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Optimization of liquid interfacial heat transfer coefficient of MARS-KS code to match SUBO data

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1. Introduction

The confidence of nuclear power plant safety analysis results is based on the accuracy of the safety analysis code and how the code is utilized. Among many factors affecting the accuracy of the code, the user effect and the physical model of the constitutive equation are dominant [1]. Therefore, to improve the accuracy of the system code from the code developer's point of view, it is necessary to develop more accurate constitutive equations based on physical model. In particular, interfacial heat transfer among the constitutive equations has higher uncertainty than near-wall terms because it is difficult to measure directly in the experiment. Recently, a research work founds that the predicted rate of bubble growth by various interfacial heat transfer models varies greatly from model to model [2]. Figure1 shows the comparison of predicted rate of bubble growth by the presented model with experimental data.

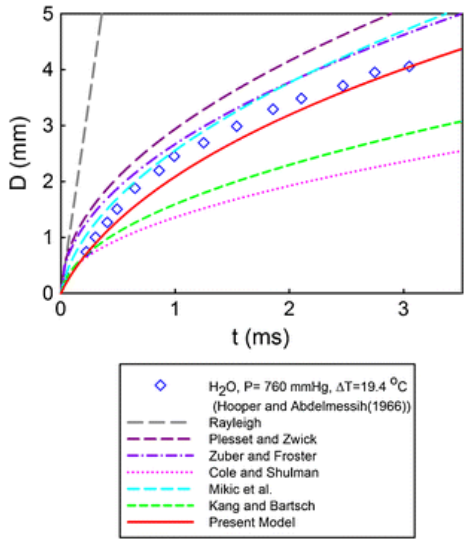

Fig. 1. Comparison of predicted rate of bubble growth by the presented model [2]

In this paper, the source code of MARS-KS 1.4 was modified to apply weights to the interfacial heat transfer coefficient for optimizing the calculated values. The interfacial heat transfer coefficient was optimized so that the code can predict the void fraction of the SUBO (Subcooled Boiling) experiment, which is a separate effect test (SET) experiment related to interfacial heat transfer, by changing the weights.

2. Methods

2.1 MARS-KS SUBO input

A new SUBO input was constructed to simulate the SUBO experiment with MARS-KS. In the SUBO experiment, there were six optical fiber sensors that measured the void fraction. The fifth sensor was located before the end of the heated length and the sixth sensor was located after the end of the heated length. However, it is confirmed that the existing MARS-KS SUBO input file calculated different trends from the experimental data. In the Base-RB case experiment, the void fraction continued to increase at the 5th and 6th measurement points, but the void fraction decreased at the 6th measurement point in the MARS-KS code calculation. Since, the position of the optical fiber sensor was not located at the end of the heated length exactly, it is confirmed that the calculated void fraction depends on how long the node length of the measurement point was taken. Accordingly, in the new input file, for the 5th and 6th sensors, the node length is shortened so that the heater effect after the 5th sensor and the condensation effect before the 6th sensor appears clearly. Before the 5th sensor, the size of each node was distributed almost uniformly. The node length of sensors from 1 to 4 is set to the size of the observation window. The sensor positions are centered on the node. The inlet and outlet boundaries are set to the corresponding pressures and temperatures where the differential pressure transmitters were located. Figure 2 shows the SUBO nodalization of the newly constructed input file, and Figure 3 shows the calculated void fraction of the old input file.

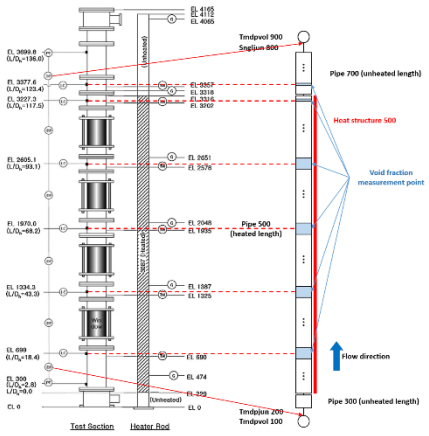

Fig. 2. SUBO input file nodalization

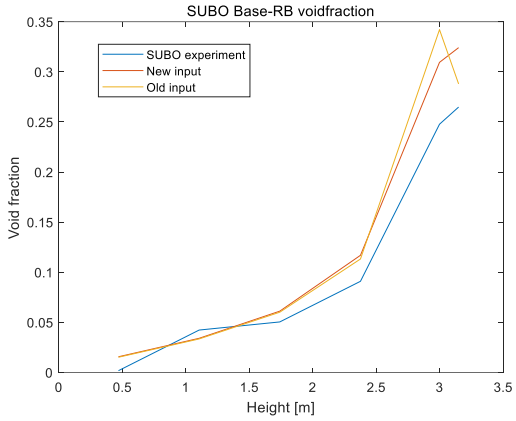

Fig. 3. Calculated Void fraction of Old input file and New input file

2.2 Optimization of interfacial heat transfer coefficient

In subcooled boiling, the condensation effect due to low liquid temperature and the liquid side interfacial heat transfer is much greater than the condensation effect due to vapor temperature and the vapor side interfacial heat transfer. Therefore, only the liquid interfacial heat transfer term, Hif, is optimized to prevent abnormally training the term of vapor interfacial heat transfer coefficient when optimizing.

