APR 1400 LBLOCA calculation using Multi-dimensional Models of MARS

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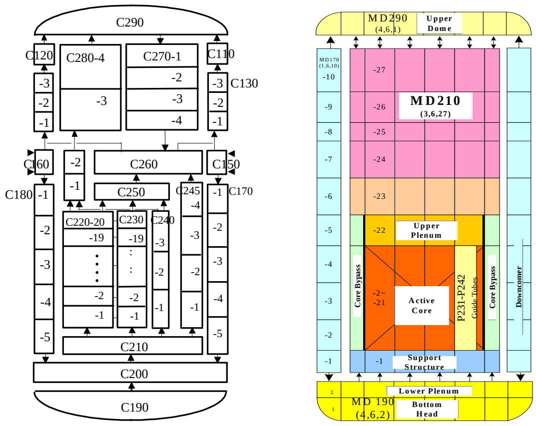
1. Introduction

The APR1400 is an advanced light water reactor adopting the advanced design feature of a direct vessel injection(DVI) configuration and passive fluidic device in the discharge line of the safety injection tank(SIT). During the Loss-of-Coolant Accident(LOCA) of Cold-leg break in APR1400, The thermal-hydraulic phenomena are different from those of the ECC cold-leg injection(CLI) adopted plant because of the DVI [1]. The multi-dimensional phenomena which are occurred in the annulus downcomer or cylindrical core are ECC bypass, mixing and upper plenum mixing. Therefore the multi-dimensional analysis capabilities are needed in the system safety analysis code. The MARS, which was developed in KAERI, also has the multi-dimensional flow analysis models(MULTID) by considering 3D convection and diffusion terms [2]. In this study, the reactor vessel and steam generator of APR1400 was modeled by using MULTID component and LBLOCA was simulated. The results were compared with those of 1D model.

2. Model description

To analyze the multi-dimensional system effect, the core, downcomer, upper head, bottom head and two steam generators were modeled by MULTID component. Figure 1 shows the nodalization features of APR1400 reactor vessel. The 1D model (figure 1-a) was changed by MULTID models (figure 1-b) which were consist of 4 MULTID components. Figure 2 shows a top view of reactor vessel and pipe connections. The reactor core was modeled with 3x6x27(r-θ-z) nodes and the downcomer has 6 azimuthal sectors with 1 radial ring. The one hot rod was simulated in the core center position. The multiple junctions were used to connect the MULTID components. The number of total system volumes is 2419 and the number of total system heat structures is 2165. This volume number is about 8 times greater than that of the original 1D model. But there are no differences of the system mass and volume compared with the 1D model.

The detailed description of steam generator model was ignored in this paper because it has no effect in the LBLOCA simulation.



(a) 1D vessel (b) MULTID vessel

Figure 1. Nodalization of Reactor vessel

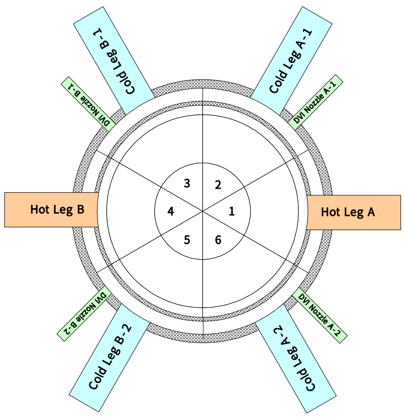


Figure 2. Top view of reactor vessel

3. Results

3.1 Steady-state calculation

The calculation results of steady-state are shown in Table 1. The design values, 1D and MULTID results are all compared. The maximum error is about ±0.1%.

Table 1. Comparison of Steady-state results

Parameter	Design	1D	MULTID
Power (102%) [MWt]	4062.66	4062.66	4062.66
Pzr Press. [MPa]	15.504	15.5137	15.5137
S/G Press.[MPa]	6.889	6.8967	6.89985
Primary flow [kg/s]	21000	20991	20998
Hot-Leg Temp.[K]	597.1	598.09	597.58
Cold-Leg Temp. [K]	563.7	564.51	563.35

