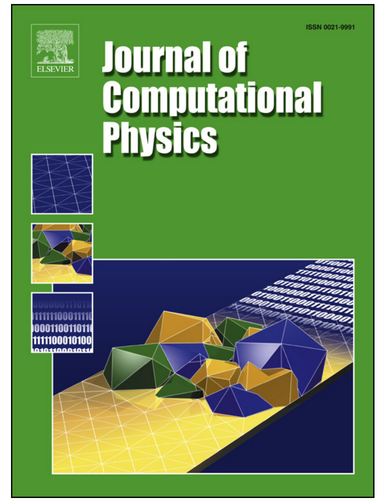
Accepted Manuscript



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PII: S0021-9991(17)30094-3
DOI: http://dx.doi.org/10.1016/j.jcp.2017.02.001
Reference: YJCPH 7132

To appear in: *Journal of Computational Physics*

Received date: 6 October 2015
Revised date: 27 May 2016
Accepted date: 2 February 2017

A sharp interface method for compressible liquid-vapor flow with phase transition and surface tension

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Abstract

The numerical approximation of non-isothermal liquid-vapor flow within the compressible regime is a difficult task because complex physical effects at the phase interfaces can govern the global flow behavior. We present a sharp interface approach which treats the interface as a shock-wave like discontinuity. Any mixing of fluid phases is avoided by using the flow solver in the bulk regions only, and a ghost-fluid approach close to the interface. The coupling states for the numerical solution in the bulk regions are determined by the solution of local two-phase Riemann problems across the interface. The Riemann solution accounts for the relevant physics by enforcing appropriate jump conditions at the phase boundary. A wide variety of interface effects can be handled in a thermodynamically consistent way. This includes surface tension or mass/energy transfer by phase transition. Moreover, the local normal speed of the interface, which is needed to calculate the time evolution of the interface, is given by the Riemann solution. The interface tracking itself is based on a level-set method.

The focus in this paper is the description of the two-phase Riemann solver and its usage within the sharp interface approach. One-dimensional problems are selected to validate the approach. Finally, the three-dimensional simulation of a wobbling droplet and a shock droplet interaction in two dimensions are shown. In both problems phase transition and surface tension determine the global bulk behavior.

Keywords:
Compressible two-phase flow, sharp interface resolution, surface tension, phase transition, Ghost-Fluid method, latent heat

1. Introduction

The numerical modeling of multi-phase flow is a very active field of research. In this paper we are interested in models for fully compressible regimes with liquid and vapor bulk phases that cope correctly with phase transition and surface tension effects. Our focus is on the direct numerical simulation where single interfaces separating the bulk dynamics have to be resolved (see e.g. [1, 2] for alternative homogenized models).

There are basically two different approaches to model compressible multi-phase flows, the diffuse interface and the sharp interface approach. In the first, a smooth internal layer represents the interface, which has to be resolved for the numerical simulation. Moreover, artificial mixture states may occur. Typically only one set of equations needs to be solved in the whole computational domain. Examples are the Navier-Stokes-Korteweg systems ([3, 4]). In the second approach, the sharp interface approach, the interface is represented as a discontinuity in the density field, separating the computational domain in two bulk regions. The fluid flow in both of the bulk regions is described by the standard single-phase conservation equations. The interface appears as an unknown interior boundary. Appropriate

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