Multi-Scale Simulation of ATLAS-MSLB Test Using CUPID/MARS Code

Ik Kyu Park[a*], J. R. Lee [a], H. Y. Yoon [a], D. H. Kang [b]
[a]*NKorea Atomic Energy Research Institute, 1045 Daedeok-daro Yuseong-gu Daejeon Korea*
[b]*Sentech, 105 Sinildong-ro Daedeok-gu Daejeon Korea*
[*]*Corresponding author: gosu@kaeri.re.kr*

1. Introduction

A coupled multi-dimensional thermal− hydraulic system code, CUPID/MARS, has been developed by consolidating the MARS and CUPID codes. A calculation set of forced convection flows in a straight channel, manometer oscillations, and Rossendorf Core Mixing(ROCOM) showed that the multi-scale approach is cheap and convenient[1]. In this study, the coupled code is applied to an integral test, so called, ATLAS-MSLB[2] in order to validate its capability to the reactor transients.

2. Methods and Results

In this section basic concept used to simulate the MSLB(Main Steam Line Break) reactor transient, steady state calculation and transient calculation are described for the ATLAS-MSLB test.

2.1ATLS-MSLB Test

SLB-GB-02T or ATLAS-DSP03[2] test was accomplished in the frame of the KAERI to simulate APR1400 MSLB and it was provided as an integral DSP(Domestic Standard Problem) to validate system safety analysis codes. The ATLAS-MSLB test was started with two break valves open of SG-1 and 4 MFIVs are closed, and MSIV was closed at LSGP(6.11MPa) of secondary. AF are applied to SG-1 continuously and applied to intact SG-2 to the level of AFAS. HP-SIP1 is operated at LPP(10.72MPa) of primary, but HP-SIP2 is assumed to be failed.

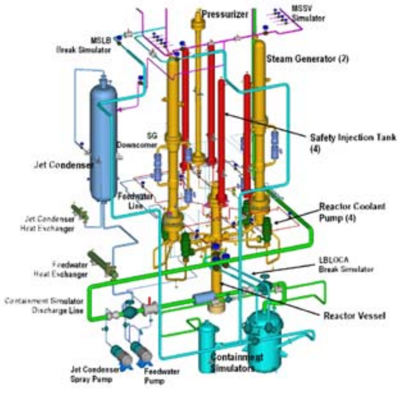


Fig. 2. Configuration of ATLAS Facilities [2]

2.2 Basic Concept

In the separate effect analysis of CUPID/MARS, the calculation was started with initial condition and was finished at given time [1]. As shown in Figure 1, a multi-scale integral effect calculation of CUPID/MARS is composed of 4 steps, which is extended from 2 steps of steady state and transient.

First, only the steady state calculation is conducted for 1-D system by MARS. The 1-D steady state calculation needs relatively long null transient time of about 5000s, and 1-D and 3-D steady state calculation is too expensive. And then, the steady state calculation for 3-D RPV (Reactor Pressure Vessel) is added to the 1-D steady state. This additional steady state calculation is not expensive because the inlet flow conditions of 3-D RPV cold legs can be obtained from the results of 1-D steady state. In the 3rd step, the 1-D and 3-D steady state are consolidated into one steady state using two restart functions of CUPID/MARS. Finally, multi-scale transient calculations can be started with the 3rd step steady state. In this ATLAS-MSLB analysis, eight CUPVOLs which connect the reactor coolant flow between 1-D system and 3-D RPV are used in four cold legs, two hot legs, and two DVI lines. It must be noted that the two DVI lines are not available because HPSIP-2 is assumed to be failed in this ATLAS-MSLB test.

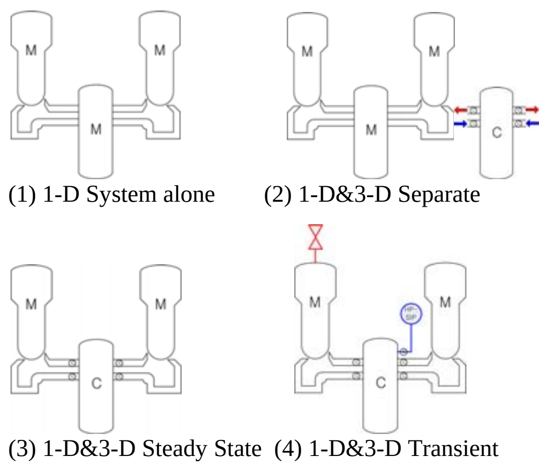


Fig. 1. Basic Concept of Multi-Scale Integral Calculation

ATLAS facilities are modeled using about two hundred 1-D volumes and 3-D mesh of 17,976 cells including 8 CUPVOL cells. In Figure 2, 1-D RPV part will be replaced with 3-D RPV part in the multi-scale simulation.

