Prediction of microstructure for AISI316L steel from numerical simulation of laser powder bed fusion

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Introduction

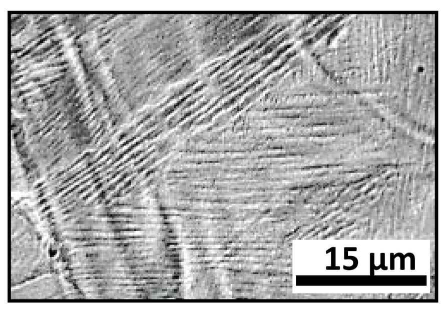
Laser powder bed fusion (**L-PBF**) is the most promising additive manufacturing technology for metals.

Many **numerical simulation** software provide solidification data useful for **microstructure prediction**, therefore they can represent a powerful tool for L-PBF improvement.

The **cooling rate** ($\dot{T}$) of the process is the key parameter determining the **microstructure** of the final component, directly responsible for the mechanical properties.

Austenitic stainless steel 316L commonly exhibits a **cellular microstructure** when produced by L-PBF.

Primary cell arm spacing (**PCAS**) is the characteristic feature of this microstructure, on which the mechanical properties such as **microhardness** (**H**) depend.



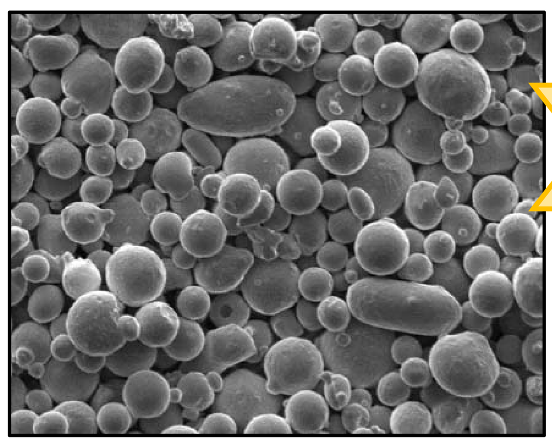
✓ Objective:

Estimate the **PCAS** and the **microhardness** of 4 single scan tracks of 316L stainless steel by using ***FLOW-3D* AM**, a commercial CFD software, and **validate** the model

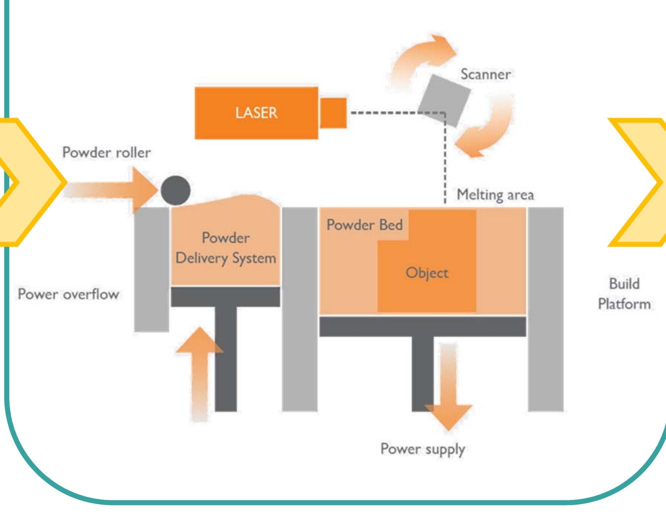
Materials and Methods

Powders

Gas atomized 316L stainless steel



L-PBF process



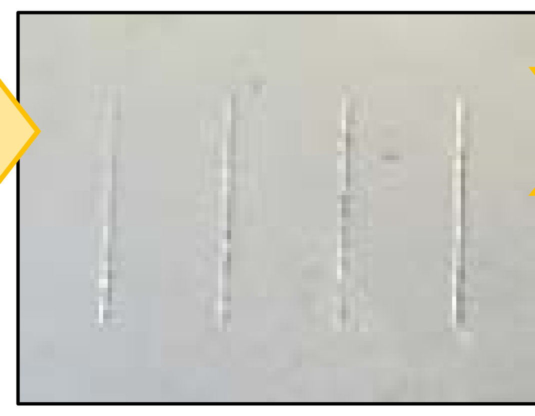
Process parameters

Laser Power = 140 W **Laser beam spot size** = 36 µm

Track	Scanning speed	Layer thickness
A	50 cm/s	60 µm
B	100 cm/s	
C	50 cm/s	90 µm
D	100 cm/s	

