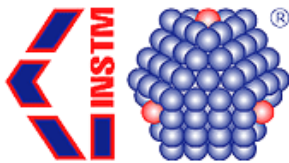




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A comparison of different approaches to study the porosity and surface defects for Electron Beam Melting

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³ Department of Production and Management, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129, Italy

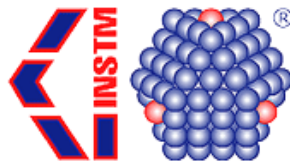


This project has received funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 821274

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AIM:

- Develop new **TiAl alloys** for EBM process for the production of the next generation of low pressure turbine (LPT) blades
- ❖ Modifications of the chemical composition with respect to the reference Ti-48Al-2Cr-2-Nb were investigated;
- ❖ Optimization of the EBM process parameters were done coupling experimental trials with the development of simulation tool;
- ❖ Full mechanical characterization of the new alloys and comparison with the reference Ti-48Al-2Cr-2-Nb alloy

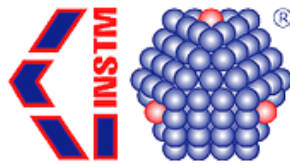


BUDGET 800.000 €





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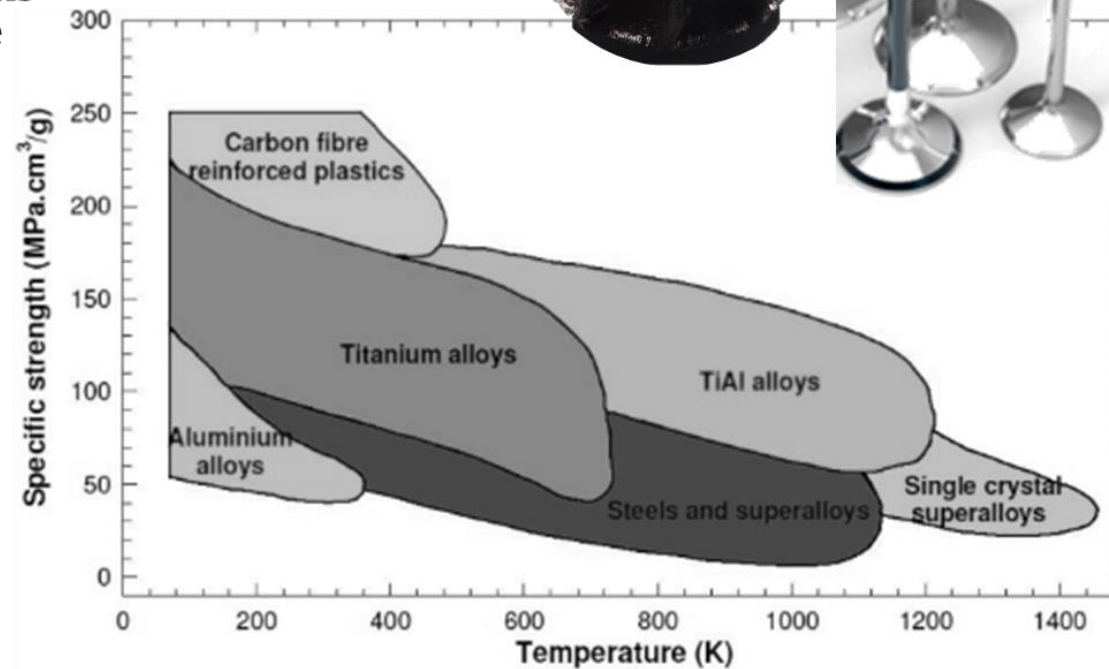


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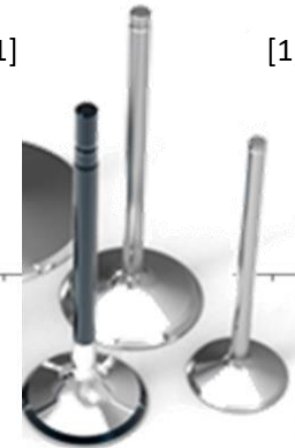
Context

TiAl alloys are attractive materials for structural aerospace applications at high T in particular low pressure turbine blades:

- Specific strength comparable to Ni-base superalloys
- γ -TiAl 4 g/cm³ vs 8 g/cm³ Ni-base superalloys
- Good oxidation and corrosion resistance up to 750-800 °C



[1]



[1]



[2]

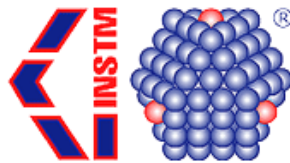
Ti-(42-48)Al-(0-4)Cr/Mn/V-(0-10)Nb/Ta/W/Mo-(0-2)Si/C/B

[1] Loria. Intermetallics-2001. "Quo vadis gamma titanium aluminide"

[2] Bewlay. Material at high temperature-2016. "TiAl alloys in commercial aircrafts engines"



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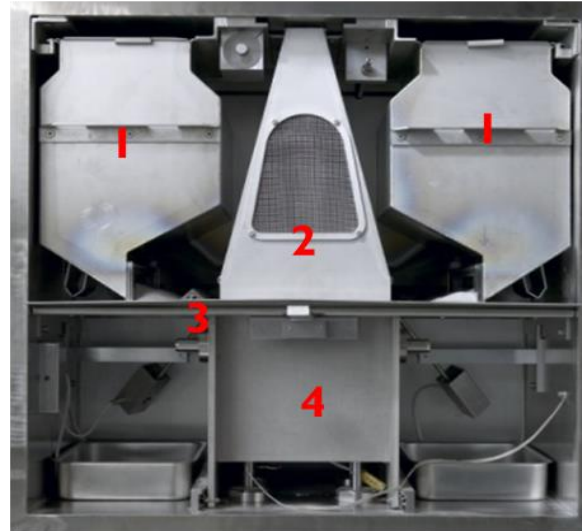
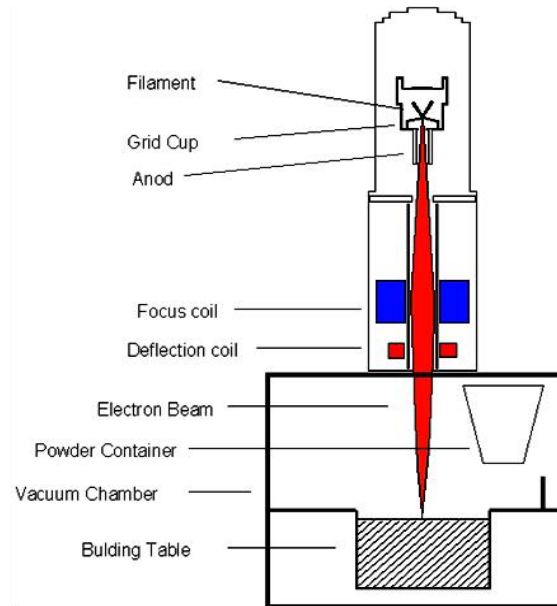
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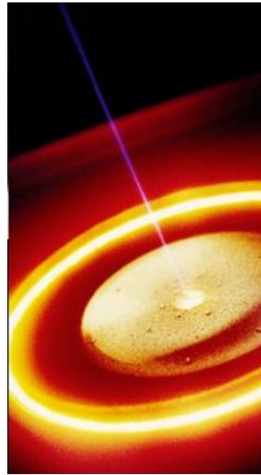


