Qualification of Additive Manufactured Components – Integration of Modeling, Measurement and Manufacturing Processes

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Additive manufacturing (AM) enables design and production of structural metallic components with complex geometries. Recent work has shown that, in addition to complex geometries, site-specific microstructures can be achieved through careful control of processing condition at every layer. These advances are made by leveraging the similarity of physics between welding and AM processes. The interactions between boundary conditions imposed by component geometry, wide variations of thermal signatures brought about by mode of energy delivery, and composition of the alloys can be used for qualification of AM components. This overview presentation will discuss pragmatic integration of recent innovations related to modeling, measurements and manufacturing methodologies with case studies from titanium and nickel alloys. In addition, unresolved challenges will be discussed.

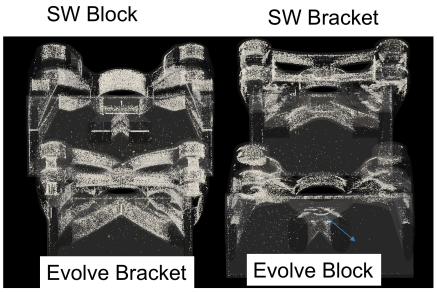

Figure 1: Identification of regions with high density of porosities based on in-situ thermal imaging during electron beam powder bed fusion of Ti6Al4V powders.

The first part of the paper will focus on the modeling tools for topology optimization of component geometry, process modeling of heat and mass transfer, solidification and solid-state transformations, plastic deformations, residual stress, distortion and performance of the components. The process flow involved in linking all these discrete modeling tools, challenges and future directions will be outlined with published examples from both welding and additive manufacturing. The second part of the paper will focus on the in-situ characterization of process and also correlation of the same to evolution of defects and microstructure in titanium and nickel alloys. The third part of the paper will focus on case studies involving both computational modeling and in-situ characterization to arrive at strategies for qualification of the AM components. For example, Figure 1 shows typical distribution of porosities within topology optimized Ti6Al4V parts manufactured by electron powder bed fusion, which is tracked by in-situ characterization. The above data suggests that scatter in AM properties can be rationalized based on such measurements. Finally, this paper will also focus on some of the unresolved questions related to stability of interfaces between liquid and solid, solid and solid, as well as, deformation conditions within the solid during additive manufacturing and approaches to address the same.

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