

# Thermo-Fluid-Metallurgical Modeling of Laser-Based Powder Bed Fusion Process

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**INTRODUCTION:** Selective laser melting (SLM) is a type of additive manufacturing (AM) technique where the parts are produced in a layer-wised manner. In this process, first a layer of fine metallic spherical particles, with sizes spanning from 20-50  $\mu\text{m}$ , will be distributed over a rigid building platform that its elevation can be readily adjusted while the part is being manufactured [1].

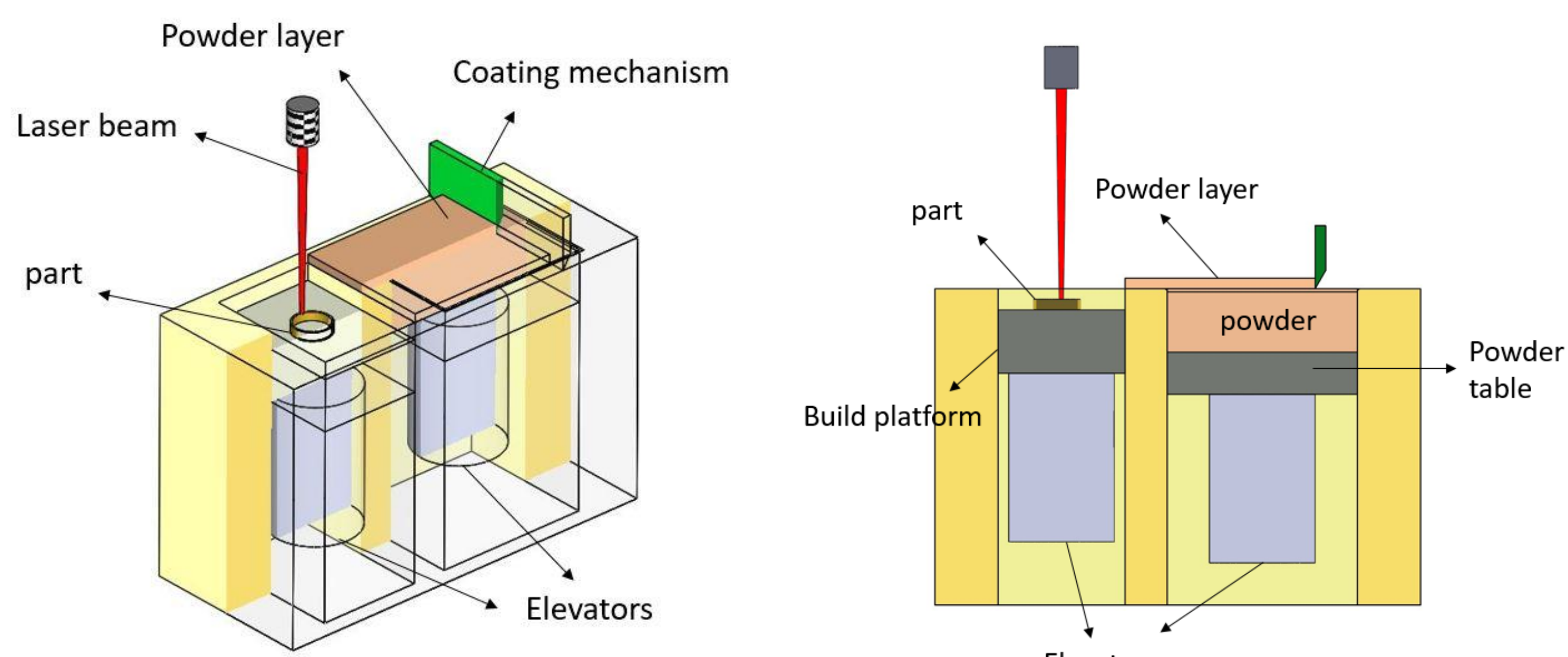


Figure 1. A schematic view of a typical SLM machine.

