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Selective laser melting (SLM), also known as powder bed fusion (PBF), is a flexible approach to fabricate complex-shaped metal parts layer-by-layer, especially for parts with complex interior shapes that are difficult to be machined conventionally. One of its typical applications is to fabricate molds consisting of conformal cooling system in which cooling channels may have to be printed horizontally without any supports [1]. Moreover, the internal channel surface cannot be further finished after SLM due to structural limitations. Thermal stress-induced deformation and surface roughness of the overhanging region are two major contributors to shape deviation and are thus concerns that must be addressed.

The simulation work presented in this abstract investigates the mechanisms of deformation and surface roughness on overhanging region induced by thermo-mechanical behavior of SLM process under different overhanging angles, laser power, and scan velocity. A 3D coupled CFD-FEM model is developed by considering the heat conduction, melting and solidification with latent heat, surface tension, as well as Marangoni convection. A quasi-randomly distributed powder bed is employed. The simulation results are validated with SLM printing experiments.

The overhanging region is nonrigid and essentially a cantilever due to the unmelted powder below. The simulation result shows that the stresses in the SLMed overhanging region are much lower than the stresses in the solid region. The stresses in the overhanging region are released, however, leading to unwanted upward deflection. The surface roughness on the overhanging region is largely determined by the shape and size of the molten pool. It increases with increasing overhanging angle and energy input per volume (i.e. increase of laser power or decrease of scan velocity). This simulation work can thus be directly used to compensate for the shape deviation in the design stage, namely design-for-AM guidelines for the additive manufacturing of internal channels. It will also be helpful for process parameter optimization in the overhanging region to minimize surface roughness.

REFERENCES

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