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Analysis of Condensation in a Vertical Tube in the presence of Noncondensable Gases using MARS code

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1. Introduction

Although many thermal-hydraulic experiments have been performed in Korea, their experimental data are not systematically managed and effectively used for nuclear power plant design or research, for example, validating MARS code. So, in order to collect experimental data and assess the reliabilities of them, the project named "Assessment of Thermal-hydraulic Experiment Database and Improvement of MARS Code" is underway. Last year, 2007, explorations on what experiments were performed and where they were performed in have been completed and procedures used to evaluate the reliability and usefulness of experiments were developed. In this year, second year, thermal-hydraulic database system will be established and simulation using MARS code will be performed. Next year, detailed comparisons experimental data with MARS code calculation results will be conducted and, as an ultimate goal, suggestions on improvement of MARS code will be discussed.

As a part of the project, the condensation experiments performed in POSTECH were investigated. Raw data, papers and reports were collected and analyzed. To assess MARS capacity on condensation, experimental data were compared with MARS code predictions. In this paper, experiment and MARS modeling are briefly described and comparison results are presented.

2. Condensation Experiments

A schematic of the experimental apparatus is shown in Fig 1. The experimental facilities consisted of a steam generator, steam flow rate control system, steam/nitrogen gas mixing system, test section, and data acquisition system. The steam/nitrogen mixture injected into the condensing tube is cooled down by cooling water through heat transfer at the condensing tube wall.

The 36 case experiments in condition of various inlet flow rate and steam/nitrogen fraction were performed to investigate the effect of noncondensable gas. Experiments showed that the local heat transfer coefficient increased as the inlet flow rate increased and the inlet nitrogen gas mass fraction decreased. Also, both case using pure steam and a steam/nitrogen mixture with a low inlet nitrogen gas mass fraction showed similar results. Therefore, the effects of noncondensable gas on steam condensation were weak in small-diameter (ID=13mm) condenser tubes.

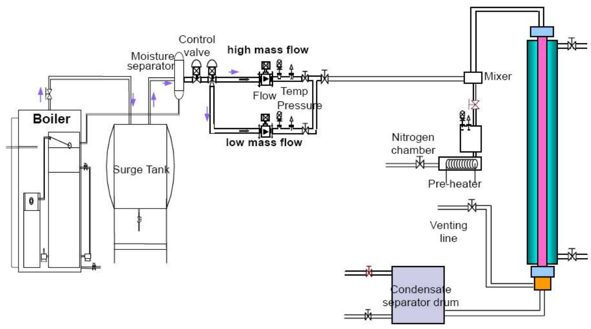

Fig. 1. Schematic diagram of the experimental apparatus.

3. Simulation using MARS code

Fig. 2 shows the nodalization scheme of MARS code for condensation experiments. Time-dependent volumes acting as infinite sources or sinks were used to represent the boundary conditions for steam and noncondensable gas flow in a condensing tube and for the coolant flow in a coolant jacket. Each flow is controlled by using time-dependent junctions.

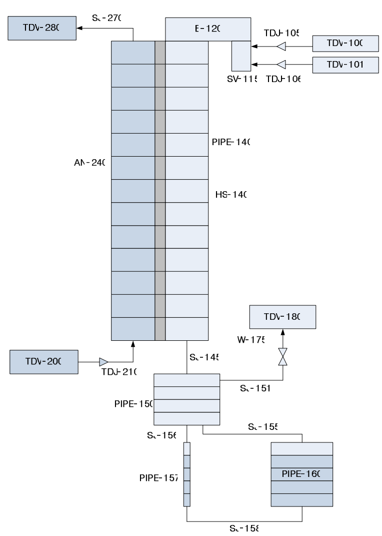

Fig. 2. Nodalization scheme of MARS code for the condensation experimental facility

Fig. 3 shows the heat transfer coefficient as the inlet flow rate increased at the same inlet nitrogen mass fraction of 10.2%. As expected, the heat transfer coefficients increased as the inlet steam as the inlet flow rate increased. Fig. 4 shows the effect of the inlet nitrogen mass fraction on the condensation heat transfer coefficients at an inlet flow rate of 11.2 kg/h. As the inlet nitrogen mass fraction increased, the local heat transfer coefficients decreased, and this was also the same as expected.

