Steady-State Calculation of RD-14M Small Break LOCA Experiments by CATHENA Code

Hyoung Tae Kim, Joo Hwan Park, Sang Baik Kim
Korea Atomic Energy Research Institute
1045 Daedoek-daero, Yuseong-gu, Daejeon 305-353, Korea
kht@kaeri.re.kr

1. Introduction

An International Collaborative Standard Problem (ICSP), "Comparison of HWR Code Predictions with SBLOCA Experimental Data," was started in 2007 November. In this ICSP, RD-14M small break tests, B9006 and B9802 were selected for comparison of code predictions obtained from six participating countries, using four different computer codes. In the present work, the steady-state results calculated by CATHENA MOD-3.5d/Rev 2 are compared with experimental data from the RD-14M small-break LOCA tests B9006 and B9802.

2. CATHENA code model

2.1 Tests B9006 and B9802

RD-14M is an 11 MW, full-elevation-scaled thermalhydraulic test facility possessing most of the key components of a CANDU PHTS (primary heat transport system). Test B9006 was a 7-mm inlet header break experiment with pressurized accumulator emergency coolant injection, performed in 1990 May. The break was represented by a fast-opening valve connected to an inlet header, and an orifice plate, scaled by the ratio of break area to loop volume to represent a feeder-sized break. This is the most complete SBLOCA test conducted in RD-14M in terms of including all the phases of the transient (blowdown, high-pressure ECI, secondary pressure ramp (crash cool), refill, low pressure ECI, exponential pump ramp, and natural circulation).

Test B9802 was a 3-mm inlet header break experiment, performed in 1998 January, to provide data on the influence of condensation rates in the steam generators on primary loop response.

2.2 Code description

CATHENA [1] is a one-dimensional, two-fluid thermalhydraulic computer code designed for the analysis of two-phase flow and heat transfer in piping networks. The primary use of the code is the analysis of the sequence of events which occur during a postulated loss-of-coolant accident (LOCAs) in a CANDU reactor. In addition, the code has been applied successfully to the simulation of a wide range of thermalhydraulic test facilities such as RD-14M [2], the Blowdown Test Facility and the CHAN Thermal-Chemical Test Facility, as well as research reactors such as MAPLE, NRU and McMaster Research Reactor.

2.3 Idealization of test facility

The CATHENA idealization of the RD-14M facility with primary and secondary side loops are shown in Figure 1. The CATHENA idealization used to simulate B9006 experiment consists of 528 thermal-hydraulic nodes, 543 links and 150 wall heat transfer models. However, in case of B9802, the numbers of thermalhydraulic nodes and links are decreased to 483 and 494, respectively, because the modeling of ECCS is excluded in the B9802 simulation.

The heater thermal power, coolant pump speeds, feedwater temperatures and flow rates, and secondary side steam outlet pressures are extracted from experimental data and used as boundary conditions.

The RD-14M primary side consists of all piping connecting the headers, heated sections, steam generators, pumps and pressurizer.

In developing the primary-side idealization, the volume, length, flow area and elevation change of each CATHENA pipe component resembled, as closely as possible, those from the RD-14M test facility description [2].

The flow area of complicated geometries, such as the end fittings, boiler plenums and coolant pumps are determined by dividing the volume of the component by the flow path length.

Secondary side idealization includes the steam generators up to the steam nozzle and that part of the feeder water line from the thermocouple location measuring the feedwater temperature to the steam generator feedwater inlets. The portion of the feedwater lines, upstream of this location is represented by flow and enthalpy boundary conditions. The secondary side steam generator outlet pressures are modelled using the pressure boundary conditions obtained from boiler steam dome pressures. Time varying feedwater flow rates, extracted from the experimental results, are imposed as the flow boundary conditions.

The idealization of the ECC system is included provision for both the high pressure ECC tank and low pressure ECC pump injection modes used in the B9006 experiment.

3. Steady State Calculations

The boundary conditions were kept constant during the steady state calculations. About 500 seconds of simulation time was spent to make the major output variables approach the constant values.

As we can see that the CATHENA prediction of channel flow rates are in good agreement with the test data in Table 1. Adjusting the flow resistance in the inlet feeder line of CATHENA input model, CATHENA calculates the nearly same flow distribution as the test data.

