Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Assessment of SPACE on DVI Line Break Test with SNUF

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1. Introduction

SPACE (Safety and Performance Analysis CodE for nuclear power plants) is a computer code under development in South Korea for analyses of thermal-hydraulic phenomena of nuclear reactor. Currently, lots of V&V (Verification and Validation) activities are on-going in order to attain reliability of the SPACE code from simple separate effect tests up to complicated integral experiments. This study assessed the SPACE code capability for prediction of the DVI (Direct Vessel Injection) system, which is adopted as a key safety system in the APR1400 reactor.

2. Modeling of Experimental Benchmark

This study selected the SNUF (Seoul National University Facility) DVI break experiment as the benchmark to evaluate the code prediction capability.

2.1 Design Features of SNUF

The SNUF is an RHRP (Reduced Height and Reduced Pressure) integral test facility which is scaled down for the APR1400. Three non-break DVI lines can supply the SI water into the upper downcomer. A DVI line which assumed to be broken is connected to the discharge tank. The height scaling ratio of the SNUF is 1/6.4.

2.2 SPACE Modeling and Test Condition

Figure 1 is a SNUF nodalization to be assessed with the SPACE. All nodes are simulated by CELL, PIPE, FACE, BRCH (Branch) and TFBC (Temporal Face Boundary Condition) which is equivalent to the time dependent volume in RELAP5. The core barrel was modelled as a heat structure to transfer the heat between the core and downcomer. The vessel and pipes were modelled as a heat structures to simulate the heat loss.

It is assumed that one of four DVI lines is broken and the others are intact. And Ransom-Trapp model is used as the critical flow model [3]. The downcomer consists of six channels to concern the crossflow effect between each downcomer. Test condition is presented in Table I.

Table I: Test Condition

Variables	**Initial Condition**
Test Time(s)	Break after 30 ~ 530
Primary Pressure(MPa)	0.6 (pressure ratio 1/13)
Temperature(K)	Secondary 428 / Coolant 423 ~ 433
Core Power(kW)	110 (~60s) / 70 (~300s) / 60 (~500s)
Flow rate(kg/s)	HPSI 0.13 / SIT 0.11
SI Temp.(K)	300.4
Discharge Coefficient	0.5, 1.2, 1.2 (Ransom-Trapp)