**COMPUTATIONAL METHODS:** To find the velocity field of the liquid metal during the SLM process, it is necessary to solve the coupled partial differential equations of balance of mass (namely continuity) and linear momentum represented in equations (1) and (2)-(3).

$$\nabla \cdot \mathbf{V} = 0, \quad (1)$$

$$\rho[\mathbf{V}_t + \mathbf{V} \cdot \nabla(\mathbf{V})] = -\nabla P + \nabla \cdot \boldsymbol{\tau}_{ij} + \mathbf{F}_V, \quad (2)$$

$$\mathbf{F}_V = -c \frac{(1 - f_l)^2}{B + f_l^3} \cdot \mathbf{V} + \rho \mathbf{g} \beta (T - T_l), \quad (3)$$

$$\rho[h_t + \mathbf{V} \cdot \nabla h] = -\nabla \cdot [-k \nabla T] + \dot{Q}'''. \quad (4)$$

The partial differential equation of balance of heat must be solved to find the temperature distribution of the computational domain, according to equation (4). The widely-used enthalpy-porosity method has been implemented to solve the equation (4).

Property	Value	Property	Value
$k_s \left[ \frac{W}{m \cdot K} \right]$	13	$\frac{d\sigma}{dT}$	-1.6e-4
$k_l \left[ \frac{W}{m \cdot K} \right]$	33	$\mu [Pa \cdot s]$	0.005
$Cp_s \left[ \frac{W}{m \cdot K} \right]$	543	$\beta \left[ \frac{1}{K} \right]$	1.1e-5
$Cp_l \left[ \frac{W}{m \cdot K} \right]$	750	$T_s [K]$	1893
$LH \left[ \frac{kJ}{kg} \right]$	280	$k_l \left[ \frac{W}{m \cdot K} \right]$	1928
$\rho_s \left[ \frac{kg}{m^3} \right]$	4510	$\alpha [-]$	0.3

