Assessment of MARS multi-dimensional component using data of LOFT L2-5 and sensitivity analysis

Bub Dong Chung, Young Jin Lee
Korea Atomic Energy Research Institute, 150 Dukjin-dong, Yuseong,Daejeon, 305-353,Korea.
bdchung@kaeri.re.kr, yjlee1@kaeri.re.kr

1. Introduction

The capability of the MARS computer code to perform multi-dimensional analysis of nuclear reactor is being enhanced through the development of multidimensional hydrodynamic component. Developmental assessment of the multidimensional model had been performed previously[1], however these developmental assessments primarily represented simple, multi-dimensional flow problems for which analytical solutions could be derived. Although the results were favorable, the multi-dimensional component has not been validate using measured data. This report describes the first assessment of the multi-dimensional component using data from an integral thermal-hydraulic experiment LOFT L2-5[2].

2. Model Description

The loop of LOFT system was modeled as one-dimensional components. The one-dimensional model represented the intact and broken loops, the steam generator secondary of intact loop, the pressurizer, the ECC system. A cylindrical three-dimensional model was applied to LOFT vessel. The vessel was divided into four 90° azimuthal sectors and four radial rings. The four azimuthal sectors corresponded to the four nozzles connecting the loops and the vessel. One radial ring represented the downcomer while the other three rings corresponded to high-, average-, and bypass regions of the core. The axial nodalization was based on that of previous one-dimensional model. The loss coefficient of axial direction has been modeled based on the experimental measurement. However the loss coefficient of radial and azimuthal direction has been determined using the appropriate value based on general source, since there are no measurement data. The three-dimensional vessel model contained 272 volumes (4x4x17 volumes), and whole system is modeled with 364 volumes, 660 junctions and 386 heat structures, as shown in Figure 1. The turbulent terms are also considered in the vessel component using simple Prantls' mixing length model. The qualification process[3] during the OECD BEMUSE program shows the developed nodalization is well within the acceptance level.

3. Results

3.1 Initial Conditions

Steady state calculations were performed for LOFT test L2-5 with three-dimensional vessel model. These calculations were done for 50 second simulation time using initial guess of uniform distribution of pressure and temperature of vessel. Since one loop is operational, asymmetry of downward flow was expected. The results shows almost uniform exit downward flows through the four azimuthal downcomer. The OECD qualification process of steady state shows that other parameter such as axial pressure drop and flow are well within the acceptance criteria.

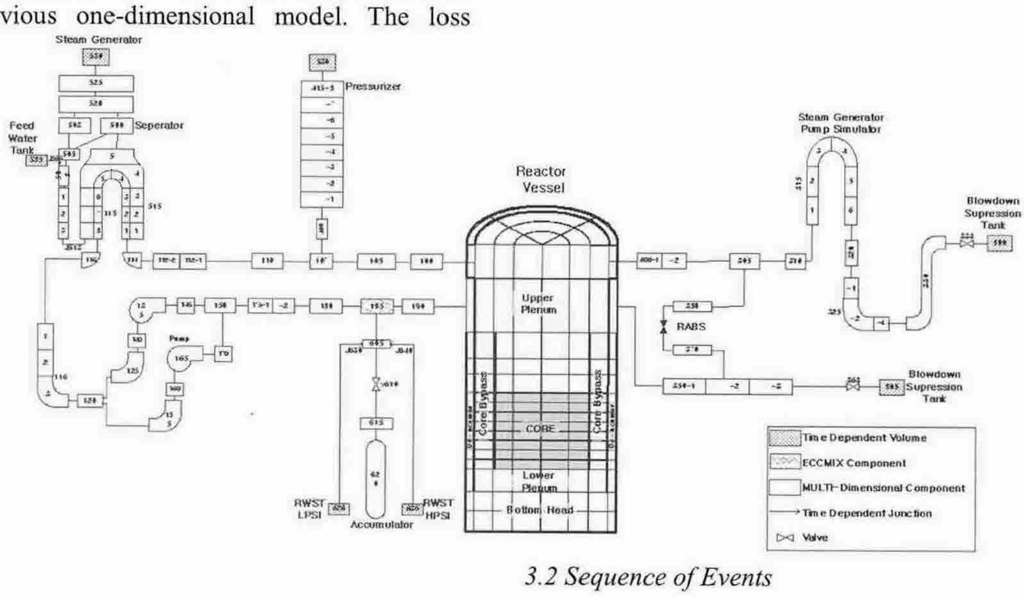

Figure 1. Nodalization of LOFT System using three dimensional vessel model

3.2 Sequence of Events

The calculated sequence of events is presented in table 1 and compared with measurement data. The calculated event times were generally in reasonable quantitative agreement with data. One exception is accumulator behavior, i.e. the initiation and emptying time of accumulator. Earlier initiation timing is inferred from the faster decrease of system pressure.

