INLET EFFECTS ON VERTICAL-DOWNWARD AIR-WATER TWO-PHASE FLOW

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ABSTRACT

This paper focuses on investigating the geometric effects of inlets on global and local two-phase flow parameters in vertical-downward air-water two-phase flow. Flow visualization, frictional pressure loss analysis, and local experiments are performed in a test facility constructed from 50.8 mm inner diameter acrylic pipes. Three types of inlets of interest are studied: (1) two-phase flow injector without a flow straightener (Type A), (2) two-phase flow injector with a flow straightener (Type B), and (3) injection through a horizontal-to-vertical-downward 90^{o} vertical elbow (Type C). A detailed flow visualization study is performed to characterize flow regimes including bubbly, slug, churn-turbulent, and annular flow. Flow regime maps for each inlet are developed and compared to identify the effects of each inlet. Frictional pressure loss analysis shows that the Lockhart-Martinelli method is capable of correlating the frictional loss data acquired for Type B and Type C inlets with a coefficient value of C=25, but additional data may be needed to model the Type A inlet. Local two-phase flow parameters measured by a four-sensor conductivity probe in four bubbly and near bubbly flow conditions are analyzed. It is observed that vertical-downward two-phase flow has a characteristic center-peaked void profile as opposed to a wall-peaked profile as seen in vertical-upward flow. Furthermore, it is shown that the Type A inlet results in the most pronounced center-peaked void fraction profile, due to the coring phenomenon. Type B and Type C inlets provide a more uniform distribution of the void fraction profile with a reduced coring effect.

KEYWORDS
Inlet effects, vertical-downward two-phase flow, flow regime map, local two-phase flow parameters, frictional pressure drop

1. INTRODUCTION

Two-phase flow is a widely observed phenomenon present in many engineering applications such as nuclear reactors as well as industrial systems. Most of these practical applications have different sizes of coolant channels in varying orientations with different types of inlets, all of which can affect the two-phase flow characteristics. The inlet configurations specifically can induce significant changes in the interfacial structures and their transport phenomena. Since the mass, momentum, and energy transfer between the two phases are greatly influenced by changes in the interfacial structures, experimental studies are crucial in improving the understanding of the inlet effects on two-phase flow.

In the present study, the effects of three types of inlets in co-current vertical-downward air-water two-phase flow are studied using flow visualization approach, frictional pressure loss analysis, and local interfacial structures analysis.

First, a detailed flow visualization study is performed. Flow regimes including bubbly, slug, churn-turbulent, and annular flow are defined, and flow regime maps are developed for each inlet configuration. Through flow visualization, it is found that vertical-downward two-phase flow has a typical center-peaked void distribution primarily caused by the lift force. The comparisons of the flow regimes maps show that Type A inlet results in a gas core near the inlet and form significant coring effect even in the downstream of the flow. Type B and Type C inlets can reduce the coring effect to a certain degree thereby reducing bubble coalescence and shifting the regime transition boundaries to higher superficial gas velocities.

Second, Lockhart-Martinelli method is used to study the two-phase frictional pressure loss in different types of inlets. The result indicates that Lockhart-Martinelli correlation is capable of correlating the two-phase frictional pressure loss for the Type B and Type C inlets with coefficient C value of 25 with an accuracy of ±5%. For the Type A inlet, the pressure loss is found to be higher. The additional pressure loss is expected to be caused by the significant coring effect. A coefficient C value of 100 is correlated to the experimental data. However, additional study may need to be performed.

Finally, local two-phase flow parameters are acquired by using a four sensor conductivity probe. The local data shows a center-peaked void profile which is consistent with the coring phenomenon observed by flow visualization. Downstream from the inlet, the Type A inlet results in the most pronounced center-peaked void fraction profile while the profile is more uniform for Type B and Type C inlets. Moreover, asymmetric bubble distribution occurs just after the Type C inlet due to the high liquid inertia.

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