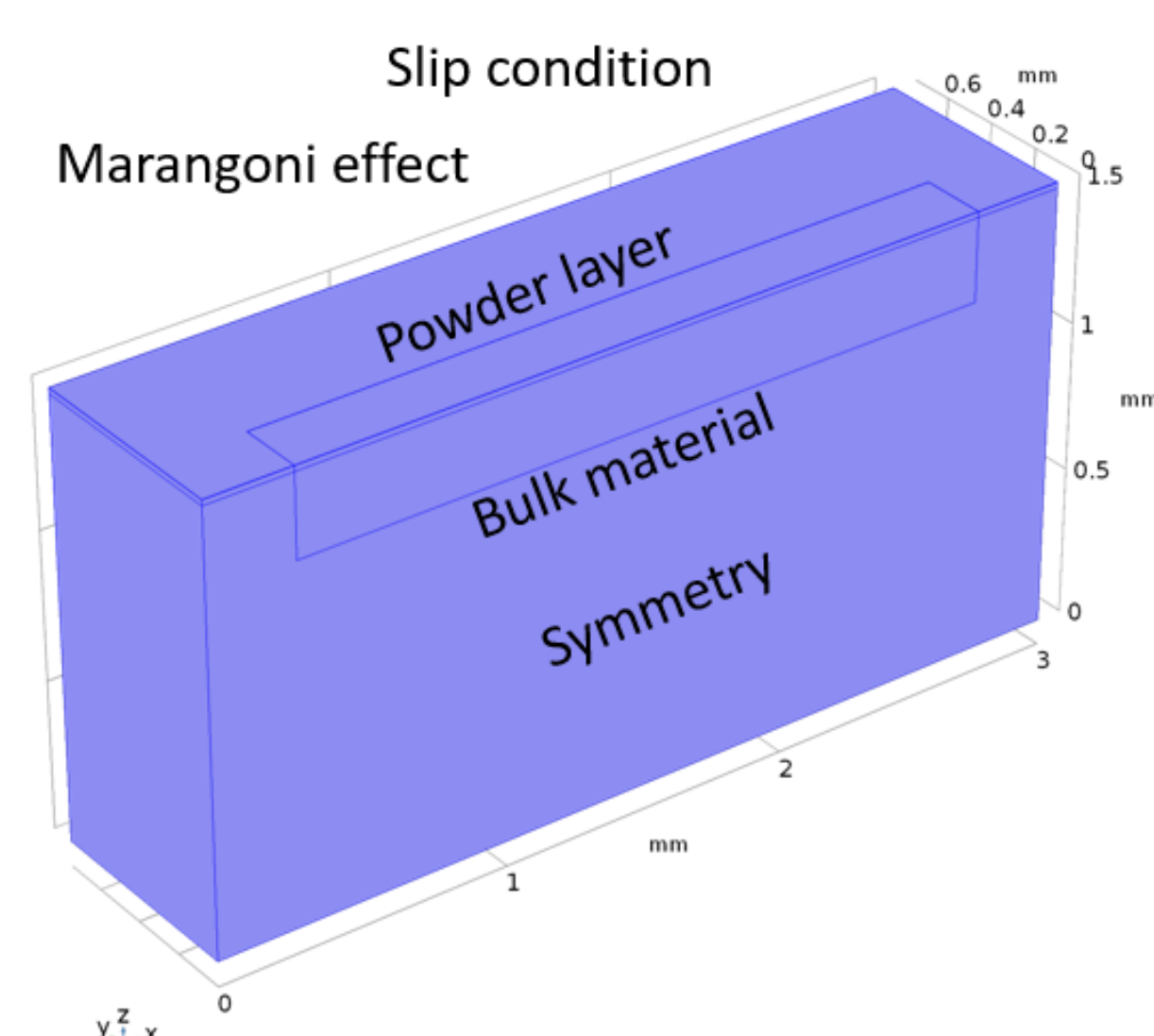


Table 1. Ti6Al4V thermo-physical properties Figure 2. 3D view of the numerical model.

**RESULTS:** The evolution of the melt pool during the single track SLM process at different timescales is shown in Figure 3.

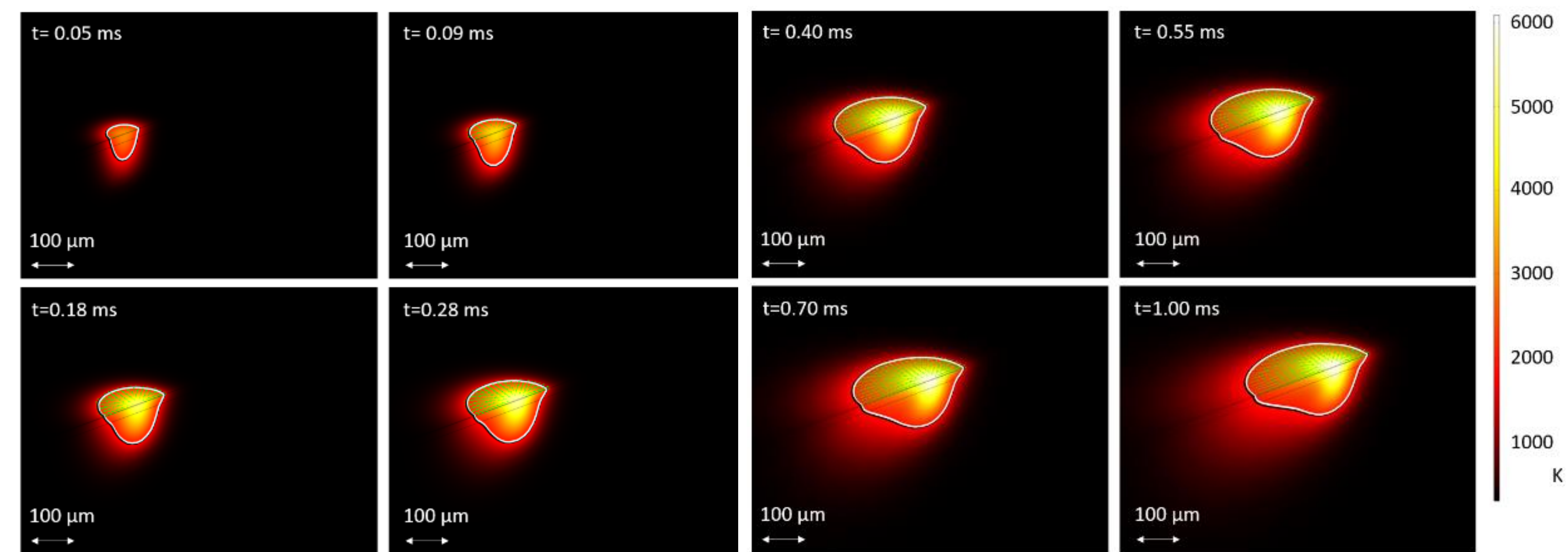


Figure 3. Melt pool morphology and its evolution.

