A Mesoscopic Approach for Modelling Laser Beam Melting (LBM)

Yaasin A. Mayi* [1, 3], Morgan Dal[1], Patrice Peyre[1], Michel Bellet[2], Charlotte Metton[3], Clara Moriconi[3] and Rémy Fabbro[1]

[1] Laboratoire PIMM, Arts et Métiers, CNRS, Cnam, HESAM Université
151 Bd de l'hôpital 75013 Paris, France
e-mail: yaasin.mayi@ensam.eu, web page: https://pimm.artsetmetiers.fr

[2] CEMEF, UMR 7635 PSL Research University MINES ParisTech
06904 Sophia Antipolis, France
Web page: http://www.cemef.mines-paristech.fr

[3] Safran Additive Manufacturing, a technology platform of Safran Tech
Rue des Jeunes Bois, Châteaufort, 78114 Magny-Les-Hameaux, France
Web page: https://www.safran-group.com

ABSTRACT

Laser Beam Melting (LBM) – also referred to as Selective Laser Melting (SLM) – is garnering industrial attention as the shape flexibility it allows is an opportunity to think differently the design and the functionalities of manufactured components. Based on the interaction between a laser beam and a metallic powder bed, LBM gives rise to complex physical phenomena (powder energy absorption, melting, convection within the melt pool, metal vaporisation, rapid solidification and so on) which must be understood to fully control the process at the industrial scale. In this regard, multi-physical simulation of laser-material interaction becomes an essential research tool to complete experimental diagnostics, to help understanding the origin of some defects such as porosities or cracks and to predict solidification conditions.

However, due to the gap between the grain scale (dozens of micrometres) and the bead scale (from the millimetre to a few centimetres) current state-of-the-art multi-physical models are computationally expensive as each powder bed grain is individually represented [1,2]. Hence, simulating more than a single LBM track in a reasonable computational time is a challenging task. To overcome this limitation, a new mesoscopic approach is proposed, based on the pioneering works of Dal et al. (2016) [3] and Chen et al. (2017) [4]. This intermediate methodology intends to bridge the gap between the fine thermo-hydrodynamic models and the purely thermal macroscopic models; but still to provide a satisfactory representation of the thermo-hydrodynamic phenomena.

The present proof of concept is performed on a 2D-axisymmetric domain, using the commercial software COMSOL Multiphysics®. The powder bed is represented by a homogeneous absorbing media with both equivalent thermal and fluid properties. A bulk heat source is considered when the laser heats the powder bed whereas a heat flux is imposed on the melted powder bed surface. Apparent viscosity and surface tension are attributed to the equivalent media so that modelling densification (due to powder coalescence) melting and spheroidization of the melt pool is made possible by solving compressible Navier-Stokes equations. Also, thermocapillary effects as well as vaporisation-induced recoil pressure are implemented, so that realistic thermo-hydrodynamic phenomena are successfully taken into account. The whole multiphase flow is computed using the pre-implemented Arbitrary Lagrangian Eulerian (ALE) algorithm.

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