Modeling and Simulation of Multiphysical Processes in Next-Generation Advanced Manufacturing and 3D Printing with New Multifunctional Materials

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ABSTRACT

Within the last decade, several industrialized countries have stressed the importance of advanced manufacturing to their economies. Many of these plans have highlighted the development of additive manufacturing techniques, such as 3D printing, which are still in their infancy. The objective is to develop superior products, produced at lower overall operational costs. For these goals to be realized, a deep understanding of the essential ingredients comprising the materials involved in additive manufacturing is needed. The combination of rigorous material modeling theories, coupled with the dramatic increase of computational power can potentially play a significant role in the analysis, control, and design of many emerging additive manufacturing processes. Specialized materials and the precise design of their properties are key factors in the processes. Specifically, particle-functionalized materials play a central role in this field, in three main ways: (1) to endow filament-based materials by adding particles to a heated binder (2) to ``functionalize'' inks by adding particles to freely flowing solvents and (3) to directly deposit particles, as dry powders, onto surfaces and then to heat them with a laser, e-beam or other external source, in order to fuse them into place. The goal of these processes is primarily to build surface structures, coatings, etc., which are extremely difficult to construct using classical manufacturing methods.

The objective of this presentation is to introduce the audience to basic techniques which can allow them to rapidly develop and analyze particulate-based materials needed in new additive manufacturing processes. This presentation is broken into two main parts: continuum and discrete element approaches. The materials associated with methods (1) and (2) are closely related types of continua (particles embedded in a continuous binder) and are treated using continuum approaches. The materials in method (3), which are of a discrete particulate character, are analyzed using discrete element methods.