HEFAT2014
10th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
14 – 16 July 2014
Orlando, Florida

NON-BOILING HEAT TRANSFER IN HORIZONTAL AND NEAR HORIZONTAL DOWNWARD INCLINED GAS-LIQUID TWO PHASE FLOW

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ABSTRACT

Heat transfer in non-boiling gas-liquid two phase flow has significant practical applications in chemical and petroleum industry. To date, majority of the research in this field have been conducted for two phase flow in horizontal and vertical pipe systems. To explore and enhance the general understanding of heat transfer in non-boiling two phase flow, the main focus of this work is to experimentally measure local and average convective heat transfer coefficients for different flow patterns in horizontal and near horizontal downward inclined two phase flow. In total, 380 experiments are carried out in a 12.5 mm I.D. schedule 10S stainless steel pipe at 0, -5, -10 and -20 degrees pipe orientations using air-water as fluid combination. For each pipe orientation, the superficial gas and liquid Reynolds number is varied from 200 to 19,000 and 2000 to 18,000, respectively. The measured values of the average two phase heat transfer coefficient are found to be in a range of 500 W/m^2K to 7700 W/m^2K. Comparisons are drawn between the two phase heat transfer coefficients in the above mentioned pipe orientations. It is found that the increase in inclination of the pipe in downward direction causes the two phase heat transfer coefficient to decrease. This trend of two phase heat transfer data is explained based on the flow visualization and establishing its connection with the flow pattern structure and the two phase flow physics.

INTRODUCTION

Investigation of heat transfer in non-boiling two phase flow in pipe is of great practical importance for industrial applications such as reduction of paraffin wax deposition in petroleum transport lines, air lift system, solar collectors, nuclear reactors and several chemical processes. Despite having great practical applications, the effect of inclination on the two phase flow in pipe has been rarely investigated. Some of the experimental data available in the two phase flow literature for horizontal, near horizontal upward inclined two phase flow is that of Ghajar and Tang [1], Tang and Ghajar [2], Hestroni et al. [3, 4]. For vertical downward flow the only experimental work available in the literature is that of Bhagwat et al. [5], Oshinowo et al. [6] and Chu and Jones [7]. In comparison to these pipe orientations there is hardly any experimental data available on downward inclined two phase flow. Tang and Ghajar [2] established that there is a significant increase in the heat transfer in two phase air-water flow when pipe is inclined slightly upward from the near horizontal position. Bhagwat et al. [5] and Oshinowo et al. [6] conducted experiments on vertical downward flow and concluded that there is reduction in heat transfer compared to vertical upward flow. The outcome of these experiments pose some fundamental questions about the reason of such increase or reduction in heat transfer and creates a room for further investigation to establish a more comprehensive qualitative and quantitative physical understanding of two phase flow at inclined orientations. Furthermore, such investigation can pave the way for the development of a robust heat transfer correlation in two phase flow which can account for the effect of pipe orientation. To accomplish this objective this study presents new data on horizontal and near horizontal downward flow at -5^o,-10^o, and -20^o using air-water mixture. The different flow patterns observed in horizontal and downward pipe inclinations are mapped using air and water mass flow rates. The flow pattern map generated in this work is useful in getting an idea of the effect of pipe orientation on the transition boundaries between different flow patterns. Due to complex nature of the two phase flow, sufficient experimental data are collected for each flow pattern and for comparable mass flow rates at different pipe inclinations so as to establish a clear trend of two phase heat transfer in downward inclinations. The experimental data are then analyzed to establish the trend of two phase heat transfer coefficient for different pipe orientations.

NOMENCLATURE

dz	[m]	Differential change in axial direction
D	[m]	Pipe diameter
G	[kg/m^2s]	Mass flux