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Influence on surface characteristics of Electron Beam Melting process (EBM) by varying the process parameters

A. Dolimont, S. Michotte, E. Rivière-Lorphèvre, F. Ducobu, S. Vivès, S. Godet, T. Henkes and E. Filippi

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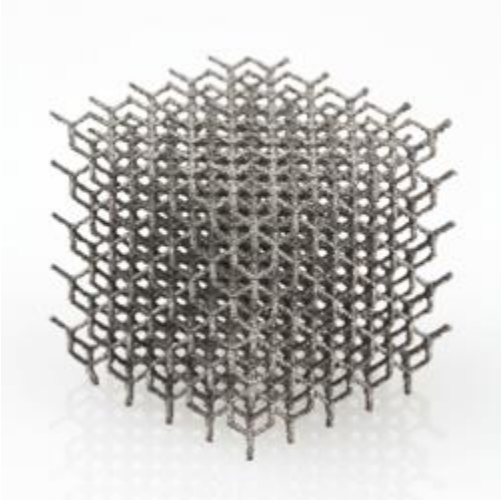
CHARACTERIZATION SYNTHESIS 4M AT RECYCLING ENGINEERING

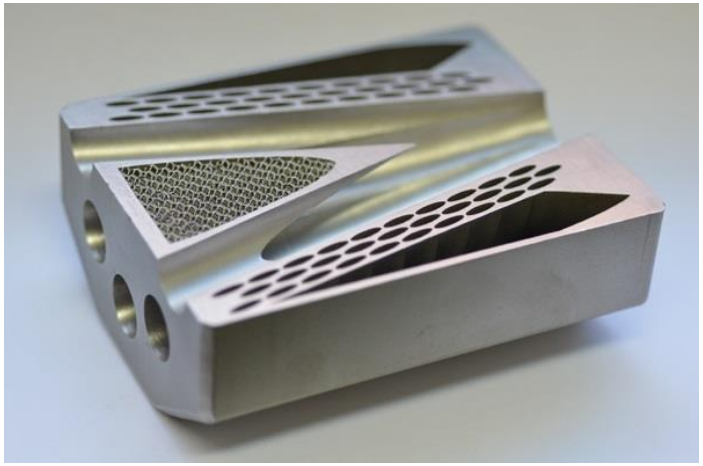
sirris
driving industry by technology

SAFRAN

Context

- AM ➔ booming field
- Rapid prototyping to production of “real” parts with required mechanical properties
- Layer by layer process
- Complexity for free





Context

- Electron Beam Melting (EBM)
- Mechanical applications ➔ contact application

solid-solid (prosthesis)

fluid-solid (turbomachine)

The roughness is high and therefore it is necessary to finish the part in such applications.

- ➔ from Ra = 25 µm to Ra = 1.6 -> 0.1 µm

Goals

- Functionality of parts build by EBM process
- Finished parts: geometrical and dimensional tolerances

- EBM Process : Process characterization (metrological analysis)
  Dimensional characterization
  Surface characterization

- Mechanical behavior of parts before and after finishing operation
  - Residual stresses
  - Static behavior
  - Etc.

Is it possible to improve surface finish by varying process parameters (scan speed, FO, beam current, etc.)?

Outline

1. EBM Process
2. Experimental procedure
3. Statistical Analysis
4. Surface characterization

EBM Process

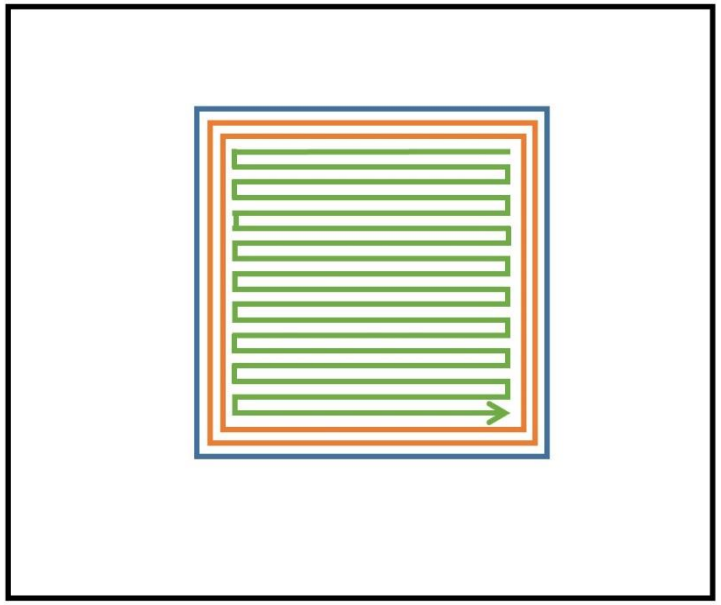
- Technologie ARCAM
  - In the early 2000's
  - Electron Beam Melting

- Layer by layer process which allows to build fully dense parts from metallic powder

EBM Process

At each layer : 3 steps

1. Pre-heating (750° C)
   - Non-focused beam , all the build surface (pre-heating 1)
   - The smaller area (pre-heating 2)
2. Contour melting (focused beam)
   - Outer contours
   - Inner contours
3. Core melting (focused beam)



Core Melting

Experimental procedure

Samples manufacturing

- **3 batches were fabricated by ARCAM A2**
- **Modification of the parameters :**

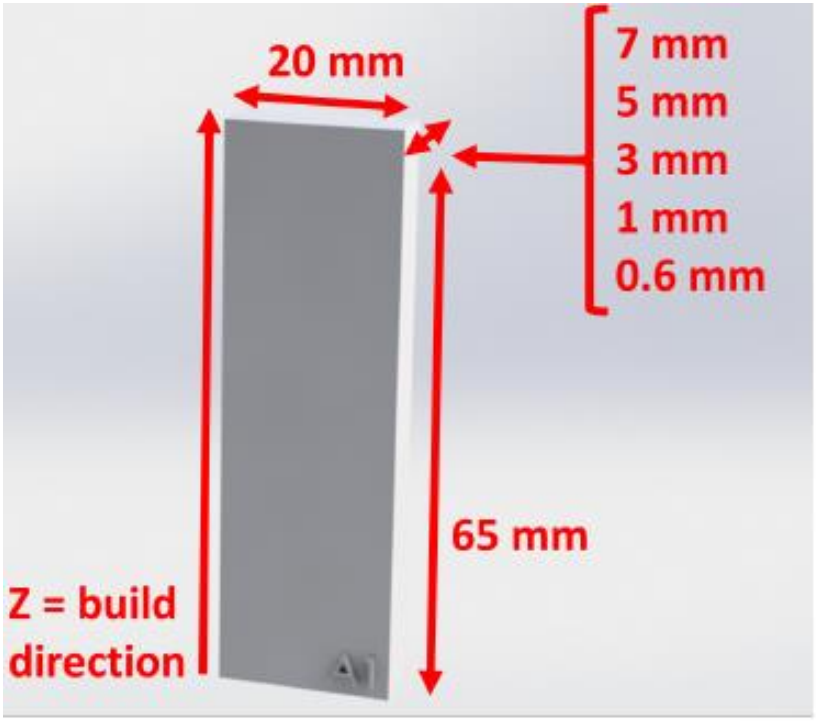
$$density\ E\ = \frac{60kV\ *\ current\ I}{spot\ size\ d\ *\ speed\ v\ *\ layer\ thickness\ t}$$

