Separate Effect Test Assessment about Interfacial Heat Transfer Model and Correlations in SPACE Code

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1. Introduction

The development of Safety and Performance Analysis CodE (SPACE) has been in the second period, in which the main goal is a validation. The source terms that are related to the models and correlations are continuously modified in view of the smoothness and robustness after the first stage development [1]. In addition, the solution quality is the next purpose in the second development period. In the second stage, it is focused to assess the physical models and correlations of SPACE code by using the well known SET problems.

For the successful SET assessment procedure, a problem selection process has been performed with the leading of KEPRI. KEPRI has listed suitable SET problems according to the individual assessment purpose. The interfacial heat transfer has 3 topic problems to validate: i) MIT ST4, ii) Super Moby Dick, iii) GE Level Swell. First topic is about the pressurizing condensation. Others are about the choking and flashing.

2. Assessment Problems

2.1 MIT ST4

It consisted of two cylindrical steel tanks: the primary tank, 1.14 m tall and 0.203 m ID, and the storage tank. 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 [2]. The vessel was modeled using 10 fluid cells. A more accurate prediction could be obtained with more cells, however, models of reactor pressurizers usually have less than 10 cells. The water level was initially in cell 4 (the void fraction was 0.22) and reached its maximum value in cell 8 (the void fraction was 0.69). The experimenters did not report on the type and thickness of the insulation covering the vessel. The code model used 8.9 cm of fiber glass insulation. As the cold water was injected into the pressurizer, the pressure increased due to compression of the steam volume. As the pressure increased the saturation temperature also increased. Energy transferred from the vapor to the wall and condensation at the liquid/vapor interface mitigated the pressure rise.

The accurate calculation of data from this test depends on accurate modeling of steam condensation on the wall as well as interfacial heat transfer between the stratified liquid and the vapor above the liquid.

2.2 Super Moby Dick

The calculation of critical flow is an important consideration in the area of nuclear reactor safety. The fluid velocity at nozzles, breaks, or other restrictions can exceed the local sound speed which causes the fluid flow rate to become insensitive to downstream pressure changes. SPACE has implemented Trapp-Ransom model as a default choking model, while Henry Fauske model is user optional choice. With the critical flow model, the interfacial heat transfer takes a roll to predict the choking and depressurized flashing.

The purpose of assessment of Super Moby Dick problem was to study steady-state critical flow in nozzles at medium to high pressure for various thermal-hydraulic conditions. SPACE was used to predict steady-state flow conditions for eight tests. Four of the tests simulate flow through a long divergent nozzle. The other four tests simulate flow through an abrupt expansion. The inlet pressure to the test section was about 12×10^6 Pa for six tests and about 4×10^6 Pa for the other two. Critical flow conditions were obtained by maintaining constant inlet conditions to the test section and lowering the downstream pressure until the drop in discharge pressure no longer influenced flow. Pressures were measured at various points along the test section [3]. The pressure profile along the vertical test section and mass flow rate are compared.

2.3 GE Level Swell

General Electric (GE) has performed a series of experiments to investigate thermal hydraulic phenomena such as critical flow, void distribution, and liquid-vapor mixture swell during blowdown conditions [3, 4]. Two experiments of the GE level swell test series were to be simulated with the SPACE. In the GE Level Swell tests, two vessels were used: one with a nominal diameter of 1 ft (0.3048 m), called "small" vessel, and other one – called appropriately "large" vessel - with a 4 ft (1.219 m) diameter.

The small vessel was made of 1 ft (0.3048 m) diameter, Schedule 80, carbon steel pipe. Its height was 14 ft (4.267 m). The vessel discharge was guided to a suppression tank via a blowdown pipe, which included an orifice mounted near the vessel. The vessel was designed to accommodate a perforated plate at about the mid-point of its height. (No plate was used in Experiment 1004-3.)

The large vessel was 4 ft (1.219 m) in diameter (47 in., 1.194 m ID), 14 ft (4.267 m) high, made out of carbon steel. For top blowdown experiments, the vessel was equipped with an inverted dip tube, which accommodated a venturi tube located near the vessel wall and exited to an atmospheric tank. The large vessel was equipped with the same kind of instrumentation as the small vessel.

Among the series of tests with the two vessels, 1004-3 and 5801-1 tests are selected for the SPACE flashing and void generation prediction capability.

3. Results

The pressure response of the upper vapor volume in MIT ST4 problem is shown in figure 1. Experimental data and MARS code calculation results are also plotted in the figure. The maximum vapor pressure is reasonably in the same value. After the end of injection from the bottom surge line, pressure results out of both codes makes a difference from the experiment. Note that the MARS calculation is done with the thermal front tracking option.

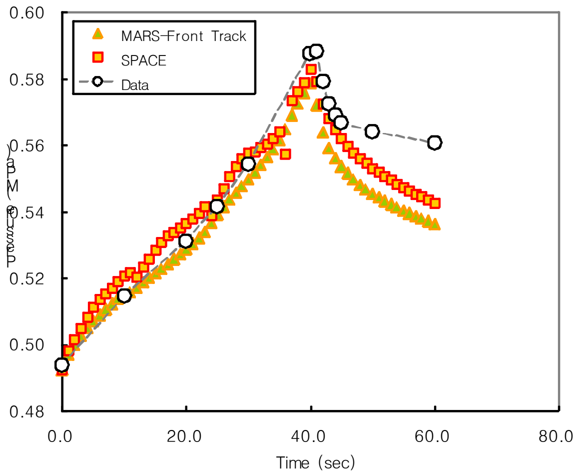

Figure 1. Pressure of vapor volume in MIT ST 4.

Figure 2 shows the pressure profile along the test section of the Super Moby Dick long nozzle test. In the experiment data, a pressure undershoot is observed.

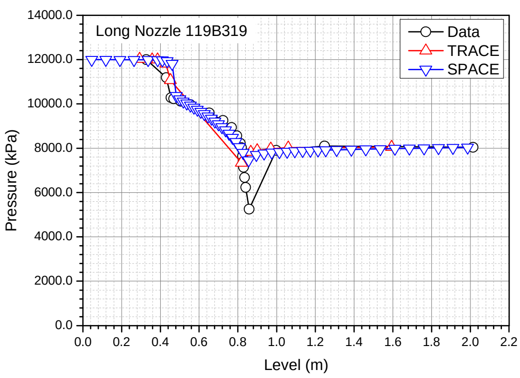

Figure 2. Pressure profile of long nozzle test

Next figure shows the pressure profile of the abrupt expansion test. The sudden pressure decrease is well predicted by SPACE. The pressure decrease trend in upstream of abrupt expansion location is also predicted well.

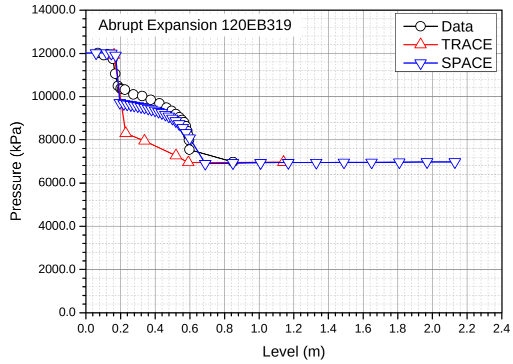

Figure 3. Pressure profile of abrupt expansion test

4. Conclusions

After the second period of SPACE code development project, interfacial heat transfer package has been modified and assessed for the selected separate effect tests. Pressurized condensation and flashing phenomena are validated with the SET problems. Further improvement and validation process will be performed for the integral effect and plant application problems.

Acknowledgements

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