3.2 LBLOCA Calculation

The cold-leg break LBLOCA was simulated. The upstream enthalpy based Henry-Fauske critical flow model was used. And the Fluidic device was also modeled. The simulation, by applying the single failure assumption, was performed under the condition of the ECC water injected through the two ECC nozzles by two HPSIP. The right upper box in the Figure 3 shows the ECC flow through the scenario. Figure 3 shows the PCT result compared with the 1D result. In this figure, both the blowdown and the reflood peak are lower than that of 1D case. The main reason of this difference is the multi-dimensional characteristics of core upper head. In the 1D case, the water in the whole core was evacuated to the hot-leg for the first 10 seconds. But in MULTID case, the whole evacuation time of upper head water was delayed about 8 seconds due to the multi-dimensional flow in the vessel. After 10 seconds, the water above the upper part flows to the hot-leg, and some fractions of water were inserted to the core. This liquid cool down rapidly the whole active core. Figure 4 shows the collapsed water level in the core and downcomer. During the late reflood phase, Water level decreasing rate of the 1D case is greater than that of MULTID case because the ECC bypass in MULTID case is lower than that of 1D case, which was showed in Figure 5.

4. Conclusion

The LBLOCA of APR1400 was simulated by using Multi-dimensional model of MARS and the results were compared with that of 1D model. As a result, the PCT of MULTID case is lower than that of 1D case due to the multi-dimensional phenomena in the core. And during the late reflood phase, the water level decrease slowly because the ECC bypass rate of 1D case is greater than that of MULTID case. Therefore, it is concluded that the multi-dimensional calculation can lead the more realistic LBLOCA behavior of APR1400, and has a great benefit in PCT margin.

Acknowledgement

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REFERENCES

[1] P.S.Damerell, et.al., Reactor Safety Issues Resolved by the 2D/3D Program, USNRC report, NUREG/IA-0127, 1993.
[2] B.D.Chung et al, Development of Multidimensional Component, MULTID for Thermal Hydraulic System Analysis Code, MARS, 2003 KNS Autumn meeting, KNS, 2003.
[3] Thermal-hydraulic Safety Research Dep. MARS 3.0 Code Manual, KAERI/TR-2811,2004.
[4] F. Reventos, et al, Contribution to Large Break LOCA analysis for commercial NPP using RELAP5-3D, RELAP5 Int'l. user seminar, 2005.
[5] K.H.Bae, et.al., Post-test Analysis for the APR1400 LBLOCA DVI Performance Test Using MARS, KAERI/TR-2137/2002.

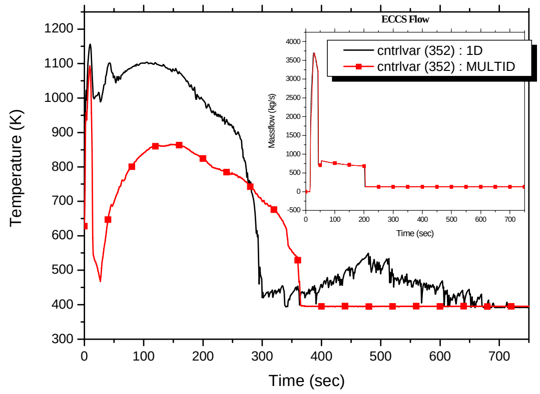

Figure 3. Comparison of Peak Cladding Temperature

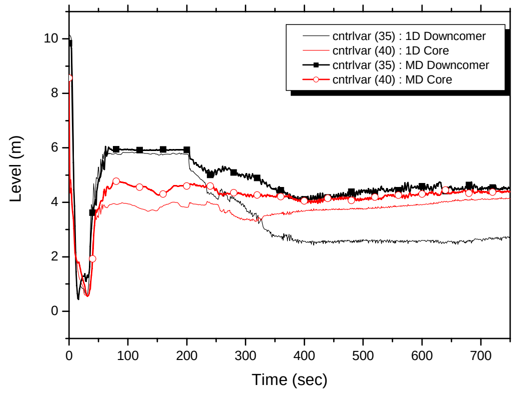

Figure 4. Water level of Downcomer and Core

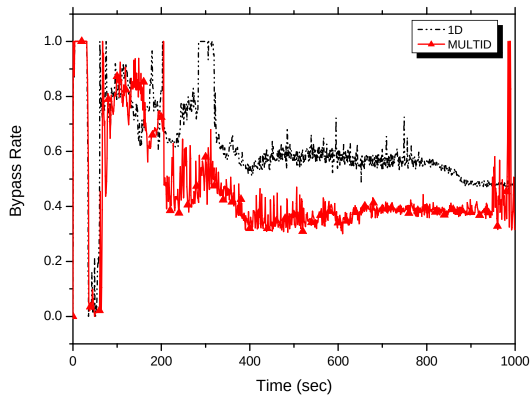

Figure 5. ECC Bypass Rate