COMPUTATIONAL ANALYSIS OF ADDITIVE MANUFACTURING

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ABSTRACT

Additive Manufacturing (AM) offers an almost unparalleled opportunity to make complex parts from steel, aluminum, titanium and nickel alloys on demand with minimal waste. AM deposits successive, discrete layers of material of finite thickness that are typically < 100μm in a transient manner to make an object of almost any shape that may be up to 10^3 times larger than the dimensions of the deposited layer. The development of deposition processes for AM currently uses a combination of experience coupled with trial and error based testing and evaluation.

To improve part quality, decrease production costs and enable on demand component delivery, predictive development of viable AM process parameters is required. Recent advances in predictive computational simulations and manufacturing process models offer methods to improve quality and affordability while simultaneously accelerating maturation of manufacturing processes and technology. Use of computational analysis of metal based AM process to overcome these limitations must consider integrating the effects of multiple physical phenomena such as:

- Molten metal flow
- Heat transfer in the manufactured component

- Liquid to solid phase change during material deposition
- Microstructural and phase evolution
- Thermal transients that promote defect evolution
- Residual stresses development during manufacture
- Distortion of the manufactured component

Simulation of each of these individual phenomena is complex and integration into a simulation tool adds further complexity due to their highly-coupled nature of the physics. In addition, many of the material properties are highly temperature dependent such that any analysis is both temporally and spatially dependent. Thus, not only do the fundamental physical phenomena interact with each other, but also the parameters that provide a mathematical description of their behaviour have complex interdependencies whose critical governing regimes are dependent on geometrically varying functions, time dependent inputs and influence ranges whose form varies with material and resultant property.

The multiphysics nature of the problem coupled with the multi-scale nature of the analysis automatically increases the number of degrees of freedom associated with an analysis and thus solution times can take longer than experimental evaluations. To enable practical use of predictive physics-based analysis of AM processes solution times must be considerably reduced. This work demonstrates the use of computational simulation of AM-based technology to identify the significance of specific physical phenomena on the accuracy of multiphysics/multi-scale analyses and the application of novel computational analysis procedures to simulate the deposition of full scale components.

This study analysed the laser powder bed additive manufacturing process. The laser is modelled as a transient moving heat source and temperature dependent material properties are included. Addition of consecutive layers is automatically integrated to allow prediction of the thermal and fluid flow behaviour of the component during deposition. The analytical approaches incorporated into the multiphysics/multiscale problem have been used to identify the most significant physical phenomena required for accurate analyses and the subsequent development of simulation methodologies that permit completion of analyses of full component builds within practical timescales.

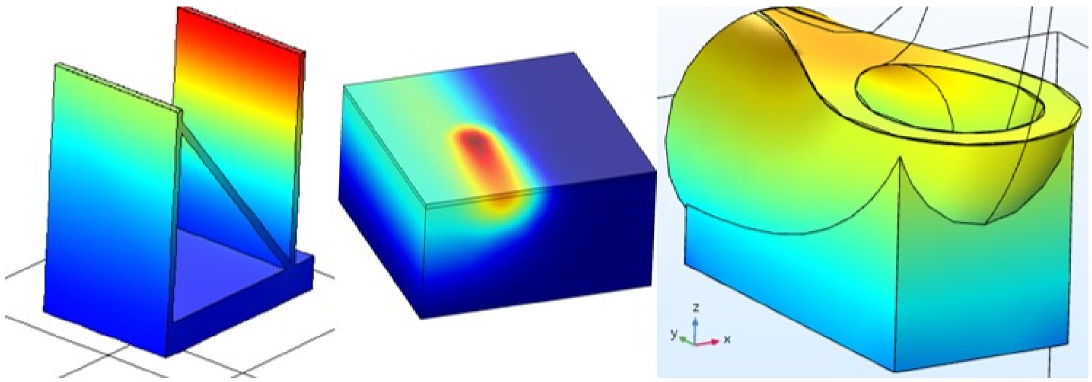

Figure 1: Thermal analysis of AM PBF processed components

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