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The EBM process:



- 1) Powder hoppers
- 2) Electron Beam path
- 3) Rake for powder distribution on the building plate
- 4) Build tank where the component is built layer by layer



Advantages:

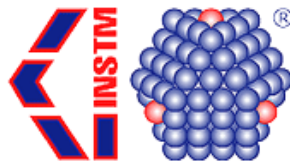
- freedom of design
- dense material with good material properties
- low material waste
- good productivity
- Vacuum melting process (no contaminations)

Technical features:

- 6 kW electron beam
- Preheating of the powder
- High preheating: up to 1000-1100 °C
- Vacuum chamber: 10^{-3} - 10^{-5} mbar
- Approximate build volume: 200x200 x380 mm³
- E-Beam rate: up to 8000 m/s
- Layer thickness: 50-200 micron
- Approximate build rate: 60 cm³/h



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Window of process parameters investigated in the process

Sample	Scanning Speed (mm/s)	Beam Current (mA)	Line Energy (J/mm)
1	2800	8	0.17
2	2200	8	0.22
3	1600	8	0.30
4	2800	10	0.21
5	2800	10	0.27
6	1600	10	0.38
7	2800	12	0.26
8	2200	12	0.33
9	1600	12	0.45

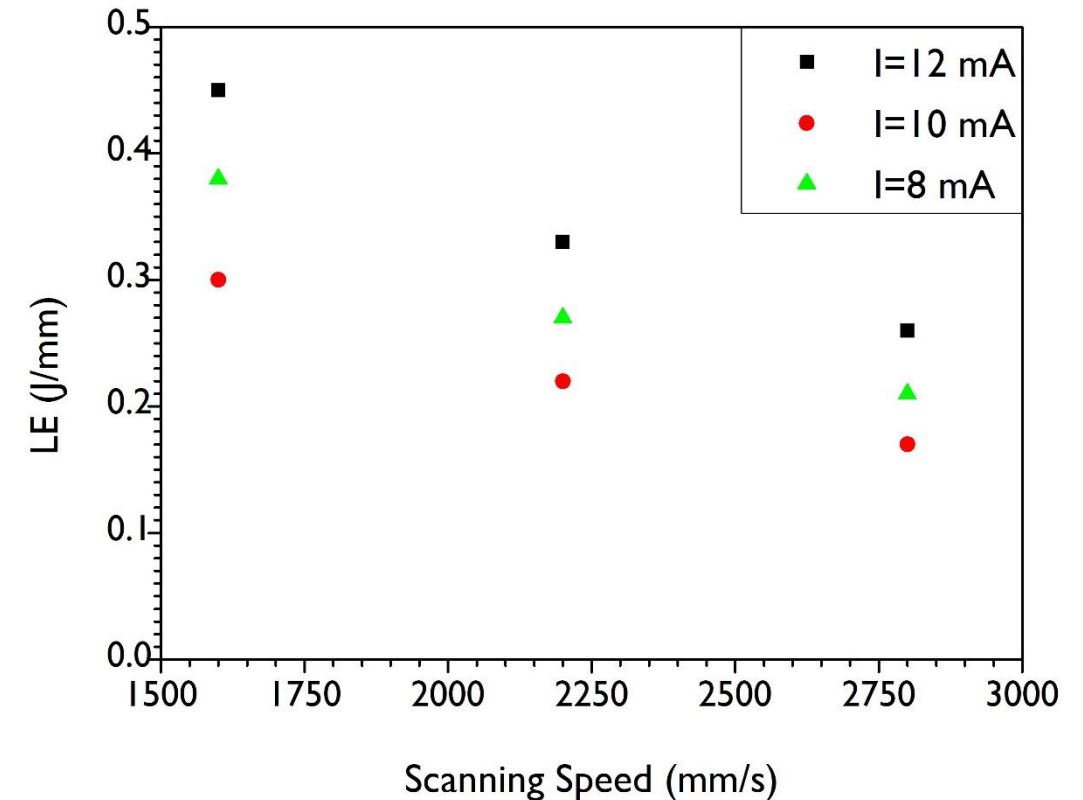
Constant parameter:

Layer thickness

Focus offset

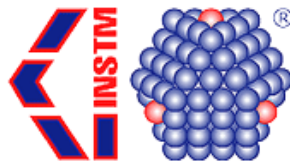
Line Offset

Pre-heating temperature





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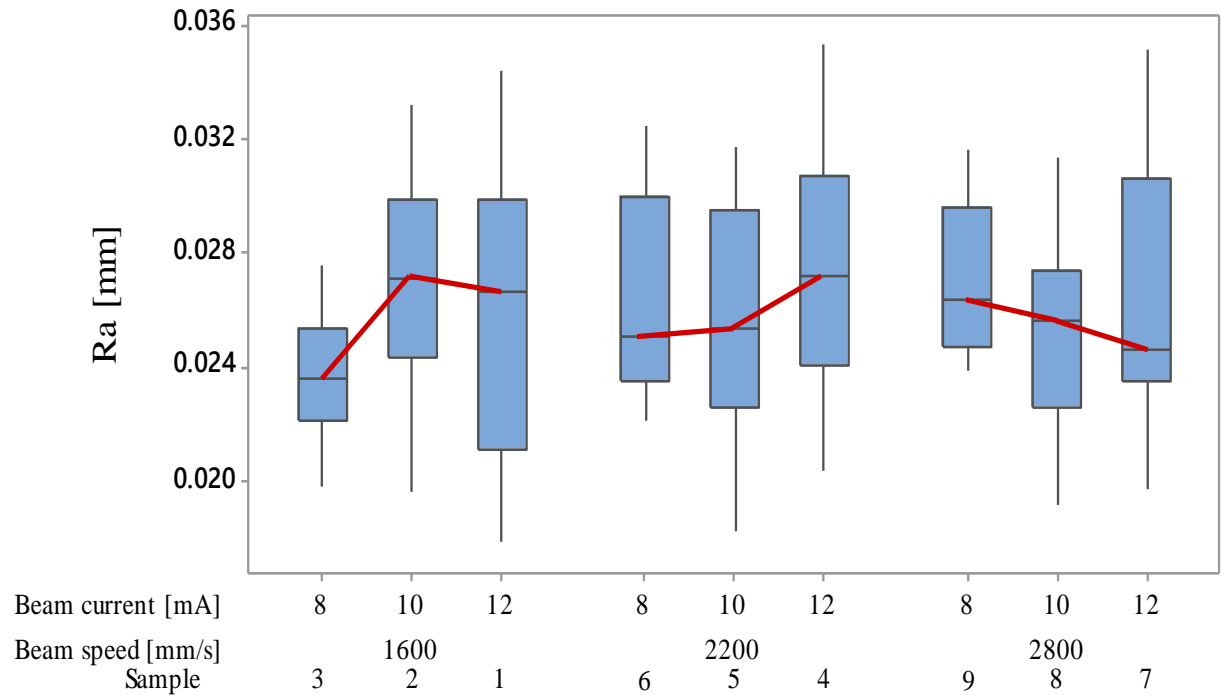
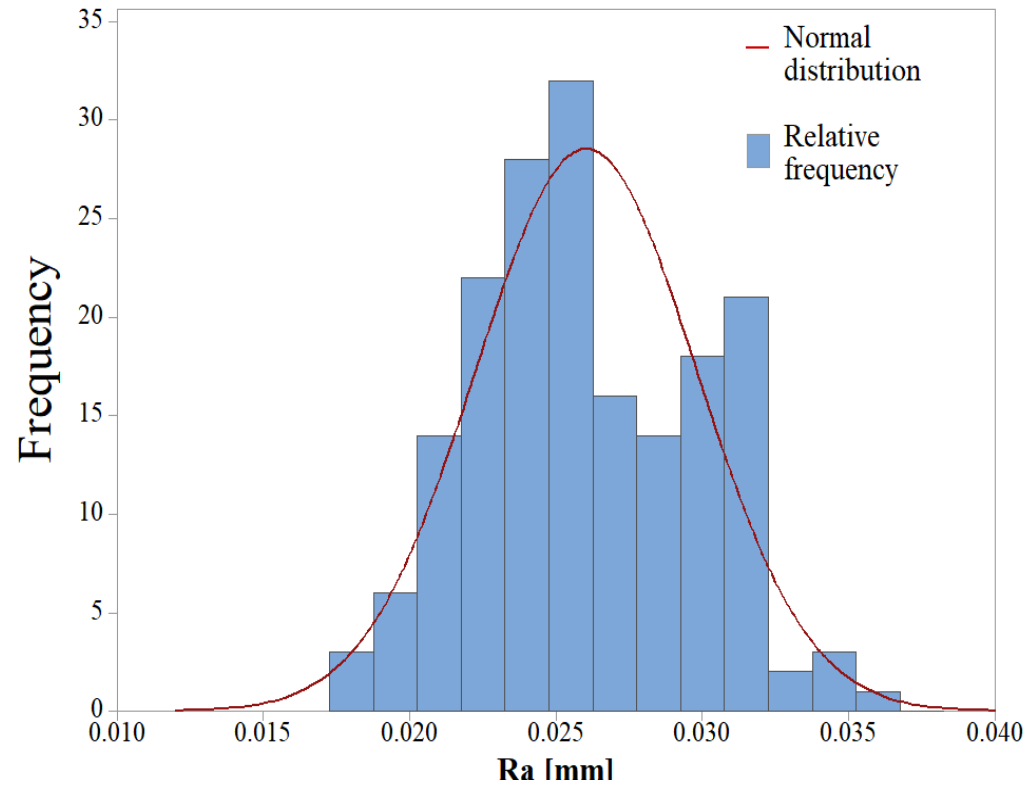
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Vertical Roughness

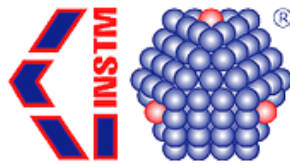


No influence of different process parameters on the Vertical roughness

Average roughness of sample = 0.026mm



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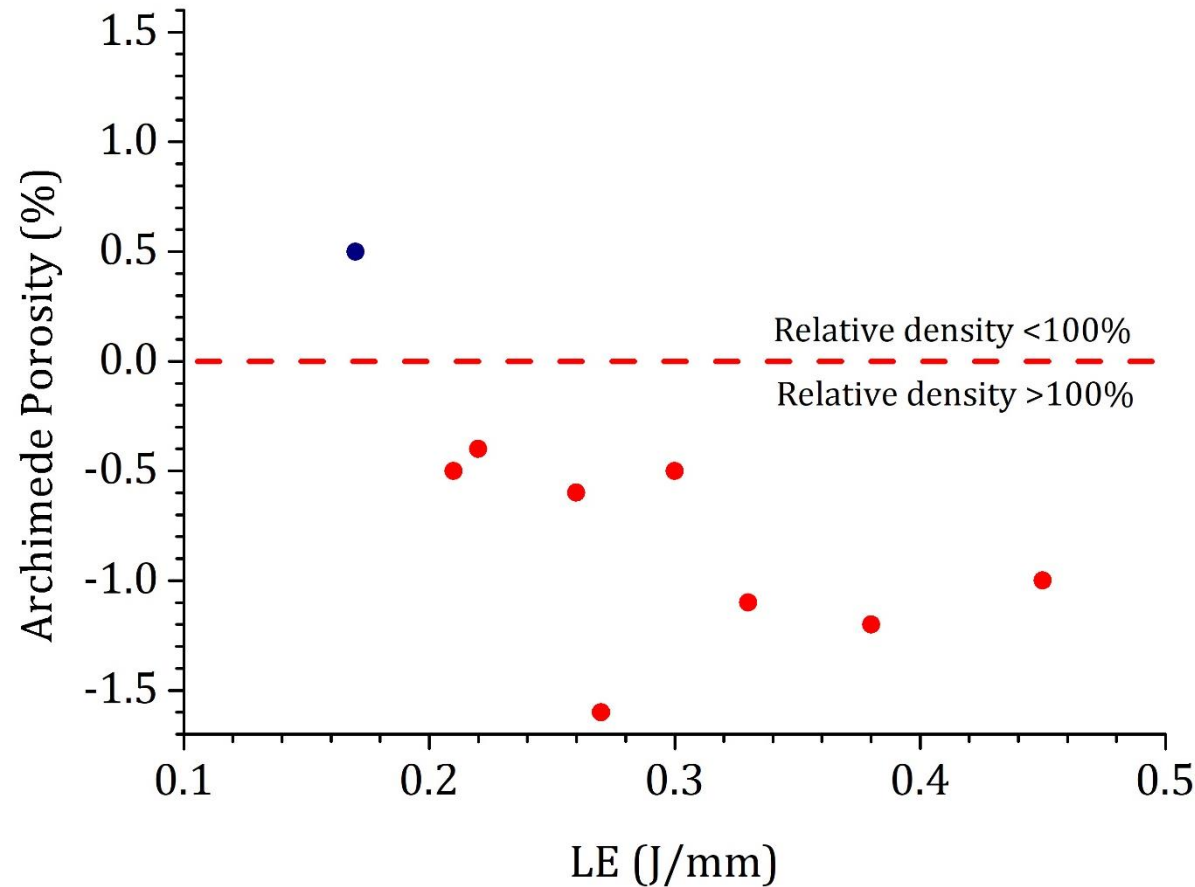