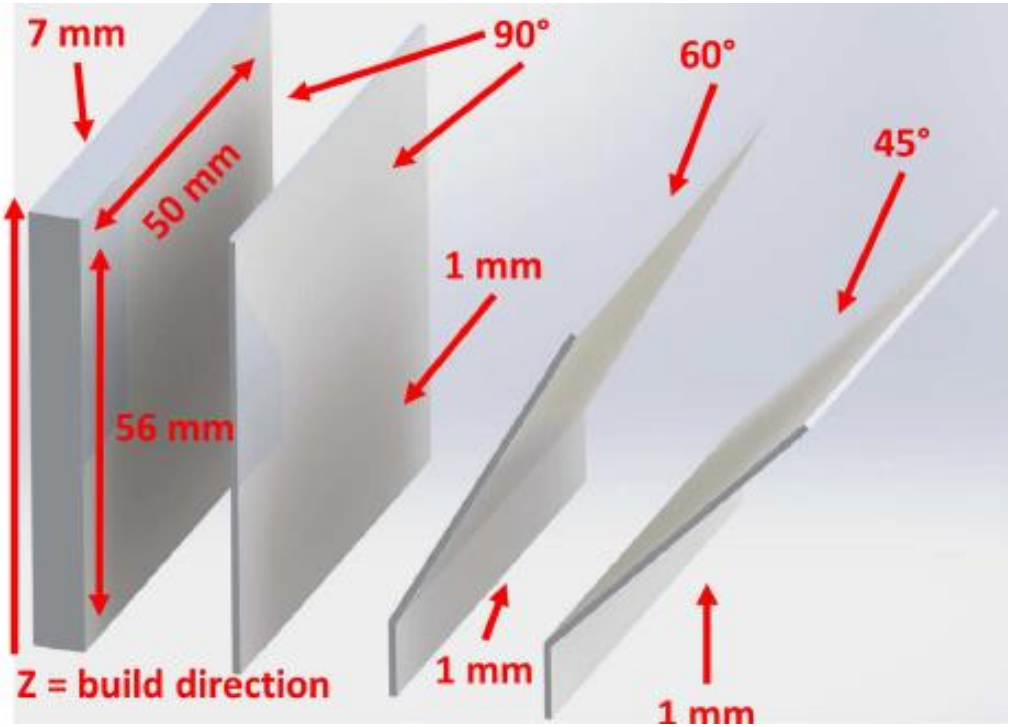
- Layer thickness : 50 µm
- On each batch at least 1 part with a set of standard parameter optimized for 50µm
- For other parts :
  - Speed function
  - Number of contours
  - Order of contours
  - Etc.

Modification of the energy density :
To compare the energy density, the proportional energy is define
(in this study the energy vary from 0.3 to 3.9 the standard value)

Samples manufacturing

- Parallelepiped rectangle with different thicknesses built along z direction and different inclination

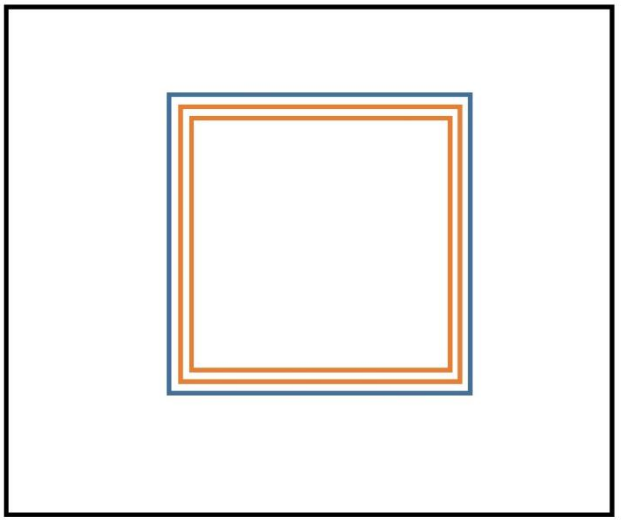


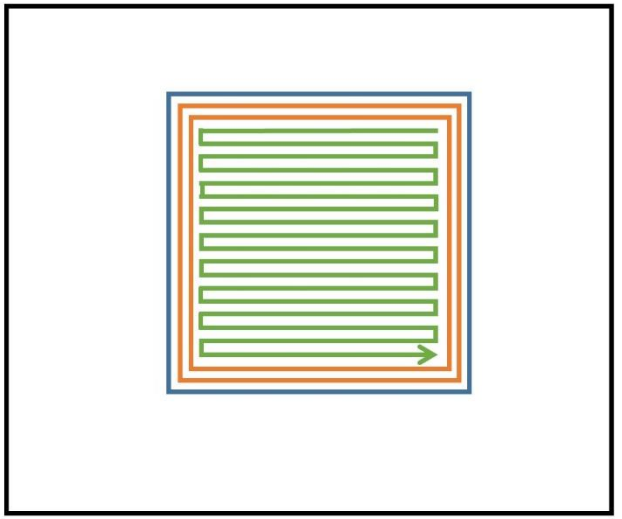


- Material : Ti6Al4V

Samples manufacturing

- **Batch 160202:**
  - Parameters linked to outer contours
  - Modification of parts thickness
- **Batch 160229:**
  - Parameters linked to outer contours
  - Modification of parts inclination (30°, 45°, 60°)
- **Batch 160318:**
  - Core melting parameters
  - Modification of parts inclination (30°, 45°, 60°)

