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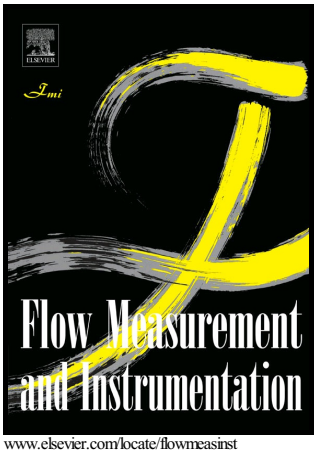

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A Method for Direct Thickness Measurement of Wavy Liquid Film in Gas-liquid Two-phase Annular Flow using Conductance Probes

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Abstract

Gas-liquid two-phase annular flow widely exists in industrial fields such as chemical engineering, petroleum, nuclear reactors and so on. The liquid film plays major influences on the performance of heat and mass transfer in gas-liquid two-phase annular flow. In this paper, a conductance probe with adjustable insertion depth is designed to measure the wavy liquid film thickness, which is a direct method unaffected by the change of conductance. Then, a calculation method of time-average liquid film thickness using duty ratio weight is proposed. The effects of the insertion depth increment and statistical time on measurement error are analyzed, and the mathematical expressions of relative error are derived. The verification experiments are carried out in the gas-liquid experimental facility at Tianjin University. Through the measurement error analysis, a system error compensation calculation method is presented, which improves the measurement accuracy obviously. The average relative error is better than 1.00% at different insertion depth increments in the statistical time T=5s. The proposed method does not need the real flow calibration because the relationship between liquid film thickness and conductance isn't involved in the process of measurement.

Key words: time-average liquid film thickness, gas-liquid two-phase flow, conductance probe, duty ratio weight

1. Introduction

Annular flow is an important flow regime of gas-liquid two-phase flow, which is widely encountered in many different industrial applications, i.e. petroleum, chemical, nuclear industry and particularly in boiling and condensing heat transfer equipment [1-3]. The characteristics of liquid film are closely related to the performance and safety of operation[4]. The liquid film surface is usually accompanied by various kinds of complicated waves, and the film thickness varies with time and space [5-7]. The accurate measurement of liquid film thickness is the basis for investigating the characteristics of the interfacial waves [8, 9]. The development of techniques to measure liquid film thickness has been an important topic in the area of two-phase flow for a long time. Many methods based on different physical principles have been constantly proposed, such as acoustic method[10, 11], conductance-based method[12], capacitance-based method[13, 14], optical method [15-17], nucleonic technique[18, 19] and so on. Among the listed methods, the conductance-based method with simple equipment and convenient operation is widely used, which can be divided into two categories, indirect method and direct method.