Sensitivity analysis on the interfacial drag in SPACE code to simulate UPTF separate effect test about loop seal clearance phenomenon

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1. Introduction

The nuclear thermal hydraulic system code known as SPACE (Safety and Performance Analysis CodE) was developed and its V&V (Verification and Validation) have been conducted using well-known SETs (Separate Effect Tests) and IETs (Integral Effect Tests). At the same time, the SBLOCA (Small Break Loss of Coolant Accident) methodology in accordance with Appendix K of 10CFR50 for the APR1400 (Advanced Power Reactor 1400) was developed and applied to regulatory body for licensing in 2013[1].

Especially, the SBLOCA methodology developed using SPACE v2.14 code adopts inherent test matrix independent of V&V test to show its conservatism for important phenomena. In this paper, the predictability of SPACE code for UPTF (Upper Plenum Test Facility) test simulating loop seal clearance of SBLOCA important phenomena and the related sensitivity analysis are introduced.

2. UPTF test and Modeling description

To investigate the flow phenomena in the primary system of a PWR (Pressurized Water Reactor) during a LOCA occurring with a small break, experiments were performed at the UPTF. The UPTF constructed and operated by Siemens-KWU is a full-scale simulation of the primary system of a 1300-MW PWR. The upper plenum of the test vessel, including original internals, the downcomer and the four connected loops are represented on a 1:1 scale. UPTF system overview and a description of the main components of the test facility are given in Reference [2].

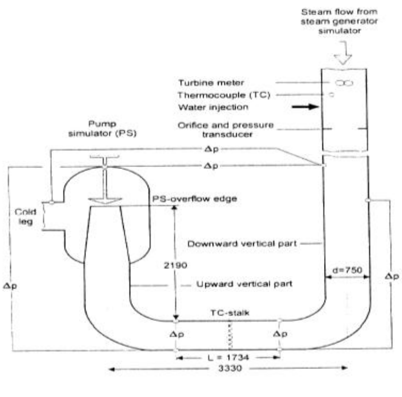

Figure 1. Configuration of UPTF loop seal test

Some SETs of various tests using UPTF facility were carried out in a single-loop operation using the loop seal of loop 2 to investigate the residual water levels, the flow patterns in and the pressure drops across the loop seal during clearing at system pressures of 3 and 15 bar. Loops 1, 3 and 4 were sealed off by closing the pump simulators. The schematic of this loop seal equipped with extend instrumentation is shown in Fig. 1[3].

Figure 2 shows nodding diagram of single loop seal for code analysis. This nodding is composed of both single PIPE component having 8 cells and 3 TFBC (Temporary Face Boundary Condition) components. To simulate boundary conditions illustrated in Reference 3, steam flows of 3-22 kg/sec. and water mass flow rates of 8, 15, 20 kg/sec. are injected to the loop seal of 3 bar through TFBC-100 and TFBC-250, respectively. At this time, mean residual water levels in horizontal pipe (C200-04 and C200-05) are evaluated for steam flow alone.

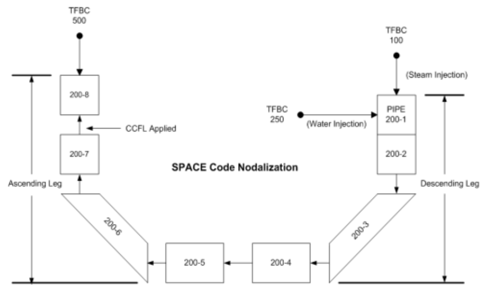

Figure 2. Noding diagram for SPACE model

3. Basecase analysis

The results of the test series of 3 bar based on dimensionless variables H/D for water levels and J_g^* (Wallis parameter) for steam flow rates through the loop seal are evaluated using RELAP5 and SPACE v2.14 as base analysis. Wallis parameter for steam flow rates can be calculated as;

$$J_g^* = j_s[\rho_s / gD(\rho_w - \rho_s)]^{1/2} \qquad (1)$$

Figure 3 shows the results of base analysis for water injection flow of 15 kg/sec. As shown in Fig. 3, The SPACE code predicts both test data and the results of RELAP5 appropriately when J_g^* is lower than 0.25, but over-predicts them when J_g^* is higher than 0.25. The same results are also obtained in the condition of 8 kg/sec. and 22 kg/sec.

