

University of Macau

Abstract

An Improved Convective Heat Transfer Correlation for
Gas-Liquid Two-Phase Pipe Flow

by

Tam Hou Kuan

Thesis Supervisor: Prof. Tam Lap Mou
Department of Electromechanical Engineering

In many industrial applications, such as the flow of natural gas and oil in pipelines and wellbores, the knowledge of nonboiling two-phase, two-component (liquid and permanent gas) heat transfer is required. Several heat transfer correlations for forced convective heat transfer during gas-liquid two-phase flow in vertical pipes have been published over the past 40 years. These correlations were developed based on limited experimental data and are only applicable to certain flow patterns and fluid combinations. Kim et al. (2000) proposed a heat transfer correlation for turbulent gas-liquid flow in vertical pipes with different flow patterns and fluid combinations. Their correlation was developed using four sets of experimental data (a total of 255 data points) for vertical pipes. The form of their correlation was based on the major dimensionless variables affecting two-phase heat transfer. The coefficients of their correlation were found by using the traditional least squares regression. Their correlation predicted the experimental data with a deviation range of -64.71% and 39.55%. Majority of the experimental data (245 data points or 96% of the data) were predicted within the $\pm 30\%$ range. Then, the correlation form with modified parameters was also used for predicting the heat transfer coefficient of the air-water two-phase flow in Kim and Ghajar (2002). The experimental data (150 data points) were categorized into several groups according to the flow patterns. All the data points were predicted with a deviation range of -25.17% and 34.42%. The ninety-eight percentage of the experimental data (147 data points) were predicted

within $\pm 30\%$ deviation range. Although the correlation is applicable, the accuracy of the prediction still has plenty of room for improvement. However, the traditional least squares method is difficult to improve the accuracy. Therefore, the purpose of this study is to apply the method of artificial neural networks (ANN) to develop a more accurate correlation. It has been shown that ANN has excellent capability of handling complicated flows in the literatures. The same sets of experimental data used by Kim et al. (2000) and Kim and Ghajar (2002) were used in this study. The ANN method employed in this study was the three-layer feedforward networks, which can work as a high dimensional nonlinear regression. To avoid over or under-fitting, the data were separated into two sets. One set was used for the networks training and the other set was used for testing. The new correlations outperform the traditional least-squares correlations and predict the experimental data within the $\pm 17\%$ range. The detail in the implementation of the ANN regression is also discussed in this study.

Keywords: Two-phase flow; Heat transfer correlations; Regression; Artificial neural networks (ANN)