Melting and Solidification in Multilayer Geometries

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Abstract

Solid-liquid phase change occurs commonly in a wide variety of engineering problems, including thermal management, energy storage and high temperature manufacturing. Similar moving boundary mass transfer problems also exist. Except for the simplest of such problems, however, exact analytical solutions are generally not available. Most of the past analytical modeling work addresses the melting or solidification of only a single-layered phase change material (PCM). This seminar will present a brief review of this field, including approximate analytical techniques, followed by a discussion of recent work on melting and solidification in multilayer geometries. The problem of melting of a PCM shielded/encapsulated by a multilayer non-melting wall is discussed. Using the method of eigenfunction expansion, an approximate solution for temperature distribution and rate of melting is derived. Two distinct timescales in the solution, related to diffusion through the wall and phase change propagation in the PCM, are identified. Practical problems related to design of an encapsulated PCM for energy storage are solved. Further, the problem of melting/solidification of a stack of two PCMs arranged in series is presented. In this case, the nature of phase change progression is found to depend on whether the lower-melting PCM is located next to or away from the hot/cold boundary. It is shown that, depending on the values of various non-dimensional parameters, up to three melting fronts may simultaneously exist in this problem. Expressions for the rates of propagation of these fronts are derived. Conditions leading to the thermodynamically favorable outcome of simultaneous completion of melting of both PCMs are determined. Theoretical models presented here improve the fundamental understanding of phase change in multilayer geometries, and offer tools for design and optimization of practical thermal systems.

Biography

Ankur Jain is a Professor in the Mechanical and Aerospace Engineering Department at The University of Texas at Arlington. His research interests include energy conversion in Li-ion batteries, phase change heat transfer, additive manufacturing, electrochemistry and theoretical thermal conduction. He has published 145 journal papers, and given over 70 invited/keynote talks, seminars and tutorials. He received the ASME K16 Clock Award (2023), UTA President's Award for Excellence in Teaching (2022), UTA College of Engineering Lockheed Martin Excellence in Teaching Award (2018), College of Engineering Outstanding Early Career Award (2017), NSF CAREER Award (2016) and the ASME EPP Division Young Engineer of the Year Award (2013). He is a Fellow of ASME. He received his Ph.D. (2007) and M.S. (2003) in Mechanical Engineering from Stanford University, where he received the Stanford Graduate Fellowship, and B.Tech. (2001) in Mechanical Engineering from Indian Institute of Technology, Delhi with top honors.