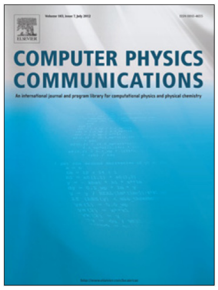
Accepted Manuscript



A unified momentum equation approach for computing thermal residual stresses during melting and solidification

Haram Yeo, Hyungson Ki

PII: S0010-4655(17)30353-3
DOI: https://doi.org/10.1016/j.cpc.2017.10.013
Reference: COMPHY 6360

To appear in: *Computer Physics Communications*

Received date : 14 March 2017
Revised date : 16 October 2017
Accepted date : 23 October 2017

A unified momentum equation approach for computing thermal residual stresses during melting and solidification

Haram Yeo, Hyungson Ki[1]

Department of Mechanical Engineering
Ulsan National Institute of Science and Technology (UNIST)
50 UNIST-gil, Ulsan 44919, South Korea

Abstract

In this article, we present a novel numerical method for computing thermal residual stresses from a viewpoint of fluid-structure interaction (FSI). In a thermal processing of a material, residual stresses are developed as the material undergoes melting and solidification, and liquid, solid, and a mixture of liquid and solid (or mushy state) coexist and interact with each other during the process. In order to accurately account for the stress development during phase changes, we derived a unified momentum equation from the momentum equations of incompressible fluids and elastoplastic solids. In this approach, the whole fluid-structure system is treated as a single continuum, and the interaction between fluid and solid phases across the mushy zone is naturally taken into account in a monolithic way. For thermal analysis, an enthalpy-based method was employed. As a numerical example, a two-dimensional laser heating problem was considered, where a carbon steel sheet was heated by a Gaussian laser beam. Momentum and energy equations were discretized on a uniform Cartesian grid in a finite volume framework, and temperature-dependent material properties were used. The austenite-martensite phase transformation of carbon steel was also considered. In this study, the effects of solid strains, fluid flow, mushy zone size, and laser heating time on residual stress formation were investigated.

Keywords: thermal residual stress; fluid-structure interaction; unified momentum equation; mushy zone;

[1] Corresponding author: hski@unist.ac.kr