Macro Scale Simulation for Distortions and Residual Stresses Prediction in Powder Bed Additive Manufacturing

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ABSTRACT

The heating and cooling process that occurs during the Additive Manufacturing (AM) based on powder bed by Direct Metal Laser Sintering (DMLS) induce distortions in the part which need to be accounted for in order to fabricate the desired final part within tolerances. AM-DMLS can be considered as a series of micro welding processes; so it presents the same problems [1] in the context of residual stresses [2] and distortions as in conventional welding.

In the AM process of a real part, two zones with different components can be distinguished, the actual part (bulk material) and the support structure. Each one has their own behaviour, so, an independent study should be developed to characterize them.

To characterize the behaviour of the bulk material regarding to the machine parameters, a thermomechanical simulation by means of Finite Element Method (FEM) of a double cantilever beam (specimen) of 316L stainless steel was carried out. However, thermomechanical simulation of an actual part would require several hours or days from the computational point of view. The proposed method reduces these times to few hours or even minutes thanks to the combination of the shrinkage method and the condensation layer technique. This simplified approach allows a fast method to determine the distortions and the residual stresses, and enables a later pre-warp study of the initial geometry to obtain the final desired part.

Moreover, in most manufacturing of actual parts, support structures are required; however, its geometrical complexity does not allow simulating them explicitly since it will dramatically increase the computational time. Thus, a FE equivalent solid model of the structure was developed determining the equivalent both in and out of plane stiffness.

Thus, once both FE models were developed and validated through an experiments program, the distortion of an actual part can be simulated in a few minutes/hours. To correct the distortions results, an iterative method was developed to calculate the pre-warped shape of the part .

In conclusion, the principles of a simplified macro scale approach which allows a fast solution for the prediction of distortions, residual stresses and support structures breakage in AM-DMLS are presented as well as the pre-warping strategy to compensate the distortions of the part prior the manufacturing process.

REFERENCES

[1] D. Radaj, *Heat effects of welding: temperature field, residual stress, distortion*, Springer Science & Business Media, (2012).

[2] L. Van Belle, G. Vansteenkiste, J.C. Boyer, *Investigation of residual stresses induced during the selective laser melting process*, Trans Tech Publ (2013) **554**:1828–1834.