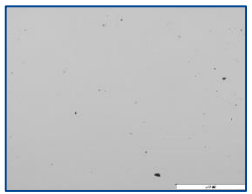


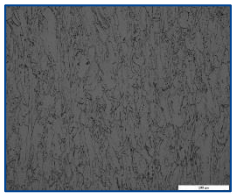
Powder n+1

Powder characterization

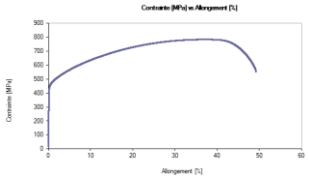
Parameters frozen

Samples : Mechanical and metallurgical evaluation



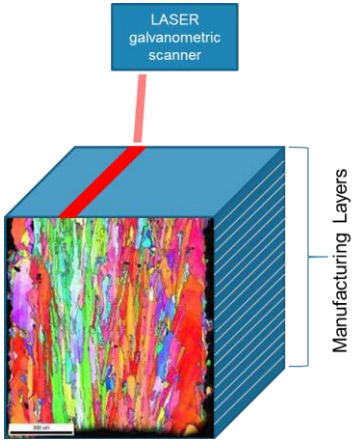


Metallurgical evaluation

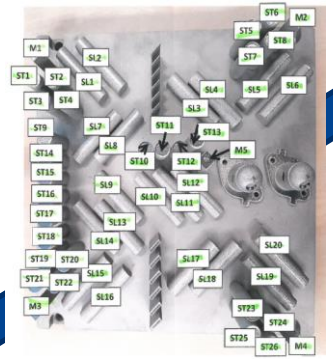


Mechanical characterization

Material evaluation – Strategy



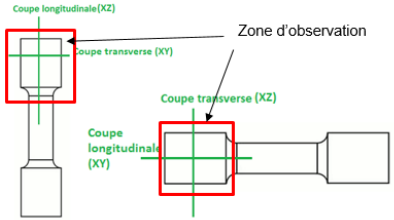
As for other elaboration process, anisotropy could be induced by SLM process



Example of manufacturing plate with mechanical and metallurgical test samples

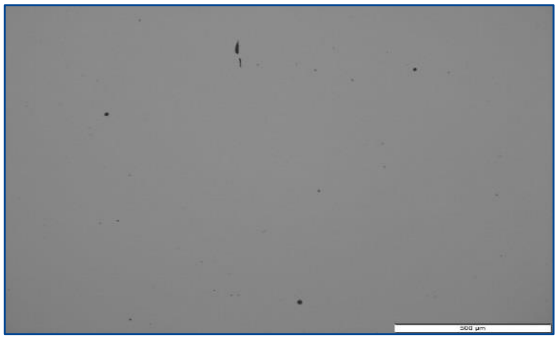
Heat treatment
→ reduce / remove anisotropy

Mechanical tests performed on horizontal and vertical samples

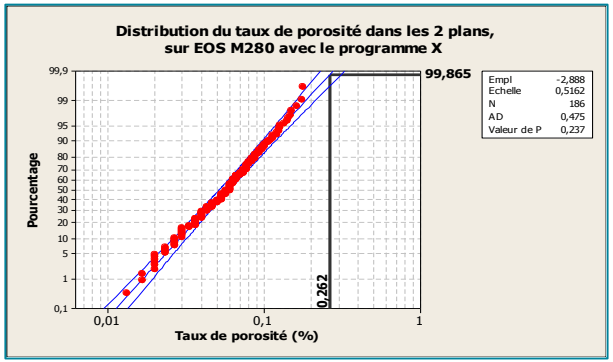


To ensure correlation between metallographic criteria and mechanical properties, analyses performed in the heads of each mechanical sample

Material evaluation – Metallurgical results



Example of metallography on Hx SLM



Example of normal distribution evaluated for porosity rates

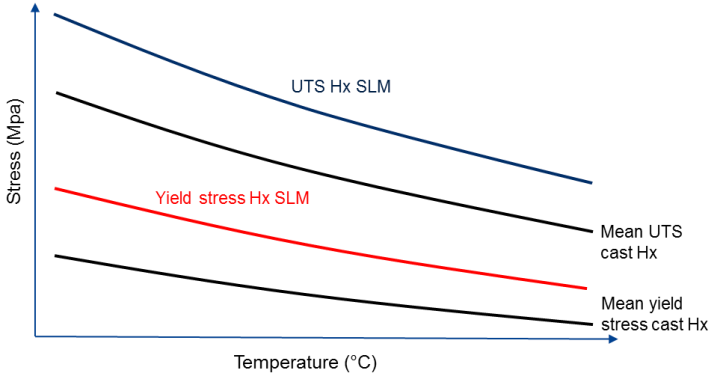
Analyses performed on samples all over the manufacturing plate

