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3D finite element analysis of molten pool behavior in selective laser melting process

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Laser-based additive manufacturing is a near-net shape manufacturing process able to produce net-shape 3D objects starting from metallic powders melted layer by layer. It permits to manufacture products that are very difficult to fabricate by the traditional processes, saving material and time. Despite the benefit, these manufacturing processes are very problematic to control because of the high number of involved parameters.
The numerical simulation can help to reduce the amount of experimental trial-and-error tests necessary to optimize the process, to minimize the time and cost of manufacture of the final product while maintaining its quality unmodified. The thermal behavior of the molten pool is one of the most critical factors that influence the laser deposition, as it affects geometrical accuracy, material properties and residual stresses. In this paper, a three-dimensional finite element model is developed to simulate the thermal behaviour of the molten pool. The analysis of laser powder bed fusion process is carried out using Ansys, a commercial finite element software.
The model is based on a discrete pulse laser scanning the material point by point. The material properties are temperature dependent and two different set of parameters are implemented for powder and solid.
The simulation makes it possible to analyse also the case of multi-path and multi-layer processes. The procedure involves a series of loop cycles that take into account the iterations on subsequent spots and layers. Due to cyclic behaviour the solution must be carried out at each iteration.
During the post process, the temperature of the elements is checked in order to evaluate which ones are over the melting temperature of the material. To track the time evolution of temperature data are stored at each solution step and then uploaded again. The elements are updated with a mapping procedure based on their number. Previous information becomes initial condition for the actual iteration [1,2]. The analysis allows also for the simulation of recoating process. The thermal behaviour of molten pool halved along the symmetry plane is illustrated in Fig. 1.

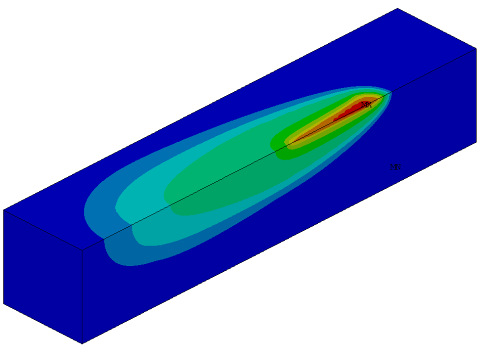

Figure 1 - Thermal behavior of molten pool.

A scanning strategy, including both a meander path and the contour, is simulated by an external software code. To track the coordinates of laser application points a path simulator is built using MatLab. The simulator imports a CAD file with the geometry. Than it slices the model and calculates the path layer by layer. Once having both the path and the geometry, the laser pulse coordinates are used by Ansys to impose the thermal load in the defined spots. To improve the performances of the simulation the two software interact each other to solve the analysis. At the beginning a calibration procedure is carried out to fit the numerical solution with the experimental data [3]. Then the tuned model is used to simulate the real process. The result of the interaction between the path simulator and the FE code is illustrated in Fig. 2.

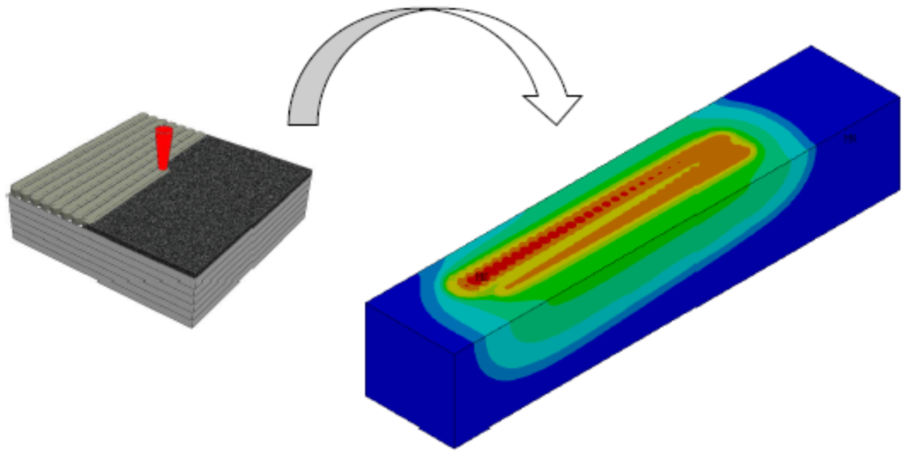

Figure 2 - From path simulator to FE analysis.

By this method, the temperature distribution and the geometrical feature of the molten pool under different process condition are investigated. Results from the FE analysis provide guidance for setting up the optimization of process parameters and develop a base for further residual stress analysis.

References

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