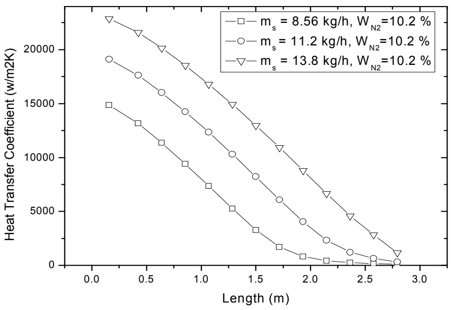

Fig. 3. Comparison of heat transfer coefficients calculated by MARS with the variation of the inlet flow rate.

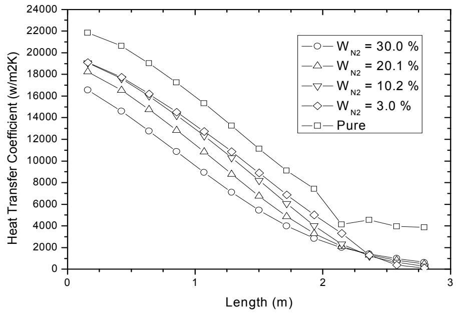

Fig. 4. Comparison of heat transfer coefficients calculated by MARS with the variation of the inlet noncondensable gas mass fraction at inlet flow rate of 11.2 kg/h

4. Comparison between experimental data and MARS code simulation

Fig. 5 and Fig.6 show heat transfer coefficients and heat flux. They show comparisons between the experimental data and MARS predictions. The calculated heat transfer coefficients from MARS code are higher than experimental data, as shown in Fig. 5. However, the calculated heat fluxes are lower than experimental data, as shown in Fig. 6. Other cases show almost same tendency.

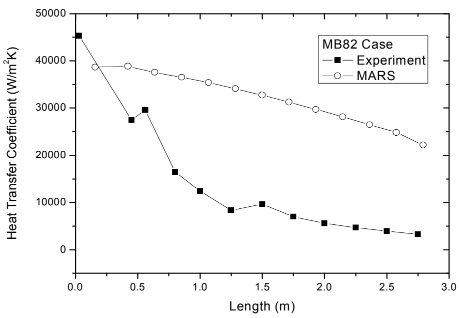

Fig. 5. Comparison of experimental heat transfer coefficient to MARS

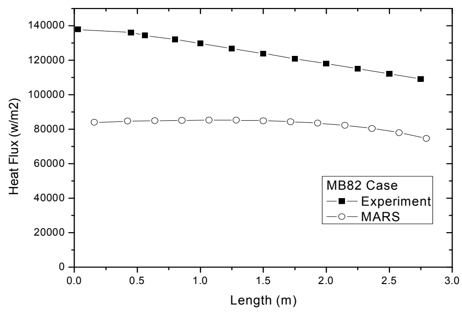

Fig. 6. Comparison of experimental heat flux to MARS

5. Conclusions

Condensation experiments were modeled for MARS code and MARS capability were briefly assessed. As a result of comparing experimental data with calculated values from MARS code, MARS code predictions showed similar tendency in term of effects such as inlet flow rate and noncondensable mass fraction in condensation heat transfer phenomena. However, in most cases, MARS code overestimated heat transfer coefficients and underestimated heat fluxes than experimental data.

To get insights on the point to be improved, several simple tests were carried out. For example, in order to check that differences between experimental data and MARS calculated values were caused only by the condensation model programmed in MARS, we modified the MARS source code in heat transfer coefficient calculating part and make heat transfer coefficient changed by a factor by 1/5 to 5 of its original calculated value. Then, we can make heat transfer coefficient the similar level to experimental data, however, heat flux still showed big difference. This means that the problem is not just in condensation model, more detailed and integrated study were necessary.

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