LIQUID FILM BEHAVIORS OF OSCILLATING SLUG FLOWS

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Abstract - Liquid film thickness is an important parameter for predicting boiling and condensation heat transfer coefficients in two-phase slug flow. In the present study, liquid film thickness of oscillating slug flow in a capillary tube is experimentally investigated.Circular tube with inner diameter of 1 mm is used for the test tube, and water and ethanol are used as working fluids. The laser focus displacement meter (LFDM) is used to measure the initial liquid film thickness.

Indexterms - Slug Flow, Capillary Tube, Liquid Film Thickness.

I. INTRODUCTION

Oscillating slug flow is encountered in many thermal and chemical engineering applications such as heat pipes, steam engine and micro reactors, etc. It is known that the liquid film thickness is one of the key parameters for predicting heat transfer coefficients in micro tubes [1-3].Han et al. [4] experimentally studied liquid film thickness of steady slug flow and suggested prediction model. Han et al. [5], and Youn et al. [6] studied liquid film thickness of accelerated slug flows and suggested prediction models.

In the present study, liquid film thickness of oscillating slug flow is experimentally investigated under adiabatic condition. The liquid film thickness in micro circular tubes is measured using laser focus displacement meter (LFDM) for working fluid of ethanol. Finally, prediction model of the liquid film thickness in the oscillating slug flow was suggested.

II. EXPERIMENTAL SETUP AND PROCEDURES

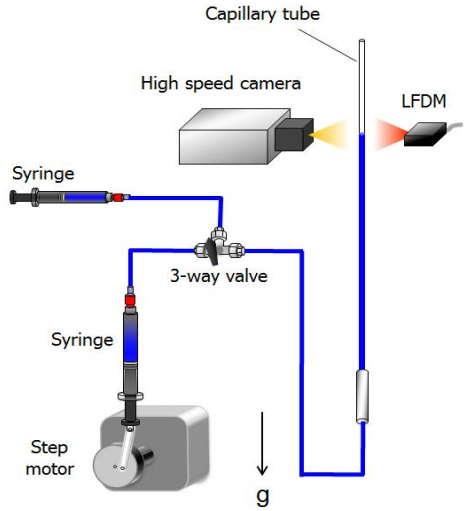

Figure 1: Experimental setup for oscillating slug flows.

Figure 1 represents the schematic diagram of the experimental setup. Step motor and controller (Oriental motor, ARL66AA and EMP401) were used to pull and push the liquid to make oscillating flow. Instantaneous bubble velocities and acceleration and deceleration rates were obtained from the images obtained by a high-speed camera (Photron SA1.1). The liquid film thicknesses were measured by laser focus displacement meter (LFDM; LT 9010M, Keyence). The driving frequency of the oscillating flow is ranged from 1 Hz to 7 Hz.

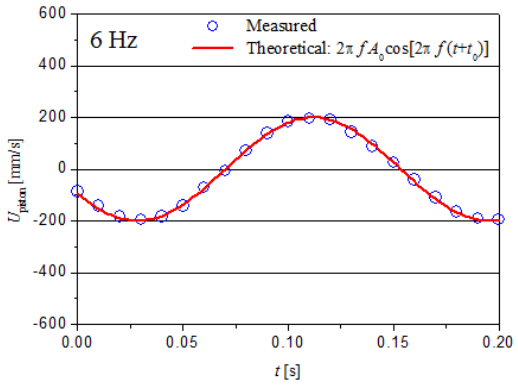

Figure 2: Measured and theoretical piston velocity variations with respect to time.

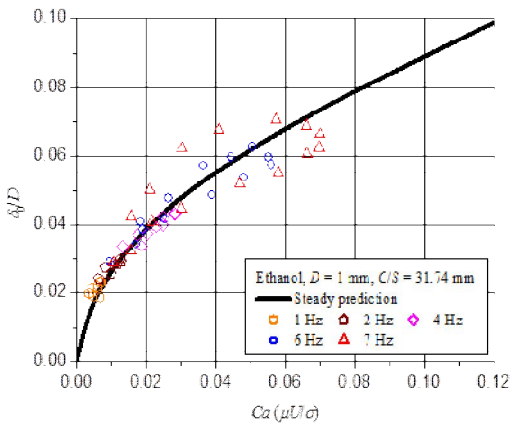

Figure 3: Measured liquid film thicknesses with respect to capillary number.

III. EXPERIMENTAL RESULTS

Figure 2 represents the measured piston velocity against time with theoretical prediction. The theoretical values well predict the experimental values. Figure 3 show the dimensionless initial liquid film thicknesses against capillary number for the ethanol/air experiment. Black-line represents the prediction of liquid film thicknesses of steady flow conditions and each symbol with different colorrepresents the measured liquid film thickness data obtained in the present study. The liquid film thickness becomes identical to the steady condition data at small capillary numbers. As capillary number increases, the liquid film thickness deviates from thesteady condition data. Instantaneous bubble velocity U are non-dimensionalized as instantaneous capillary number $Ca = \mu U/\sigma$. In order to express the bubble acceleration and deceleration effect, Bond number based on the bubble acceleration rate is introduced as follows:

$$Bo = \frac{\rho |a| D^2}{\sigma} \quad (1)$$

where$a$ is the bubble acceleration rate. Note that the absolute value of a is used for the Bond number, i.e. $Bo > 0$.

Based on the scale analysis and experimental data, prediction model for predicting liquid film thickness of oscillating slug flow was suggested. It well predicts the liquid film thicknesses of the oscillating flows within 15%.

CONCLUSION

Liquid film thickness of oscillating slug flow in a capillary tube was investigated under adiabatic condition. As the frequency and corresponding stroke increase, the liquid film thickness deviates from the steady condition and becomes much thinner or thicker at large distance from the top dead center due to acceleration effect and deceleration effect, respectively. It is concluded that acceleration and deceleration effects should be considered on the liquid film thickness of oscillating flow.

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