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Archimede's relative density



Skeletal density of the powder used as theoretical density

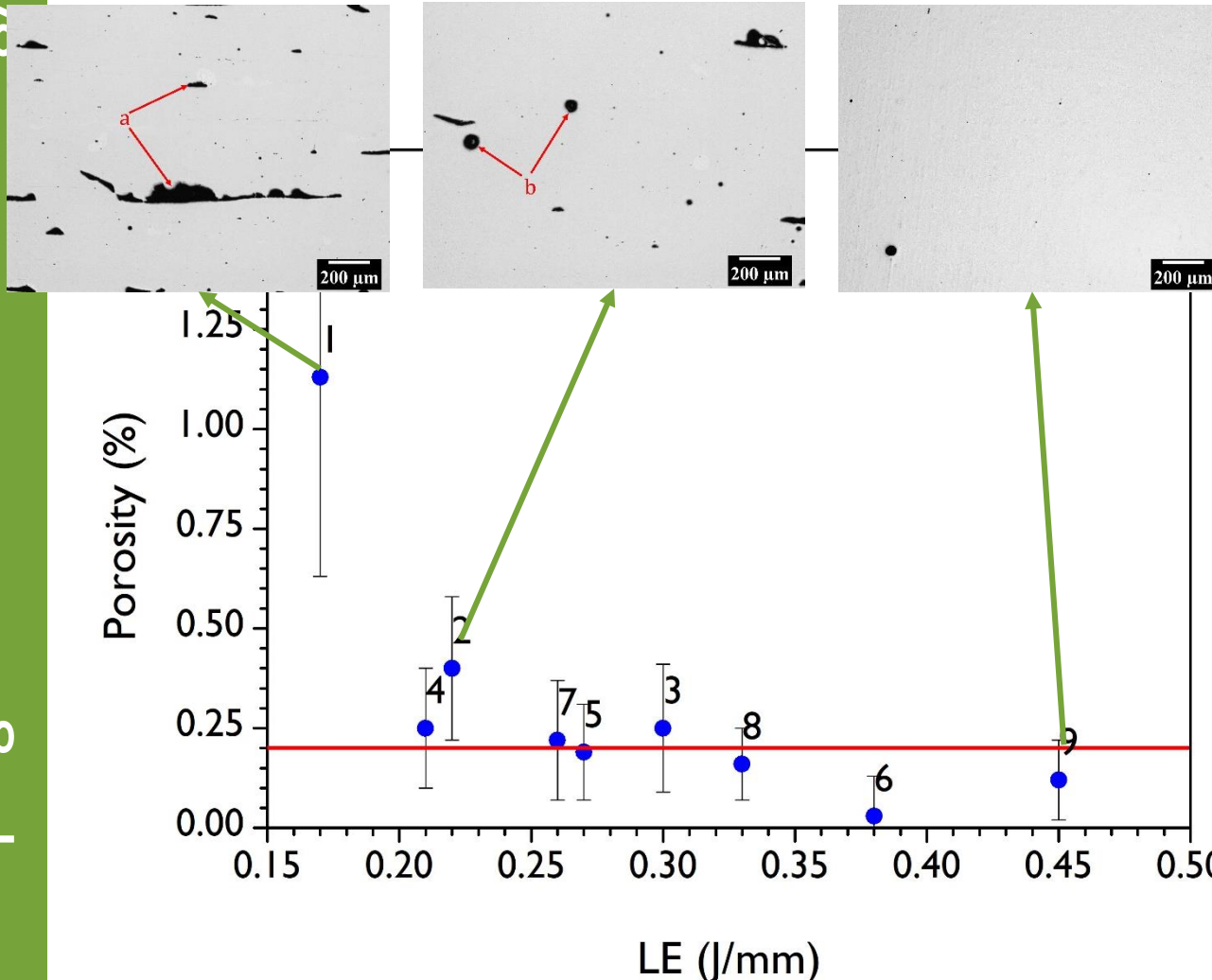
Archimede's method critical issues:

- Highly dependence on the interaction fluid sample surface
- Measurement of theoretical density (TiAl EBM case: Al% dependence with process parameters)
- No information on the geometrical features of the internal defects

Useful information:

- Trend of relative density respect to the process parameter

Optical microscope porosity analysis



OM porosity method critical issues:

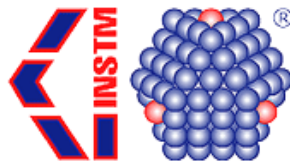
- Measuring the pore quantity and geometrical feature in a 2D-plane
- Depending on the material, the preparation of specimens could be time consuming
- High number of images and sections are necessary to have a more precise quantification

Useful information:

- Trend of relative density respect to the process parameter
- Shape and dimension of pores (key factors for design of process optimization)
- Quantitative analysis (2D-plane)