The temperature and heating/cooling rates along the central scanned line are shown in Figure 4 and 5 at different times during the SLM process, respectively.

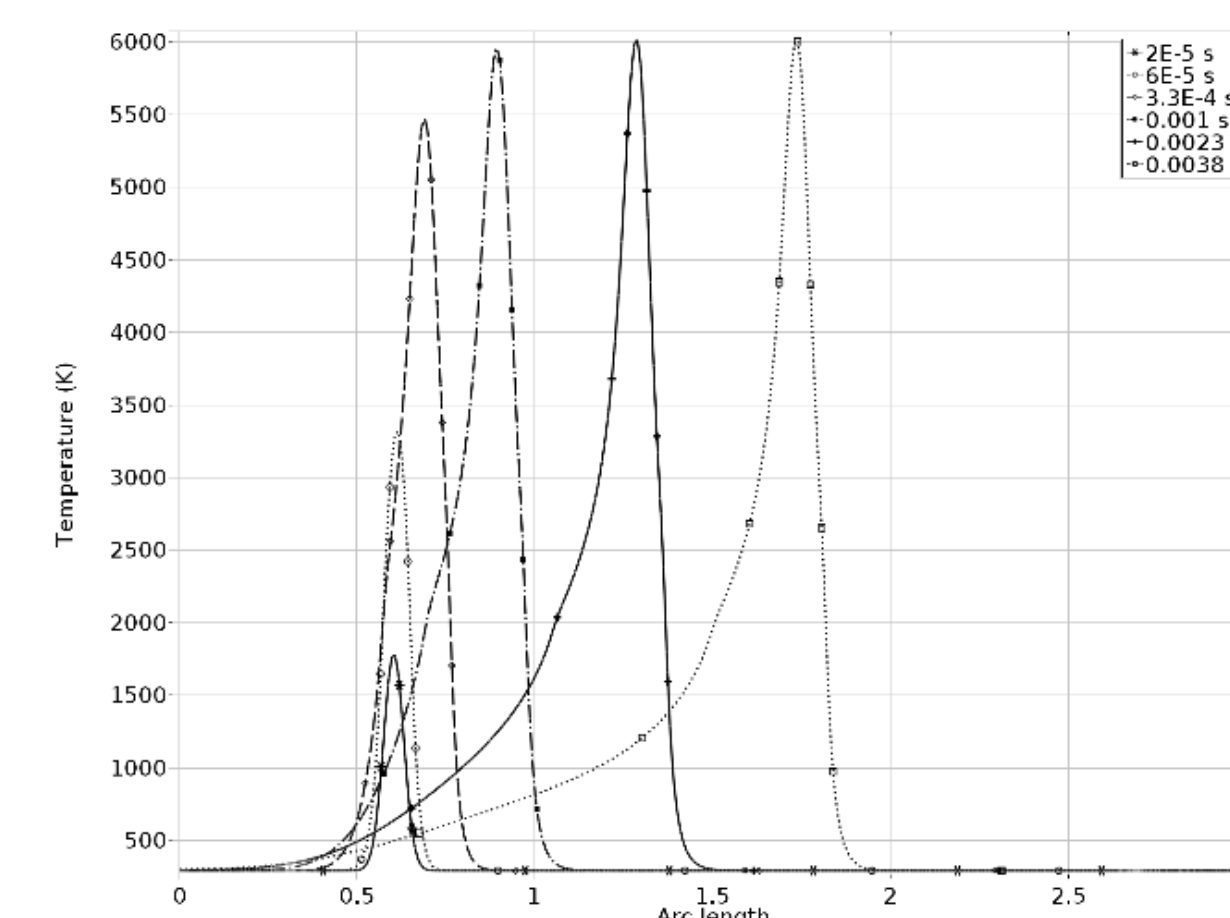


Figure 4. Temperature at the central line for different time scales.

