CEMMPRE Meeting 2021

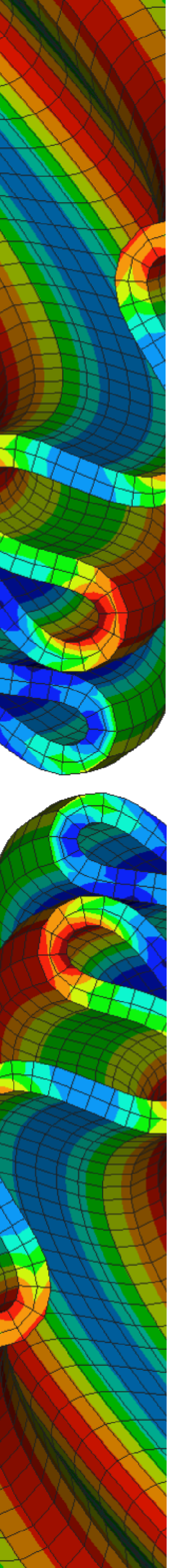
Thermo-mechanical modelling of the Selective Laser Melting process at meso-scale to evaluate residual stresses and distortions

Carlos M. Andrade[(1)]

Diogo M. Neto[(1)], Marta C. Oliveira[(1)], José César de Sá[(2)]

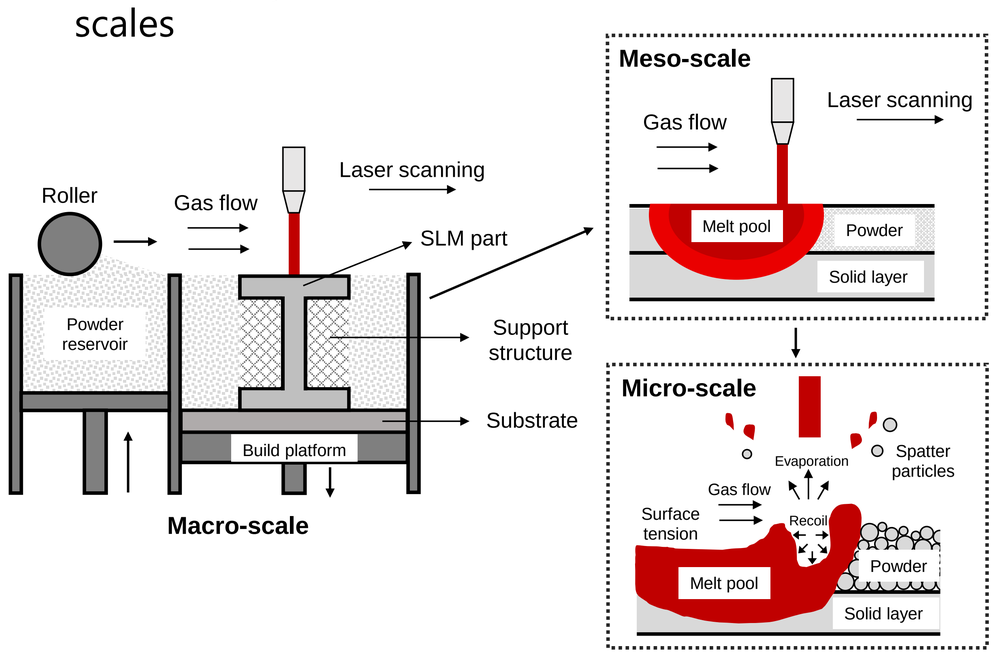
(1) CEMMPRE, Department of Mechanical Engineering, University of Coimbra, Polo II, Rua Luís Reis Santos, Pinhal de Marrocos, 3030-788 Coimbra, Portugal

(2) INEGI, Department of Mechanical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal



Motivation

- The Selective Laser Melting (SLM) process is a powder-based Additive Manufacturing technology that offers the possibility to build complex components
- Numerous parameters need to be fine-tuned in order to obtain defect-free parts
- The interaction between parameters governs multiple physical phenomena that occur at different scales



Methodology

- The developed algorithms will be implemented in the in-house finite element code DD3IMP

Numerical model

- Development of an efficient transient thermo-mechanical model to evaluate temperature and residual stress fields
- Modelling the material solid-state phase transformations, through a metallurgical phase transformation framework
- Development and implementation of a modified adaptive mesh refinement algorithm

