Assessment of TRACE Code for MIT Pressurizer Tests to Review Industrial Code

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1. Introduction

Korea Institute of Nuclear Safety (KINS) has initiated to review the industrial code for safety analysis of nuclear power plant, in which MARS-KS and TRACE codes are being used to support the understanding of specific phenomena and code prediction. For this aspect, the TRACE code was assessed for the MIT pressurizer test. The TRACE code has been developed continuously, and NRC released the TRACE code version 5.0 patch 4 recently. This updated version has some improvement from version 5.0 patch 3. In this paper, TRACE code calculations with version 5.0 patch 3 and patch 4 for 3 cases of MIT pressurizer tests have been performed to assess the applicability of the TRACE code for verification of industrial codes. The MIT pressurizer test is one of the fundamental separate effect tests and frequently simulated to verify safety analysis codes. Predictability of the system code for the behavior of pressurizer in the plant is very important because it has an effect on the progress of accidents such as loss of coolant, control rod withdrawal, and loss of feedwater flow, etc. In the reactor protection system, the high pressurizer pressure trip signal provides an assurance of the integrity of the RCS boundary for AOOs that could lead to an over pressurization of the RCS. Also, the low pressurizer pressure trip signal provides an assistance for the ESF during the system pressure reduction events and a LOCA.

2. MIT Pressurizer Test Facility

Several types of pressurizer experiments were performed at MIT by Saedi and Griffith[1], and Kim[2]. The MIT pressurizer experimental apparatus is shown schematically in Fig. 1. The pressurizer (primary tank) was a stainless steel tank 1.143m tall with an inside diameter of 0.203m. The thickness of the stainless steel wall was 9.5mm. It had a sight glass for measuring water level and was equipped with six immersion heaters with a total power of 9kW. Heat losses were estimated at 1.1kW through the calibration tests. The storage tank was pressurized with nitrogen to force the liquid into the pressurizer. As shown in the Fig.1, the line connecting two tanks consists of two quick-opening valves for rapid inputs, an orifice to measure mass flow rate and a control valve. Pressure was measured at the top of the pressurizer. Thermocouples were placed along the centerline of the pressurizer to measure fluid temperatures and along the wall for steel temperatures.

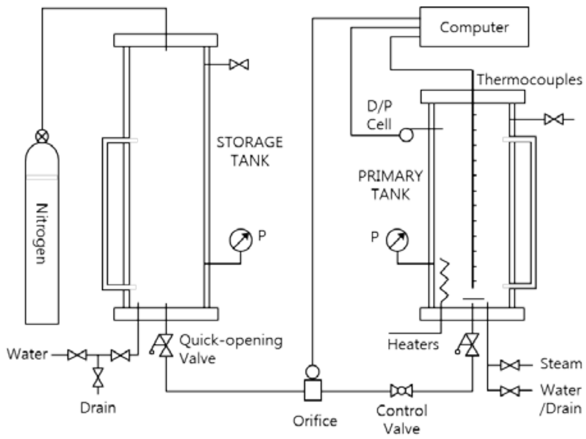

Fig. 1. Schematic of the experimental apparatus for the MIT pressurizer test.

3. Methods

The MIT pressurizer tests were simulated using TRACE version 5.0 patch 3 and patch 4 by varying the number of cells, N=10 and 20. Constant heat flux (HF) 1400W/m^2 was used for the heat losses through the wall base on the experiment. Table 1 shows the initial conditions of experiments and simulations for insurge and outsurge tests. The pressurizer was partially filled with saturated water. Cold water of 294.26K and 297.04K was injected into the bottom of the pressurizer for the Test ST4 and Test A, respectively. For the Test B, saturated water was discharged from the bottom of the pressurizer. Mass flow rates shown in Fig. 2 were used as the inlet boundary conditions in the simulation. A vertically oriented PIPE component was used to describe the pressurizer in TRACE code. A FILL component was attached to the bottom of the PIPE to set the flow and fluid temperature conditions during the simulations. The results of industrial code (Ind. code in figures) which are used as references were obtained by digitizing figures in the topical report. The pressurizer was modeled using 10 fluid cells with industrial code.

Table 1. Initial conditions of experiments and simulations

	ST4	A	B
Test type	Insurge	Insurge	Outsurge
Water level, m	0.4318	0.353	0.7493
Pressure, MPa	0.49	0.689	0.86667

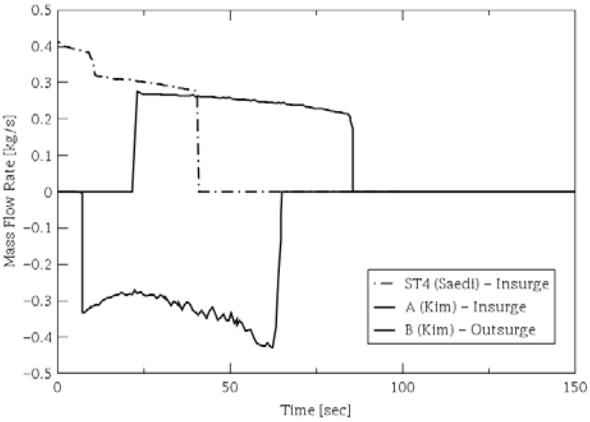

Fig. 2. Water injection rates of experiments and simulations.