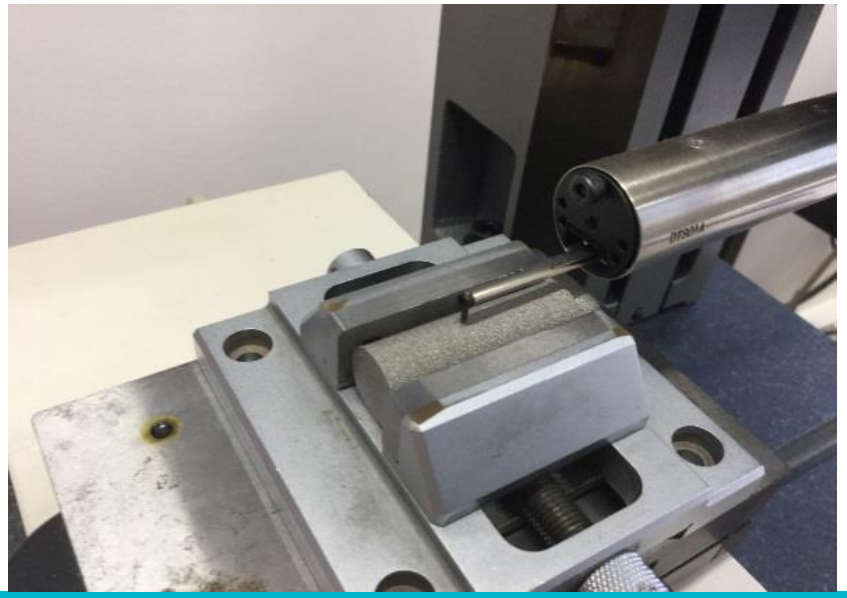




Experimental setup and method

- Characterization of the surface finish
- ISO 4288 standard
- Measuring equipment : SURFCOM 1400D-3DF

Focus on Ra and Rt values
3 measures conducted on each face of the sample.



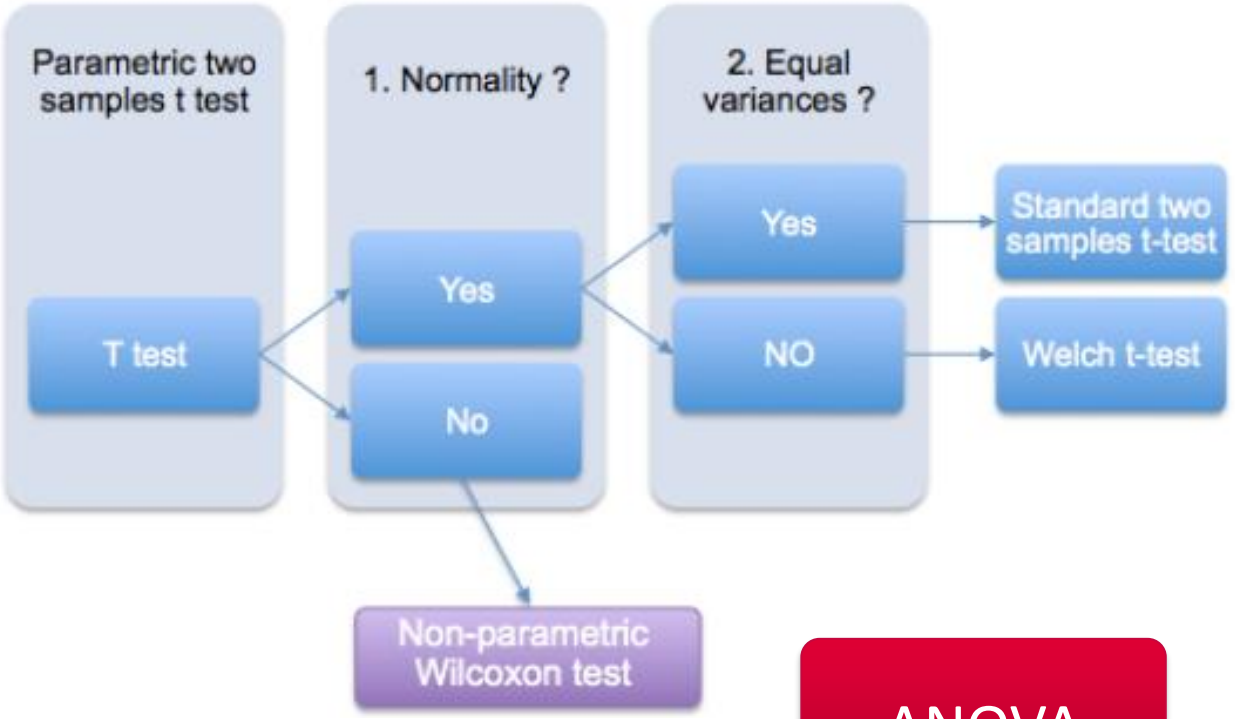
Statistical analysis

Statistical Analysis

- **Goal of a statisitical test:**

  Reject or not a hypothesis formulated on one or more sample (s)

