Addition of a finite element activation method in an existing thermomechanical finite element code to model additive manufacturing

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ABSTRACT

With the rise of Additive Manufacturing (AM) technologies in the industry, it becomes more and more important to have a good understanding of such processes. However, there is still a crucial lack of fundamental knowledge regarding AM. Hence, there is a high demand for the implementation of a model to accurately simulate an AM process. The complexity of such a simulation comes from multiple sources. Firstly, from the nature of the process. Indeed, it requires geometrically non-linear thermo-mechanical simulations. Secondly, the modeling of the material law is complex. Lastly, the geometry of the process imposes a very fine discretization (layers can be as small as a few µm). This creates models that are computationally costly. Moreover, the process requires altering the geometry of the model during the simulation to model the addition of matter, which is a computational challenge by itself.

This work presents the addition of additive manufacturing in the fully implicit in-house Finite Element code "Metafor" [1], which considers large strains and includes thermo-mechanical simulations and crack propagation simulations. The focus of the work is to add an "additive manufacturing module" to the existing thermomechanical code Metafor. The implemented method to activate elements and to activate and deactivate boundary conditions during a simulation is adapted from the element deletion algorithm implemented in Metafor in the scope of crack propagation [2]. Indeed, in crack propagation the deactivation of an element in a simulation was already possible, i.e. an element could be deactivated based on a certain crack propagation criterion. This algorithm is modified to allow the activation of elements based on a criterion (which can, in the case of AM, be the presence or not of the element in a certain "activation volume" modeling the moving laser). After implementing other AM specificities (heat source model, annealing temperature for alloys, etc), an effective thermomechanical simulation of Additive Manufacturing is obtained.

The model is then compared against the literature, including numerical and experimental results from a thermal experimental calibration [3] and a thermo-mechanical analysis [4] of blown powder laser solid forming of Ti-6Al-4V. Temperature, deformation and stress fields are analyzed as well as the influence of different process parameters.

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