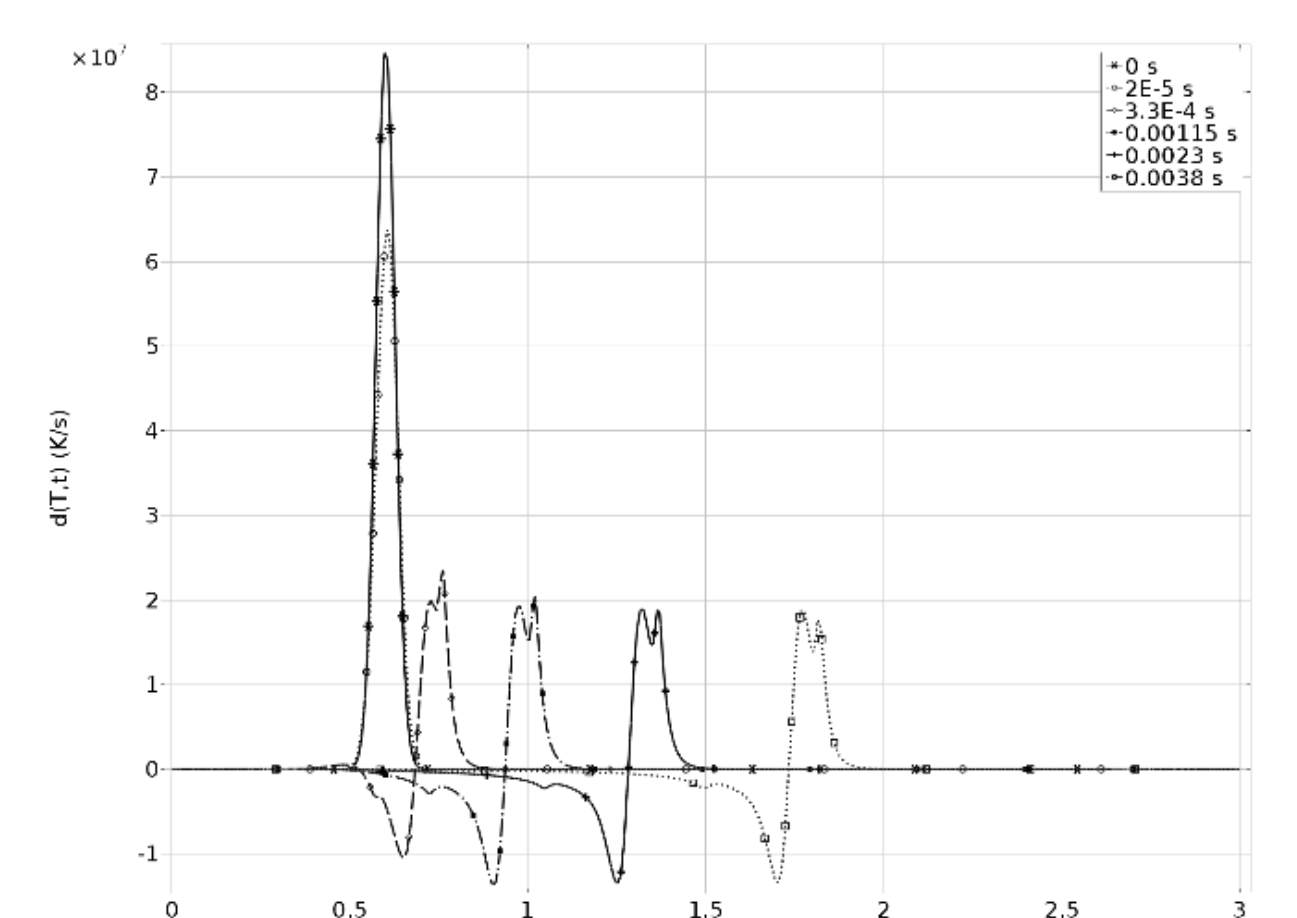


Figure 5. Heating/cooling rates at the central line.

The important microstructural parameters are calculated on the border of the melt pool and at the end of the solidification, via LiveLink™ for MATLAB®.