- **Comparison of 2 samples:**



- **Comparison of K samples:**

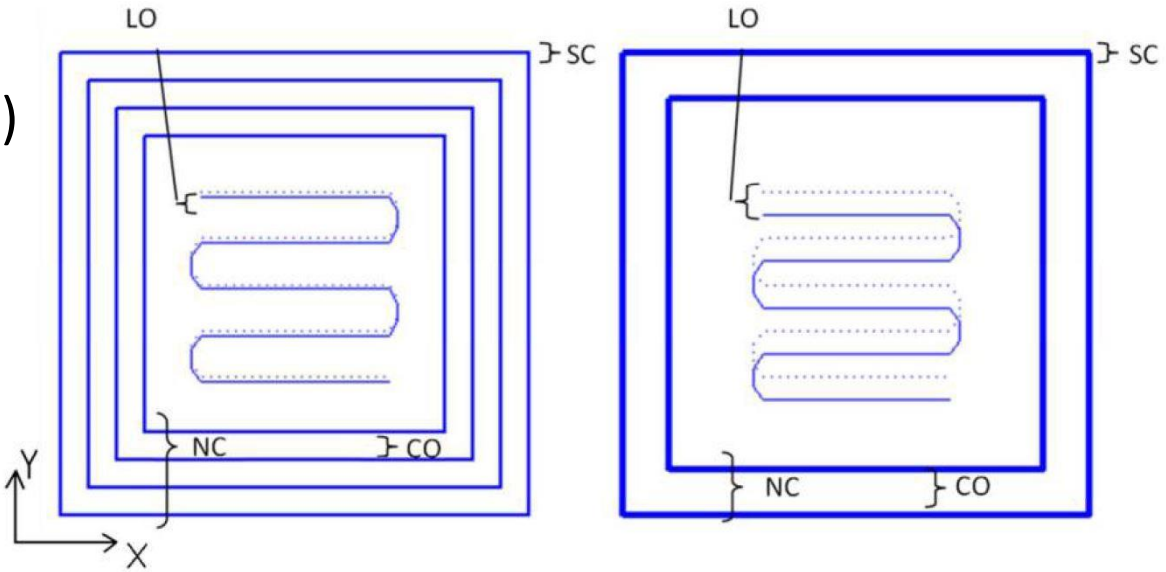
ANOVA

Surface characterization

Surface characterization

State of the art : no much article on surface improvement of EBM process

- Touch probe to evaluate the surface roughness
- Studied parameters
  - Number of contours (NC)
  - Contour offset (CO)
  - Speed contours (SC)
  - Line offset(LO)

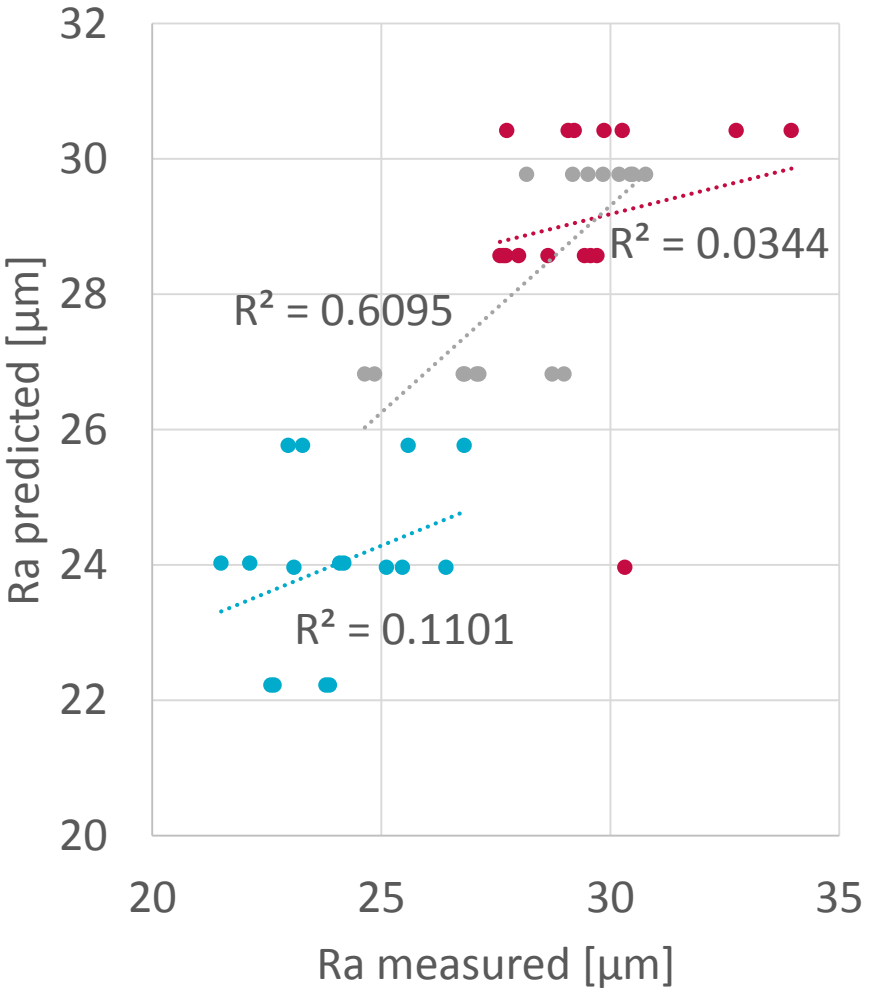


Ref: R. Klingvall Ek, L.-E. Rännar, M. Bäckctöm, and P. Carlsson. The effect of ebm process parameters upon surface roughness. *Rapid Prototyping Journal*, 22(3) :495-503, 2016

Surface characterization

State of the art:

- Ra=f(NC, CO, SC, LO)
  - $R_a = 24 + \frac{1{,}74 \times CO - 1{,}5 \times SC + 1{,}2 \times NC \times CO}{2}$
  - $R_a = 29{,}5 + \frac{1{,}85 \times NC}{2}$
  - $R_a = 28{,}3 - \frac{2{,}95 \times SC}{2}$
- Bad results
  - R^2 values vary from 3% to 61%
  - Best Ra =21,5µm



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Surface characterization

Batch 160202:

- 140 parts
- 6 parameters studied
  - Number of contours
  - Order of contours
  - Speed of outer contour
  - Focus offset of outer contour
  - Beam current of outer contour
  - Multispot of outer contour
- Recycled powder

