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COMPUTATIONAL CO-DESIGN OF PART GEOMETRY AND MATERIAL PROPERTIES FOR METAL ADDITIVE MANUFACTURING

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MINISYMPOSIUM

As metal additive manufacturing (MAM) increasingly gains traction for making mission-critical parts with a wide selection of alloy compositions, the time is ripe to take advantage of the design freedom it enables. In particular, the ability to deposit graded material compositions opens the door to the creation of novel computational design approaches that combine design space exploration (DSE), geometric and physical modeling, and material informatics (MI), to enable optimal co-design of MAM-able part geometry and material properties. Most of the traditional shape/topology optimization (SO/TO) approaches treat material selection as a separate activity, with available properties often pre-determined based on already qualified materials for traditional processes (e.g., metallurgical casting and forging). While MAM opens up an enormous design space with complex shapes and new alloys (with potentially graded composition and properties) that were not possible before, it also presents challenges due to intertwined shape, manufacturing process, and as-built properties. Early multi-material TO algorithms that allowed for voxel-level material composition design either overlooked or oversimplified metallurgical considerations such as alloy compatibility and heat treatment effects. Material design and discovery (e.g., based on CALPHAD and experimental characterization), on the other hand, operate independently of geometric part design, how it may benefit from new properties in different spatial locations to achieve better function, and how it may be constrained by MAM process (e.g., shape determined heat transfer, which, in turn, affects as-built material properties).

This minisymposium aims to present opportunities and challenges in using computational design tools that treat spatial distribution of material properties as an explicit design variable, alongside shape and topology, navigating inherent tradeoffs among geometric and metallurgical feasibility, interfacial compatibility, and additive or hybrid manufacturability. Multi-disciplinary approaches using model-based geometric and physical reasoning, integrated computational materials engineering (IMCE), and data-driven MI are encouraged. Recent advances in machine learning and AI present unique opportunities for DSE, MI, surrogate modeling for rapid geometric and physical reasoning within DSE, and for their efficient integration, and hence fall within the scope of the minisymposium. Also in scope are methods that present partial solutions to this challenge.