Abstract

The present study has attempted to investigate the hydrodynamics of liquid-liquid two-phase upflow through a vertical pipeline. Blue dyed kerosene and water has been selected as the test fluids. A novel non-intrusive optical probe has been designed and fabricated to identify the phase distribution during flow through the conduit. It is based on the difference in optical properties of the respective phases and works on the basis of the proportion of light attenuated and scattered by the two-phase mixture. Two types of time series analysis namely the probability density function (PDF) analysis and the wavelet multi-resolution technique of the probe signals have been adopted for a better understanding of the flow phenomena. The distribution has been observed to be bubbly at low flow rates of both the liquids. Core annular flow has been identified at low water and high kerosene velocities. The transition from bubbly to core annular flow occurs through a chaotic distribution of both the liquids where the dominating phase shifts from water to kerosene. This is named as the churn-turbulent flow pattern. Flow pattern data thus obtained from the analysis of the optical probe has been verified by conductivity probe. Three different designs of conductivity probe have been adopted for the same. The flow pattern data has been represented as a flow pattern map and the pattern boundaries have been compared with the existing theoretical and empirical models.

Studies have next been performed to develop a unified model for the prediction of flow patterns in liquid-liquid flows such that the analysis will be applicable to horizontal, vertical and inclined pipes over a wide range of fluid properties and pipe dimensions. It is noted that each transition is governed by a separate mechanism and a knowledge of the physics of flow is required for modeling the pattern transitions. Considering all these an artificial neural network (ANN) with feed forward back propagation (FFBP) technique has been adopted to predict the liquid-liquid flow patterns. The network has been trained with the experimental flow pattern data of the present study as well as the data available in literature. The network predicted flow pattern maps are in close agreement to the theoretical and empirical models available in literature.

Extensive experimental investigation has been carried to study pressure drop and holdup in different flow patterns. The measured pressure drop and holdup have been analysed with suitable two-phase flow models. The analysis shows that the homogeneous model is appropriate for the dispersed bubbly pattern while in bubbly and churn-turbulent pattern the pressure drop and holdup are better predicted by the drift flux model. In case of core annular flow, the two-fluid model can be adopted to predict pressure drop with high accuracy.

Finally, the study has been performed to investigate the influence of a venturimeter on liquid-liquid phase distribution during upflow through the vertical pipe. The optical probe has been adopted for this purpose. The probability density function and the wavelet multi-resolution analysis of the random probe signals have provided an insight into the details of the flow patterns and the intrinsic differences at the upstream, throat and the downstream sections. The experiments have indicated similar phase distribution at the three sections. However, the transitions have been observed to occur at lower velocities in the downstream region for the majority of the cases. The differences in phase distributions under these conditions have further been verified by the cross correlation technique. It has also been noted that the venturimeter can be used as an effective flow-metering device for liquid-liquid upflows using homogeneous theory for dispersed pattern and drift-flux theory for bubbly and churn-turbulent patterns.