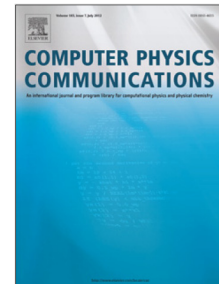


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# A unified momentum equation approach for computing thermal residual stresses during melting and solidification

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## 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;

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