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The split of stratified gas–liquid flow at a small diameter T-junction

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Abstract

The present work reports a study of phase split at a horizontal T-junction with main and side branches of 0.005 m diameters. The experiments were confined to the stratified flow pattern and the effects of phase velocities and pressure on the split were examined. The results were also compared with those reported for larger T-junctions. The side arm take-off tends to be richer in the gas phase with increase in pressure under all flow conditions. The reason has been attributed to the complex effect of pressure on the interface position (characterised by the dimensionless liquid height, h/D) which in turn determines the gas and liquid momentum.

Keywords: Gas/liquid; T-junction; Phase separation; Small diameter; Horizontal

1. Introduction

Two-phase flow through T-junctions is most often characterised by a maldistribution of the phases between the outlets. Apart from being a topic of fundamental interest, this phenomenon

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is of significant technical concern. The maldistribution in the downstream equipment can cause major problems in operation and control of the process and power industries as well as in oil and gas production. On the other hand, one may take advantage of it to build compact and comparatively inexpensive separators for the partial separation of gas–liquid mixtures (Azzopardi, 1993; Azzopardi et al., 2002).

Over the last two decades, numerous efforts have been made to study the phenomenon of phase separation through T-junctions both by experimental investigation and theoretical analysis. The problem has also been addressed in several state of the art reviews, e.g., Azzopardi and Hervieu (1994), Lahey (1986), Muller and Reimann (1991) and Azzopardi (1999). The research effort has shown that in general the prediction of flow distribution is difficult due to the complexity of the flow phenomenon. It is also an established fact that the orientation of the junction and the flow pattern approaching it largely influences the flow separation. Keeping relevance to the present work, the discussion is mainly focussed to stratified flow through T-junctions with horizontal main and side arms.

One of the earliest works relevant to the present study was that of Hong (1978). He performed extensive experiments through a horizontal T-junction of 9.525 mm diameter He studied the effect of varying phase velocities and liquid viscosity for stratified wavy and annular flow patterns at the inlet. He reported that the fraction of liquid taken off increases with increasing gas and decreasing liquid velocity. It was suggested that the liquid taken off is governed by the competing centripetal force exerted by the gas phase due to an abrupt change in its direction and the inertial force of the liquid. This is in agreement to the suggestion of Oranje (1973).

Shoham et al. (1987) used a larger diameter (50 mm) T-junction and noted the inlet flow pattern to exert a strong influence on the splitting phenomena. Although they obtained trends similar to Hong and Oranje, their data gave a higher liquid take off than Hong at a low gas take off while a lower liquid take off at a higher gas take off. They further proposed a flow pattern specific model to predict the flow splitting for the stratified and the annular flow patterns. Subsequently, Penmatcha et al. (1996) and Marti and Shoham (1997) have extended the model to calculate flow splits in T-junctions with inclined and reduced side arms.

Azzopardi and Memory (1989) investigated phase split for wavy stratified and annular flow patterns for a junction with a main pipe diameter of 38 mm. They performed experiments with both equal diameter and reduced arm T-junctions at pressures of 150 and 300 kPa. They postulated the change in the slope of the take-off curves to be a function of phase momentum flux. They further performed an experiment with same liquid but two different gas velocities at different pressures to maintain identical superficial momentum of the gas for both the cases. The identical phase split curves for the two cases once again demonstrated the importance of momentum on the splitting phenomena.

Hart et al. (1991) proposed a "Double Stream Model" to predict the preference of liquid route during separated gas–liquid flow through horizontal main and side arms. The model was primarily applicable for low liquid holdup ($\varepsilon_L < 0.06$). According to the model, the mass of liquid diverted through the branch is a function of gas mass intake fraction, geometry of the junction and the ratio of the kinetic energy per unit volume of inlet gas and liquid flow. The authors reported a good agreement with the experimental results over a wide range of transport properties and superficial phase velocities for both regular and reduced T-junctions. Subsequently, Ottens et al. (1995) had extended the model by relaxing some of the original assumptions.