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HEAT TRANSFER MEASUREMENTS AND CORRELATIONS ASSESSMENT FOR DOWNWARD INCLINED GAS-LIQUID TWO PHASE FLOW

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ABSTRACT

Non-boiling heat transfer in downward inclined gas-liquid two phase flow is quite intriguing and is one of the least studied phenomenon in the two phase flow literature. To explore and understand this phenomenon, experiments are carried out to measure the local and averaged non-boiling two phase heat transfer coefficient (h_{TP}) in 0, -5, -10, -20, -30, -45, -60, -75 and -90 degrees of pipe inclinations. The experiments are carried out with uniform wall heat flux boundary condition in 12.5 mm I.D. stainless steel pipe that uses air-water as fluid combination and consists of all flow patterns that covers the gas and liquid superficial Reynolds numbers in a range of 270 to 19000 and 2300 to 17000, respectively. It is observed that an increase in downward pipe inclination from horizontal initially exhibits a decreasing tendency of h_{TP} till -30 degrees and thereafter increases consistently with further increase in the pipe inclination towards vertical downward direction. The general trends of two phase heat transfer coefficients are found to be closely related to the physical structure of the flow patterns and their morphological variations as a function of pipe orientation and phase flow rates. The measured data is compared against some of the non-boiling two phase heat transfer correlations available in the two phase flow literature. Based on a statistical comparison, the relatively top performing correlations are identified and a scope for further improvements is established.

KEY WORDS: Two phase flow, non-boiling heat transfer, downward inclination, flow pattern, stratified flow.

1. INTRODUCTION

Heat transfer in gas-liquid two phase flow is of practical significance in wide range of industrial applications such as those in chemical processes, nuclear reactors, pipe lines conveying mixture of oil and gas and evaporator and condensers used in solar power generation and HVAC. In particular, during the production of two phase hydrocarbon fluids from oil reservoirs and its transportation to the surface processing facilities, the temperature of hydrocarbons drops drastically and is favorable for hydrates formation and wax deposition. Wax deposition can result in problems including reduction of inner tube diameter causing blockage, increased surface roughness of tube leading to restricted flow line pressure, decrease in production, and various mechanical problems. In such situations, the correct knowledge of heat transfer coefficients in non-boiling two phase flow is crucial for the purpose of flow assurance in oil and gas industry. In comparison to the horizontal two phase flow, very little work has been done for understanding this phenomenon in inclined two phase flow systems. Some of the experimental and modeling work in the field of non-boiling two phase heat transfer in non-horizontal systems is that of Chu and Jones [1], Oshinowo et al. [2], Hestroni et al. [3] and Ghajar and Tang [4]. Chu and Jones [1] and Oshinowo et al. [2] measured two phase heat transfer coefficient in vertical upward and downward pipe inclinations using air-water as working fluids. They found that in comparison to vertical downward flow, the two phase heat transfer coefficients in vertical upward flow were substantially higher particularly in intermittent and annular flow

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