In the SUBO experiment, the void fraction increases as the water rises from bottom to top along the heated pipe. Accordingly, a bubbly regime is formed near the pipe inlet, and when the void fraction increases above a certain value, a slug regime is formed.

The optimization was performed by multiplying weights to bubbly regime and slug regime liquid interfacial heat transfer coefficient. MARS-KS source code is modified to multiply weight to the coefficients after calculating the original Hif. By varying the weights, weights for bubbly and slug regime were found where the result of the MARS-KS code calculated void fraction is close to the experimental data.

However, since there is also uncertainty in the experimental value, it is necessary to optimize the multiplier not to be too far from the original constitutive equation in the process of optimization. Therefore, as shown in the following equation, the difference in modified values from the original MARS-KS values was simultaneously optimized.

$$\text{Distance function} = 0.95 * \sum_i |\alpha_{exp} - \alpha_{MARS-KS}| + 0.05 * \sum_i \left|\frac{Hif_{modified} - Hif}{Hif}\right|$$

3. Results

Figure 4 shows the change of the distance function according to the change of two multipliers.

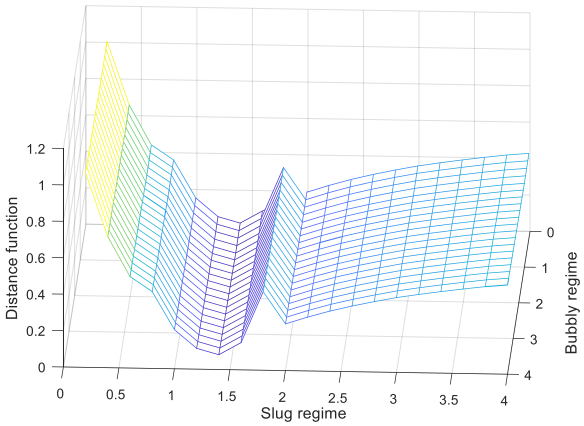

Fig. 4. Change of the distance function according to the change of two multipliers

It is confirmed that the calculated void fraction result of the modified MARS-KS code is similar to the SUBO experimental value when the bubbly regime weight is 1 and the slug regime weight is 1.4. Figure 5 shows the calculated void fraction of original MARS-KS, modified MARS-KS, and experimental data.

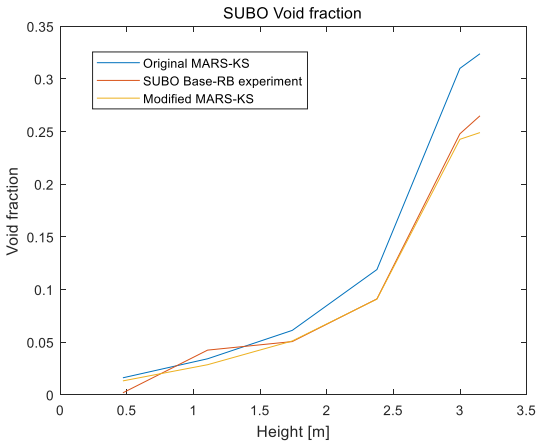

Fig. 5. Calculated void fraction of original MARS-KS, modified MARS-KS, and experimental data

In the original MARS-KS code, the sum of the difference of void fractions at 6 measurement points is 0.1821, but in the modified MARS-KS, the sum of the difference of void fraction is 0.0471. Through this, it is confirmed that the MARS-KS code accuracy of the void fraction prediction is increased.

4. Conclusions

As a result of the study, it was possible to optimize the liquid interfacial heat transfer coefficient to better match

the experimental void fraction data. It is confirmed that void condensation in the subcooled boiling was more accurately simulated by using 1.4 times higher liquid interfacial heat transfer coefficient value than the original MARS-KS in the slug regime. If this method is applied to various SET experiments, it is expected that it will be possible to correct interfacial heat transfer term in various thermal hydraulic conditions which is difficult to measure directly in experiments.

REFERENCES

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[2] M.R. Abdollahi, M. Jafarian, and M. Jamialahmadi, The rate of bubble growth in a superheated liquid in pool boiling, Heat and Mass transfer, 2017