Evaluation of steam-water annular flow characteristics under BWR operating conditions based on experiments with simulant fluids

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Abstract
This study overcomes the limitation of studying liquid film behavior of steam-water annular flow under operating conditions of BWRs characterized by high temperature and high pressure (285°C and 7 MPa), by developing a novel HFC134a–ethanol annular flow system. This system operates at lower temperature and pressure (40°C and 0.7 MPa) while simulating the steam–water annular flow under BWR conditions.

Keywords: Two-phase flow, Annular flow, Liquid film, Boiling water reactor, Disturbance wave

1. Introduction

In this study, HFC134a–ethanol upward annular flow experiments in a 5.0 mm ID tube are conducted to simulate the steam–water annular flow in BWRs. The liquid film thickness is measured by using the CECM technique and the flow pattern is observed using a high–speed camera. The flow characteristics including base, average, and maximum film thickness and height, velocity, and frequency of disturbance waves, together with the interfacial shear stress were obtained.

2. Experimental apparatus and procedure

To obtain the liquid film time trace, the conductance probe method is used to measure the time-varying liquid film thickness [1]. Two sets of sensors with an accuracy of ± 5% are installed in the test section for the film thickness measurement. From the obtained film thickness time trace, the frequency of film thickness is calculated. We define the film thickness with the highest frequency as the base film thickness denoted by t_{Fbase} and the film thickness with the 99% cumulative frequency as the maximum film thickness denoted by t_{Fmax}. Then, the disturbance wave height, H, is defined as the difference between the base and maximum film thicknesses. The average film thickness, t_{Fave}, is the arithmetic mean value of film thickness.

3. Results and discussion

Fig. 1 (a) and (b) shows the comparison between measured t_{Fbase}, t_{Fave}, and t_{Fmax}, and H of HFC134a–95% Ethanol and other systems respectively. It is confirmed for the first time that, t_{Fbase}, t_{Fave}, t_{Fmax}, and H can be converged by the gas Weber number $We_G = \rho_G j_G^2 D/\sigma$, for the HFC134a–95% Ethanol which simulates the steam–water annular annular flow under BWR operating condition. The probable reason is that the surface tension force tends to maintain the shape of the gas–liquid interface against the drag force acting on the disturbance wave and We_G converges the effect of surface tension force and drag force.

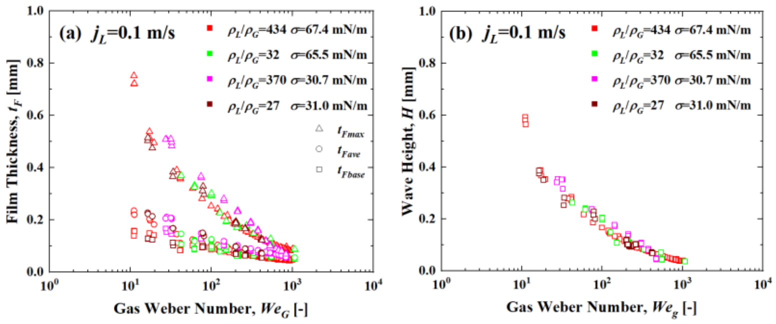

Fig. 1 Comparison of (a) t_{Fave} and (b) H against We_G under $j_L = 0.1$ m/s.

4. Conclusions

In the present study, the experiments of HFC134a–95% Ethanol annular flows with fluid properties that are close to the steam and water under the BWR operating condition are performed. The obtained film thickness is compared with the previous experimental investigation. For the first time, t is found that the base, average, maximum film thickness, and wave height of HFC134a–95% Ethanol system and other systems, collapse onto a single curve when plotted against the gas Weber number.

References

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