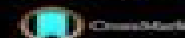


REVIEW

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# Metal additive-manufacturing process and residual stress modeling

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## Abstract

Additive manufacturing (AM), widely known as 3D printing, is a direct digital manufacturing process, where a component can be produced layer by layer from 3D digital data with no or minimal use of machining, molding, or casting. AM has developed rapidly in the last 10 years and has demonstrated significant potential in cost reduction of performance-critical components. This can be realized through improved design freedom, reduced material waste, and reduced post processing steps. Modeling AM processes not only provides important insight in competing physical phenomena that lead to final material properties and product quality but also provides the means to exploit the design space towards functional products and materials. The length- and timescales required to model AM processes and to predict the final workpiece characteristics are very challenging. Models must span length scales resolving powder particle diameters, the build chamber dimensions, and several hundreds or thousands of meters of heat source trajectories. Depending on the scan speed, the heat source interaction time with feedstock can be as short as a few microseconds, whereas the build time can span several hours or days depending on the size of the workpiece and the AM process used. Models also have to deal with multiple physical aspects such as heat transfer and phase changes as well as the evolution of the material properties and residual stresses throughout the build time. The modeling task is therefore a multi-scale, multi-physics endeavor calling for a complex interaction of multiple algorithms. This paper discusses models required to span the scope of AM processes with a particular focus towards predicting as-built material characteristics and residual stresses of the final build. Verification and validation examples are presented, the over-spanning goal is to provide an overview of currently available modeling tools and how they can contribute to maturing additive manufacturing.

**Keywords:** Metal additive manufacturing, Powder bed, Blown powder, Wire feed, Process modeling, As-built porosity, Residual stress, Distortion, Multi-scale modeling, Multi-physics modeling, ICME


## Review

### Introduction

Metal additive manufacturing (AM) utilizes several processes such as powder bed processes (ALM/SLM/DMLS/DMLM), blown powder (DLMD/LMD/EMD/LENS) and wire feed processes (W/AAM). Whereas the processes vary widely in their details, the common denominator for all additive-manufacturing processes is the ability to nearly “net-shape” manufacture complex products:

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