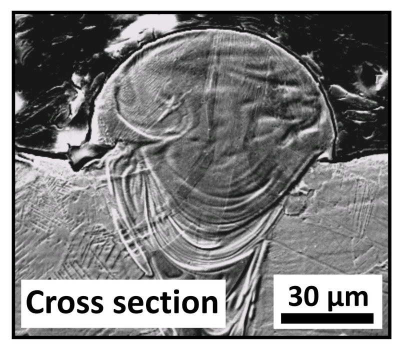
Real samples

4 single scan tracks of 10 mm



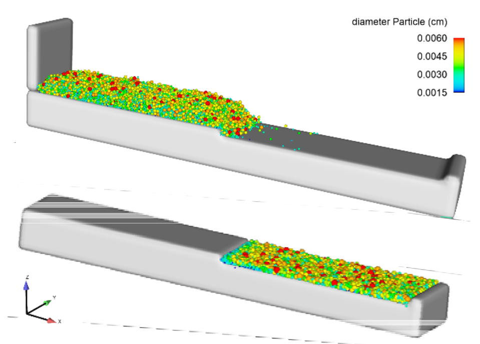
Characterization

PCAS and **microhardness** measurements on the cross section

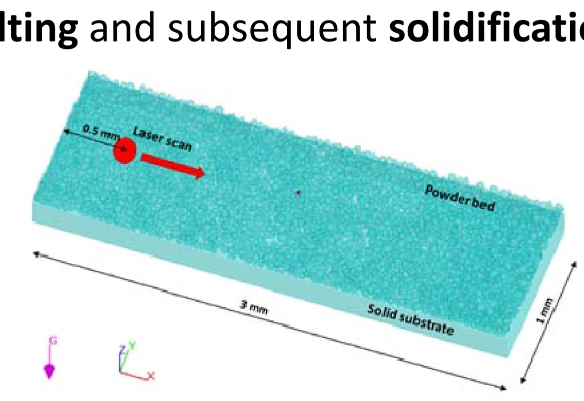


Model

Discrete Element Method (DEM) of *FLOW-3D* AM was used to **create the powder bed**

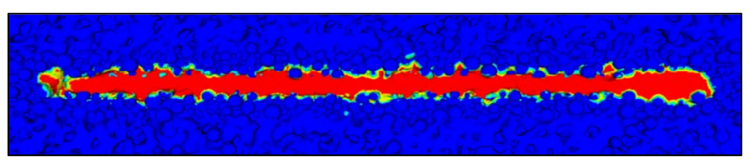


Finite Volume Method (FVM) of *FLOW-3D* AM was used to reproduce powder **melting** and subsequent **solidification**



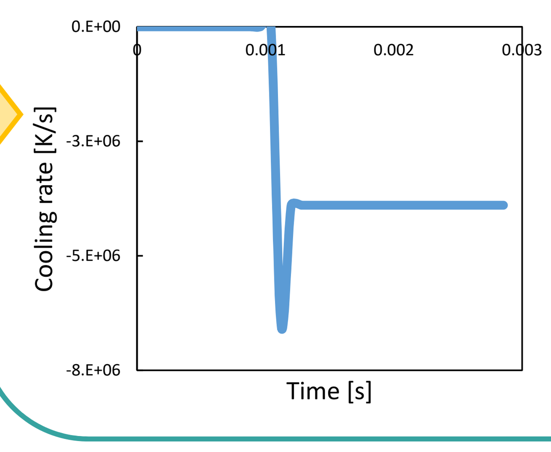
Simulated samples

A preliminary phase of calibration for the **absorption coefficient** allowed the obtainment of the **first 2 mm** of the track



Characterization

Cooling rate data $\dot{T}$ evaluation



Estimation of PCAS and **H** through the **empirical formula**:

$$PCAS = 80\ \dot{T}^{-0.33}$$

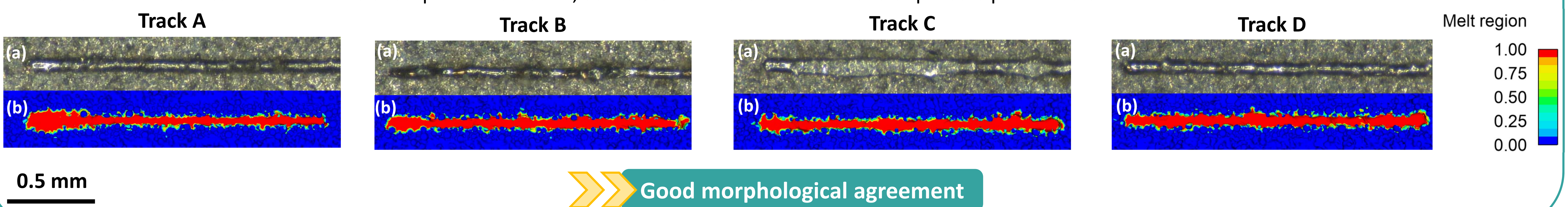
$$H = 152 + 498 d^{-0.5}$$

where d is the grain width, calculated in turn from $\dot{T}$

Results and conclusions

Model calibration

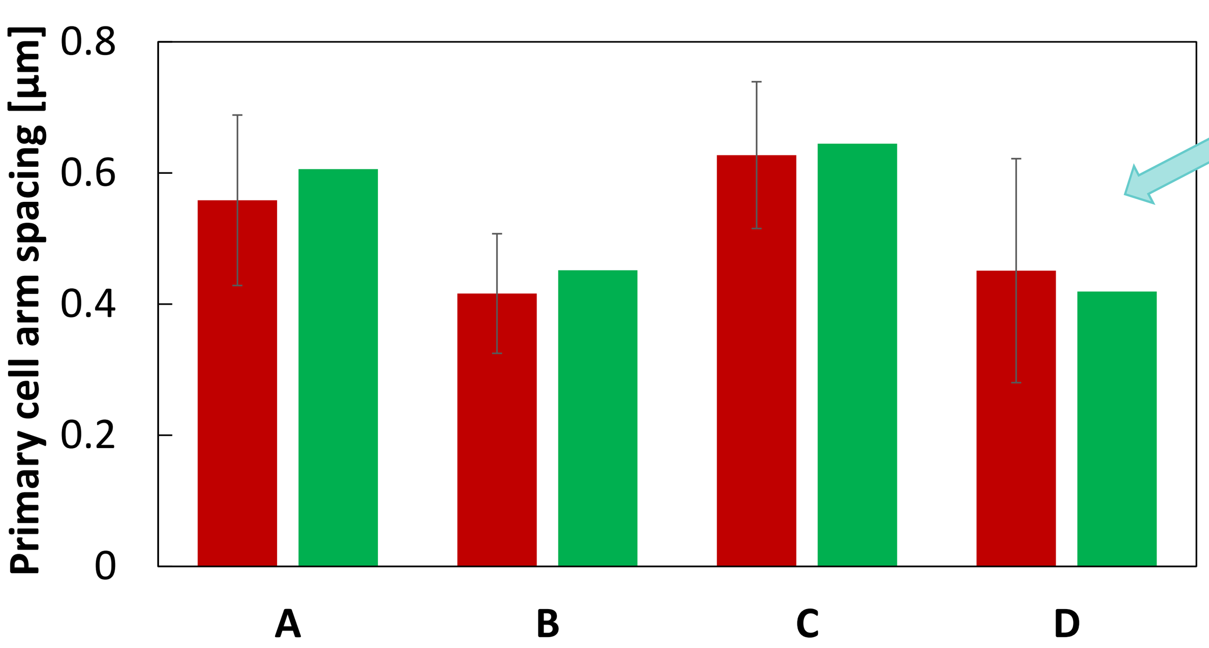
The confrontation between the top view of the track shows **good agreement** between results, as the morphology of the real track (a) is well predicted by simulations (b). This denotes a correct calibration of the absorption coefficient, set to **0.6** for these combinations of process parameters.



