Simulation of SHRT-17 test using SSC-K

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1. Introduction

A multiple channel approach in reactor safety analysis which a channel represents a many subassemblies ignores lateral temperature and flow variations within a subassembly and a hot channel factor which includes considerable uncertainty is used to take into account of lateral variations. An accurate theoretical evaluation of the reactivity feedbacks enhances the code predictability and decreases the uncertainties in reactor safety margins in accident situations. For the above purpose, KAERI and Argonne National Laboratory (ANL) developed a detail three-dimensional reactor core thermal hydraulic model through the INERI (International Nuclear Energy Research Initiative) project. The model has been included SSC-K [1] and SASSYS-1 LMR system code of ANL.

The inherent safety of liquid metal cooled fast reactor with metallic fuel refers to the tendency of the reactor to transition to a much lower power level as results of various reactivity feedbacks whenever temperatures rise significantly. There are several reactivity coefficients with the major importance, such as, axial fuel expansion, sodium temperature, Doppler, fuel-element bowing, and radial expansion of core. The reactivity feedback due to the radial expansion of core is important because the feedback is the biggest factor causing the negative reactivity in metal core [2]. These reactivity models need the detailed information about whole core interior region.

Analysis of the SHRT-17 test [3] in the EBR-II reactor was conducted to verify the SSC-K with the multi-dimensional thermal hydraulic model which developed through INERI project.

2. SHRT-17 Test

To obtain the detailed core temperature distribution data, the thermocouples for instrumentation were installed in the subassembly XX09. For the measurement of the coolant flow rate into the subassembly, two flow meters were placed in series in the inlet section of XX09. Many of the wire wrap spacers on the fuel pins of XX09 which was driver subassembly were replaced by thermocouple leads. Figure 1 shows the locations of the thermocouples placed in the coolant near the cladding.

A MK-IIA driver subassembly which was simulated by XX09 contained 91 pins. The most outer row of pins was eliminated to make room of thimble flow between thimble wall and subassembly wall. Thus XX09 contained 61 pins.

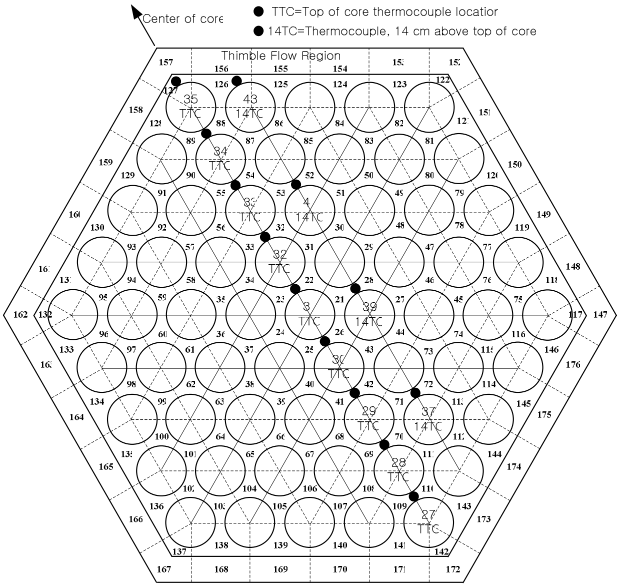

Fig. 1 Instrumentation and channel representation in XX09 subassembly

3. Modeling of EBR-II

The PHTS (primary heat transport system) of EBR-II plant consisted of two primary pumps, two piping system which pushed coolant into the lower plenum, core, pipe from the core outlet to the inlet of IHX (intermediate heat exchanger), IHX, and cold pool[4].

The whole core of EBR-II plant was modeled for the simulation of SHRT-17 using the SSC-K with the multi-dimensional model. Also, the PHTS(primary heat transport system) and the intermediate heat transport system were modeled. However, the pipe from the core outlet to the inlet of IHX was replaced by the hot pool model of SSC-K because of the nodding scheme of SSC-K. Other differences between real system and the model were piping system from the pump to inlet plenum. Actually, the primary flow to the reactor splits into two stream, one entering the high-pressure plenum, the other entering the low-pressure plenum, however, in the SSC-K model the primary pump pushes the flow into the common inlet plenum through single piping system.

