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Heat Transfer Measurements and Correlations Assessment for Upward Inclined Gas-Liquid Two Phase Flow

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ABSTRACT

Non-boiling heat transfer in gas-liquid two phase flow embraces some of the practical applications pertinent to chemical and oil and gas industry. In comparison to horizontal and vertical two phase flows, very little information is available about non-boiling heat transfer in upward pipe inclinations. To further understand this phenomenon, 679 experimental measurements of the local and space averaged two phase heat transfer coefficients are carried out in 0^o, $+5^o$, $+10^o$, $+20^o$, $+30^o$, $+45^o$, $+60^o$, $+75^o$ and $+90^o$ degrees of pipe inclinations using air-water fluid combination in a 12.5 mm I.D. stainless steel pipe. The measured non-boiling two phase heat transfer coefficients are found to be influenced by phase flow rates, pipe orientation and flow patterns. The two phase heat transfer coefficient is observed to increase with increase in pipe orientation from horizontal in the vicinity of $+45^o$ to $+60^o$ and then shows a decreasing trend as the pipe is inclined towards vertical position. The effect of change in flow pattern structure on the measured two heat transfer coefficient is noticeable for bubbly and slug flows compared to that in intermittent and annular flow patterns. The heat transfer coefficient in two phase flow is found up to 5-6 times greater than that in single phase flow. The experimental data (679 data points) measured in this work are also used to scrutinize the performance of some of the existing non-boiling two phase heat transfer correlations available in the literature. Based on a statistical performance, the top performing correlations for different flow patterns and pipe orientations are recommended.

KEY WORDS: Two phase flow, non-boiling heat transfer, upward inclination, flow patterns, heat transfer correlations

1. INTRODUCTION

Several practical applications occurring such as those seen in power plants, nuclear reactor cooling, heat exchangers (evaporators and condensers) in heating and cooling systems and simultaneous transport of oil and gas in petroleum industry involve gas-liquid two phase flow. The two component (non-boiling) two phase flow is of prime interest in chemical and petroleum industries. In particular, correct knowledge and proper understanding of this non-boiling flow of gas and liquid phase is essential to solve flow assurance related problems some of which involve gas hydrates formation and wax deposition on the inner wall of pipes carrying natural gas and hydrocarbons. These residues in the pipe block the flow causing heavy loss to the oil and natural gas industry which is shown in McClaflin and Whitfill [1]. To address these issues and have a proper understanding of the heat transfer phenomenon in non-boiling (without phase change) two phase flow, it is very crucial to know the interrelationships between the two phase heat transfer and two phase flow parameters such as flow patterns, void fraction, phase flow rates, fluid properties and pipe orientation.

In comparison to horizontal and vertical pipe orientations, not much is known about the two phase heat transfer phenomenon in upward inclined systems. Some of the existing studies focused on understanding the two phase heat transfer phenomenon in upward inclined systems are those of Hestroni et al. [2], Ghajar and Tang [3], Kalapatapu et al. [4] and Lips and Meyer [5]. Hestroni et al. [2] measured two phase heat transfer

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