Multi-scale simulation of the thermal problem with phase change of the SLMP Additive Manufacturing process

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ABSTRACT

Through its unique principle of adding solid matter at very small scales, Additive Manufacturing (FA) allows an unrivalled freedom of creation. Even if the interest in Seletective Laser Melting Process (SLMP) continues to grow, the use of the parts thus created remains marginal for frequent non-compliance with the specifications by these parts; the main cause being the lack of control of the process. Experimental procedures are still the principal way to determine the optimal process parameters, such as the velocity and power of the laser(s) or the diameter of the powder particles. In this context, the numerical simulation of the SLMP becomes an extremely advantageous tool, which can, if not replace, at least be synergised with experimental tests.

The problem resulting from the modeling of the SLMP process is so complex that its approximation undermines the effectiveness of conventional simulation methods. This complexity arises, in particular, from the nature of multi-physical phenomena extremely localized in the powder, in the vicinity of the impacts of powerful heat sources evolving rapidly over time. Phase-transformation-related phenomena: from granular, to fluid, to solid, through mixtures. A lot of work has been done to model the SLMP (see [1]).

Our work focus on the numerical simulation of the thermal evolution at macroscopic scale where two major numerical difficulties arise. The first one is the evolution of the mesh size which is impossible to be addressed in a monolithic way and the second one comes from the thermal gradients that appear under the laser and that must be correctly detected. In addition, as the laser moves at very high speeds, methods allowing flexible remeshing become essential. Moreover the non-linearity of the phase change phenomenon, located in the laser wake, is also very localized and reinforces the need for targeted local refinement.

The purpose of our work is to develop models and methods allowing for a fine analysis of the complex physical moving problems in the scanning zones based on the Arlequin framework for computation of the thermal field evolution. The Arlequin framework is a multimodel, multiscale method first introduced in [2], it's flexibility is used here to catch the moving strong and localized thermal gradients, the material addition, and to localize the numerical treatment of the phase change phenomena, allowing to significantly reduce calculation costs. It open also the possibility to introduce model reduction methods at different scales.

REFERENCES

[1] Meier and Penny and Zou and Gibbs and Hart *Thermophysical Phenomena in Metal Additive Manufacturing by Selective Laser Melting: Fundamentals, Modeling, Simulation and Experimentation* (2017).

[2] Ben Dhia, Hachmi *Multiscale mechanical problems: the Arlequin method* Comptes Rendus de l'Academie des Sciences Series IIB Mechanics Physics Astronomy, vol. 326, no. 12, pp. 899-904, (1998).