Mechanistic Models of Powder Bed Fusion and directed Energy Deposition Processes

T. DebRoy
Department of Materials Science and Engineering
The Pennsylvania State University, University Park, PA 16802, USA
debroy@psu.edu

There are three compelling reasons why the optimization of part quality in additive manufacturing (AM) cannot follow the usual trial and error testing adapted in welding: (a) building parts is much slower, (b) equipment and feedstock are orders of magnitude more expensive and (c) cooling rates and solidification parameters are strikingly sensitive to the selection of AM variants and process variables. Building and validating mechanistic models based on the numerical solution of the equations of conservation of mass, momentum and energy can provide a viable path to optimize microstructure and properties. This approach can reduce the number of expensive and time-consuming part testing and qualification, and compute the causative variables that affect microstructure, properties and defects. This presentation will discuss how heat transfer and fluid flow calculations for powder bed fusion and directed energy deposition processes, when adequately validated, can provide insight about the evolution of solidification structure, microstructure and common defects. In particular, the ability of mechanistic models in evaluating features of solidification structure, microstructure, lack of fusion defects and residual stresses and distortion will be examined. The application of these models to understand printability of different alloys will also be discussed.

Biography

Dr. DebRoy is Professor of Materials Science and Engineering at The Pennsylvania State University, an Honorary Member and Fellow of American Welding Society and a Fellow of ASM International. His research focuses on mechanistic modeling of welding and additive manufacturing based on transport phenomena. His models compute the most important factors that affect metallurgical product quality such as temperature and velocity fields, cooling rates and solidification parameters by solving tens of billions of equations efficiently. Specially structured for integration with genetic algorithms and other search engines, these simulations can be made bi-directional, greatly expanding their utility by switching traditional input and output variables, tailoring product attributes, optimizing production variables, reducing defects and improving product quality. His papers, at the cross roads of metallurgy, welding, additive manufacturing and numerical heat transfer have been recognized by many awards and honors. They include the UK Royal Academy of Engineering's Distinguished Visiting Fellowship, a Fulbright Distinguished Chair in Brazil, The Arata Award of the International Institute of Welding (IIW), France, Easterling Award of the University of Graz, Austria and IIW, Penn State's Faculty Scholar Medal and many best paper awards from the American Welding Society. He is a Founding Editor of "Science and Technology of Welding and Joining."