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

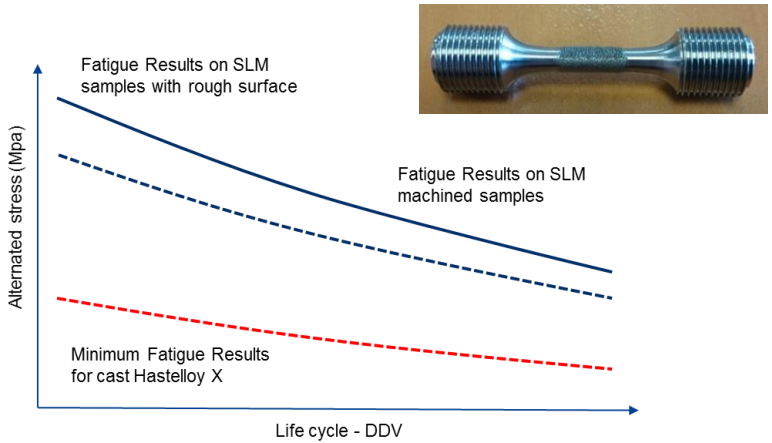
These analysis allow to determine maximum size and amount of indications that are statistically representative of the metallurgical soundness :

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

Material evaluation – Mechanical results



Tensile properties

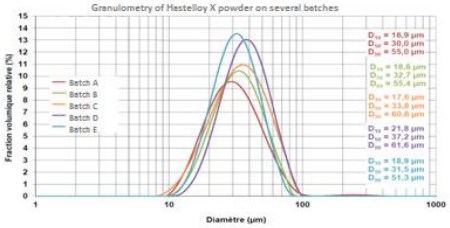


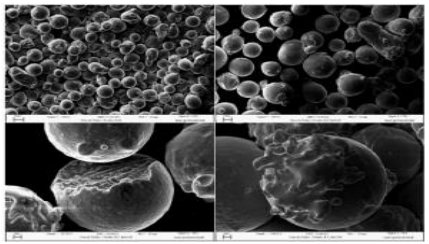
Fatigue properties on Machined and rough Hx SLM samples

Mechanical tests performed to evaluate :

- Tensile properties
- Fatigue properties including with higher surface roughness

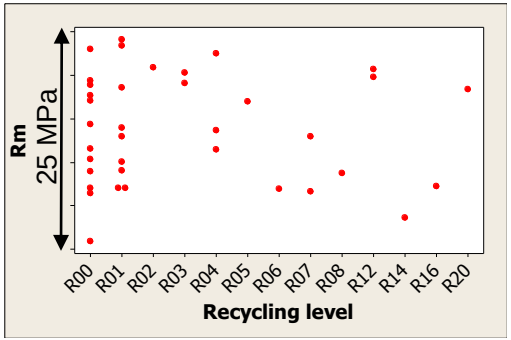
Material evaluation – Recycling and powder characterization

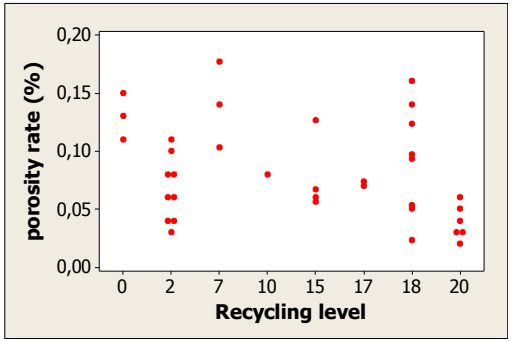




Powder characterization at different recycling levels (Granulometry, Chemical composition, Morphology, …)

Manufacturing of samples





- **Parameters frozen**
- **Powder from different batches, recycling levels**

➔ **No impact on metallurgical and mechanical properties**

Material evaluation

These analyses also allow to validate :

