Abstract

Two-phase flow, particularly gas-liquid flow, is prevalent in various industrial applications. Accurate measurement of two-phase parameters is crucial for equipment design, product quality, safety, and overall process efficiency. However, due to the inherent complexity of such flows, predicting these parameters remains a challenging task, necessitating the development of dedicated sensors. This dissertation focuses on measuring liquid film thickness, a key parameter in several flow regimes, using impedance sensors, specifically conductivity and capacitance probes.

In the first objective, a simple measurement scheme is proposed to reconstruct the geometry of an axisymmetric void passing through a conducting liquid contained in a circular conduit using a pair of parallel wire conductivity probes. Analytical modelling and numerical simulation have been adopted to correlate the resistance between the wire electrodes and the thickness of the film surrounding the void. The time-varying probe response and the propagation velocity of the void are obtained experimentally. Then, the developed electrodynamic models, with the help of the above two information, estimate the film thickness profile and reconstruct the void geometry. For validation, this scheme has been used to reconstruct the shape of a rising Taylor bubble.

The second objective addresses the limitation of conductivity probes for non-conductive liquids by employing parallel wire capacitance probes to predict the morphology of a moving axisymmetric void quantitatively. A methodology similar to the previous approach is adopted, involving an experimental study to capture the sensor’s capacitive response to the void profile, along with mathematical and numerical modelling of probe capacitance in multi-dielectric media. Finally, the reconstructed void shapes are compared with actual images obtained through high-speed photography and image processing.

The third objective presents a novel coplanar five-electrode conductivity probe designed to measure liquid film thickness while compensating for random conductivity fluctuations. The proposed design features a shared source electrode with two sets of measuring electrodes on either side, functioning as two independent sensors. This configuration conserves a significant space when deployed in an array. The electrode dimensions are numerically optimized before fabrication, and the sensor's performance is evaluated through static experiments. Initially, the probe's efficacy is tested on a flat surface, followed by its integration into an array mounted around the pipe circumference to measure circumferential film thickness. The probes exhibit a consistent response across water samples with varying conductivities, validating their reliability for liquid film thickness measurement under harsh conditions.

Keywords: Liquid film thickness, two-phase flow, conductivity probe, capacitance probe, axisymmetric void, sensor array.