NUMERICAL SIMULATION OF THE AIR-WATER SLUG FLOW AT A T-JUNCTION MICRO-CHANNEL

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ABSTRACT

With the development of Micro-Electro-Mechanical-Systems (MEMS) technology, the use of micro-structured devices (micro channels with diameter lower than 1 mm) has gained importance in several industrial applications. The flow in a micro-channel is typically laminar, thus transfers between phases are dominated by diffusion. Two-phase flow can enhance the performance of these microfluidic devices, where capillary forces dominate over body forces. The hydrodynamic characteristic of the flow plays a very important role on the device design.

Depending upon the properties and flow rates of the fluids, various flow patterns such as bubbly, slug or Taylor, churn, annular flow occur in gas-liquid flow in micro-channels. Taylor flow is one of the most important flow patterns. It is characterized by gas bubbles that almost fill the channel, separated by liquid slugs. A thin liquid film separates these bubbles from wall and also connects the two successive liquid slugs separated by the gas bubble. Due to its interesting flow characteristics, this problem has received enormous attention over the years and has been studied experimentally, analytically and using computational fluid dynamics (CFD). Recently, there has been some discussion regarding the numerical prediction of the liquid film surrounding the gas bubble in a Taylor flow [1, 2].

The aim of the present work is to numerically predict the air – water slug two-phase flow in a micro-channel with the commercial CFD package FLUENT, and compare with available literature data [3, 4]. A 2D plane T-junction micro-channel with cross-sectional width of 0.5 mm is considered (Fig.1), as applied by [4]. The isothermal flow (at room temperature) without any chemical reaction is considered. Uniform inlet superficial gas and liquid velocity varying from 0.02 to 0.15 m/s are considered. Atmospheric pressure is imposed at the exit. At these operating conditions, the flow falls within the Taylor slug regime in micro-channels.

The volume of fluid (VOF) method was employing, in order to track the interface between the liquid and gas slugs. The continuum surface force proposed by Brackbill was used to represent the surface tension which adding a source term to the momentum equation. The numerical parameters selected to solve the problem were: PRESTO scheme for the pressure interpolation, PISO scheme for the pressure-velocity coupling, QUICK scheme for the momentum equation, the geometric reconstruction scheme for the interface interpolation, implicit body force treatment for body force formulation. The domain was discretized with 6720 nodes as in [4] and Courant number was set as 0.25.

Figure 2a shows the volume fraction contour of slug flow development in the T-junction geometry for \( U_G = U_L = 0.05 \text{m/s} \), corresponding to a Capillary number \( 10^{-3} \). It can be seen that the water and air entering through the T rapidly forms the slug pattern, with approximately equal length for the gas bubble and liquid plug equal to 1.8 mm agreeing with the numerical prediction of [4]. The slug shape also agree quite well with the visualization of [5] for \( U_G = 0.154 \text{m/s} \) and \( U_L = 0.213 \text{m/s} \) shown in Fig. 2b.
Figure 3 shows the pressure profile along the axial direction. Fig. 3a corresponds to \( U_G = U_L = 0.05 \text{m/s} \) obtained in the present work. It can be seen a small perturbation when the slug is formed. Fig. 3b illustrates the results of [4] for \( U_G = U_L = 0.02 \text{m/s} \). In both cases, as expected, there is a large pressure drop when the slug is formed. It can be seen a smaller pressure drop along the bubbles (higher pressures) than along the liquid slug (lower pressures). Although the velocities were different, the same overall behavior was obtained.

The results obtained for the prediction of the slug in a microchannel with the VOF method agreed well with available experimental and numerical data. The future steps of the present analysis consist in investigating the influence of temperature and mass transfer.

**Acknowledgements**
The authors thank CNPq for supporting the development of this work.

**References**