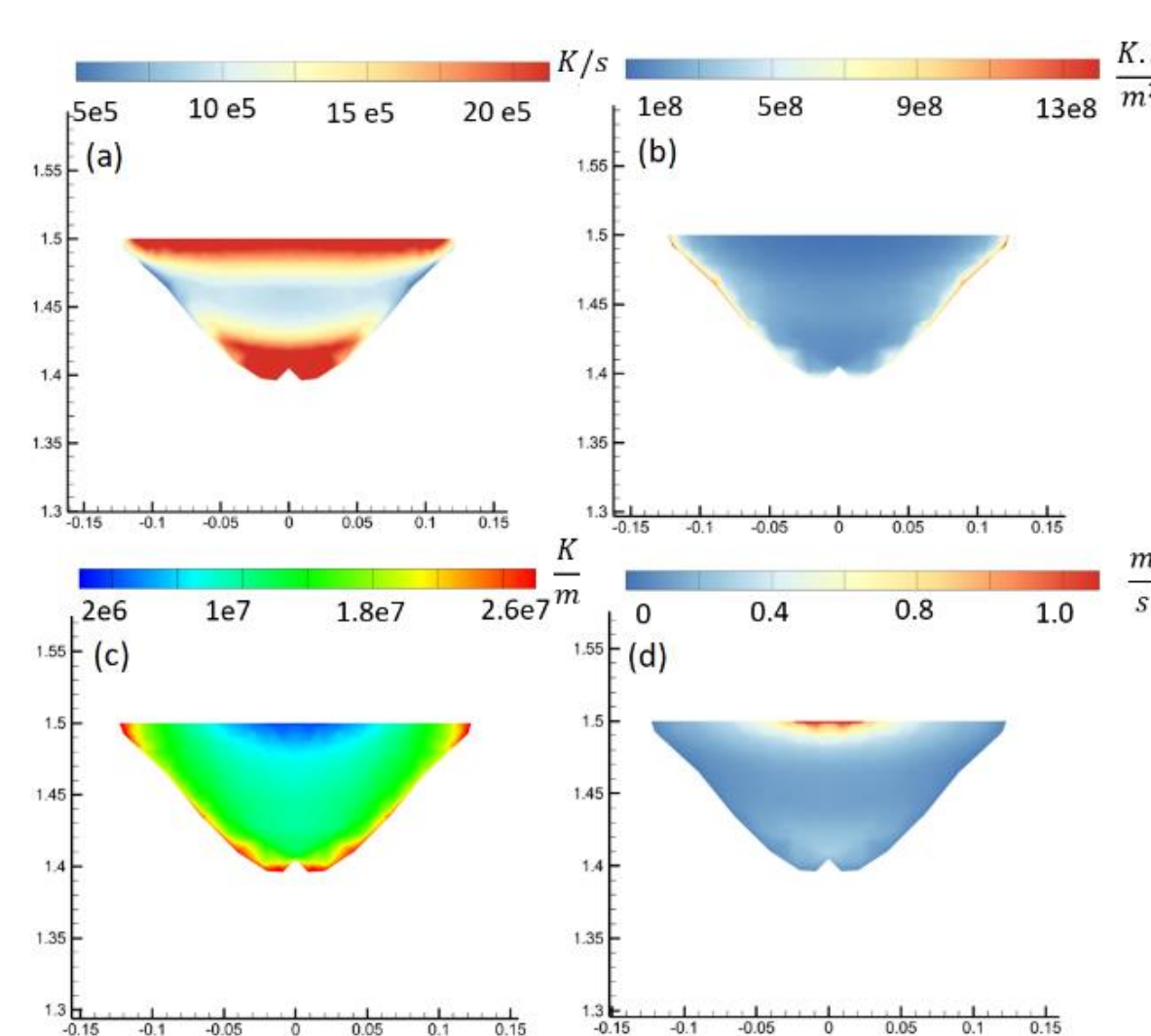


Figure 6. Calculated important solidification parameters.