- A set of manufacturing parameters

That allow to obtain

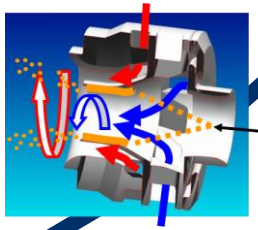
- Robust and repeatable mechanical properties
- Robust and repeatable metallurgical properties

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

Part validation process

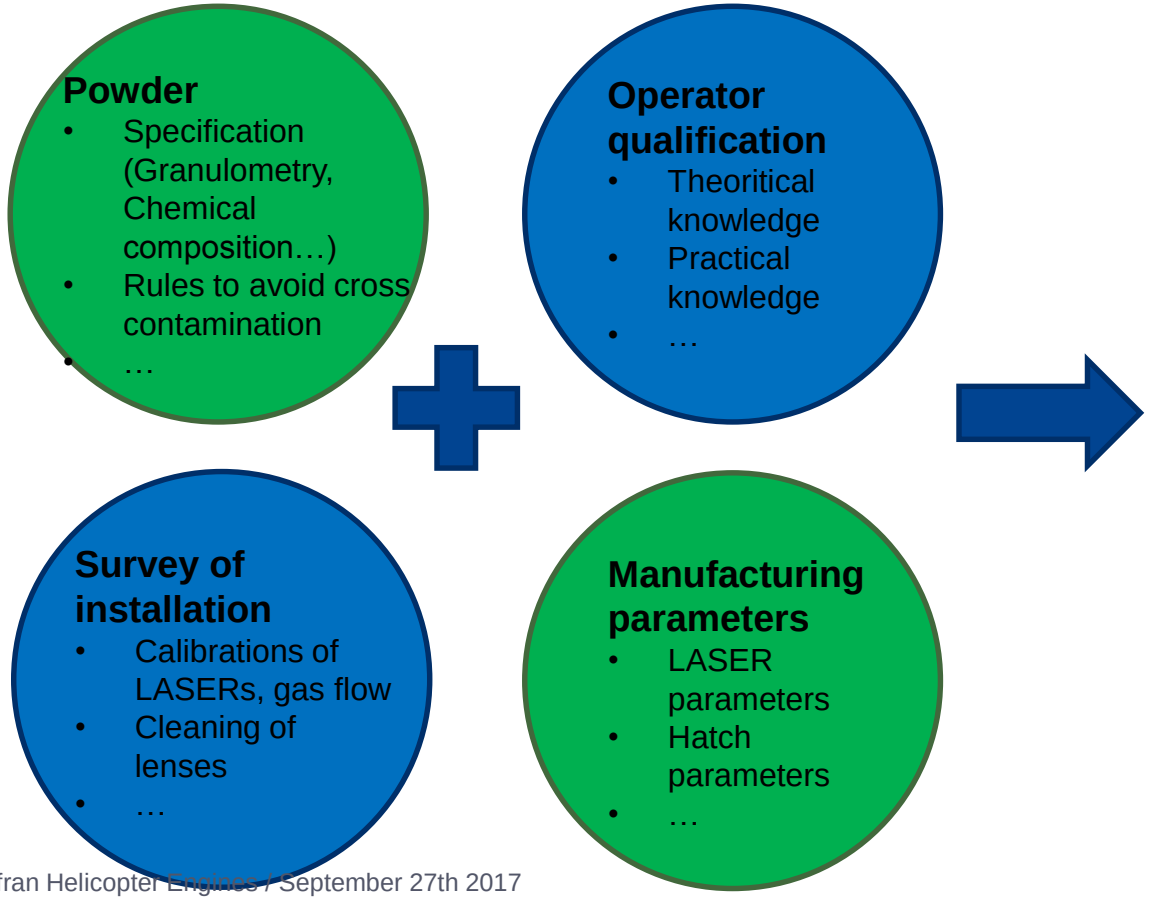
Material
Evaluation

Machine / process
Qualification



Part
Validation

MACHINE / PROCESS QUALIFICATION

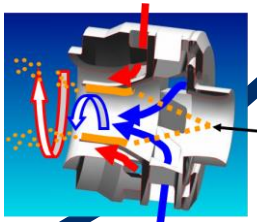


- **Repeatable Metallurgical, mechanical and dimensional properties of rough parts**
- **Every change must be validated through :**
  - Risk analysis
  - Possible metallographic or mechanical complementary trials

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**
  - Apropriate 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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