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FREE SURFACE STABILITY IN AN OPEN CAPILLARY CHANNEL IN MICROGRAVITY

Abstract

Results of the Capillary Channel Flow experiment will be presented. The experiments were performed via telescience on the ISS at intervals between 2010 and 2012. The focus of the experiment setup consists of an open test channel with a constant cross section including at least one interface with a stagnant gaseous atmosphere [1]. Steady, single phase flow is forced through the test channel causing the shape of the gas-liquid interface to alter, thus balancing the pressure difference between the liquid and the atmospheric conditions in accordance with the Young-Laplace equation. Parametric studies were performed to find critical flow rates, above which the aforementioned pressure difference can no longer be balanced by the curvature of the interface, mainly due to the geometrical constraints of the test channel and the physical properties of the fluids involved. The examined test channel geometries comprise parallel plates, a rectangular groove, and an isosceles triangular wedge. Experiments were performed at approximately isothermal conditions and within the transition area of convective and viscous dominated laminar flow regimes. Additional experiment modes were performed with the same channels including multiphase flow, accelerated flow, and flow with imposed oscillations on the interface. Experiment result data consists of flow rate measurements and various video sources including high speed imaging of the interface.

Predictions of the critical flow rates and the shape of the free surface are based on a previously published extended Bernoulli model [2]. Critical flow rates are estimated by solving the balance equation for increasing flow rates until the solution becomes unphysical. The numerical results are found to be in good agreement with the acquired experiment data within appropriate physical boundaries. Discrepancies between the 1D model and experiment results are attributed to the situational importance of additional sources of pressure loss that are not included in the model such as flow separation. Additionally, three-dimensional CFD simulations were performed using the multiphase VOF method that is included in the open source toolbox OpenFOAM. A comparison of the three data sets (experiment, 1D-numeric, and 3D-numeric) shows that the physics of the flow problem can be captured in numerical simulations with satisfactory accuracy.

[1] P. J. Canfield et al.: The capillary channel flow experiments on the International Space Station: experiment set-up and first results, Exp. Fluids 54, 1 (2013)

[2] Rosendahl, U., Ohlhoff, A., Dreyer, M. E., Choked flows in open capillary channels: theory, experiment and computations, J. Fluid Mech., 518 (2004)