Applications of Immersed Boundary Methods for Laser Powder Bed Fusion Additive Manufacturing

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ABSTRACT

The extreme scale ranges in both space and time involved in laser powder bed fusion (LPBF) process as well as the geometrical complexity of the parts produced by means of LPBF technology call for flexible numerical approaches. Therefore, immersed boundary methods seem to offer a valid alternative to the traditional mesh-conforming finite element method. In the present contribution, we adopt two methods of such a family of numerical methods to investigate some of the most challenging problems in LPBF process and product simulations.

A well established immersed methodology is the so-called Finite Cell Method (FCM). In our work, we apply FCM in the context of high-fidelity thermal and thermomechanical analyses of LPBF processes. The proposed numerical scheme [1] is first validated with respect to experimental measurements obtained by means of a high-speed thermal camera and then applied to investigate the influence of material discontinuities on the melt pool morphology, providing a valuable tool to further understand the complex process-structure-property relationship in LPBF components.

Another promising immersed boundary technique is the two-level method, where the local and global scales of the problem are solved on two separate, weakly coupled meshes [2]. To address the spatio-temporal scale range issues that burden LPBF processes simulations, we have combined the two-level formulation with a multi-rate time integration based on a predictor-corrector type scheme. Exploiting the peculiarity of the two-level method, we are able to treat differently - in a smooth and simple workflow - local and global effects in both the spatial and the temporal scale.

Finally, we address the geometrical issues in LPBF lattice components. In fact, it is well known from the literature that the elastic behavior of lattice structures is dramatically underestimated when computed on the as-designed geometry. Therefore, the actual 3D printed geometry as acquired for instance by Computed Tomography (CT) scan has to be used for the analysis. However, such a geometry can be very challenging to mesh, thus an immersed boundary approach is employed to perform accurate yet cost-effective image-based numerical simulations of 3D printed lattice components [3].

REFERENCES

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