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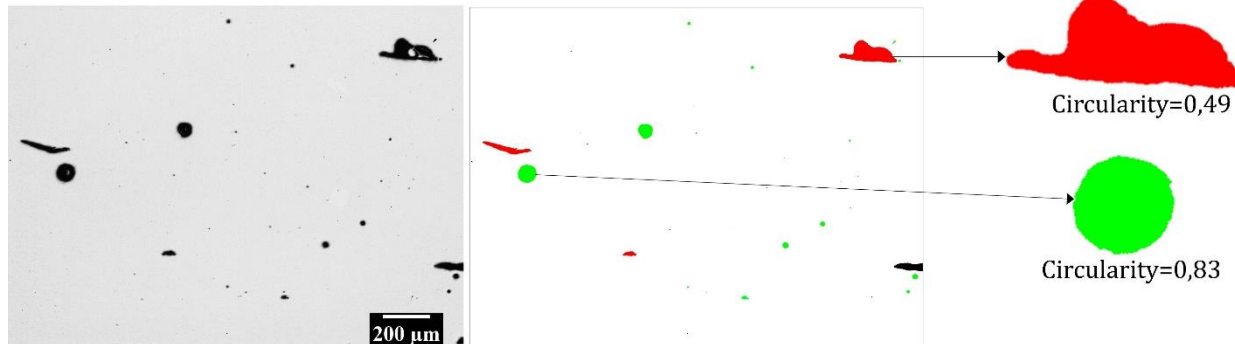
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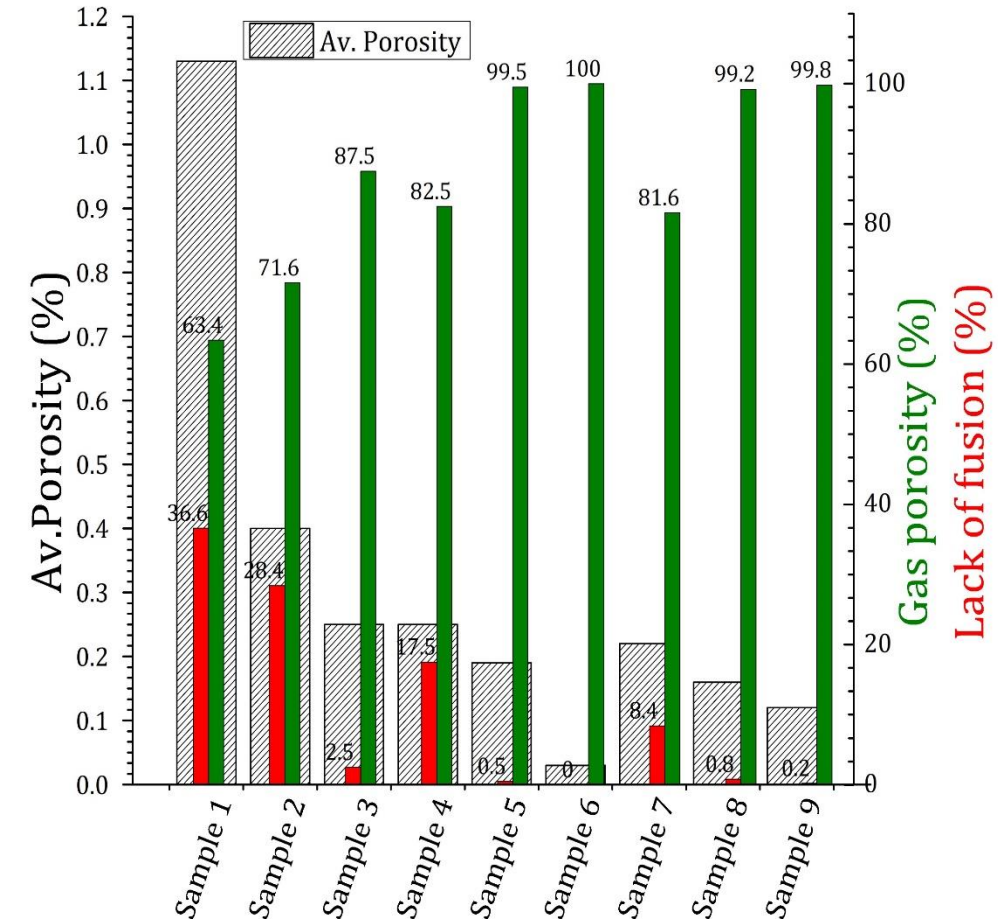
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Defects type

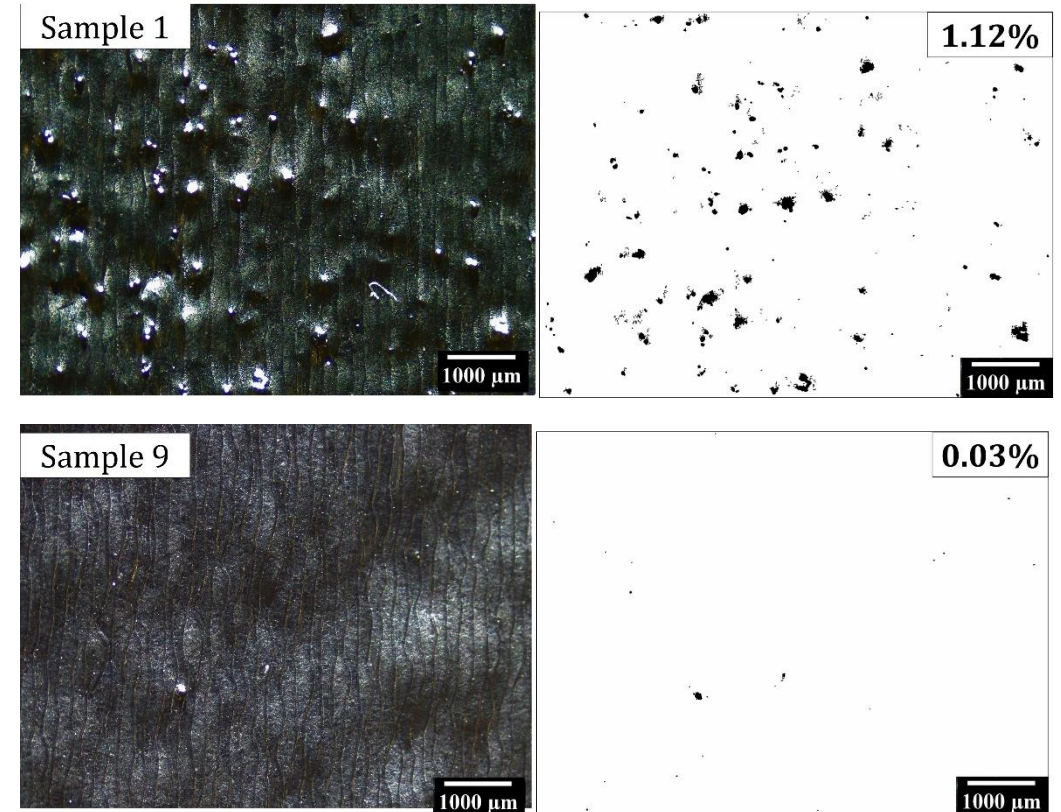
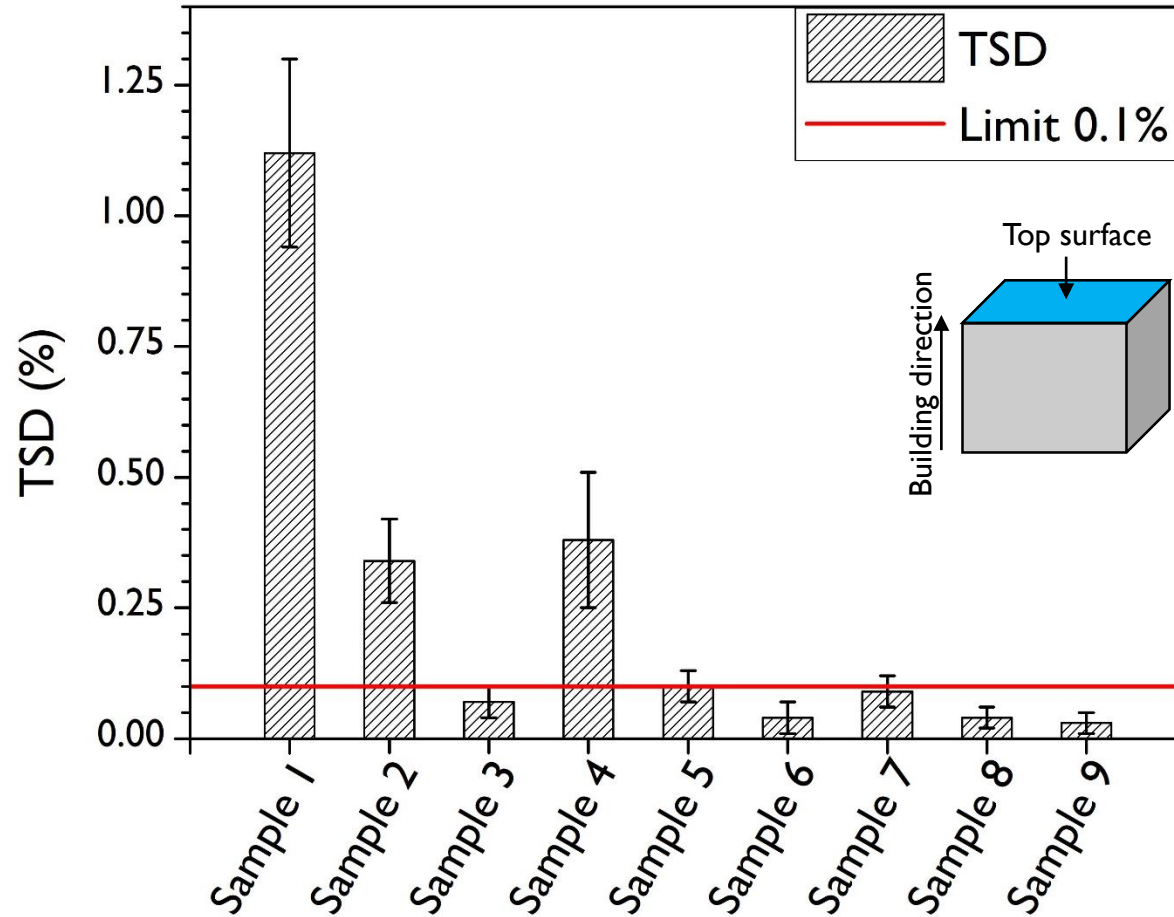
Analysis on the geometrical features of pores allow to evaluate the amount of process defects (Lack of Fusion) and the amount of powder related defects (gas porosity)



