Improvement of Interfacial Heat Transfer Model and Correlations in SPACE Code

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1. Introduction

The SPACE code development project has been successfully proceeded since 2006. The first stage of development program has been finished at April 2010. During the first stage, main logic and conceptual structure have been established under the support of Korea Ministry of Knowledge and Economy [1][2].

In the second stage, it is focused to assess the physical models and correlations of SPACE code by using the well known SET problems. A problem selection process has been performed under the leading of KEPRI. KEPRI has listed suitable SET problems according to the individual assessment purpose[3].

Among the SET problems, the MIT pressurizer test [4] reveals a improper results by using SPACE code. This paper introduce the problem found during the assessment of MIT pressurizer test assessment and the resolving process about the interfacial heat transfer model and correlations in SPACE code.

2. MIT Pressurizer Test

2.1 Facility Description and SPACE modeling

The experimental facility consists of two cylindrical steel tanks: the primary tank, 1.1.4 m tall and 0.203 m ID, and the storage tank, as in figure 1. The primary tank had six windows and was equipped with six immersion heaters with a total power of 9 kW. The storage tank was pressurized with nitrogen to force the liquid into the primary tank.

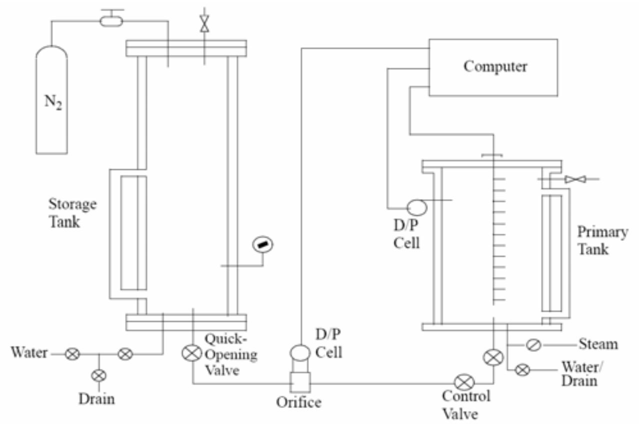

Figure 1. experimental facility of MIT pressurizer test

The test began with the liquid level in the primary tank at 0.432 m from the bottom. The average level rise velocity was 0.0115 m/s over a 41 second time period. The primary tank was modeled with a ten cell pipe, each with a heat structure at the saturation temperature of the initial pressure of 0.49MPa. A TFBC flow boundary cell is connected to inject water at the specified rate to the primary tank volume. The initial subcooling as the water entered the tank was 129 K. As the liquid level in the primary tank rose during the subcooled liquid injection, little mixing occurred between the initial saturated fluid in the primary tank and the incoming highly subcooled liquid. The heat losses of primary tank were estimated at 1.1 kW. SPACE nodalization is described in figure 2.

In the SPACE nodalization, the initial water level is in cell 4. The void fraction was 0.22. The level reached its maximum value in cell 8. At that instance, the void fraction of cell 8 was 0.69.

