Verification of the Natural Circulation in TASS/SMR-S code

See Darl Kim, Soo Hyoung Kim, Guy Hyung Lee, Young-Jong Chung
Small & Medium Reactor Development Division. KAERI, sdkim2@kaeri.re.kr

1. Introduction

TASS/SMR-S (Transient And Setpoint/Small and Medium Reactor) code [1] is a computer program developed for the performance and safety analysis of SMART (System-integrated Modular Advanced Reactor). Since the technologies used for SMART design are different from existing reactors, the analytical capability of TASS/SMR-S code has to be verified for its application to a system analysis of SMART. Also the reliability of the analysis results of the code need to be verified using proper experimental data. In this paper, the natural circulation problem was analyzed by TASS/SMR-S code and the results were compared with the theoretical results or analytic solutions.

2. Methodology

Basic conceptual and analytical problems are selected to evaluate the fundamental numerical analysis capability of TASS/SMR-S code. Five problems including mass and energy conservation problems were selected [1]. The Natural circulation problem was one of them.

2.1 Physics context

If we add energy to one place and remove it from the other place in a closed loop, natural circulation occurs according to the change in the density of the fluid. The PRHRS (Passive Residual Heat Removal System) of SMART adopts this concept of natural circulation as the ultimate heat sink. The natural circulation needs to be confirmed by analysis.

2.2 TASS/SMR Code Input Modeling

The nodalization diagram is shown in Figure 1. There are eight nodes. The length of node(1) through node(8) is 0.1m with an inside diameter of 0.1m.

We supplied three different powers (5kW, 10kW, 15kW) to node 1 and removed the same power from node 5 in order to simulate the energy transfer from PRHRS. We simulated the flow variation due to the power change at node 1 and node 5 caused by the energy inflow and outflow. The natural circulation flow rates were calculated for three different energy in and out of 5kW, 10kW and 15kW. Table 1 shows analysis initial condition.

3. Results

Natural circulation flow rate in simple closed-loop geometry was calculated according to the correlation from Duffey, etc [2] and the related expressions were as follows:

$$W_{1\phi} = \left| \frac{2A^2 \beta g \rho_l^2 Q_0 \Delta L}{C_p K_l} \right|^{1/3} \qquad (1)$$

where

A = path area

β = liquid volumetric expansion coefficient

g = acceleration of the gravity

ρ_l = liquid density

Q_0 = heat input

ΔL = elevation between thermal centers

C_p = liquid specific heat

K_l = loss coefficient for flow

The transient calculation was carried out for steady state condition using TASS/SMR-S code. Comparisons were made between the analyzed solution and calculated solution. Figure 2 shows the natural circulation flow rate at power variation. Table 2 shows the comparison of natural circulation flow rate.

As shown in the Table2, the results of TASS/SMR – S code are in good agreement with the analyzed solution and TASS/SMR-S code was able to reproduce the physical characteristics of natural circulation.

4. Conclusions

TASS/SMR-S code has an appropriate ability related to the natural circulation problem compared with the analytical reference solution. The code predicts the several cases well compared with the analytical solution.

Table 1 Initial conditions

	Case1	Case2	Case3

Input Power(kW)	5.0	10.0	15.0
Flow Area(m^2)	0.01	0.01	0.01
Pressure loss coefficient	1.0	1.0	1.0
Temperature (K)	383.38	383.38	383.38
Pressure (MPa)	0.2	0.2	0.2

Table 2 Comparison of natural circulation flow rate

Input Power (kW)	Analytical Solution (kg/s)	TASS/SMR-S Result (kg/s)	The rate of error (%)
5.0	0.399	0.395	-0.99
10.0	0.503	0.498	-0.92
15.0	0.575	0.570	-0.93

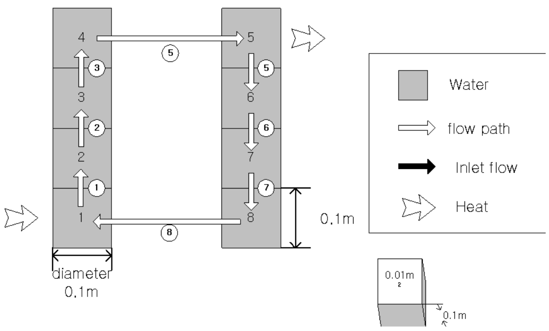

Figure 1 TASS/SMR-S nodalization for the natural circulation

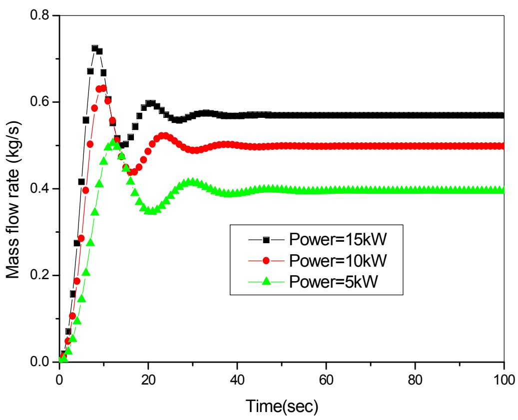

Figure 2 Natural circulation flow rate at power variation

Acknowledgement

This study has been performed under the R&D program supported by Korea Ministry of Education, Science and Technology.

REFERENCES

[1] S.H. KIM, "Topical Report of TASS/SMR-S Code", 911-TH464-003(Rev01), December 2010.

[2] R.B DUFFEY and J.P. SURSOCK, "Natural Circulation Phenomena Relevant to Small Breaks and Transients", Nuclear Engineering and Design 102(1987), p 115-p128, 1987.