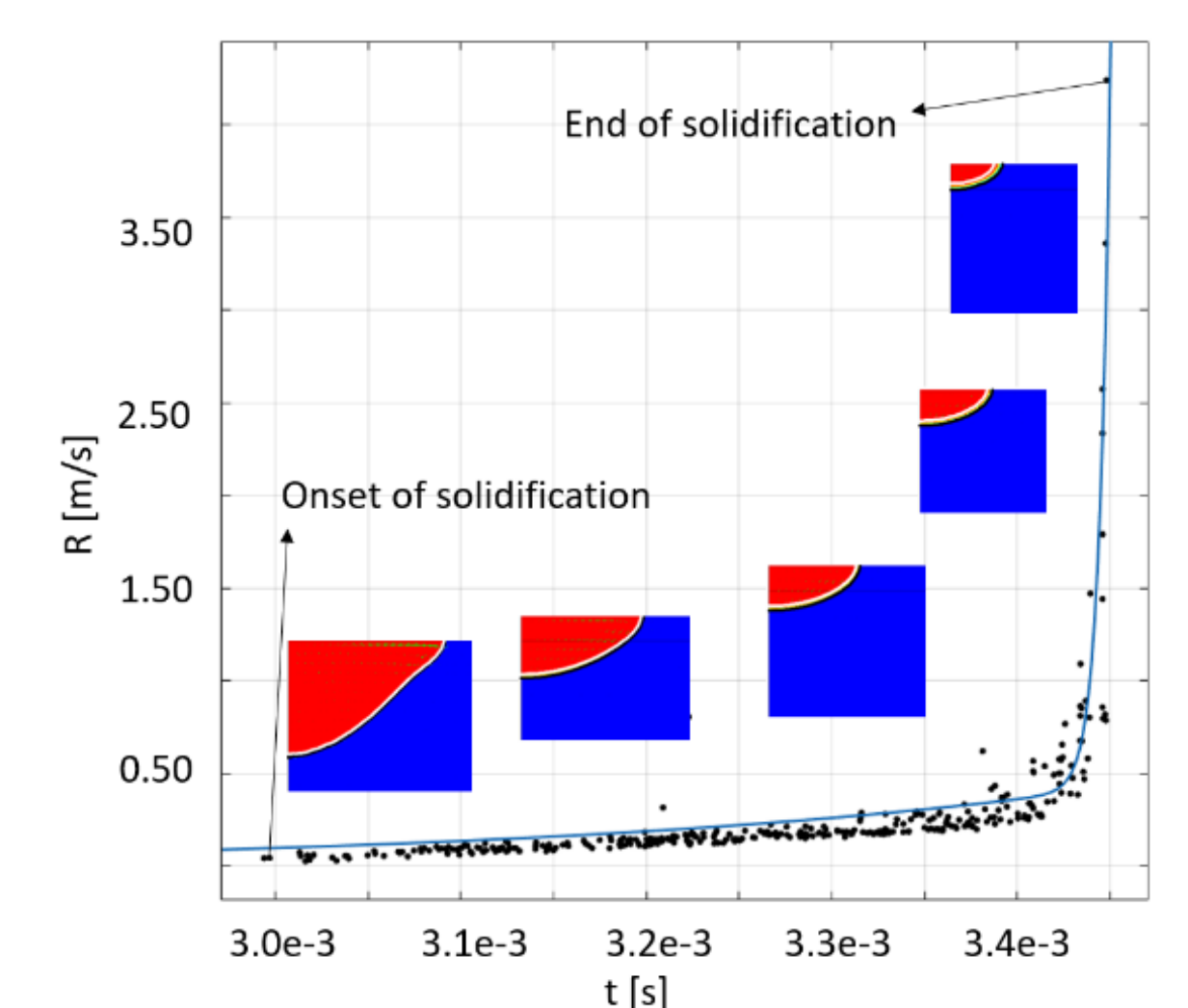


Figure 7. The plot of solidification growth velocity versus time.

**CONCLUSIONS:** In this work a multiphysical numerical model for the SLM process has been developed that includes thermal model, fluid dynamics model, porous medium and a microstructural model. The results suggest that the melt pool reaches a pseudo-steady condition after about 1.9 ms. Important solidification data are also calculated by means of the microstructural model.

## REFERENCES:

1. T. DebRoy et al., "Additive manufacturing of metallic components – Process, structure and properties," Prog. Mater. Sci., vol. 92, pp. 112–224, 2018. Author, Article Title, Journal, Volume, Page numbers, (year)