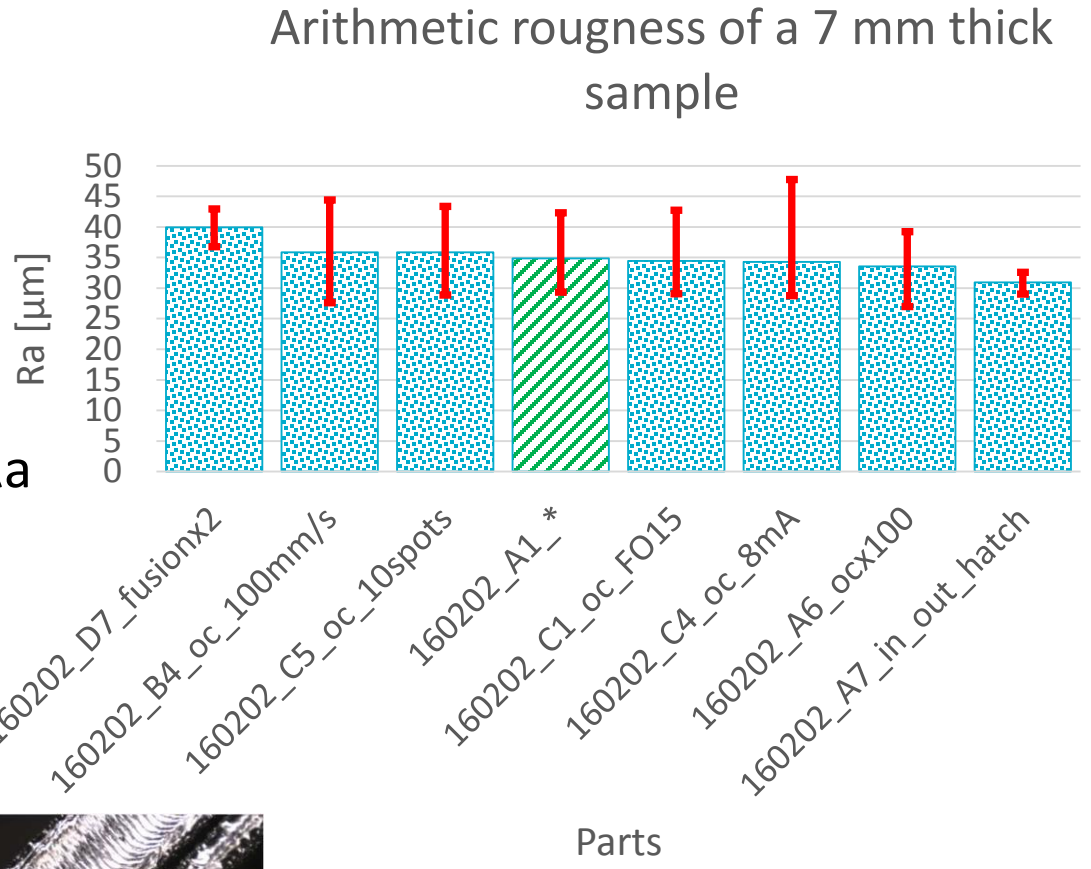
Surface characterization

Batch 160202:

- Conclusions
  - All the value are close
  - More low thickness, more Ra and Rt are low
  - Best Ra= 28,2µm
  - Best Rt= 231,5µm

BUT

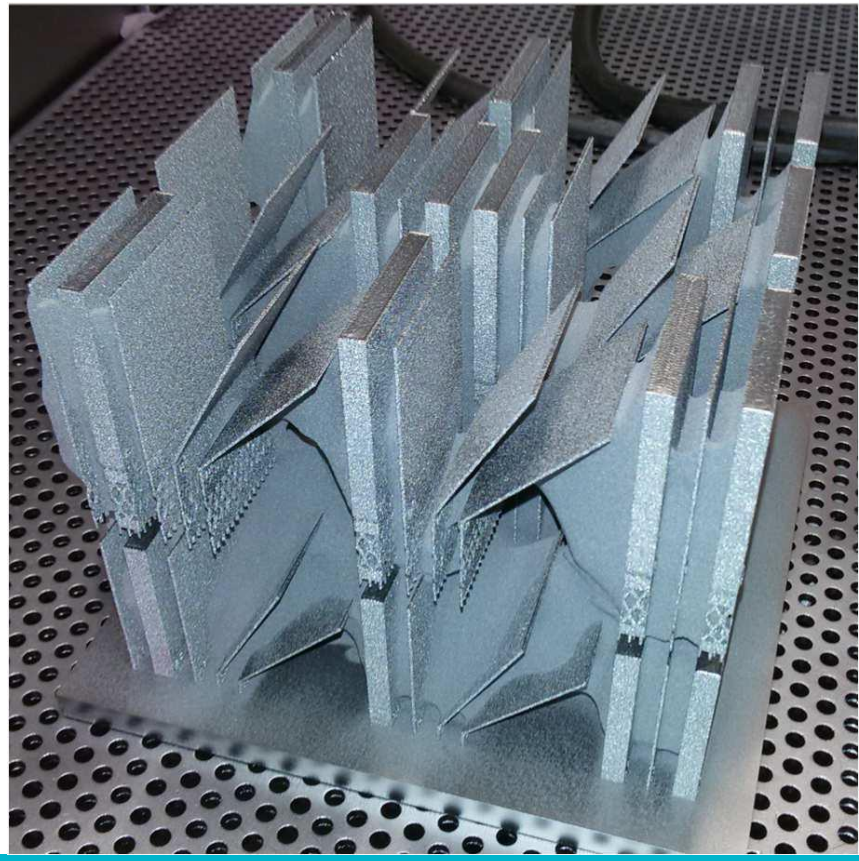
  - Ra>25µm
  - Rt>250-300µm



Surface characterization

Batch 160229:

- 72 parts
- 4 parameters were studied :
  - Number of outer contours
  - Speed of outer contours
  - Focus offset of outer contour
  - Multispot on outer contours
- Several parts with standard parameter
  - Influence of the environment?
- New Powder



