ENI AWARD 2017
Debut in Research: Young Talents from Africa

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Winner

Thesis: A Study on Spherical Cap Bubble Transition Boundary for Bubbly to Slug flow._

Project: A Study on Energy Efficiency of Off-grid renewable energy systems in Nigeria.

Thesis Description

The scope of the research involved detailed analysis of experimental void fraction data obtained from electrical capacitance tomography (ECT) and wire mesh sensor (WMS) utilizing two-phase air-silicone oil flow with an inclinable 6 m long and 67 mm internal diameter pipe flow rig at 90° angle of inclination. The gas superficial velocities considered spanned from 0.047 - 0.945 m s^{-1}, whilst liquid superficial velocities ranged from of 0.047 - 0.378 m s^{-1}.

Flow assurance which involves the application of knowledge gained from multiphase flow technology has been a major bone of contention in many industries where multiphase flow is encountered and the complex nature of multiphase flow poses problems of understanding, analyzing and modeling multiphase flow systems. More so, the main purpose of this study was to understand the basic physical mechanism of Spherical Cap bubble transition.

It was found that transition between flow patterns is never sharply defined. As the flow rates changes and the patterns start altering, one detects attributes or aspects of the flow, which may be peculiar with one or more patterns. The bubbly to slug flow transition is due to collisions between small bubbles, with a fraction of these collisions resulting in coalescences. Bubbly to slug transitional flow pattern is typified by the uneven distribution of the concentration of minute bubbles in the flow direction. Small bubble coalescence intermittently arises in the part of elevated bubble concentration, and as a result a spherically capped bubble is formed. In addition, the transition from bubbly flow to slug flow is considered with the spherical cap bubble been highlighted as transition/boundary between the aforementioned flow patterns. All transitions from bubbly flow to slug flow are characterized by a "cap" formation. Bubbly to slug flow transition is characterized by a general grouping together of bubbles, until the formation of a cap, which accelerates the process to completion. The process governing the transition from bubbly flow to slug flow is the formation of a cap which is formed after a sufficient number of small bubbles coalesce.

From the analysis carried out on experimental data, the flow regimes observed included; Bubbly flow, Spherical cap bubble and Slug flow. The spherical cap bubble transition occurred at low gas superficial velocity and relatively low liquid superficial velocity with mean void fraction in the range of 0.10 to 0.20. The mean void fraction and superficial gas velocity increased as the flow pattern changed progressively from bubbly through spherical cap bubble to slug flow. Also, from the modified application of Taitel et al. (1980) model, the transition from bubbly to slug flow was simulated and found to better mimic the experimental data than the Kaya et al. (1999) model and the proposed application of the Taitel et al. (1980) model which suggested a single threshold value for this transition boundary.

This study provided more fundamental insight into the basic physical mechanism of Spherical Cap bubble transition under various flow conditions. Some conclusions were drawn such as the fact that as the experimental average void fraction and superficial gas velocity increased, the flow pattern changed progressively from bubbly through spherical cap bubble to slug flow which was in agreement with findings made by previous published studies, the spherical cap bubble transition occurred at low superficial gas velocity and relatively low superficial liquid velocity with values of the void fraction ranging from 0.10 to 0.20, the Electrical Capacitance Tomography (ECT) and Wire Mesh Sensor (WMS) measurements taken produced the same flow pattern on Shoham's mechanistic model (FLOPATN) to mention a few.

Also, another suggestion with respect to application of Taitel et al. (1980) model for bubbly to slug flow transition was proposed in that, the mean void fraction obtained be utilized rather than a single value of critical void fraction suggested. In addition, this proposed modification was found to conform better to the experimental data than the original application of Taitel et al. (1980) model and Kaya et al. (1999) model. It was recommended that further investigation was required in order to consider the effect of fluid properties (viscosity, density and surface tension) on transition boundaries which would be of particular interest in the oil and gas industry applications where liquids and gases have different properties from those involved in the present work, other multiphase fluids than those used in this work as well as computational fluid dynamics simulation of spherical cap bubble flow may be conducted using the volume of fluid (VOF) method coupled with the Lagrangian model. After which, results may be validated with experimental data, which will also help tune computational models.