Experimental tests and model validation

- Small builds produced with different sets of input process parameters allow to evaluate:
  - In-situ temperature
  - Build distortion and residual stresses
  - Microstructure
  - Hardness gradients

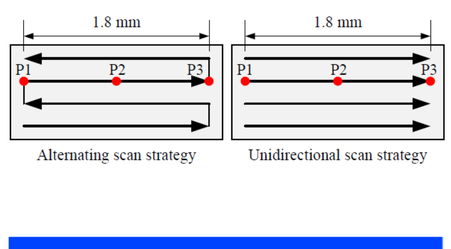
Parametric study and SLM process optimization

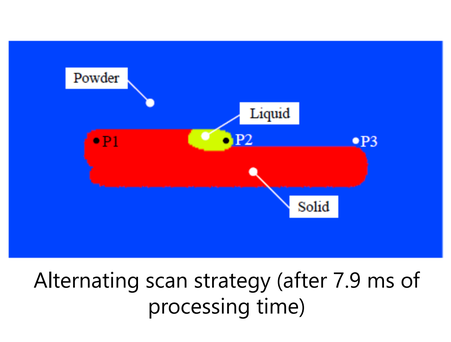
Objectives

- Despite being a very promising technology, the current level of maturity is still insufficient to guarantee on demand reliable solutions
- The main objective of this thesis is the development of advanced simulation methods to perform the analysis of the SLM process at the meso-scale
- The Finite Element Method will be used in the numerical simulations, which aim at:
  - Improving knowledge about material and process parameters
  - Support the gradual replacement of the costly trial-and-error approaches by a simulation-driven method
- The study is focused on the Ti-6Al-4V alloy, an industrially relevant material

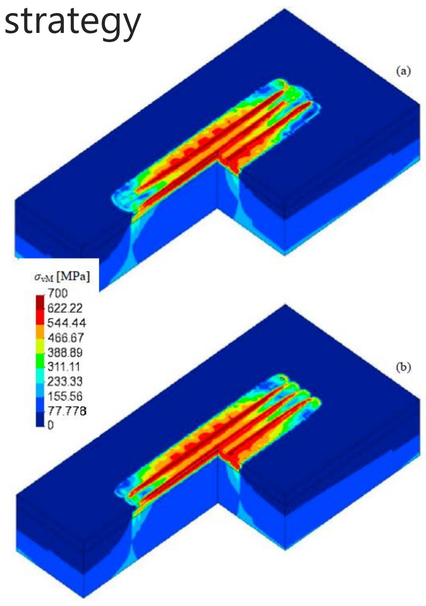
Results

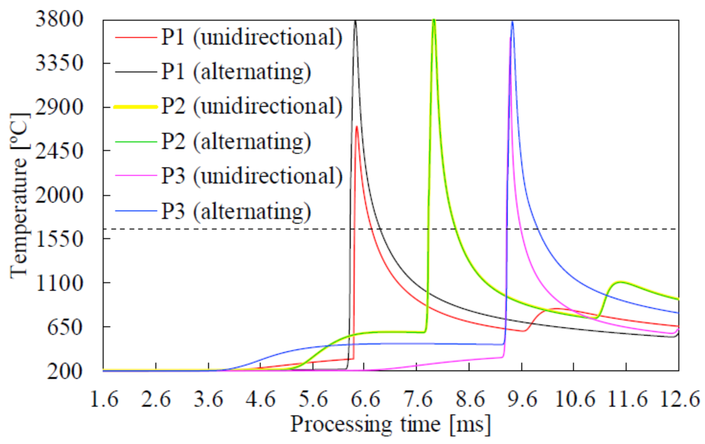
- Finite element model considering:
  - Coupled thermo-elasto-plastic constitutive model
  - Moving heat source according to the laser path
  - Temperature-dependent thermo-physical properties
- SLM numerical results comparing:
  - a) Alternating scan strategy
  - b) Unidirectional scan strategy





Alternating scan strategy (after 7.9 ms of processing time)





The authors gratefully acknowledge the financial support of the Portuguese Foundation for Science and Technology (FCT) under the project with reference PTDC/EME-EME/31657/2017 and UIDB/00285/2020. The first author is also grateful to the FCT for the PhD grant with reference 2020.07178.BD.