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Experimental investigation of two-phase flow splitting in an equal-sided impacting tee junction with inclined outlets

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ABSTRACT

Phase-distribution data have been generated for two-phase (air–water) flow splitting at an impacting tee junction with a horizontal inlet and inclined outlets. This investigation also considered the possibility of full separation at the junction and the effect of the outlet angle of inclination on partial separation at various inlet conditions. A flow loop with the ability to incline the outlets from horizontal to vertical was constructed. The operating conditions were as follows: test section inside diameter (D) of 13.5 mm, nominal junction pressure (P_s) of 200 kPa (abs), near ambient temperature (T_s), inlet superficial gas velocities (J_{G1}) ranging from 2.0 to 40 m/s, inlet superficial liquid velocities (J_{L1}) ranging from 0.01 to 0.18 m/s, inlet qualities (x_1) ranging from 0.1 to 0.9, mass split ratios (W_3/W_1) from 0 to 1.0, and inlet flow regimes of stratified, wavy, and annular. The data reveal that the degree of maldistribution of the phases depended on the inlet conditions, the mass split ratio at the junction, and the inclination angle of the outlets.

1. Introduction

Two-phase flow passing through tee junctions is relevant to many industrial systems including power, chemical process, nuclear energy, and hydrocarbon production industries. Junctions may be used either to combine two inlet streams into one outlet stream (combining tees) or to divide one inlet stream into two outlet streams (dividing tees). Junctions where two-phase flow is divided between the outlets (impacting or branching tees), are common in the power generation, process and hydrocarbon production industries.

When two phases flowing in a pipe encounter a dividing tee junction, almost inevitable maldistribution of the two-phase flow between the outlets takes place, i.e., the qualities in the outlets are different, and they are both different from that of the inlet. This phenomenon is influenced by a number of factors that include: inlet flow regimes, mass split ratios, junction geometry, and angle of inclination. This unpredictable nature of splitting of the two phases between the junction outlets can have a major effect on the behavior of equipment downstream from the junction. Severe maldistribution of the phases can lead to all of the liquid flowing into one outlet and at other conditions all the gas may flow into the same outlet. However, this maldistribution may be desirable in some cases where the tee is used as a partial separator. The compact dimensions, and the small weight of tee junctions can make them a desirable separator. In the so called multi-bottle slug catchers used in offshore oil and gas production, a two-phase flow is divided in a series of tee junctions into a number of large-diameter pipes at small downward inclination. Each pipe contains a tee junction with one vertically upward outlet used to withdraw the majority of gas. All gas outlets are combined together in a manifold, and a similar arrangement is made for the liquid.

Most of the research work in the past was directed to the geometry of branching tees. The early work with branching tees was limited to horizontal tees with a horizontal branch arm. Later work was directed to the case of branching tees with an inclined side arm. A summary of the available literature for two-phase flow splitting in branching tees with a horizontal branch arm can be found in [1,2].

Although in many industrial applications, impacting tee junctions with inclined outlets are in use, publications considering the inclination effect cannot (to the best of the authors knowledge) be found in the open literature. Most of the previous researchers on impacting tee junctions have concentrated on impacting tee junctions with a horizontal inlet and horizontal outlets. A summary of the available literature for horizontal impacting tee junctions was given by El-Shaboury et al. [3]. These include the experiments by Hong [4], Hwang et al. [5], Chien and Rubel [6], Ottens et al. [7], Hong and Griston [8], Fujii et al. [9], and Asano et al. [10]. All these studies used equal-sided tees with inside diameters ranging from 9.5 to 49.3 mm. For a large majority of the conditions tested in the studies mentioned above, it was concluded that the phases do not split evenly at the junction. The manner by which the phases distribute themselves at the junction was found to depend on the inlet conditions and the total mass split at the junction.

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