Table 1. Comparison of sequence of events of L2-5 test

Events	Experiment(sec)	Calculation(sec)
Experiment L2-5 initiated	0	0
Subcooled blowdown ended	0.043 ± 0.01	0.1
Reactor scrammed	0.24 ± 0.01	0.24
Cladding temperatures initially deviated from saturation (DNB in core)	0.91 ± 0.2	1.2
Primary coolant pumps tripped	0.94 ± 0.01	0.94
Subcooled break flow ended in cold leg	3.4 ± 0.5	3.2
Partial top-down rewet initiated	12.1 ± 1.0	9.1
Pressurizer emptied	15.4 ± 1.0	15.3
Accumulator A injection initiated	16.8 ± 0.1	12.9
Partial top-down rewet ended	22.7 ± 1.0	14.4
HPIS injection initiated	23.90 ± 0.02	23.9
Maximum cladding temperature reached	28.47 ± 0.02	39.1
LPIS injection initiated	37.32 ± 0.02	37.32
Accumulator emptied	49.6 ± 0.1	57.1
Core cladding fully quenched	65 ± 2.0	65.7
Blowdown Suppression Tank maximum pressure reached	72.5 ± 1.0	72
LPIS injection terminated	107.1 ± 0.4	

3.3 System and Core Response

The results of calculations are presented in the form of comparison plots, which show measured values taken from reference 2. Although the calculated primary pressures were slightly less than data, all other pressures are in reasonable agreement. The response of ECC system is reasonable, but the calculated accumulator flow has not been confirmed since there is no direct measurement data.

Figure 2 present the measured cladding temperatures at top location in the peripheral bundles. The calculation did not catch the multidimensional effect, and it was inferred from coarse mesh modeling.

3.4 Model Sensitivity

As a pre-step for model uncertainty quantification, the sensitivity calculations have been done to qualify the MARS multidimensional model. As sown in Fig. 3, the calculation has been accomplished for the sensitivity items proposed by OECD BEMUSE program. These items are break area(S1), gap conductivity(S2), gap thickness(S3), clud effect(S4), fuel conductivity(S5), core pressure drop(S6), CCFL at tie plate(S7), decay power(S8), scram time(S9), and so on.

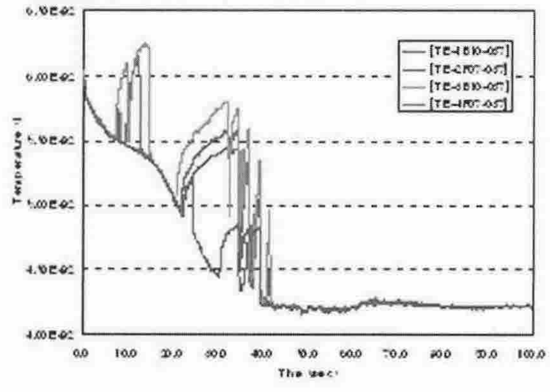

Figure 2. Measured clad temperature in peripheral assemblies

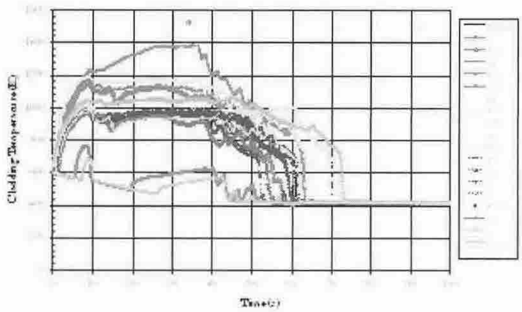

Figure 3. Sensitivity results of calculated cladding temperature in hot spot

4. Conclusion

System model with MARS MULTID-vessel component has been assessed using LOFT L2-5 test. Although the MARS calculation did not catch details of multidimensional effect in LOFT core, the sensitivity results show the model can be applied to plant application with reasonable propagations of model uncertainty.

REFERENCES

[1] B.D.Chung et al, Development of Multidimensional Component, MULTID for Thermal Hydraulic System Analysis Code, MARS, 2003 KNS Autumn meeting, KNS, 2003.

[2] P.D.Bayless, J.M. Divine, "Experimental Data Report for LOFT Large Break LOCA Experiment L2-5", NUREG/CR-2826, EGG-2210, August, 1982

[3] D'Auria F et. al., "Outline of the uncertainty methodology based on UMAE", OECD-CSNI Special Workshop on Uneratinty Analysis Method, London(UK), March 1994, J. Nuclear Tech. Vol.109, pp 21-38, 1995