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Multi-dimensional Analysis for Upper Plenum Injection using MARS-KS Code

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1. Introduction

A new multi-dimensional component in MARS has been developed to get the flexible three dimensional capabilities in the system, and to allow the user to model more accurately the multi-dimensional hydrodynamic features of reactor applications [1]. The previous study of Bae et al.[2] showed that the MARS multi-dimensional analysis had meaningful agreement in the phenomenological validity about the ECC water behaviors in the upper plenum. In this study, UPTF UPI test (Test 20) is simulated to assess the predictability of MARS-KS multi-dimensional analysis for the behavior of ECC water. The preliminary calculation results are compared with the UPTF experimental data.

2. UPTF UPI Test (Test 20)

The UPTF is a full scale of simulation of 3900 MWth (1300 MWe) KWU 4-loop PWR. The upper plenum has full-size internals. The core was simulated by injecting steam and water beneath dummy fuel assemblies [3]. The main objective of UPTF Test 20 was to investigate the steam/water flow phenomena in the upper plenum of UPI plants. In Test 20, there are two intact loops, one broken loop, and one loop blocked to inject UPI water, assuming a single LPCI failure. The test was run in three phases (A, B, and C) to study the effects of core power level and profile on UPI delivery to the core. Table 1 shows the core simulator steam-water injection and UPI ECC water injection rates for each phase [4].

Table 1 Boundary conditions of UPTF UPI test

Phase	Core Steam (kg/s)	Core Water (kg/s)	UPI (kg/s)
A	87	24.5	257.4
B	99	22.4	257.4
C	83	24.7	257.4

3. MARS-KS Model

Fig. 1 shows the MARS-KS noding for the UPTF Test No. 20. The reactor vessel is simulated by the cylindrical multi-dimensional component with five rings in radial direction (r1~r5), eight sectors in azimuthal direction (θ1~θ8), and fourteen axial levels (z1~z14). The mesh intervals of r1, r2, and r3 are specified as 1.041 m, 0.431 m, and 0.331 m, respectively so that the flow area of inner 3 grids would be the same. The mesh interval of r4 designates the space between the core barrel and core shroud. The mesh interval r5 designates the downcomer.

It is assumed that the upper plenum internals and the dummy fuel assemblies are homogeneously distributed in inner 3 radial grids. The form loss coefficients for the cross flow in the upper plenum and in the dummy fuel assemblies are calculated using Zukauskas's method [5]. The one dimensional loops are connected at the axial level of z10.

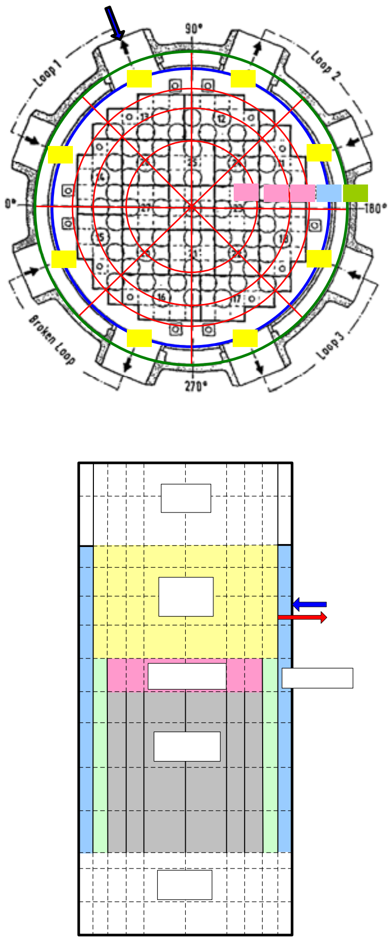

Fig. 1. MARS-KS nodalization of UPTF reactor vessel.

4. Calculation Results

The preliminary results of MARS multi-dimensional analysis are compared with the UPTF UPI test data. Fig. 2 shows the accumulated water flow penetrating the upper core support plate. The calculation results indicate that, as in UPTF test, water downflow occurs in stable channels that is located in front of the ECC injection point inside the outer region of core flow area.

