Preliminary Performance Analysis of SMART Research Reactor using TASS-3D Code

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1. Introduction

SMART (System-Integrated Modular Advanced ReacTor) [1] is a small sized integral-type reactor developed by the Korea Atomic Energy Research Institute (KAERI) for an application to seawater desalination and a small-scale power generation. At present, a construction project fro the SMART research reactor is being progressed within the framework of the technology verification program of SMART. The flow geometry of the rector coolant system of SMART is complicated, because all the major components are installed in a single pressure vessel. In addition, an asymmetric flow and temperature distributions are expected during operational transients such as a partial operation of steam generator modules and main coolant pumps. Therefore, an accurate prediction of the flow distribution and the thermal mixing in the complex geometry, which require a three-dimensional calculation, are important for the performance analysis of the SMART research reactor.

In the present study, a three-dimensional simulation code TASS-3D is applied to the performance analysis of the SMART research reactor. It is composed of three program modules for calculating the core kinetics, primary coolant dynamics, and secondary system.

2. Mathematical Models

The TASS-3D code consists of three program modules of MASTER[2], FAST[3], and TASS/SMR[4] which have been developed at KAERI for the calculation of the core kinetics, primary and secondary system thermal hydraulics respectively. The code module TASS/SMR plays a main routine role and the other two code modules are called as subroutines.

2.1 Primary Coolant System Model

A three-dimensional fluid dynamics code FAST (Fluid Analyzer for System Transients) has been developed for the primary coolant system. Three-dimensional mass, energy, and momentum conservation equations are solved for the thermal hydraulic analysis of the primary coolant system. The primary coolant is a single phase liquid and is assumed as an incompressible fluid. The governing equations are discretized using the FVM (Finite Volume Method). Unstructured as well as structured grids are allowed for the application of the complex geometries. The code module uses an orthogonal computational grid for a fast convergence of the solution. All the variables such as the pressure, velocity, and temperature are defined at the cell center. To avoid the pressure oscillation which usually occurs in the collocated grid, the Rhie-Chow interpolation method was applied for the cell face velocity correction. The linear set of the equations obtained from the governing equations is solved using the SMAC algorithm for the transient calculation.

The computing cells of the primary coolant system have a hexagonal structure in the x-y plane for the simulation of the hexagonal core. Figure 1 shows the computing cells whose total number is 39907.

2.2 Reactor Kinetics Model

The core of the SMART research reactor has 295 fuel assemblies and the assembly fission power is calculated by MASTER (Multi-purpose Analyzer for Static and Transient Effects of Reactors) computer program developed at KAERI. It is a nuclear design code based on the two-group diffusion theory for calculating a steady state and transient PWR core in a three-dimensional Cartesian or hexagonal geometry. It has been designed to cover various PWRs including SMART as well as the WH (Westinghous) and the CE (Combustion Engineering) type reactors, for providing the data required in their design procedures.

2.3 Secondary Coolant System Models

The computer code TASS/SMR (Transient And Setpoint Simulation) developed by KAERI has been utilized for the secondary coolant system including a passive residual heat removal (PRHR) and a balance of the plant (BOP) systems. It is a one-dimensional performance and safety analysis code where six conservation equations are employed for the mixture mass, liquid mass, non-condensable gas mass, mixture energy, steam enthalpy, and mixture momentum respectively. Specific heat transfer models are included for the heat transfer calculation of the steam generator and PRHR heat exchanger.

The secondary side of steam generator, PRHR, feed water, and main steam systems are modeled as 95 one-dimensional nodes and 101 flow paths.

3. Results

Four modes in a normal operation are allowed in the SMART research reactor depending on the status of the main coolant pump. These are 5-100%, 5-50%, 5-25%, and 20-25% of the full power operations with the main coolant pumps are at a high (3600 rpm), medium (1800 rpm), low (900 rpm), and zero speed respectively. The core is cooled by a natural circulation when the main coolant pumps are stopped. The SMART research reactor also allows for abnormal operations such as a 50% power operation with one main coolant pump stopped or a steam generator two section isolation. These transients are important with respect to the core thermal margin since an asymmetric temperature distribution is expected in the core.