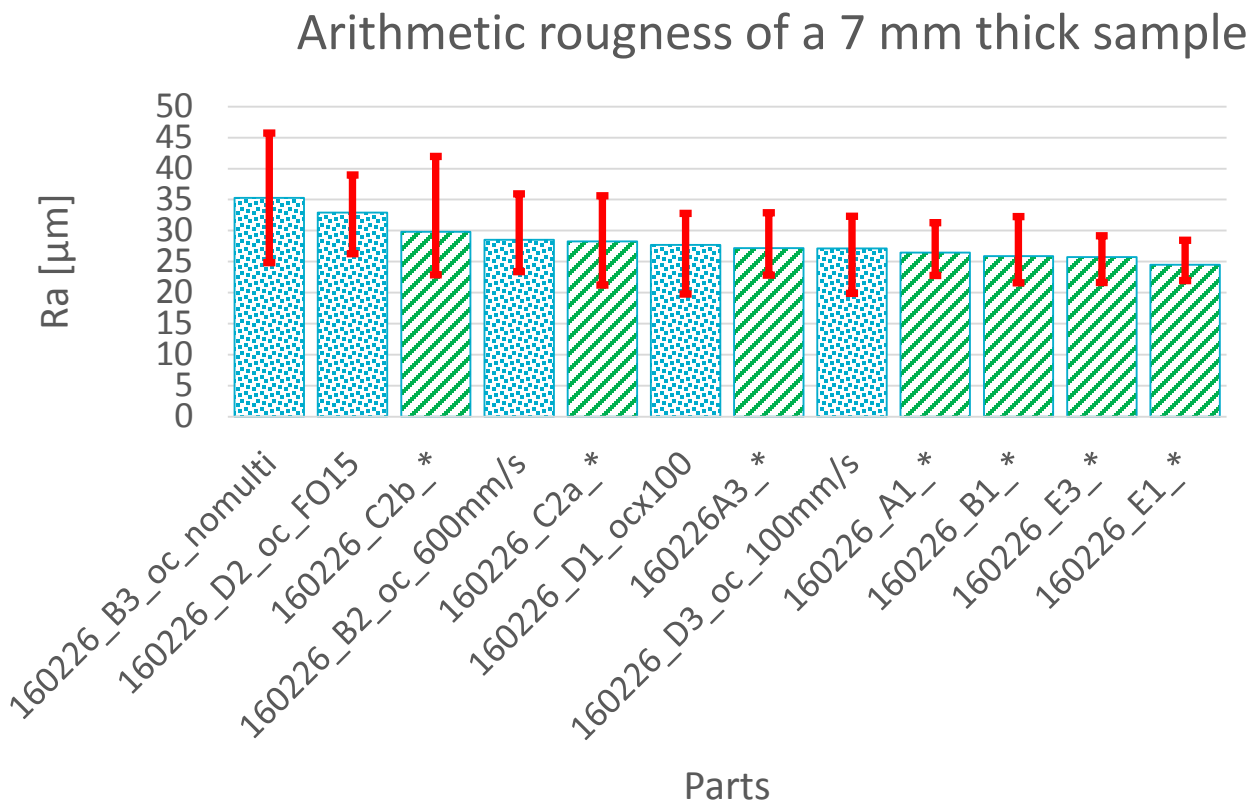
Surface characterization

Batch 160229:

- Conclusions
  - ➢ Standards parameters = Best compromise
  - ➢ No improvements with inclinations
  - ➢ Best Ra= 24,5µm
  - ➢ Best Rt= 198,5µm

BUT

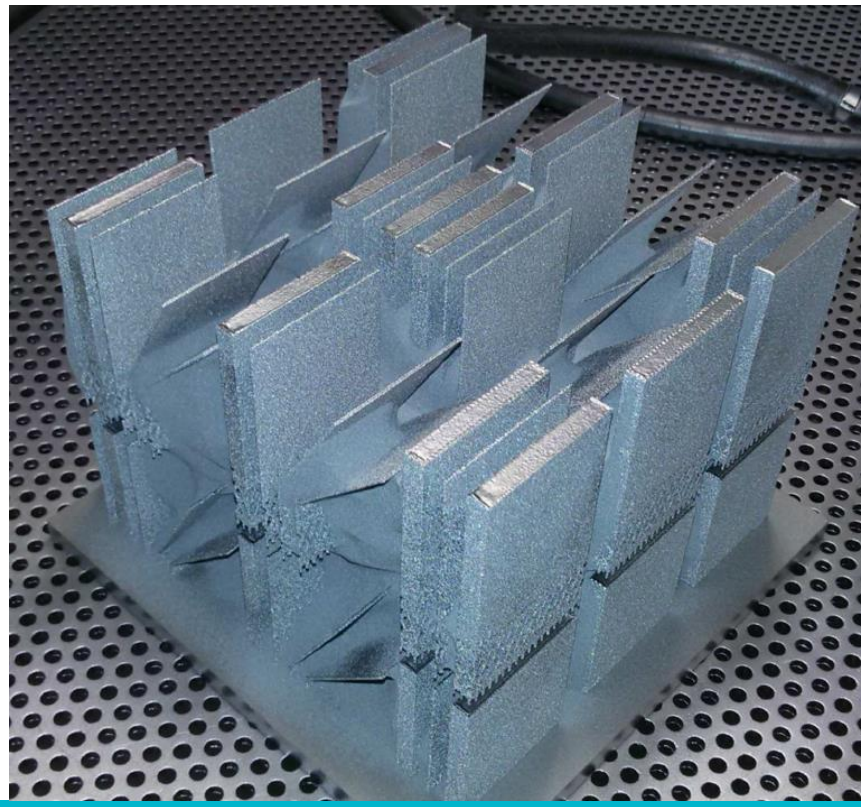
- ➢ Significantly different results for standard parameters➔ influence of sample position



Surface characterization

Batch 160318:

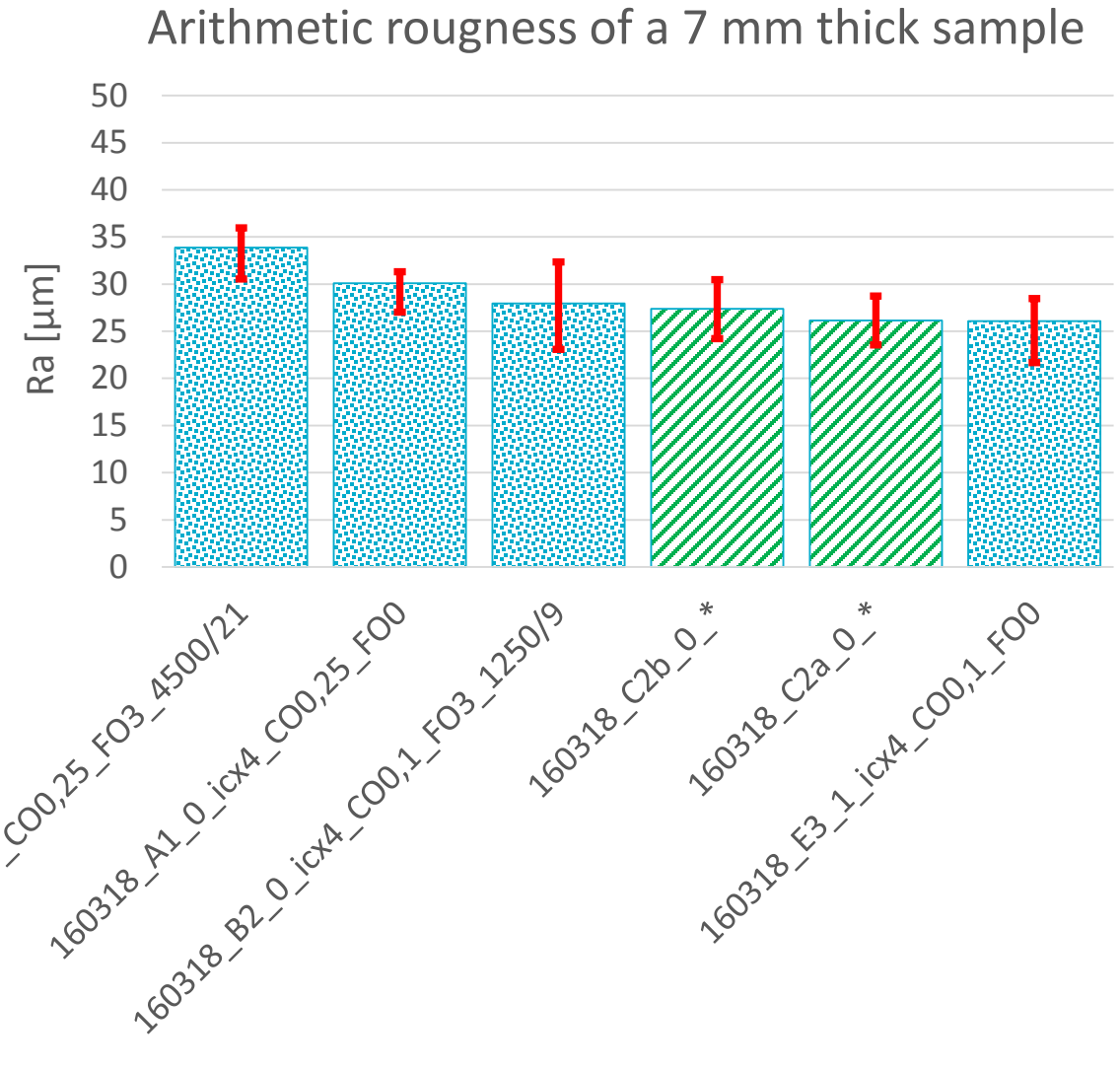
- 72 parts
- 5 parameters were studied
  - Number of contours
  - Inner contour offset
  - Speed of inner contour
  - Focus offset of inner contour
  - Beam current of inner contour
- Nearly new powder (only 1 use..)



