ABSTRACT

The present work has investigated the hydrodynamics of gas-liquid two phase flow through a concentric annulus. The study is primarily confined to experimental investigations of such flow through three annuli of different dimensions by using air and water as the two phases. A unique parallel plate type conductivity probe along with its processing circuitry has been developed in the present work in order to obtain a comprehensive idea about the different hydrodynamic parameters. Besides the experimentations, theoretical models have been developed to predict the behaviour of two phase flow through this geometry. A comparison of the theoretical models with the experimental data proves their validity. The velocities of the two phases have been so selected that they cover the flow regimes in and around the slug flow regime namely the bubbly, the slug and the churn flow regimes.

The initial studies have been concentrated on the rise of isolated Taylor bubbles through stationary annular columns of water. The experiments have been executed for measuring the rise velocity and length of individual bubbles from signals of a pair of probes located at a known distance apart from one another. The analysis considers an elliptic nose of the bubble. It is a modified form of inviscid flow solution which considers potential flow at the nose and the liquid bridge and incorporates the effect of viscosity at the films.

Both the experimental and theoretical investigations are directed towards obtaining the rise velocity and geometry of Taylor bubbles as functions of bubble volume and annulus dimensions. They have shown that the rise velocity is independent of bubble volume and a function of annulus dimensions only. The analysis has obtained the function in the form of a Froude number by deducing the characteristic dimension as (D_1+D_2). This is different from the hydraulic diameter of an annulus, characterising it during single phase flow and also explains the increase in rise velocity with increase in either of the dimensions of an annulus. The Froude numbers thus obtained have a value between 0.321 - 0.325 for the annulus dimensions used in the present work and reported in literature. Moreover, the predicted and measured rise velocities are in excellent agreement with one another

for a wide range of annulus dimensions. The bubble geometry obtained from experiments and theory are in close agreement which probably indicates that the assumption of elliptic nose of a Taylor bubble in an annulus is reasonable.

The studies have then been carried out to investigate the phase distribution during the simultaneous flow of the two phases through this geometry. The interfacial configurations have been detected by an elaborate arrangement of eight conductivity probes located at various axial and azimuthal positions in the test section. The PDF analysis of the probe signals has been carried out for a better appraisal of the flow situation. Both these methods detect the existence of the flow regimes by means of different quantitative measures of these objective methods. They clearly bring out the asymmetry of the bubbly-slug, the slug and the slug-churn flow regimes while indicating the bubbly and churn flow to be symmetric. They have also thrown light on the development of flow along the length of the test section and the mechanisms governing the transition from one regime to the other. On this basis, the bubbly-slug transition has been postulated to occur when the cap bubbles are large enough to form Taylor bubbles and the resulting liquid slugs are longer than the wake of the Taylor bubbles. The slug-churn transition has been observed to initiate with the collapse of the liquid bridge due to an increased bubble concentration in it and flooding has been postulated as the mechanism of transition. The Wallis correlation for flooding has, therefore, been adopted to describe the transition with an average value of C as 0.85. A theoretical flow regime map has been constructed by locating the boundaries from the analytically modelled transitions and it has been observed to agree well with the experimental data of the present work and those reported in literature.

Finally, the studies have been extended to measure the liquid holdup of the flowing mixture through this geometry. The experiments have been carried out by using the quick closing valve technique and they indicate the holdup values to be insensitive to annulus dimensions but a strong function of flow regimes. The drift flux model has been adopted for the theoretical predictions of the same. However, the parameters of the model have been suitably modified to incorporate the characteristics of the different flow regimes. The close agreement of the model with the experimental data in the bubbly, the dispersed bubbly and the slug flow regimes have been observed for data of the present work as well as those reported in literature. This proves the validity of the models. Finally, several empirical correlations and simple analytical models have been tried to predict the voidage in the churn flow regime. It has been observed that the Hughmark's correlation yields the best results.

KEYWORDS :

Two phase flow, concentric annulus, bubbly flow, slug flow, churn flow, Taylor bubble, rise velocity, flow regime, liquid holdup, conductivity probe, PDF analysis, drift flux model, flooding, Froude number, bubble geometry.