4. Results and Conclusions

Pressure responses for Test ST4, A and B are shown in Fig.3, Fig.4 and Fig.5 respectively. According to the results, node effect was significantly reduced at patch 4 compared with patch 3 of TRACE version 5.0. For insurge tests, as shown in Fig.3 and Fig.4, the TRACE code version 5.0 patch 3 calculations with N=20 were in a better agreement with the experiment than the case N=10. Based on the prediction of Test ST4 and Test A, at least 20 cells are needed to predict pressurizer insurge behavior reasonably. However, the results of patch 4 show that 10 cells are enough to simulate the transient behavior of pressurizer. Otherwise, it is found that the time step size, Δt_{max} have stronger effect on the results than patch 3. For patch 4, therefore, Δt_{max} should be carefully determined than patch 3 to get a reliable results. For outsurge case B, there was no major difference between patch 3 and patch 4 even though it was not shown in this paper. The TRACE code calculations with 10 cells were suitable for the results and the value of Δt_{max} had little effect on the results for Test B. The different trends for node, Δt_{max}, and patch sensitivity were observed between insurge and outsurge cases.

Overall, the results of the TRACE code version 5.0 patch 4 fit well with those of experiments. Based on the findings on node sensitivity and different trends of prediction from TRACE, those sensitivities and trends should be investigated on industrial code calculations.

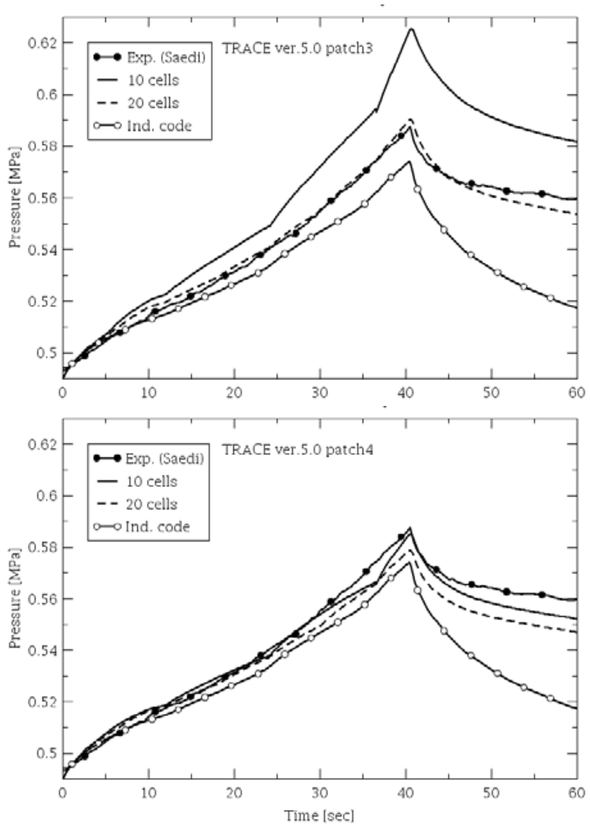

Fig. 3. Test ST4 pressure prediction for patch 3 and 4.

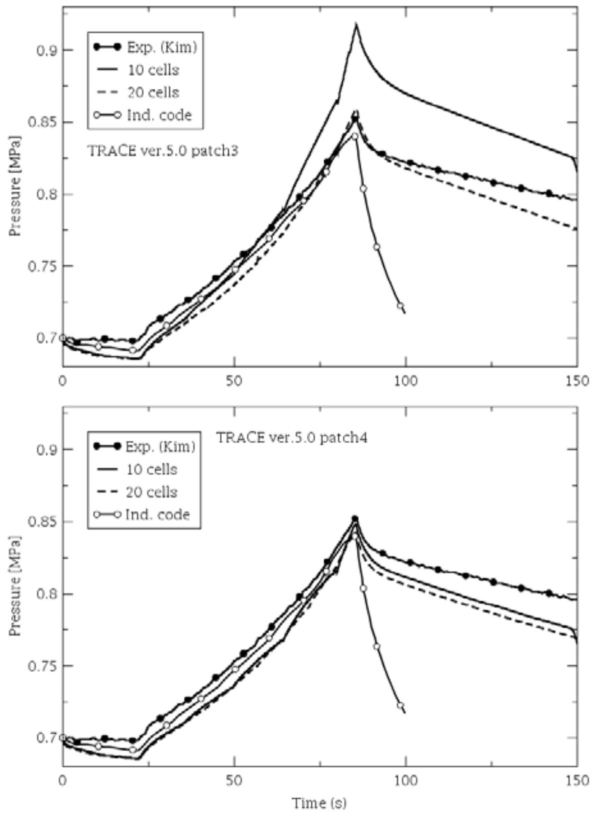

Fig. 4. Test A pressure prediction for patch 3 and 4.

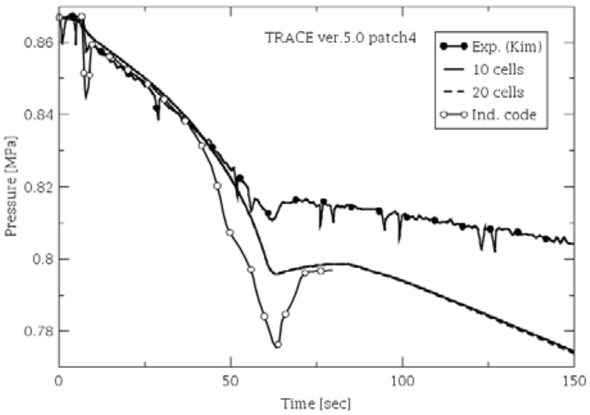

Fig. 5. Test B pressure prediction for patch 4.

REFERENCES

[1] H.R. Saedi, and P. Griffith, “The Pressure Response of a PWR Pressurizer During an Insurge Transient,” ANS Annual Meeting, Detroit, Michigan, 1983

[2] S. Kim, “Experimental and Analytical Model of a PWR Pressurizer during Transients,” Submitted to the Dep. Of Nuclear Engineering in Partial Fulfillment of the Requirments for the Ph.D. at Massachusetts Institute of Technology, 1984