ME Seminar

Finite Domain Moving Boundary Problems in Heat Transfer: Direct and Inverse Formulations

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ABSTRACT

Thermal conduction and thermoelastic stress considerations of a solid media with moving boundaries are of great interest in many research areas. Unfortunately, it is very difficult to find analytical or semi-analytical solutions for the single-phase thermal conduction equation in real time with a growing or receding boundary. While analytical solutions for infinite and semi-infinite domains are available, these cannot accurately model many common situations met in industry. To overcome this shortcoming, a semi-analytical solution for the heat equation for a single phase, homogeneous, and finite-slab with a growing or receding boundary under unit loading is derived. Conformal mapping is then used to solve a similar problem for a hollow cylinder with a moving boundary. A methodology based on Duhamel's and Laplace convolution theorems is derived to solve the unsteady heat conduction problems on the above-mentioned finite domains under time dependent arbitrary thermal loading. The resulting semi-analytical solutions are then used to determine the transient thermoelastic stresses. Lastly, a straightforward approach is developed that solves the inverse heat transfer problems on finite domains with moving boundaries. An important application of this model with an increasing thickness could be used in the prediction and/or verification of numerical and/or experimental studies of the temperature and thermal stresses in real time during solid state additive manufacturing as seen with cold-spray methods. Moreover, similar calculations could be employed to assess temperature, thermal stresses, growth and/or recession rates during machining and/or eroding surfaces. Indeed, the resulting solutions might be utilized to remotely assess surface temperature and/or erosion/wear and/or oxidation/growth rates in severe conditions where direct measurements are not feasible.

ABOUT THE SPEAKER

Dr. Pavan Kumar has a Ph.D. in Engineering Science and Mechanics from Pennsylvania State University. He also received a Master of Arts in Mathematics from Penn State. Prior to attending Penn State, he earned a Master of Science in Mechanical Engineering from University of Tennessee, Knoxville. He also holds Master of Technology and Bachelor of Technology degrees in Mechanical Engineering from Indian Institute of Technology, Kanpur. His research interests are in Applied Mathematics, Solid Mechanics, Heat Transfer, and Artificial Intelligence. In his doctoral research, he developed semi-analytical solutions for elasticity and conduction problems on a finite domain (slab or cylinder) with a growing or receding boundary under complex loading. To-date, no known semi-analytical solutions have been presented that can solve or even approximate the transient response as detailed in this work. In addition, he is also working to address two of the primary challenges to widespread adoption of Scientific Machine Learning (SciML) methods: Modeling of large-scale problems with highly complex physics and the simultaneous quantification of uncertainty. The potential applications of this SciML research are to model fracture in additively manufactured composites and rock fracture for ultra-high-speed fluid flow problems, constitutive equations for large deformation problems, etc.

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