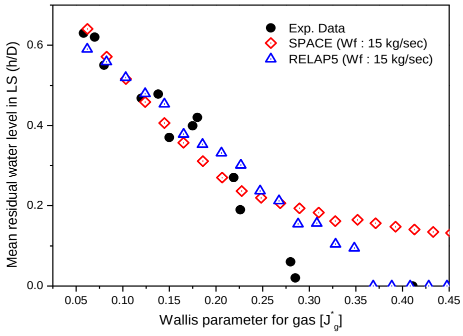

Figure 3. Base analysis results

As compared with RELAP5, water level in ascending leg is not predicted well when J_g^* is higher than 0.25. This is assumed for the difference of interfacial drag from annular flow regime in ascending leg. Flow regime in ascending leg is shown in Fig. 4. Annular flow regime appears over the whole period.

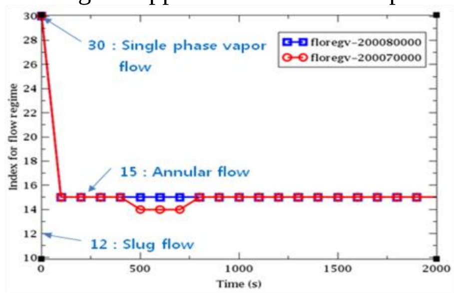

Figure 4. Flow regime in ascending leg from base analysis

4. Sensitivity analysis

Interfacial drag is one of the key factors to handle various phenomena happened in loop seal. From base analysis, we assume that interfacial drag in SPACE is relatively small compared to both test and RELAP5.

So, we conducted sensitivity analysis by applying various factors for interfacial drag in annular flow regime. Figure 5~6 show sensitivity results when 4.0 and 6.0 are applied as multiplier. According to the increase of interfacial drag as shown in figures, SPACE code predicts well both test data and the results of RELAP5, respectively.

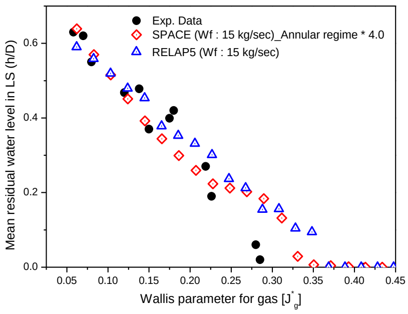

Figure 5. Interfacial drag modification in annular flow regime (Multiplier = 4.0)

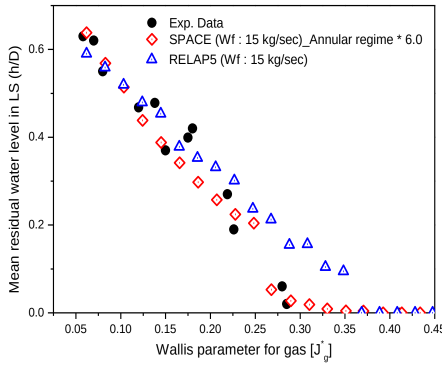

Figure 6. Interfacial drag modification in annular flow regime (Multiplier = 6.0)

4. Summary and Further study

The predictability of SPACE code is evaluated for UPTF separate effect test simulating loop seal clearing phenomenon. The base analysis shows that the SPACE code predicts small interfacial drag in annular flow regime for high steam flow. So, we conduct sensitivity analysis and obtain the closest prediction to both test and RELAP5 by increasing interfacial drag in annular flow regime.

Further evaluation, however, should be made from other tests having similar condition to quantify this characteristic of SPACE code.

Acknowledgements

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Nomenclature

j_s	*vapor superficial velocity*
D	*pipe diameter [m]*
ρ_s	*vapor density [kg/m^3]*
ρ_w	*liquid density[kg/m^3]*
g	*gravity accelation [m/sec^2]*

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2. Weiss, P., Sawitzki, M. Winkler, F., 1986. UPTF, a full-scale PWR loss-of coolant accident experiment program. Atomkernenerg. Kerntech. 49, 1-2
3. J. Liebert and R. Emmerling, "UPTF experiment flow phenomena during full-scale loop seal clearing of a PWR", NED 170 (1998) 51-64, 1998.