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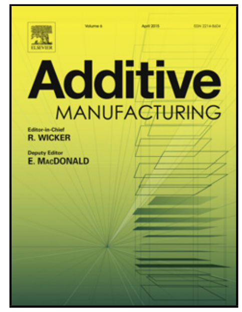

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Limitations of the Inherent Strain Method in Simulating Powder Bed Fusion Processes

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Abstract

Process optimization has always been a crucial step for effective usage of metal additive manufacturing (AM) processes: it consists in establishing quantitative relations between final part's characteristics and process parameters to find their optimal combination and obtain a fully functional mechanical component. Experimental investigation techniques are usually employed for this purpose but they can be extremely expensive and time-consuming, especially when the output of the process depends on a large number of parameters, like for AM. Numerical simulation could represent an alternative solution: by reproducing the real process characteristics, a simulation could provide useful insights, allowing to evaluate the performance of the process for different parameter combinations without relying exclusively on expensive experimental campaigns.

In this work, a finite element AM simulation based on the Inherent Strain (IS) method was developed and the prediction performance in terms of part's residual deformation was evaluated by comparing the numerical results with the measurements carried out on an experimental campaign. A new model calibration approach for prediction improvement was also implemented and it allowed to discover an unexpected behaviour of the model that strongly affects the validity of this method for AM simulation.

Keywords: Additive Manufacturing (AM), Inherent Strain (IS), Simulation, FEM, Calibration, Validation

1. Problem Statement

In the last years, Additive Manufacturing (AM) processes gained popularity in manufacturing industry thanks to their unmatched characteristics in terms of product design flexibility. However, a few key issues (e.g. dimensional accuracy, residual tension, porosities) affect the final products and they are limiting the diffusion of this new technology. For this reason, process optimization is always required to produce a fully functional mechanical component: it consists in testing different combinations of process parameters to find the optimal process window, that is the parameters combination region that meets the performance requirements. There are many different parameters that must be set for an AM process, a few of them are reported in the following list:

- scan strategy (path and speed);
- pre-heating temperature;
- layer thickness;
- beam size and power;
- powder size and morphology;

Their influence on the output quality of every new build should be carefully evaluated. This is clearly a multi-variable problem because the process window for the production of each component will be a specific combination of the aforementioned parameters.

Today's process optimization is exclusively carried out relying on expensive experimental campaigns. This approach has the advantage of being the most accurate solution, since results come directly from the machine, but it is a slow iterative approach which is highly expensive both in terms of times and costs because it relies on quality measurements of parts which must be directly built, thus wasting material and energy. For these reasons, a new process optimization approach based on simulation would be extremely appealing. Following the same iterative optimization path, it would allow to avoid all the wastes (build/quality measuring costs and times) of the test-based approach, supporting the design with useful process insights by simulating the process performance with different combinations of process parameters without building the component. The fully functional part can then be built the "first time right", once its production is optimized. In this work, the AM simulation topic is thoroughly discussed and the capabilities of this kind of approach in improving the process design are evaluated and directly tested by developing a new AM simulation model.

The paper is focused on obtaining an accurate prediction of the residual stress state of the built component. This output determines the final part deformation and

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