CATHENA predictions of FES temperatures are compared with tests B9006 and B9802 in Figs. 2 and 3, respectively.

4. Conclusion

RD-14M test facility was idealized for the CATHENA input model. With given boundary conditions, CATHENA code calculations reach the steady state conditions. Main parameters well agree with the steady state data; header to header pressure drop and inlet and outlet temperatures of each steam generator.

With a given pump speed data (RPM), loop flow rate (kg/sec) is reproduced by the code calculation; flow split to the multiple channels within 3% of error and FES temperatures within about 10^{o}C of difference compared with experimental data.

Temperature predictions for the disconnected FES are well agreement with the data.

REFERENCES

[1] B.N. Hanna, “CATHENA: A Thermalhydraulic Code for CANDU Analysis”, Nuclear Engineering and Design (180), pp. 113-131, 1998.
[2] RD-14M Facility Description and Characterization, AECL Report, COG-00-034-R1

Table 1. Distribution of channel flow rates at steady-state

Heated Section	B9006		B9802	
	Exp. (kg/sec)	CATHENA (kg/sec)	Exp. (kg/sec)	CATHENA (kg/sec)
HS 5	3.88	3.94	3.4	3.39
HS 6	3.96	4.05	3.42	3.44
HS 7	4.75	4.86	4.13	4.12
HS 8	4.98	4.94	4.28	4.18
HS 9	3.88	3.92	3.39	3.33
HS 10	3.8	3.84	3.31	3.3
HS 11	3.96	3.98	3.16	3.23
HS 12	5.22	5.12	4.47	4.38
HS 13	4.83	4.86	4.16	4.17
HS 14	3.88	3.92	3.25	3.37

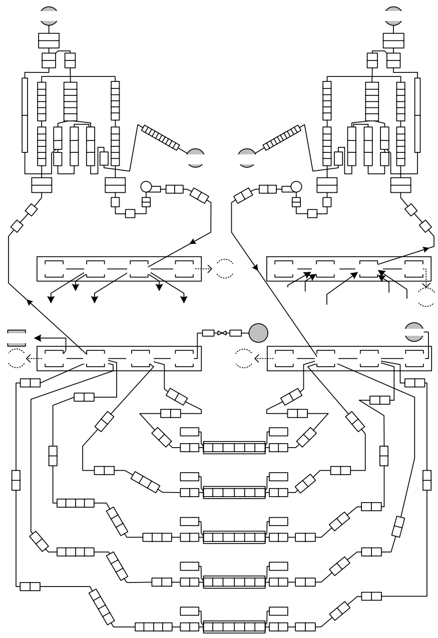

Fig. 1 CATHENA Idealization

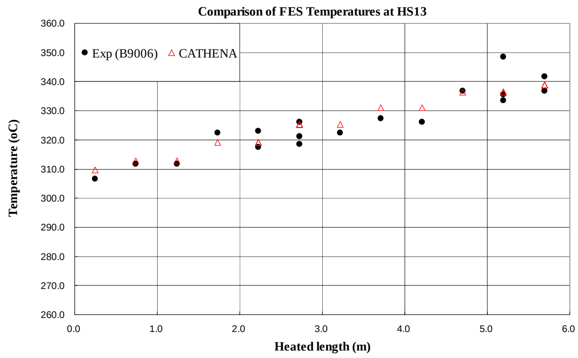

Fig. 2 Comparison of FES Temperatures between Test B9006 Data and CATHENA Results

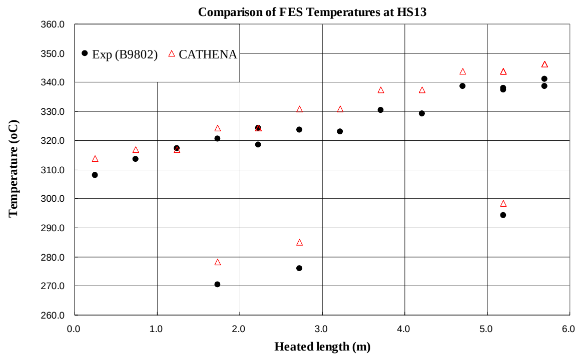

Fig. 3 Comparison of FES Temperatures between Test B9802 Data and CATHENA Results