Experimental validation of the PRHRS model in the TASS/SMR-S code

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1. Introduction

In order to identify the applicability of the TASS/SMR-S (Transient and Setpoint Simulation/ Small and Medium Reactor) code to the safety analysis of the advanced integral reactor, the code should be validated by using proper experimental data. An experimental study has been performed to investigate the high pressure steam condensation heat transfer in a large diameter condenser tube.

This paper deals with the validation of the TASS/SMR-S code by using a separate effect test. Firstly, the TASS/SMR-S code is briefly introduced and the experimental validation of the TASS/SMR-S code follows. The experimental validation of the TASS/SMR-S code is explained by focusing on the heat transfer at a heat exchanger of a PRHRS. On the other hand, the behaviors of the major thermal hydraulic parameters including the system pressure, fluid temperature and mass flow rate are mainly described. Finally, the conclusions are drawn.

2. Methods and Results

2.1 Overview of the TASS/SMR code

To analyze the thermal hydraulic performance of an advanced integral reactor under a full range of reactor operating conditions, KAERI has developed the TASS/SMR code. The basic structure of the TASS/SMR code adopts a one-dimensional geometry by using a finite volume method. All of the primary and secondary systems are represented by nodes, which indicate the mass and energy of the fluid, and the flow-paths connecting the adjacent nodes, which symbolize the fluid momentum.

The core power in the TASS/SMR code is calculated by the point kinetics model with six delayed neutron groups, which is generally used in the transient analysis codes for a nuclear power plant including RELAP5/MOD3. A number of specific models reflecting the peculiar design of an advanced integral reactor, such as the heat transfers at a helically coiled steam generator and a heat exchanger of the PRHRS, and a pressurizer, are incorporated in the TASS/SMR code. The fluid properties have been calculated by using the IAPWS (The international Association for the Properties of Water Steam) industrial formulation 1997 for the thermodynamic properties of water and steam.

2.2 Validation against the heat transfer rate through a PRHRS

A condensation experiment facility was developed to identify the heat transfer characteristics at a heat exchanger of a PRHRS and its schematic is illustrated in Fig. 1. The experimental facility is designed with a maximum pressure of 7.5 MPa and a maximum temperature of 300℃. The main components of experimental facility are the steam generator which supply the steam with the maximum capacity of 200kWe, the condenser tube with the outer diameter of 50.8 and the length of 1.8 m, and other auxiliary equipments such as thermocouples and pressure sensors, the data acquisition system and the control system.

The test section is a stainless steel 316 tube with an outer diameter 50.8 mm, a thickness of 2.3 mm and a length become 1.8 m, because the upper part of condenser tube is insulated. To reduce the entrance effect, a 0.5 m long, 50.8 mm O.D. tube enclosed with Teflon insulation blocks. The test tube is submerged in a 1.2 m x 1.2 m width, 2.5 m height pool.

To measure the hot temperature at 10 different axial locations of the tube, 23 K-type thermocouples were also installed at the tube. Condensation experiments using pure steam under four different steam flow rates (0.048, 0.064, 0.069, and 0.087 kg/s) have been considered in this analysis. And the condensation heat transfer correlation by considering the effect of a non-condensable gas on a heat transfer is not adopted in the TASS/SMR code.

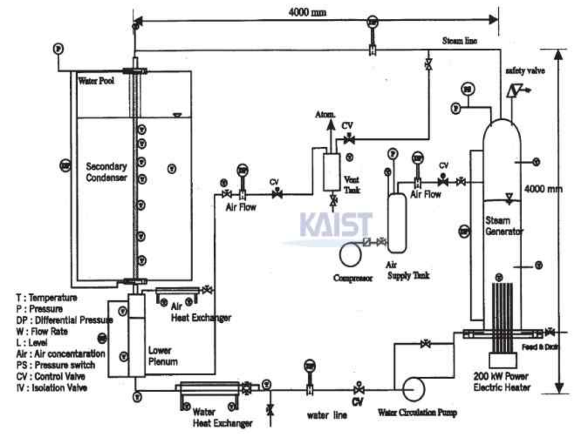

Fig. 1. Schematic diagram of the condensation experiment facility

The nodalization for a validation of the heat transfer model of a PRHRS is shown in Fig. 2. The condenser tube and cooling pool are fully represented by 23 nodes and 21 flow-paths, respectively. In the nodalization, the mass flow rates and enthalpies at the inlet positions of the condenser tube and the cooling jacket are treated as boundary conditions. In addition, the exit positions of the condenser tube and the cooling pool (node numbers 12 and 23) are modeled as pressure boundaries.

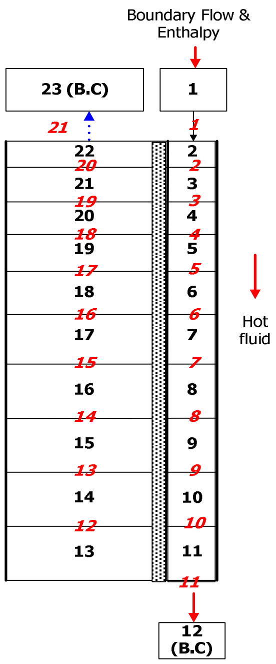

Fig. 2. TASS/SMR nodalization for the condensation experiment facility

2.3 Results

The tube side coolant temperatures and pool side coolant temperatures are shown in Figs. 3. As the exit positions of both the tube and pool sides are simulated as boundary conditions, the calculated temperatures are nearly the same as the experimental data, as shown in Figs. 3.

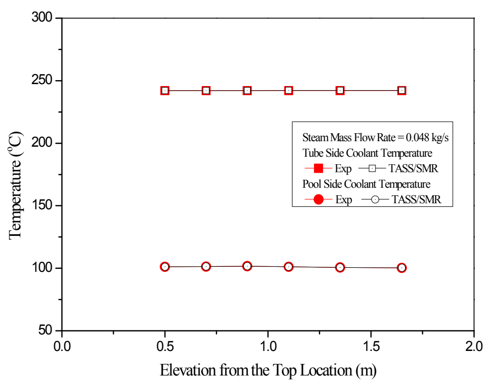

Fig. 3. The tube and pool temperatures with axial location

Overall heat transfer rates through a heat exchanger pipe are shown in Fig. 4. The heat transfer rates for the experiment are calculated by using the mass flow rates and the enthalpy differences between the inlet and exit positions of the tube side. According to the analysis results, the TASS/SMR code predicts the heat transfer rates at a heat exchanger within a 15% error.

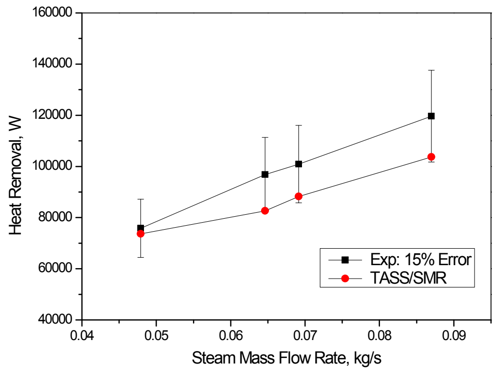

Fig. 4. Heat transfer rate with the steam mass flow rate

3. Conclusions

A validation of the TASS/SMR code has been performed by using a separate effect test related to the heat transfer at a heat exchanger of a PRHRS. Validation analysis shows that the TASS/SMR code is applicable to the safety analysis and performance evaluation for an advanced integral reactor. In addition, it shows that some modifications are necessary to improve the prediction capability of the TASS/SMR code and to overcome its weak point from the viewpoint of its predictions for the local thermal hydraulic parameters.

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