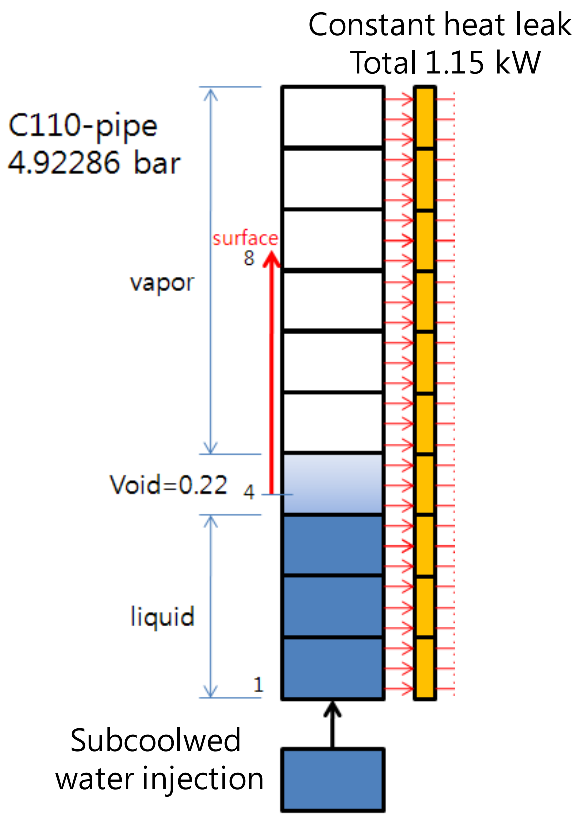

Figure 2. SPACE nodalization of MIT ST4

2.2. Modification of Model

The SPACE calculation of MIT ST4 has been performed with the Unal correlation[5] as the subcooled liquid interfacial heat transfer correlation for the annular, the vertical stratified, and the bubbly flow regimes. The bubble shaped interface has been assumed in these three flow regimes. The Unal correlation value at the low vapor fraction region is very high. Figure 3 shows the Unal correlation result for the 0.2 MPa condition.

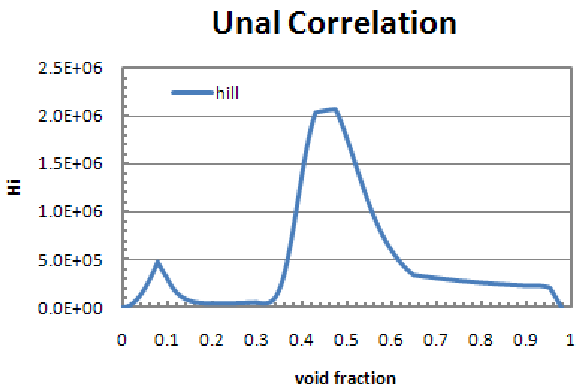

Figure 3. Subcooled liquid interfacial heat transfer coefficient by Unal correlation

Because of the high interfacial heat transfer coefficient in the low void fraction region, the SPACE result of pressure shows improper decreasing trend during the water injection period. In order to resolve the problem, the Ranz and Marshall correlation[6] is reviewed. Ranz and Marshall correlation has the vapor bubble Reynolds number parameter in its formula. Thus, if the vapor fraction is low or bubble velocity is low, the interfacial heat transfer coefficient value is small sufficient to minimize the liquid phase change.

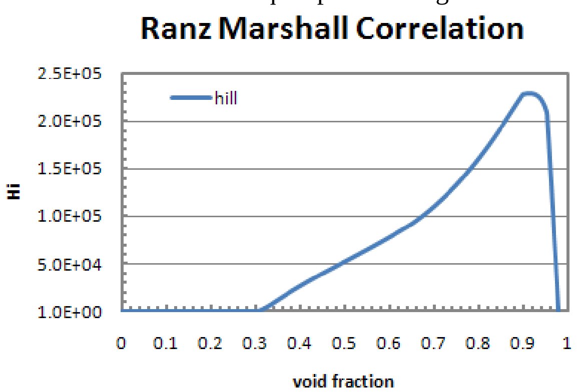

Figure 4. Subcooled liquid interfacial heat transfer coefficient by Ranz and Marshall correlation

3. Results

Figure 5 shows the pressure calculation result for MIT ST4 by using modified SPACE code. The pressure increasing trend is similar to the MARS result. The experiment data are larger than the results of both codes. After the liquid injection is over, however, the pressure decreasing is much larger for SPACE code.

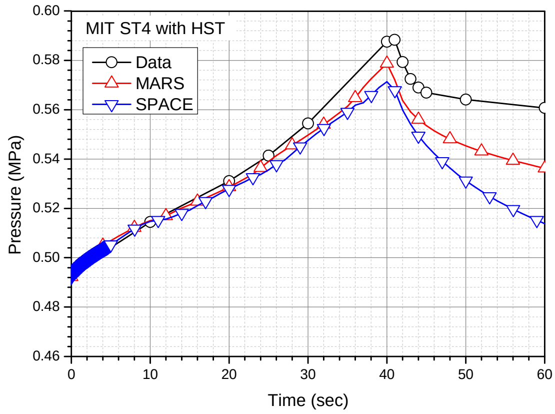

Figure 5. Modified SPACE result for pressure calculation

4. Conclusion

An interfacial heat transfer coefficient correlation for the subcooled liquid surrounding vapor bubble is replaced to enhance the predicting capability of pressurizing condensation phenomena. MIT ST4 experiment is the selected SET problem. For the low vapor fraction region, excess heat transfer results in improper pressure decrease. Replacing the heat transfer model which provides the smaller heat transfer coefficient in low void region make a reasonable improvement.

Acknowledgements

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