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 UPWARD INCLINED GAS-LIQUID TWO PHASE FLOW

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ABSTRACT

Heat transfer in non-boiling gas-liquid two phase flow finds its practical application in chemical and petroleum industries. So far, majority of the research dedicated to study heat transfer in non-boiling two phase flow is limited to horizontal and vertical pipe orientations with very little attention given to the study of this phenomenon in inclined systems. To contribute and further 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 upward inclined two phase flow. In total, 368 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 and the measured values of the averaged heat transfer coefficient were found to be in a range of 1300 W/m^2K to 8000 W/m^2K. The two phase heat transfer coefficients are compared among the above mentioned orientations. It is found that the two phase heat transfer coefficient increases from 0^o to $+5^o$ and $+10^o$ degree and then decreases at +20 degree.

INTRODUCTION

Non-boiling two phase flow is a common and important occurrence in industries, especially in the oil industry. The temperature of the hydrocarbon fluids flowing in the pipe during transportation changes due to the difference in temperature of the surface and the oil reservoir. This results in wax deposition in the inner walls of the pipe blocking fluid flow thereby causing severe mechanical problems. Increasingly, inclined pipes are being used in the transportation of the fluids. Due to the lack of literature regarding flow regimes and thermo-fluid dynamics in inclined pipes, experimental work in this study is carried to fill the gap in literature and enhance understanding of the two phase heat transfer phenomenon in inclined non-boiling systems. The available experimental data in two phase flow literature for horizontal and near horizontal upward inclined pipes is that of Ghajar and Tang [1], Tang and Ghajar [2] and Hestroni et al. [3, 4]. It is important to note that the experiments conducted by Tang and Ghajar [2] deal with pipe diameter of 25 mm and that of Hestroni et al. [3, 4] are for pipe diameters 25 mm and 50 mm. Both of these studies have observed a significant enhancement in two phase heat transfer with the increase in inclination from the horizontal. The current experiments analyses the two phase heat transfer in a pipe of diameter 12.5 mm and the results agree with that observed by the above mentioned authors to some extent. The results of these different experiments show that the heat transfer coefficient also depends on the pipe diameter along with flow pattern and pipe inclination. The experimental data from these investigations can be used to develop heat transfer correlations accounting for the above mentioned factors. In the present study the data is collected for 0°, +5°, +10°, and +20° using air-water mixture and is measured at similar mass flow rates for all orientations. The flow patterns observed in different inclinations are mapped to have a better understanding of the effect of pipe inclination on the transition between different flow patterns. The experimental data of two phase heat transfer coefficient is analyzed as a function of gas and liquid flow rates and their magnitude is compared for different pipe orientations.