The downflow region does not change during the transient. The size of the downflow area is about 16.7% of the core flow area and is comparable to the result of 10% in UPTF test.

Fig. 3 illustrates the water carryover rate to the loops. The amount of water carried into the hot legs (intact loops and broken loop) at the end of each phase is about 18.4-42.5% of the UPI flow and is constant during the transients. The UPTF results showed that the amount of water swept into the lot legs is 6-10% of the UPI flow. This result indicates that MARS considerably overpredicts the amount of water carryover to the hot legs. .

The water distribution in the upper plenum can influence the location of water downflow. Fig. 4 shows calculation results of the upper plenum collapsed water level which forms on the upper core support plate and its distribution. The MARS result indicates that collapsed water levels in downflow region (four channels) are about 60-200 mm. In the other twenty channels, on the other hand, the collapsed water levels are about 1.4-44 mm. The highest water level forms in front of the UPI point, while the lowest level forms in opposite inmost channel. The UPTF results showed that the water distribution across the flow area is uniform (20-50 mm high) except at the downflow region where more water accumulates. This indicated that the MARS slightly underpredicts the collapsed water level in the upper plenum.

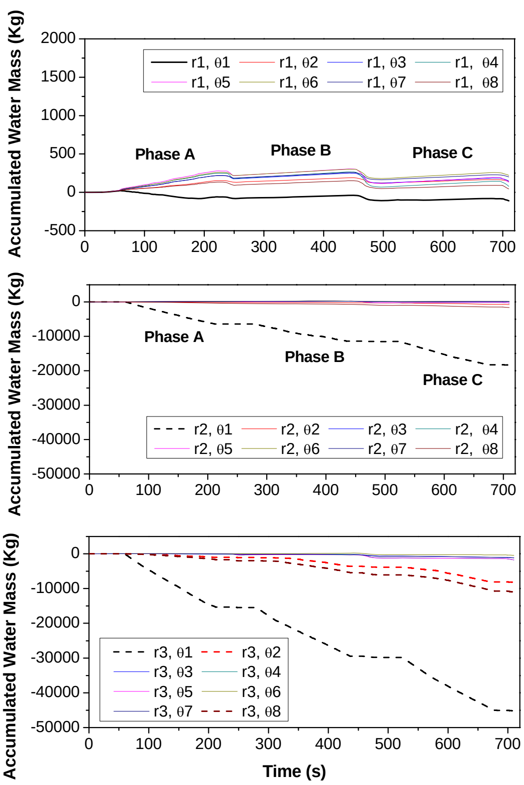

Fig 2. Accumulated water flow penetrating the upper core support plate.

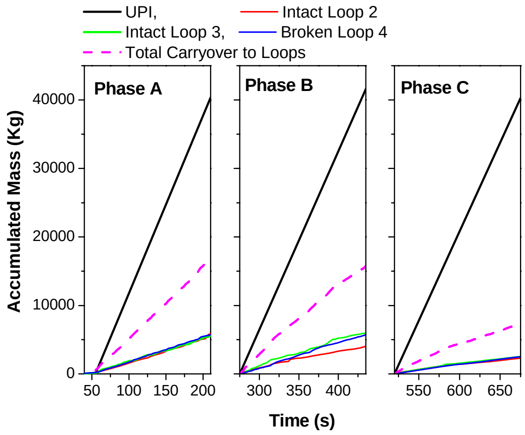

Fig. 3. Rate of water carryover to loops.

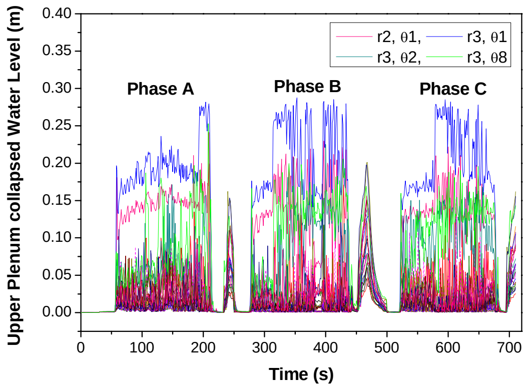

Fig. 4. Upper plenum collapsed water level in core flow area.

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