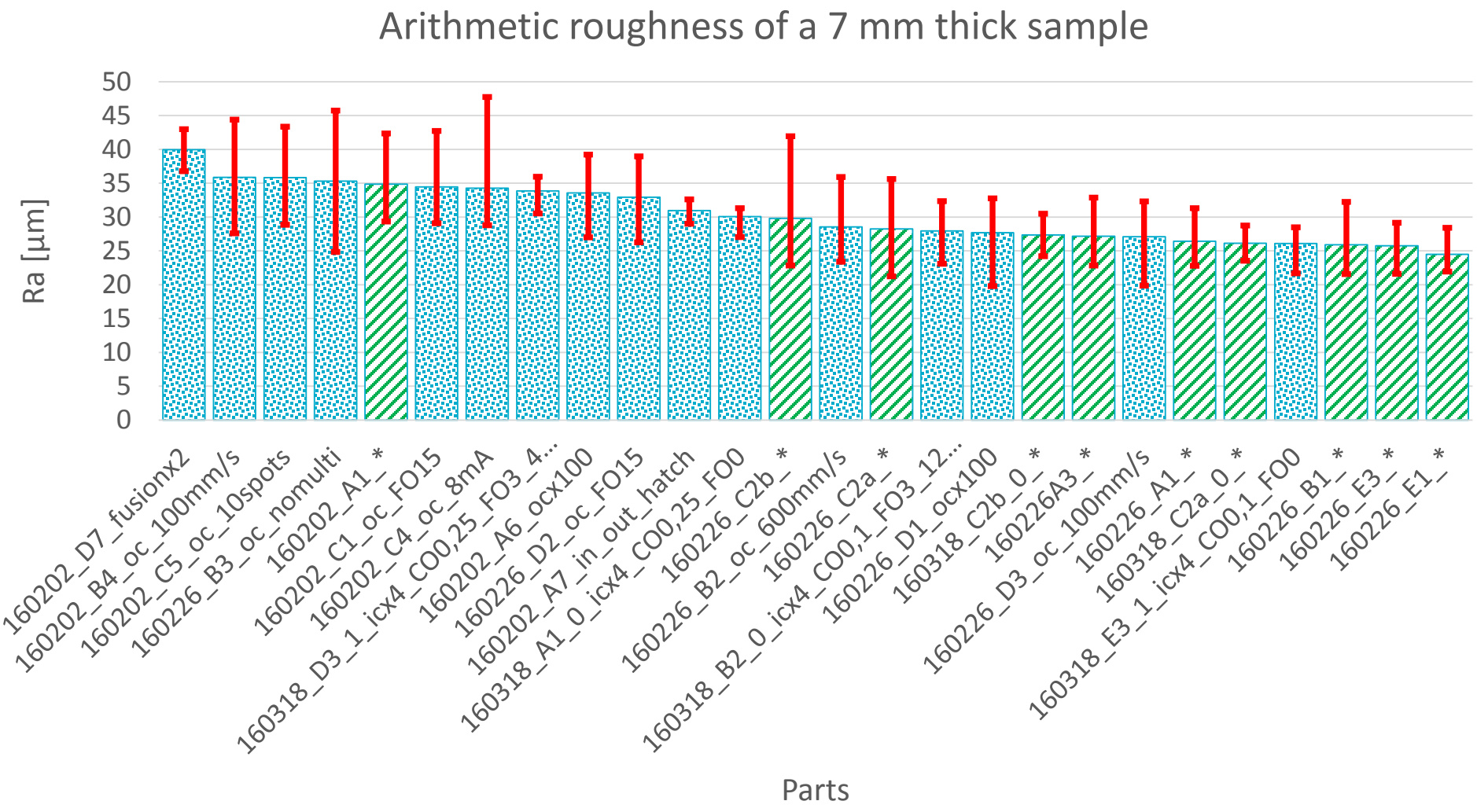
Surface characterization

Batch 160318:

