Mechanical Engineering Doctoral Defense

Process Modeling and Optimization of Powder Bed Additive Manufacturing of Inconel Material

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Abstract

Laser powder bed fusion (LPBF) additive manufacturing (AM) has received widespread attention due to its ability to produce parts with complicated design and better surface finish compared to other additive techniques. LPBF uses a laser heat source to melt layers of powder particles and manufactures a part based on the CAD design. This process can benefit significantly through computational modeling. The objective of this thesis was to understand the thermal transport, and fluid flow phenomena of the process, and to optimize the main process parameters such as laser power and scan speed through a combination of computational, experimental, and statistical analysis. A multi-physics model was built using to model temperature profile, bead geometry and elemental evaporation in powder bed process using a non-gaussian interaction between laser heat source and metallic powder. Owing to the scarcity of thermo-physical properties of metallic powders in literature, thermal conductivity, diffusivity, and heat capacity was experimentally tested up to a temperature of 1400 degrees C. The values were used in the computational model, which improved the results significantly. The computational work was also used to assess the impact of fluid flow around melt pool. Dimensional analysis was conducted to determine heat transport mode at various laser power/scan speed combinations. Convective heat flow proved to be the dominant form of heat transfer at higher energy input due to violent flow of the fluid around the molten region, which can also create keyhole effect. The last part of the thesis focused on gaining useful information about several features of the bead area such as contact angle, porosity, voids and melt pool that were obtained using several combinations of laser power and scan speed. These features were quantified using process learning, which was then used to conduct a full factorial design that allows to estimate the effect of the process parameters on the output features. Both single and multi-response analysis are applied to analyze the output response. It was observed that laser power has more influential effect on all the features. Multi response analysis showed 150 W laser power and 200 mm/s produced bead with best possible features.

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