Simulation for Additive Manufacturing
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Finite element simulation of Ti-6Al-4V direct metal deposition

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The numerical modelling of additive manufacturing processes can help to predict the residual stresses and permanent strains in mechanical parts at the end of fabrication. The initial CAO and the machine parameters can then be optimized "a priori" in order to minimize these residual stresses and get the expected final geometry. An accurate prediction of the micro-structure generated by additive manufacturing process is also useful in order to forecast the mechanical properties of the manufactured material. It is particularly important in the case of Ti-6Al-4V alloy for which the final micro-structure is highly dependent on the process parameters namely the laser power, the laser speed or the powder mass flow [3]. The manufactured part can be at the end composed of the phase α which is hexagonal close packed (HCP), the phase β which is body centred cubic (BCC), the martensitic phase α', or a homogeneous or heterogeneous mixture of two or three of these phases.

The prediction of the metallurgical phases at the end of the fabrication requires an accurate knowledge of the thermal path experienced by each point of the manufactured part. For that purpose, a thermal finite element model of direct metal deposition has been developed by A.Longuet [1] and G.Marion [4] and validated using some comparisons with experimental measures. The temperature fields obtained from these simulations are then used as an input of a metallurgical model in order to predict the evolution of phases all along manufacturing process. The final metallurgical state obtained for four different sets of process parameters are compared with the corresponding experimental measures in order to validate the modelling approach.

The thermal and metallurgical fields obtained form both present model are then used as inputs of a mechanical finite element simulation of the direct metal deposition process. A mean field mechanical model is build based on the mechanical behaviour of each phase [2], and used in the finite element mechanical simulation in order to evaluate the residual stresses and strains at the end of manufacturing. The deflection of the manufacturing substrate obtained from the simulation is found to be in good agreement with the corresponding experimental measures.

This three step (thermal - metallurgical - mechanical) finite element analysis can be used to simulate the manufacturing by direct metal deposition of simple industrial parts, and can help to optimize the process parameters, or the initial geometry or the part, in order to minimize the residual stresses and strains.

Références

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