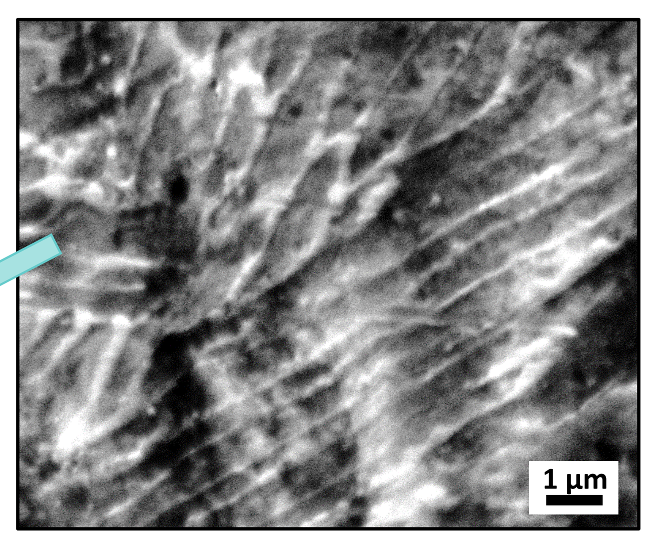
Good morphological agreement

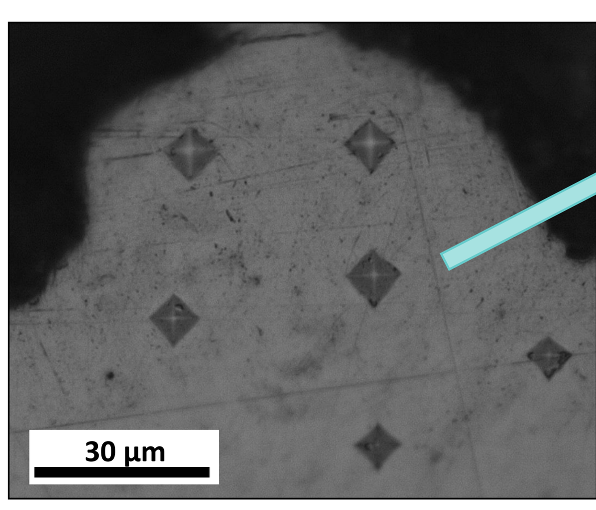
Prediction of Primary Cell Arm Spacing

The simulated results show **high agreement** with the experimental data. The deviation between real and simulated results varies **from 2% to 8%**.



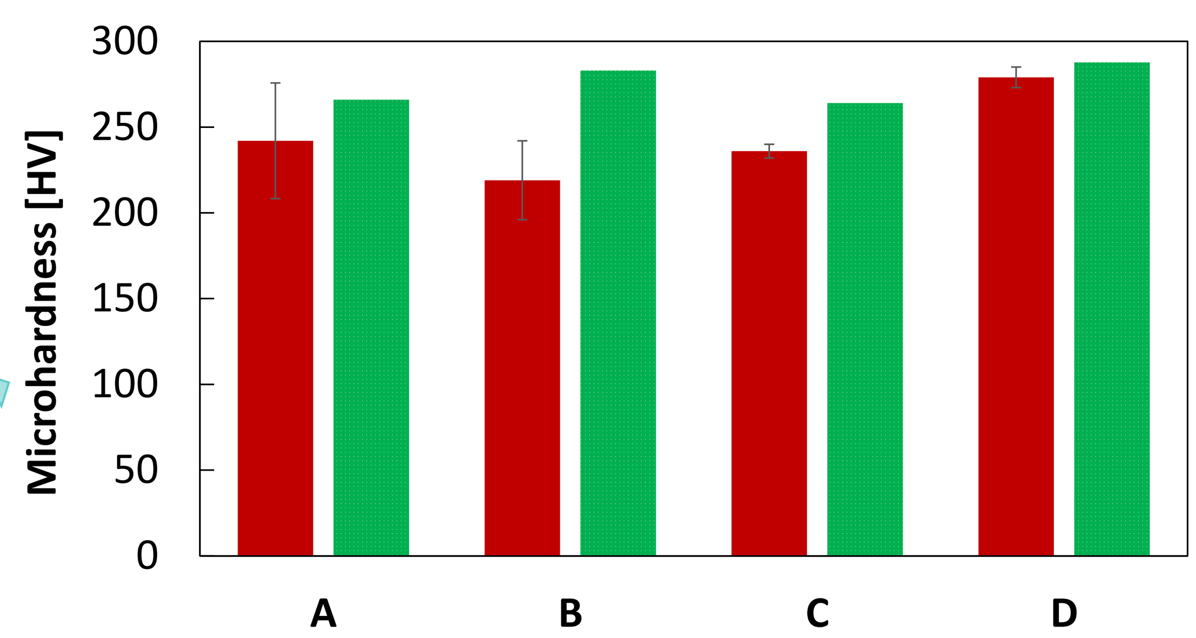
Confirmation of the model validity and its potential in obtaining reliable results for microstructure prediction





Prediction of Microhardness

The predicted values **overestimate** the microhardness of the samples. The deviation between real and simulated results varies **from 3% to 22%**.



Overestimation of the model with respect to the real microhardness of the tracks

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