Circularity limit = 0.75
Roundness limit = 0.70
Resolution limit = $176 \mu\text{m}^2$

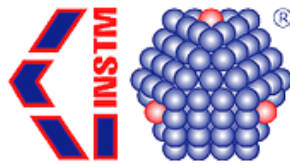


Top surface defects analysis





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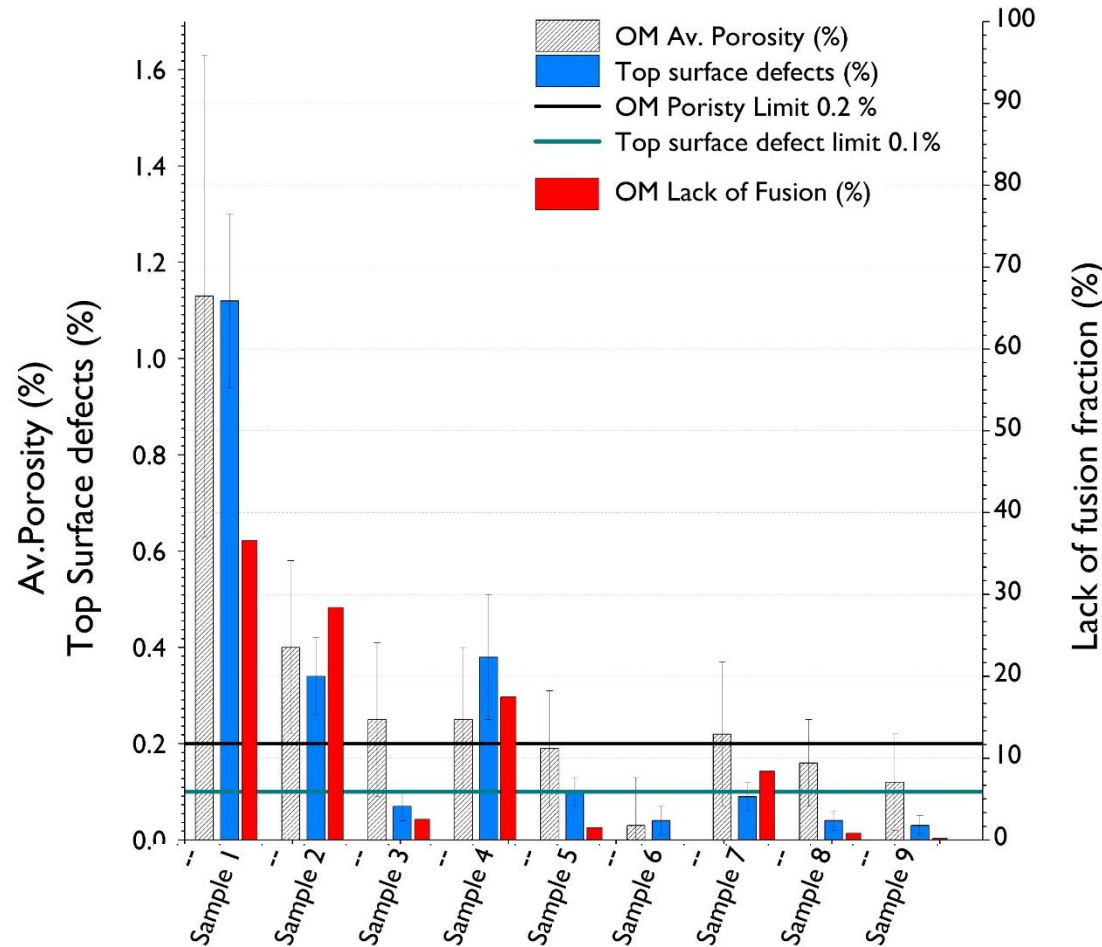


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Correlation Top surface defects and OM



Top surface defect critical issues:

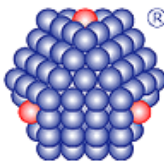
- Measuring the top surface defects on generally flat surfaces
- Indirect measurement of internal defects

Useful information:

- Trend of relative density respect to the process parameter
- Direct correlation with Lack of fusion content
- Quantitative analysis (2D- dimension)