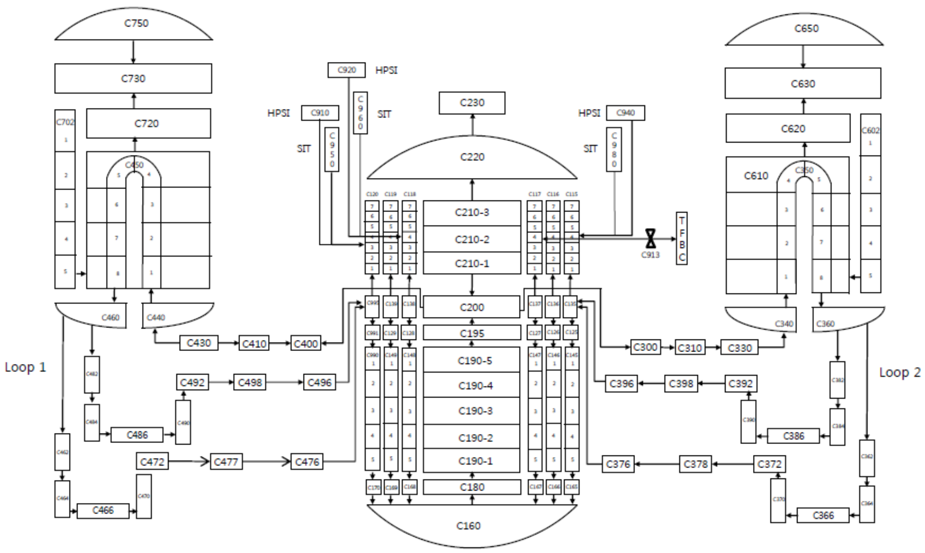

Fig. 1. Nodalization of the SNUF

3. Assessment Result of SPACE

3.1 Preparation of Initial Condition

The SNUF did not have a sufficient heat sink in the secondary side to maintain the continuous steady-state because it was designed for simulating accident scenarios within primary loop, especially. Therefore, the initial condition of the test should be first obtained by preliminary calculations. To obtain the initial condition, the SPACE calculation was simulated to following the increasing pressure with induced power. To confirm and verify the SPACE input, MARS code was also used as benchmark. Target value of primary pressure was about 0.6MPa. Figure 2 shows the comparison result.

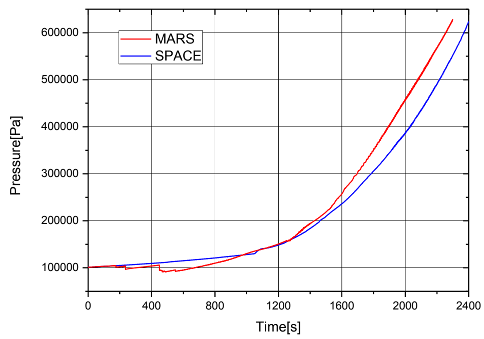

Fig. 2. Pressurization Process for Initial Condition

3.2 Transient simulation

The Ransom-Trapp critical flow model was used for simulating DVI line break. This model needs three discharge coefficients belong to each flow regimes; subcooled, two-phase and superheated. The best result was the case with 0.5, 1.2 and 1.2, respectively. These three values were taken from sensitivity test ranges from 0.5 to 1.5. The subcooled discharge coefficient played a dominant role in very short time range after break, and it determined the primary break flow rate.

It was impossible to measure the break flow rate of experiment, the MARS was used as benchmark for validation as shown in Fig. 3. The best MARS transient result was also taken by sensitivity test, but with Henry-Fauske model of discharge coefficient 0.55.

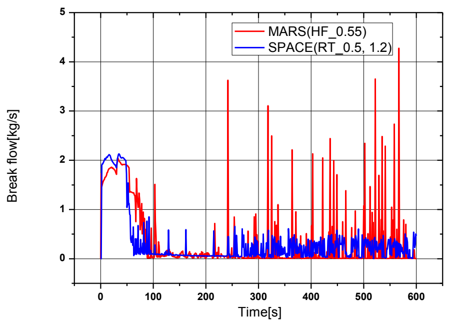

Fig. 3. Break Flow Rate

3.3 Validation with Experimental Result

The pressure decrease rate of upper head (C220) presents on Fig. 4. As shown in this figure, the SPACE yields good agreement result with experimental one. Although the discharge coefficients of Ransom-Trapp model are feasible to be varied by user's intend, but reasonable prediction is possible with particular discharge coefficients.

SPACE and MARS results show the good agreement with experimental one in the early part. After 250s, though the SPACE traced well the experimental result, but the MARS result yielded some deviation by experimental result. It is due to that Ransom-Trapp which was used in SPACE was able to be adjusted in two-phase or superheated discharge coefficients, but Henry-Fauske in MARS couldn't have been changed except the subcooled discharge coefficient.

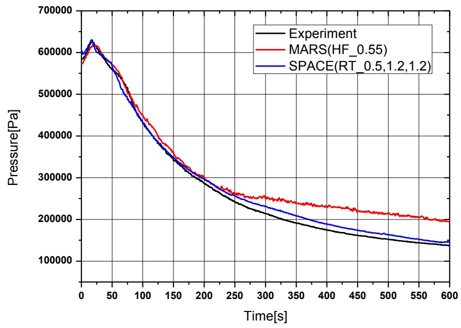

Fig. 4. Primary System Pressure

4. Conclusion

Assessment of SPACE as to DVI line break was carried out. Comparison results show the SPACE can be used to simulate the DVI line break well with particular discharge coefficients of the Ransom-Trapp critical flow model.

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