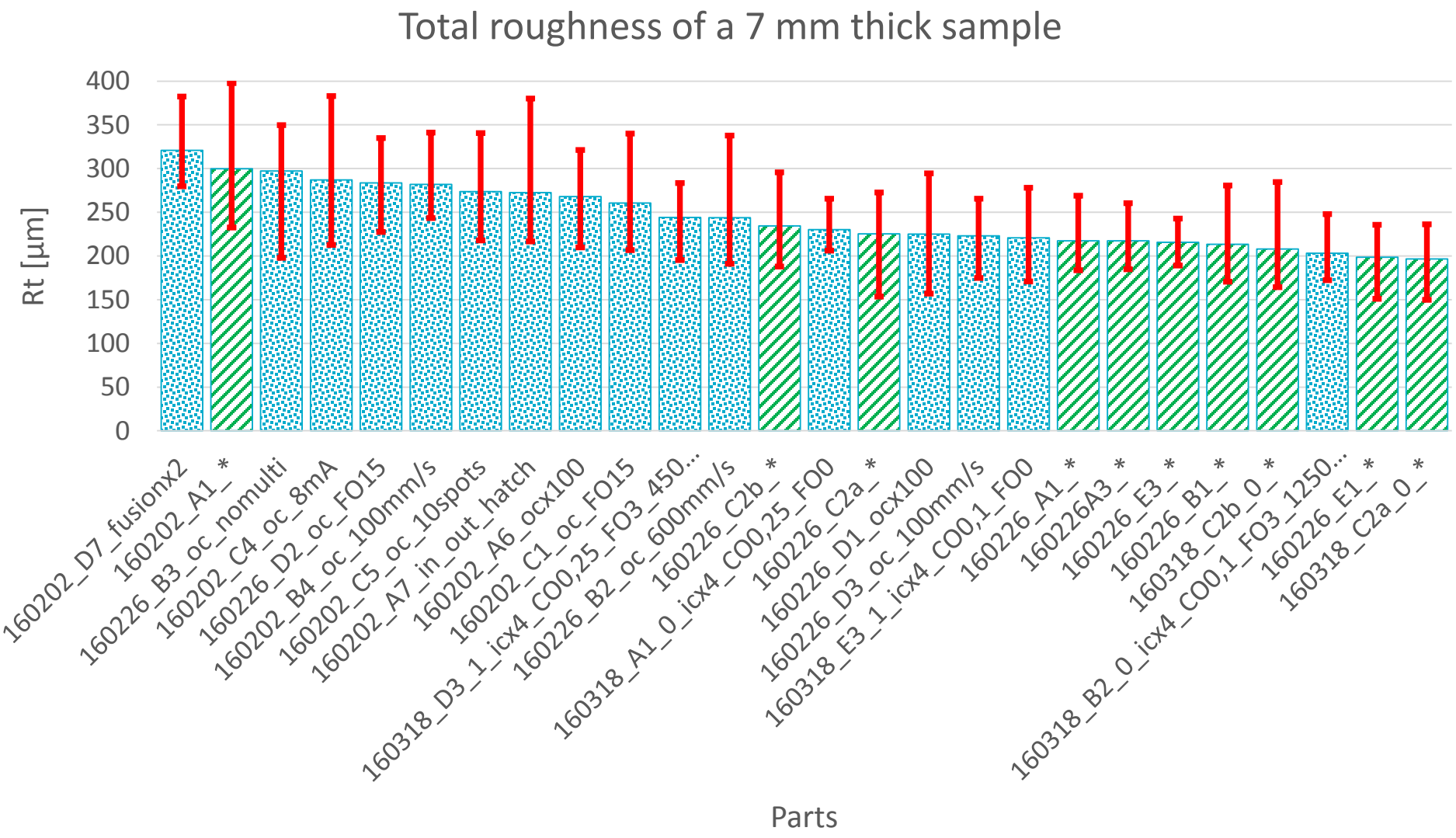
- Conclusions
  - Standards parameters = Best compromise
  - No improvements with inclinations



Surface characterization

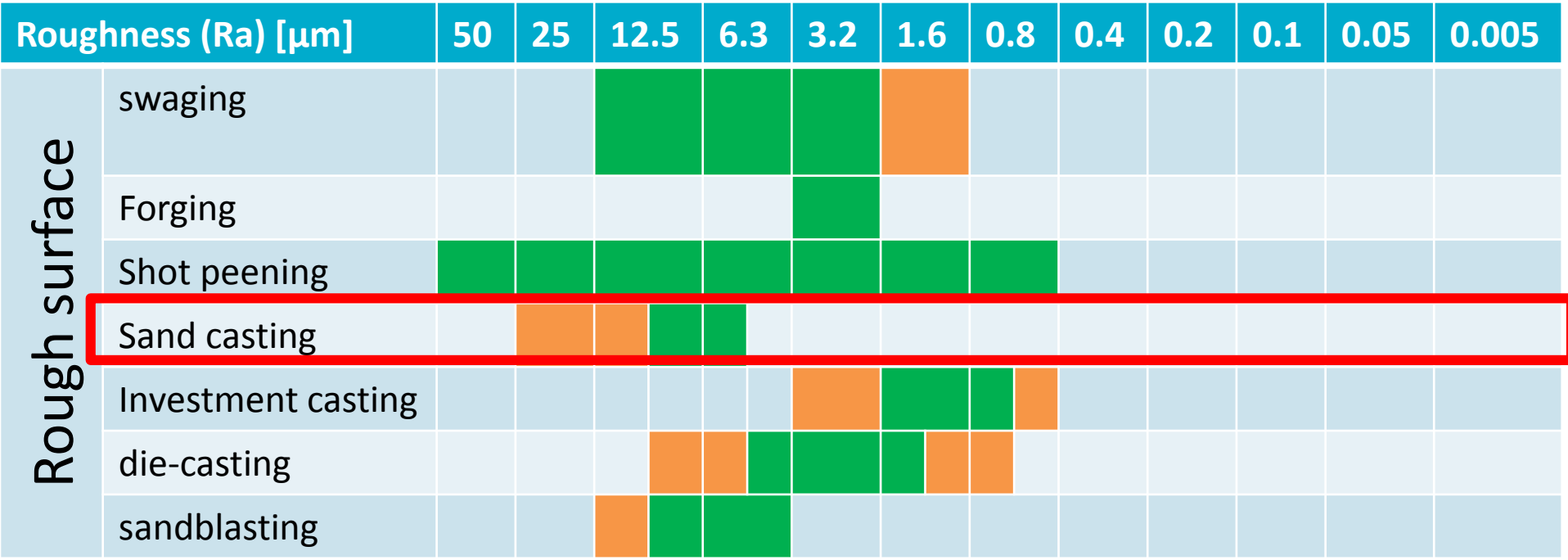


Surface characterization



Surface Characterization

- Surface Roughness measurement
- Ra = 25-40 µm ➔ Near Sand casting!



Conclusions

- 586 measures were conducted on EBM samples with different parameters.
  - Standard parameters = Best compromise
  - No improvments with inclination
  - The more powder is new, the greater the value of the Ra near 25 µm
  - Machining required to obtain Ra of 1.6µm

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Functionalization of Electron beam melting parts by Machining

Promoteurs académiques : Prof. E. Rivière, Prof. E. Filippi

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Ir. Adrien Dolimont