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Multiscale Modeling of Thermal and Mechanical Behaviors in Powder Bed-Based Additive Manufacturing

Patcharapit (Joe) Promoppatum
Graduate student, Mechanical Engineering

ABSTRACT

Powder bed-based additive manufacturing (AM) enables the construction of a three-dimensional object through melting and solidification of metal powder. The primary advantage of AM over the conventional process is providing manufacturing flexibility, especially for highly complicated products. The quality of AM products depends upon various processing parameters such as laser power, laser scanning velocity, laser scanning pattern, layer thickness, and hatch spacing. The improper selection of these parameters would lead to parts with defects, severe distortion, and even cracking. I herein perform numerical and experimental analysis to investigate the interplay of processing parameters on defect generation. The analysis aims to resolve issues at two different scales, micro-scale and product-scale. At the micro-scale, the numerical model has been developed to investigate the interaction of the laser with materials in the AM process. Numerical results have been verified by a series of experiments. Moreover, together with existing AM process criteria, a numerical processing window has been developed as a guideline for AM users to avoid common defects at this scale including lack of fusion, the balling effect, and over-melting. Even though the micro-scale analysis can resolve some common defects in the AM process, it is not capable of predicting the product-scale responses such as residual stress development and the entire product's distortion. As a result, the multiscale modeling platform has been developed to perform the numerical investigation at the product level. The influence of multiple layers, energy density and scanning pattern on the residual stress of the product have been addressed, which leads to the prediction of the residual stress development during the fabrication. The distortion of products due to the residual stress can also be described by the product scale model. Ultimately, the present work illustrates the integration of the computational methods as tools to provide manufacturing qualification for part production using AM processes.

BIOGRAPHY

Joe completed his bachelor's in Mechanical Engineering at King Mongkut's University of Technology Thonburi, Thailand. Since 2014, Joe has worked with Professor Shi-Chune Yao and started developing numerical models to reveal physical behaviors in the AM process. After completing his Master's in 2015, he continued working with Professor Yao as a doctoral student, in which his works have resulted in several publications. In 2017, his developed numerical scheme won the AM modeling challenge in a competition organized by AmericaMakes. During his graduate studies, he is awarded the Royal Thai Government and the Bertucci Graduate Fellowships.