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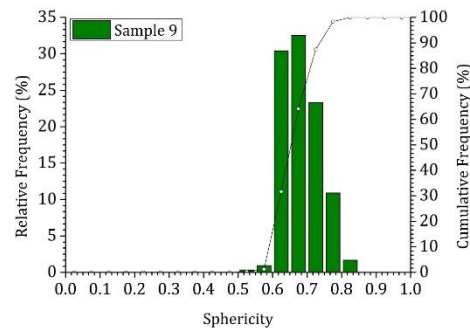
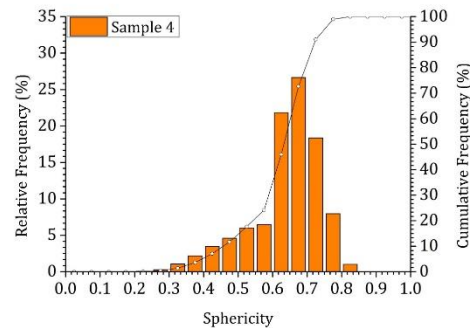
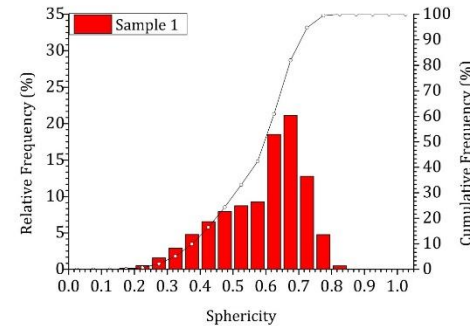
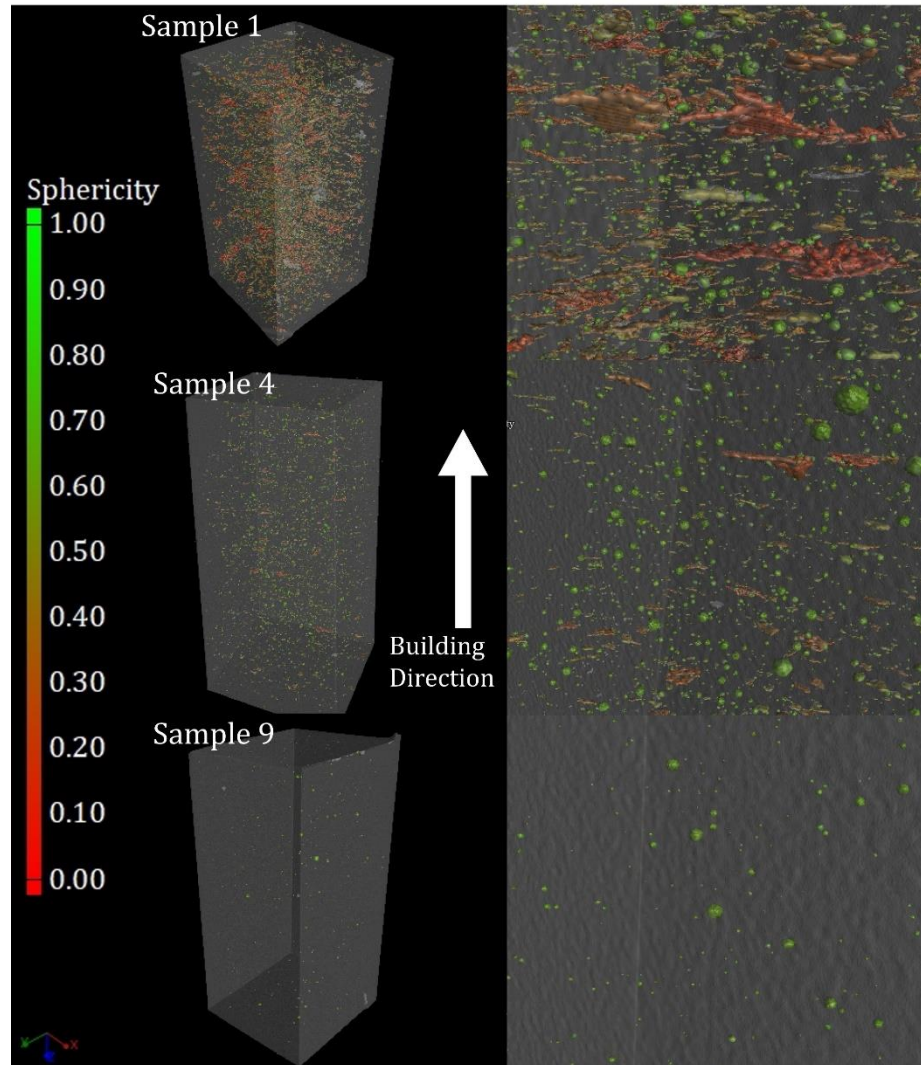
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X-CT scan analysis porosity



X-CT critical issues:

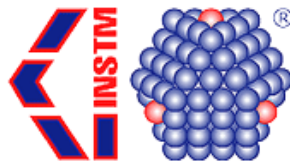
- High capital cost
- High number of sample require high time of analysis

Useful information:

- Information rich analysis
- Quantitative analysis (3D-quantification)
- 3D visualization of internal pores



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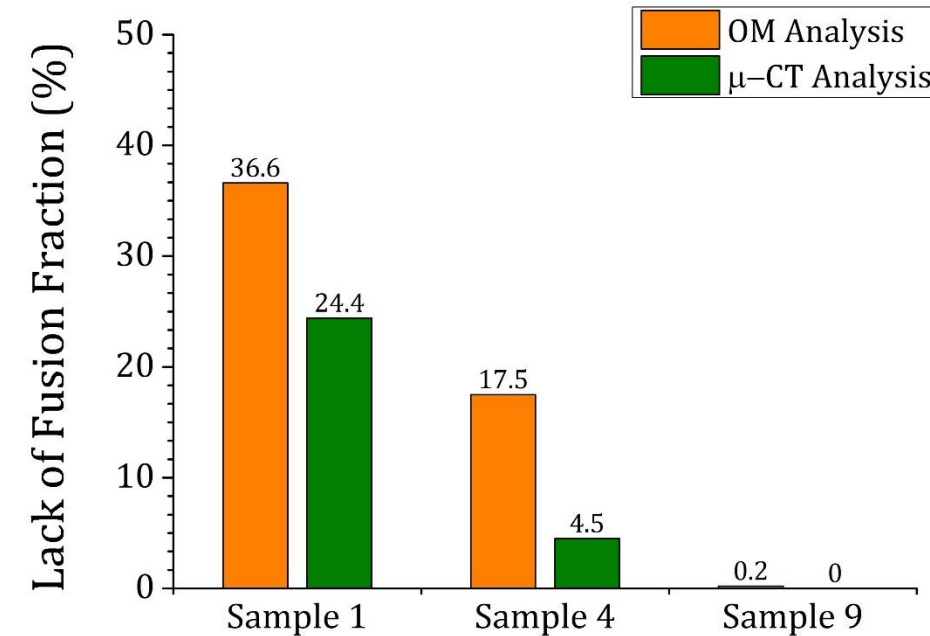
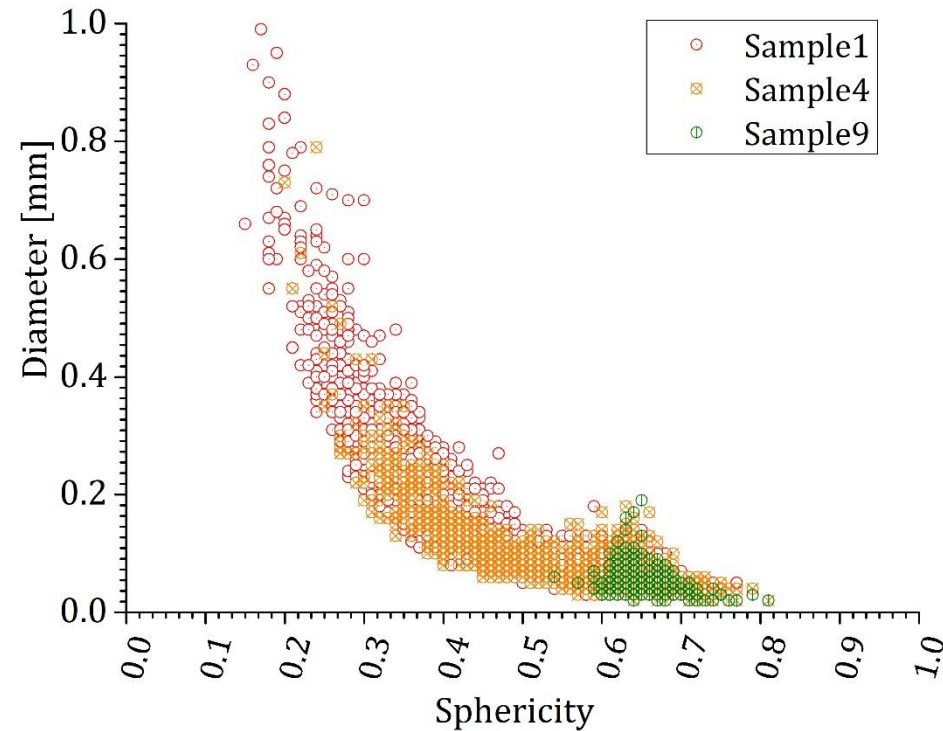