Figure 2 compares the core inlet and outlet temperatures at normal operating conditions. The calculation results indicated as diamond symbols agree well with the design values. Figure 3 and 4 show the steam generator inlet and outlet temperatures for 2 SG isolation and 1 MCP stop operations respectively. The core power is 50% in both cases. The coolant from the isolated SG is hardly mixed with that of the intact SG. However, the temperature differences are small at the SG outlet in case of 1 MCP stop operation. The maximum coolant temperatures at SG outlet are far below the saturation temperature (613 K) so a boiling crisis is not expected during the abnormal operation.

4. Conclusion

Performance of the SMART research reactor has been analyzed using TASS-3D. The calculation results of the TASS-3D code for a normal operation and the operational transients agree well with the design values. The asymmetric temperature distribution is predicted well by the code and the results show that the maximum coolant temperature is lower than the saturation temperature.

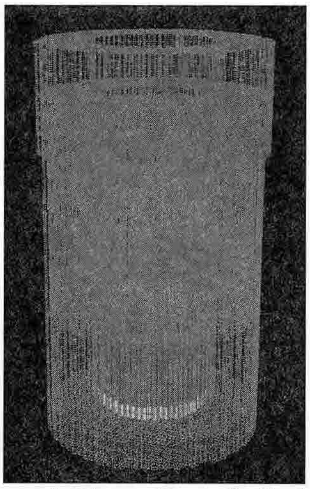

Figure 1. Computing cells for FAST

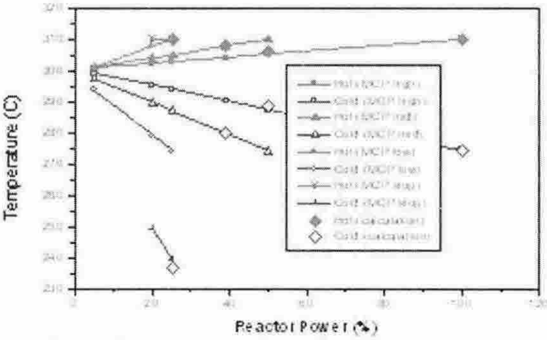

Figure 2. Core inlet and outlet temperatures

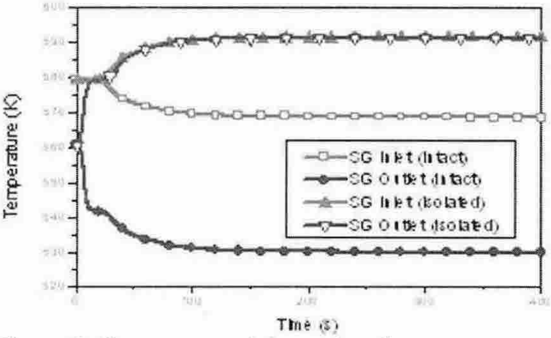

Figure 3. Core average inlet and outlet temperatures (2 SG isolation)

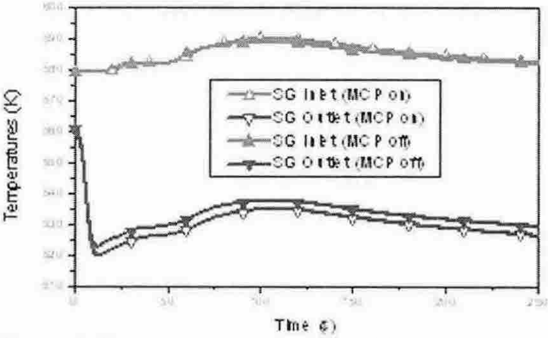

Figure 4. Core average inlet and outlet temperatures (1 MCP stop)

REFERENCES

[1] M. H. Chang et al., "Development of Design Technology for Integral Reactor", *KAERI/RR-2223/2001*, 2001.

[2] B. H. Cho et al., "MASTER-2.0 : Multi-purpose Analyzer for Static and Transient Effects of Reactors," *KAERI/TR-1211/99*, 1999.

[3] H. Y. Yoon et al., "Development of a 3-D Flow Analysis Computer Program for Integral Reactor," *2003 KNS Meeting, Yongpyong*, 2003.

[4] H. Y. Yoon et al., "Thermal Hydraulic Model Description of TASS/SMR," *KAERI/TR-1835/2001.*, 2001.