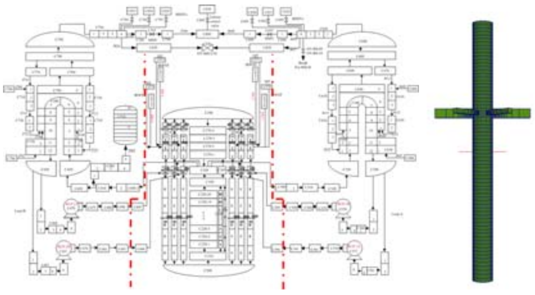
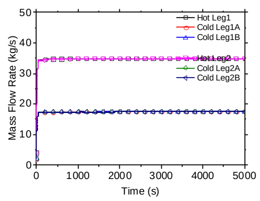


Fig. 2. 1-D Nodalization and 3-D RPV Mesh

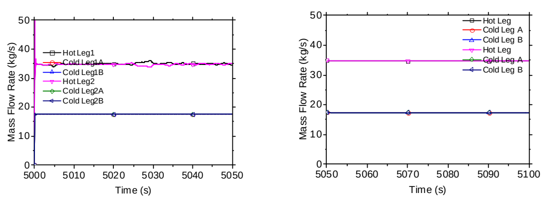
2.3 Steady State Calculation

In the 1st step 1-D calculation, the steady state is obtained for the entire 1-D system under 1.634 MW heat power and 15.56MPa pressurizer pressure. The mass flow rates at four cold legs are the same as 17 kg/s and the mass flow rates at two hot legs are the same as 34 kg/s. The pressures at two hot legs are the same as 1.555 MPa. In the 2nd step 1-D & 3-D separate calculation, the cold leg mass flow rates of 17kg/s and the hot leg pressure of 1.555 MPa are used for inlet flow conditions and for outlet pressure of 3-D RPV, where four inlets and two outlets of separate 3-D RPV corresponds to the four cold legs and two hot legs.

After the flow conditions at the outlet reach steady state, the 1-D RPV is replaced with 3-D RPV and multi-scale steady state calculation is started in the 3rd step. The obtained flow rates are similar to 1-D steady stated results as shown in Figure 3(3).



(1) 1-D Steady State

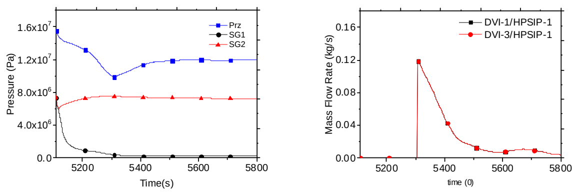


(2) 3-D Steay State (3) Multi-Scale Steady State

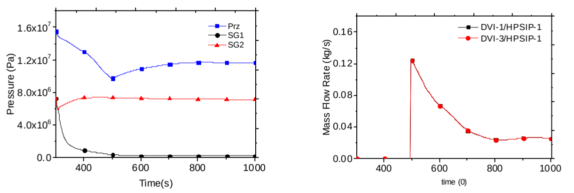
Fig. 3. Mass Flow Rates at Four Cold Leg and Two Hot Legs

2.4 Transient Calculation

Finally, the multi-scale transient calculation can be conducted using the 3rd step calculation results and the restart functions of CUPID/MARS, which maintains its own individual characteristics. As mentioned in above Section 2.1, the ATLAS-MSLB simulation is started with the two main steam line break valves open. The primary pressure and failed SG-1 decreases sharply to about 10 MPa as shown in Figure 4(1), but the intact SG-2 pressure recovers its steady state value immediately due to the SFAS and no loss of steam. DVI flow rates reach 0.12 kg/s as soon as HPSIP-1 is actuated and primary pressure increase to stable value at about 12 MPa, and therefore the DVI flow rates fall to stable low value at about 0.02 kg/s. These pressure transient of pressurizer and two transient S/Gs and the DVI flow rates coincide with the transient result of MARS 1-D calculation results as shown in Figure 4.



(1) CUPID/MARS Multi-Scale Calculation



(2) MARS 1-D Calculation

Fig.4. Comparisons of Primary Pressures and DVI Flow Rates

3. Conclusions

In this paper, the coupled CUPID/MARS code is validated against the ATLAS-MSLB test, in which 1-D system and 3-D RPV are in charge of MARS and CUPID, respectively. The four step calculation concept was set up based upon the conventional two step method of the system code. The calculation results that the calculated primary pressure and the DVI flow rates of HPSIP-1 are really similar to the MARS standalone calculation, indicates that the coupled CUPID/MARS can be applied to the reactor transient on the purpose of multi-scale thermal-hydraulic analysis in a 3-D component.

ACKNOWLEDGMENT

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[2] K. H. Kang et al., Experimental Study on the Guillotine Break Accident of the Main Steam Line with the ATLAS Thermal Hydraulic Integral Effect Test Facility,KAERI/TR-5963/2015