Model reduction technique for evaluation of residual stresses and deformation of parts obtained by additive manufacturing

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ABSTRACT

Additive manufacturing offers numerous advantages in term of conception and is rapidly growing in industrial application. However parts obtained by such process must fulfill some specific requirements in order to be successfully manufactured. Simulation is required at the conception stage to optimize orientation regarding to the build direction, generate supporting structure and account and compensate for residual deformations. The presented method aims to accelerate the simulation of the manufacturing at the scale of the entire part in order to predict the deformations and stresses during the fabrication. The key idea of the method is to use a separation of variables approach in order to reduce the size of the computational domain, but still accounting for non-linearities of the model.

Additive manufacturing, and more precisely powder bed technologies for metallic parts is the technology of interest in this study. The essence of the considered manufacturing process is to build a part layer by layer (from 50 to 100μm thick), selectively melting metallic powder until the part is fully formed. This process generates extremely high gradients in terms of heat distribution, therefore inducing elastic and plastic deformations. A model predictive enough is needed to capture those deformations and also ensure that no collision occurs between the part and the roller spreading the powder.

A traditional finite elements based method accurate enough to capture the considered physics can be prohibitive in terms of simulation time [2], even using relatively simple inherent strain elasto-plastic model [3]. The main idea developed here is to use a separation of variables approach [1] in order to reduce the size of the computational domain, and consequently the computing time. For instance, the expression of the displacement field for an increment of the elasto-plastic model is expressed under the form $\mathbf{U}(x,y,z,n) = \sum_{i=1}^{N} \mathbf{U}_{(xyz)}(x,y,z) \cdot \mathbf{U}_{(n)}(n)$, where (x,y,z) are the spatial coordinates in a reference domain representing any layer, and n is the number of the layer. Such decomposition allows to run the simulation with a 3D discretization of the building volume of only one layer, drastically reducing the number of unknowns of the problem. As a consequence, every time a new layer is added, the simulation domain only increase by one degree of freedom in the dimension n.

In conclusion, the presented method does not features new physics or model for additive manufacturing, but drastically reduces the computational cost of the simulation. Such reduced cost is an asset that can be used to run more simulations and better understand the process or increase the quality of the parts.

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