Adaptive Local-global Multiscale Simulation for Thermal Analysis of Powder Bed Additive Manufacturing

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ABSTRACT

Thermal simulation of powder bed fusion additive manufacturing (PBFAM) processes such as selective laser melting (SLM) and electron beam melting (EBM) is a challenging task. It involves calculation of a highly localized transient temperature field generated by a laser or electron beam with a typical radius of 30-100 μm and a velocity of 100-1000 mm/s. Reliable numerical analysis of these processes requires fine space and time discretization on the order of micrometers and microseconds, respectively. On the other hand, PBFAM builds are typically in the range of centimeters and their manufacturing takes hours. Thus there is a clear discrepancy between the scales of conventional PBFAM simulations and actual parts.

While small-scale approaches can provide relatively accurate results, their high computational cost is a major drawback in part-scale simulations. On the other side of the spectrum, simplified approaches have been developed for macro-scale simulations employing large elements and time steps, but they suffer from a lack of accuracy. Therefore, new methods that can reduce the computational cost of part-scale PBFAM thermal simulations with minimal loss of accuracy are needed.

A multiscale simulation approach is developed in this study for continuum based thermal modeling of the PBFAM processes (Fig. 1). The approach is based on an adaptive local-global strategy and employs results from one global coarse-mesh and multiple local fine-mesh models. First, the laser movement is simulated in the global model using relatively large element size and time steps. The resulting temperature field is valid in regions far enough from the heat source. Afterwards, laser path is divided into segments and thermal history is recalculated using the far-field temperatures from the global simulation as boundary conditions in a fine-mesh local model. Finally, the temperatures from these two simulations are combined to obtain an accurate description of the temperature history over the whole body.

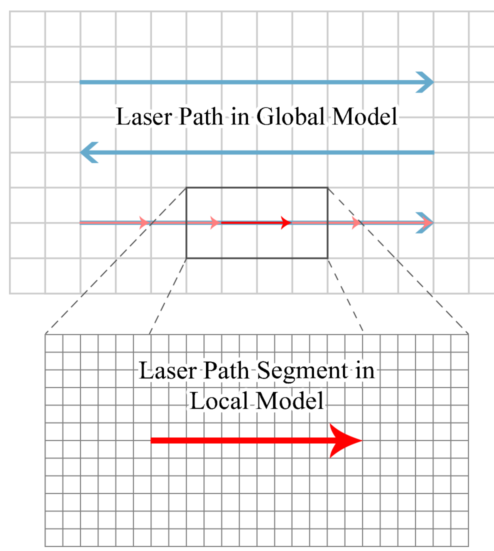

Figure 1: Local-global multiscale simulation strategy for thermal analysis of PBFAM.

This modeling approach has been implemented in Abaqus finite element software package, and verified for 2D thermal simulations. The results indicate that the high accuracy of a fine mesh grid is maintained while the computational costs are reduced. Additionally, there is the possibility of using a surrogate model for local simulations in order to increase the calculation speed even further.

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