For XX09 and its six neighbors a detailed representation was used. For these subassemblies every coolant subchannel and every fuel pin were simulated as shown in figure 1. The other subassemblies in the core were modeled with single channel. Axially 15 nodes for the fuel region, 6 nodes for the gas plenum region, 7 nodes for the shield region below the fuel pins, and 11 nodes for the shield region above the fuel pins were used.

The nominal power in EBR-II was 62.5 MW_t and the primary flow was 485 kg/s. At the beginning of the SHRT-17 test the measure power was 60.5 MW_t, thus 60.5 MW_t was used as the initial power for this calculation. The measured pump speed as a function of time was used as input in the calculations. Then the primary pump head was calculated by the SSC-K as a function of flow rate and pump speed.

4. Calculation Results

Figure 2 shows the transient coolant flow rate in XX09. During the early part of the transient of pump coast down, the computed flow rate agrees well with the measure flow rate. But, the pump stopped about 10 seconds more quickly in the calculation because the build-up of natural circulation head is large due to the different PHTS modeling.

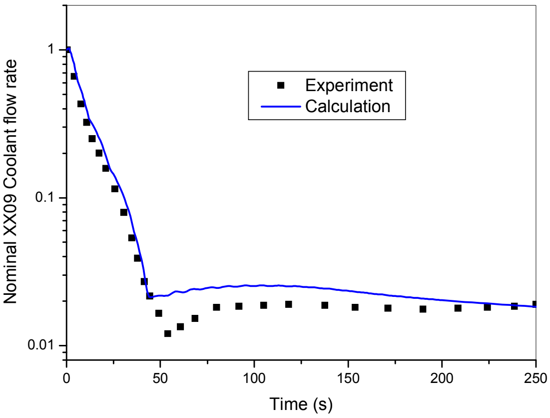

Fig. 2 Transient flow rate

Transient peak coolant temperatures near the top of the core according to time are shown in figure 2. After the control rods scram at time zero the power drops very rapidly, leading to a sudden drop in coolant temperature. Then, as the pump coast down and stop the flow rate drops, the coolant temperatures continue to increase until natural circulation heads build up and increase coolant flow rates leading to a drop in coolant temperature.

The calculated temperature for XX09 subassembly shows the delayed peak because of the bigger natural circulation flow than that of the experiment. As has been mentioned in the former section, the core subassemblies are connected two different inlet plenums. The temperature behavior of the XX09 subassembly was resulted from the single piping system modeling from the pump to the inlet plenum because we don't have the accurate data of the EBR-II plant. The temperature behavior of other subassembly model, such as X393, has better agreement with the experiment data trend. The calculated peak temperature is about 30 °C lower than the peak in the experiment. Although the input data is inaccurate, the trends of the transient well agree with the experimental data.

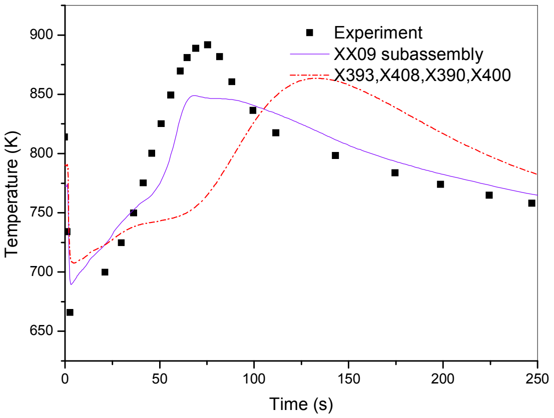

Fig. 3 Transient peak coolant temperatures near the top of the core

4. Conclusion

For the application of detailed reactivity models, SSC-K and multi-dimensional program has been numerically coupled. The coupled code has been proved by comparing the analysis results using the code with the experimental data for the SHRT-17 test. The calculated trends of the transient well agree with each other.

ACKNOWLEDGMENTS

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