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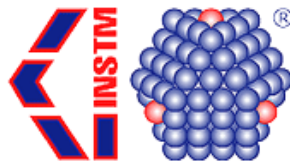
X-CT scan analysis correlation with OM porosity analysis



Good correlation between the trend of Lack of fusion % from the 2 different methods



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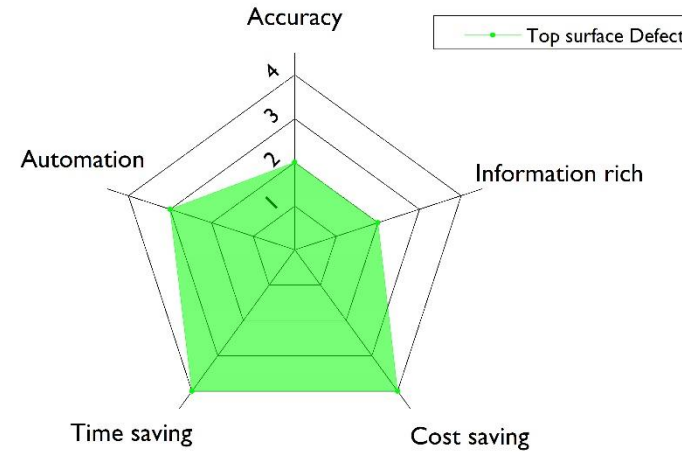
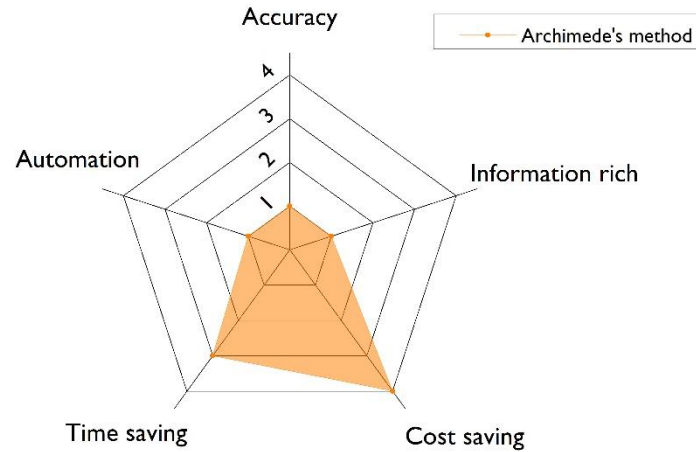


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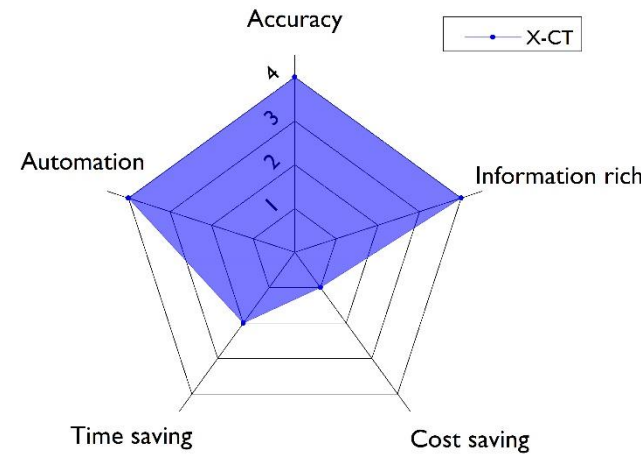
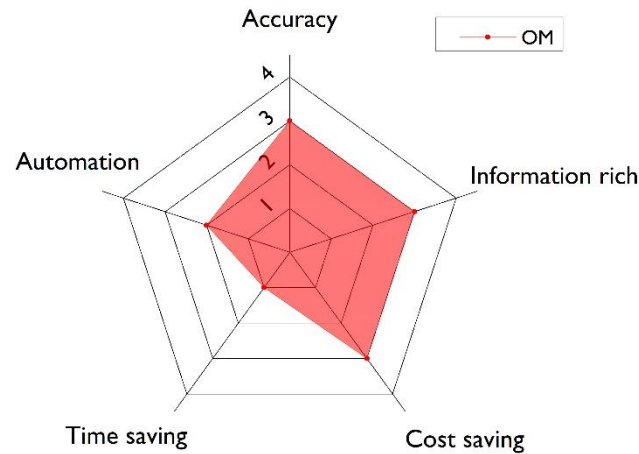


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Comparison of all the Measurement



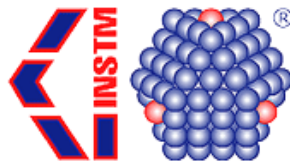
- Top surface defects useful for preliminary optimization process. economic and time saving method



- OM and X-CT analysis useful for more precise analysis.



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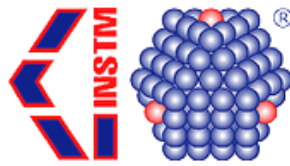
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Conclusion

- Average roughness for all the combination of process parameters is 0.026mm
- Archimede's method can be useful to identify the highest relative density, but high error can occur for the quantification of porosity from the theoretical density.
- Optical microscope image analysis after cut-up of the specimens give useful information of kind of internal porosity. A residual porosity below 0.2% is an appropriate threshold to select the most promising conditions for a further fine tuning of the process parameters.
- Top Surface Defect analysis by stereomicroscopy is a powerful tool that can help in a preliminary selection of the most promising conditions for the subsequent process parameters optimisation in a more rapid and less labour consuming way than OM and X-CT image analysis after cut-up.
- CT scan is extremely accurate technique. but due to the high cost cannot be considered for the optimisation of process parameters also considering the number of samples and the time necessary for an accurate measurement.



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NEWTEAM 

Thanks for the attention!

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