Modeling of vapor flow in the powder bed fusion process of metallic materials

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ABSTRACT

Recently there have been significant advances in the field of modeling of the powder bed fusion process of metallic materials using a laser beam. Since the spatial and temporal scale of the process spans multiple orders of magnitude though, there is no holistic model to describe the process. Instead multiple models on different temporal and spatial scales incorporating different physical phenomena have been developed by a large number of groups. In this work we focus on the simulation of the melt pool. It has been shown that the evaporation induces a flow inside the build chamber that can affect the powder bed and lead to the creation of defects in the part [1, 2]. Due to the high computational cost involved many models neglect the modeling of the vapor plume and model only the resulting force on the liquid surface due to the evaporation [3]. A first approach to include the vapor has been shown in [4]. Due to modeling assumptions and simplifications used within this FE model, the model overestimates in our opinion the temperature in the melt pool and plume.

We use a high fidelity CFD model that includes melt flow, phase transitions and evaporation and to our knowledge presents the first model at the melt pool scale that includes the vapor plume and induced gas flow in the build chamber. We show first results from these simulations suggesting a more moderate temperature distribution inside the melt pool and vapor plume. The induced velocities of the gas are compared with reported experimental measurements. Due to the high computational cost involved the simulation of the vapor plume and induced gas flow is not always feasible. Therefore we also discuss the relevance of these effects towards melt pool dimensions and defect mechanisms and suggest processing windows in which the modeling of them can be neglected with an acceptable error to the predicted results.

REFERENCES

[1] Guo, Q. et al. Transient dynamics of powder spattering in laser powder bed fusion additive manufacturing process revealed by in-situ high-speed high-energy x-ray imaging. *Acta Materialia* (2018) **151**:169–180.

[2] Ly, S. et al. Metal vapor micro-jet controls material redistribution in laser powder bed fusion additive manufacturing. *Scientific Reports* (2017) **7.1**:1–12.

[3] Khairallah, S. A. et al. Mesoscopic simulation model of selective laser melting of stainless steel powder. *Journal of Materials Processing Technology* (2014) **214.11**:2627–2636.

[4] Bidare, P. et al. Fluid and particle dynamics in laser powder bed fusion. *Acta Materialia* (2018) **142**:107–120.