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# MATERIALS PROCESSING CONTROL USING ELECTRIC AND MAGNETIC FIELDS

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## ABSTRACT
This lecture will present a variety of mathematical models governing fluid flow and possible solidification processes under the influence of pressure, temperature, electric and magnetic fields. It will also illustrate a few applications of such combined fields when they are optimized in order to achieve certain desired features of the flow-field and the solid accrued during solidification. Finally, it will present a vision of the fully automated optimally controlled additive manufacturing using such fields combined with the optimized time-varying chemistry of the mixture of powders used in additive manufacturing.

Creation of arbitrarily shaped objects with specified functionally graded, spatially varying physical properties requires development of algorithms for optimal control of the manufacturing processes that include thermal, electric and magnetic fields. In case of creating composite materials, the fundamental concept is based on specifying a desired pattern of orientations and concentrations of microfibers in the final composite material product. Then, the task is to determine the proper strengths, locations, and orientations of magnets and/or electrodes that will have to be placed along the boundaries of the curing composite part so that the resulting magnetic and/or electric field lines of force will coincide with the specified (desired) pattern of the coated microfibers' distribution. The basic idea is that the coated fibers will align with the local magnetic lines of force. The pattern of these lines depends on the solidifying resin flow-field and the variation of the applied magnetic field.

Thus, the successful accomplishment of the proposed solidification process involves the development of an appropriate software package for the numerical solution of the partial differential equations governing combined Electro-Magneto-Hydro-Dynamics (EMHD) or Magneto-Hydro-Dynamics (MHD) or Electro-Hydro-Dynamics (EHD) involving liquid flow, electric field, magnetic field, and heat transfer that includes solid-liquid phase change.

In the case of additive manufacturing, this concept requires determination of spatial variation of physical properties that will create desired effects on the boundary of the functionally graded object by optimally time-varying chemical composition of the mixture of alloying powders, intensity and frequency of the melting high energy beam and the motion of the beam or the substrate.

In addition, it involves development of a constrained optimization software package that is capable of automatically determining the correct strengths, locations, and orientations of a finite number of magnets and electrodes that will produce the desired magnetic and electric field force pattern in the melt of the solid object been created.

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Professor George S. Dulikravich (Ph.D., Cornell'79; M.Sc., Minnesota'75; Dipl.-Ing., Belgrade'73) worked as a NRC Associate Fellow at NASA LeRC, a Visiting Scientist at DFVLR-Goettingen, Assistant Professor at University of Texas-Austin(‘82-’86), Associate Professor at the Pennsylvania State University (‘86-’99), Professor at Univ. of Texas at Arlington (’99-’03), and MME Department Chairman (’03-’09) and Professor (’03-present) at Florida International University. He has authored and co-authored over 500 technical publications in diverse fields involving computational and analytical fluid mechanics, subsonic, transonic and hypersonic aerodynamics; inverse design and shape optimization of airfoils, wings and winglets; theoretical and computational electro-magneto-hydrodynamics and conjugate heat transfer including solidification; optimization of cooling protocols for human organs; acceleration of iterative algorithms; computational grid generation; multi-disciplinary aero-thermo-structural inverse problems; design and constrained optimization in turbomachinery; fluid flow and heat transfer in networks of micro/nano passages and arrays of pin-fins, and multi-objective design optimization of chemical compositions of arbitrary alloys. He is the founder and Editor-in-Chief of the international journal on Inverse Problems in Science and Engineering (founded in 1994) and an Associate Editor of ten additional journals. He is also the founder, chairman and editor of the sequence of International Conferences on Inverse Design Concepts and Optimization in Engineering Sciences (ICIDES) and International Symposium on Inverse Problems, Design and Optimization (IPDO). Professor Dulikravich is a Fellow of the American Academy of Mechanics, a Fellow of the American Society of Mechanical Engineers, a Fellow of Royal Aeronautical Society, and an Associate Fellow of the American Institute of Aeronautics and Astronautics.