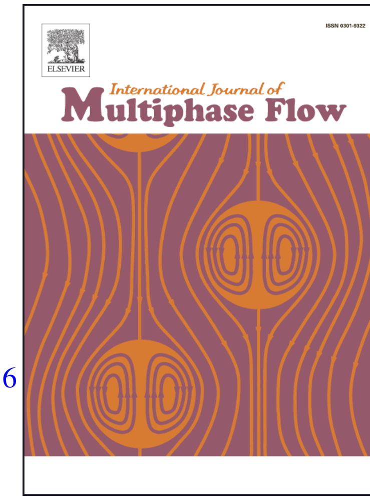

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A Study on Large Bubble Motion and Liquid Film in Vertical Pipes and Inclined Narrow Channels

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ABSTRACT
The objective of this paper is to discuss the results of a combined physical and computational analysis of the dynamics of large deformable bubbles in conduits of different geometries and orientations.The situations analyzed included a vertical circular pipe and a narrow rectangular channel of different inclination angles. Three-dimensional simulations were performed at a DNS-scale using the PHASTA code combined with the level set method for interface tracking. The results of computer simulations for Taylor bubble flow in a vertical pipe have been verified against a simplified theoretical model and validated against available general evidence deduced from various experimental studies. The predictions for bubbles flowing along inclined rectangular channels have been validated against the experiments of Maneri [1970]. Several modeling and numerical issues have been investigated, including the effect of a liquid microfilm between the bubble and the wall above it, and the impact of the blending region arising from the level-set model formulation on the accuracy of results.

Keywords: Two-Phase Flow, Level Set Method, DNS, Liquid Microfilm, Taylor Bubbles, Narrow Channels.

1. INTRODUCTION

Experimental and numerical studies of bubbles moving in conduits of different orientations and shapes have many practical applications. The development of methods to accurately predict the bubble shape and motion is important for a wide range of systems used by the gas/oil industry, nuclear power plants, chemical processing plants, microchannels employed by pharmaceutical devices, etc.

The purpose of this paper is to combine theoretical analysis with advanced computer simulation methods, to perform a comprehensive study on the mechanisms governing the motion of large deformable bubbles in narrow vertical and inclined conduits.

The computer simulations were performed using a complete three-dimensional first-principle model of gas/liquid flow. The DNS-scale model has been implemented in the PHASTA (Parallel Hierarchic Adaptive Stabilized Transient Analysis) computer code, with a modified Level-Set Method (LSM) used to capture the liquid/gas interface. Whereas previous two-phase flow applications of PHASTA have been mainly for dispersed bubbly flows, the current study has been focused on the analysis of the fluid mechanics of large bubbles confined between, and interacting with, solid walls. The results of the combined theoretical investigations and computer simulations have been extensively tested parametrically, verified against other models and validated against experimental data.

2. BACKGROUND

A thorough literature review has been performed to identify the existing experimental evidence about bubbles moving in narrow channels of various orientations, and to identify a meaningful frame of reference for the validation of the proposed model. The needed information included: detailed geometry and dimensions, fluid properties, and flow conditions. Another issue of practical importance was concerned with the compatibility of the experimental time scale with the size of the corresponding computational problem, to assure that meaningful numerical simulations could be performed at reasonable computational costs. A brief overview of selected relevant information is given below.

Local flow measurements of vertical upward bubbly flow in an annulus have been reported by Hibiki et al [2003], including the following parameters: void fraction, interfacial area concentration and interfacial velocity, liquid velocity and turbulence intensity.

Yadigaroglu et al. [2008] published a set of experimental data for bubbly plumes and jets. Some of these data were ensemble- or phase-averaged to filter out large-scale meandering and oscillations of coherent structures and to make the time-dependent small-scale effects and local stress terms more visible.

Wilmarth et al. [1994] studied adiabatic concurrent vertical and horizontal two-phase flows of air and water through narrow rectangular channels. Their study was mainly focused on flow regime transition criteria.