Sensitivity of semi-infinite and finite bubbles to channel-depth perturbations

The transport of a gas-liquid phase in a quasi-two dimensional geometry is commonly encountered in a variety of natural phenomena or in technical processes such as gas manipulation. On the other hand, these systems are as diverse as complex with high density contrast, surface tension effects introducing nonlinearities, and frequent topology changes. Here, we approach the investigation of these two-phase flows using a simplified system where a centred step-like perturbation is introduced in a rectangular channel. We focus first on the propagation of semi-infinite bubbles revealing multiple modes of propagation: symmetric, asymmetric and oscillatory states. Laboratory experiments show that the system becomes more sensitive as the aspect ratio of the channel (width/height) increases so that smaller relative step changes are required to produce the same multiple solutions. These results are found in quantitative agreement with a previously developed depth-averaged model once the aspect ratio becomes sufficiently large. By extrapolating the model, we find that the multiplicity of solutions at finite step heights arises through interactions of the single stable and multiple unstable solutions already present in the absence of the step. The high sensitivity of the system and the appearance of symmetric and asymmetric states have been confirmed when finite bubbles are propagated in channels with a small depth variation: the channel sides are slightly deeper than the middle. Hence, the system may be exploited as a mean for passively manipulation of bubbles. We then demonstrate that finite bubbles with sizes similar to the width of the step can be transported stably either on the step or in a side-channel. We show how the details of this stability feature can be applied to passively segregate bubbles by size.