Detecting Heat Accumulation in Additive Manufacturing Parts using Computationally Efficient Thermal Models

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ABSTRACT

One of the primary advantages that Additive Manufacturing (AM) offers, as opposed to conventional manufacturing techniques, is the increased design freedom. The layer-by-layer deposition of material enables manufacturing of highly complex, high performance engineering structures without increasing the associated cost. Powder Bed Fusion (PBF) processes are the most commonly used industrial AM techniques for fabricating metal parts. Although, they are capable of producing parts with mechanical properties at par with conventional subtractive methods, they still suffer from certain critical issues which need consideration at the design stage. One such issue is the local heat accumulation which leads to surface defects such as melt ball and dross formation. Moreover, slow cooling rate due to local heat accumulation has adverse influence on resulting micro-structures. It is observed that certain geometrical features such as overhangs, thin intersections contribute significantly to this issue [1]. Therefore, considerations for identifying and avoiding such features should be made at an early design stage. Thermal modeling of the AM process can be utilized for evaluating the geometries from the context of heat accumulation [2]. However, the associated computational cost makes it extremely difficult to perform part-level predictions in reasonable time frame.

In this paper, first a transient layer-by-layer heat addition model is presented which is utilized for detecting the local heat accumulation in a given geometry. However, due to the transient nature of analysis and continuously growing domain size, the computational cost of this model still remains high. Therefore, a set of physics based approximations are presented which reduce the overall computational burden with limited impact on accuracy. The approximations are motivated using an analytical solution of the transient 1D heat equation with boundary conditions inspired by AM process. One of the approximations utilizes the steady state thermal response of a geometry for predicting its heat accumulation behavior. This offers a significant computational advantage as compared to using a detailed transient analysis. Next, the presented approximations are applied on a complex geometry and their validity is thoroughly investigated by comparing the results with the aforementioned layer-by-layer model. The computational gain and loss in accuracy related to each approximation is reported. Development of this computationally efficient physics based model, next to fast detection of problematic geometries in the design process, also opens up the possibility of integrating it with the topology optimization method, which is foreseen as the next step of this research work.

REFERENCES

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