Performance Evaluation for the Diameter and Material of Condensation Heat Exchanger Using the TASS/SMR-S code

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1. Introduction

The SMART (System-integrated Modular Advanced ReacTor) has a passive safety system such as a Passive Residual Heat Removal System (PRHRS). When a secondary system can't operate because of the malfunction of a feedwater system or a loss of off-site power (LOOP), the core decay heat is removed using the Condensation Heat Exchanger (CHX) in the PRHRS with natural convection. The CHX has 500 tubes submerged in an emergency cooling tank [1]. So the heat removal performance can be affected by the material and diameter of the CHX tube.

In this paper, the heat transfer performance for the diameter and material of the CHX tube was evaluated using the TASS/SMR-S (Transient And Setpoint Simulation/System-integrated Modular Reactor-Safety) code with the POSTECH CHX heat transfer test. The TASS/SMR-S code has several heat transfer models for the PRHRS CHX [2]. The role of these models is to calculate the heat transfer coefficient in the CHX by the relevant correlations for all of the heat transfer modes.

2. Performance Evaluation for the CHX Tube

2.1 Overview of the POSTECH CHX Test

The heat transfer test for the diameter and material of the CHX tube was carried out at POSTECH [3]. The test facility consists of a steam supplying system, coolant supplying system, and test section (CHX tube) shown in Fig. 1. The test section is composed of a vertical tube with a length of 1.5 m and a coolant jacket with a 45.0 mm by 45.0 mm inner cross-section. The CHX tube is located within the coolant jacket. To evaluate the tube diameter and material effect, three test sections were selected with an inner diameter of 12.52 mm SUS-316L tube and an inner diameter 12.52 mm Inconel-690 tube. For three kinds of test sections, the performance test was performed as a function of mass flux (20, 50 kg/m^{2}s) and pressure (2.0, 4.0 and 6.0 MPa).

2.2 TASS/SMR-S Code Modeling

Fig. 2 is the TASS/SMR-S code nodalization for the POSTECH CHX test. The tube and coolant jacket side of the test section consist of 15 nodes, respectively. The upper and lower nodes of each section are connected to the boundary condition. The coolant is put into node 1 of the coolant jacket section. The superheated pure steam is injected into node 18 of the CHX tube section.

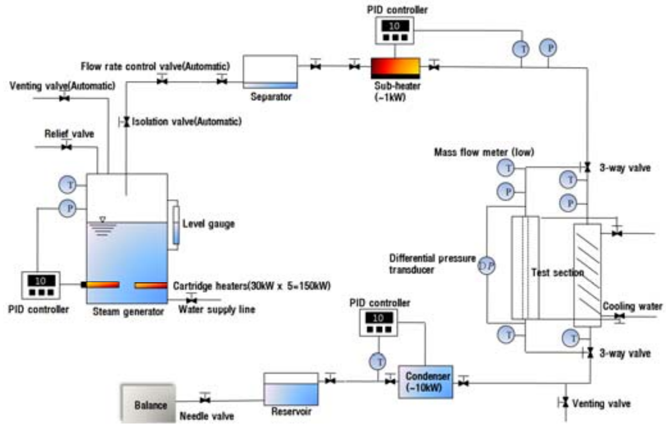

Fig. 1. Diagram of POSTECH CHX heat transfer test

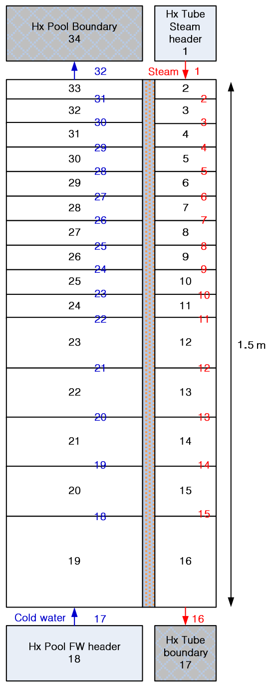

Fig. 2. TASS/SMR-S nodalization for the validation

2.3 Evaluation Results

Fig. 3 ~ Fig. 5 show a comparison of the local heat transfer coefficient (HTC), steam quality and fluid temperature in the CHX tube by the tube diameter. According to the test and calculation results, in the small diameter the steam quality and local HTC are low and the full condensation length along the tube short under same conditions. When same mass flux steam is put into the tube, the condensation film thickness is increased more quickly in the small diameter tube. Because of this effect the steam quality and HTC are decreased more quickly and the full condensation is occurred early in the small diameter tube. The heat transfer rates removed through the CHX show an increasing trend by an increase in the tube diameter shown in Fig. 6.

Fig. 7 shows the local heat transfer coefficients until the full condensation region by the tube material. According to the test and calculation results, the local HTC is not affected by the tube material. There is little difference in conductivity between Inconel-690 (16.1 W/m °C) and SUS-316L (18.6 W/m °C).

In comparison with the test results, the TASS/SMR-S code under predicts all trends rather than the test.

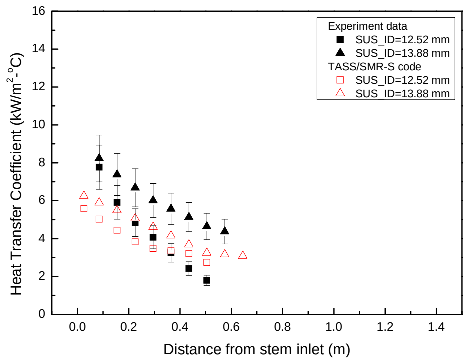

Fig. 3. Local HTC by the tube diameter (6.0 MPa)

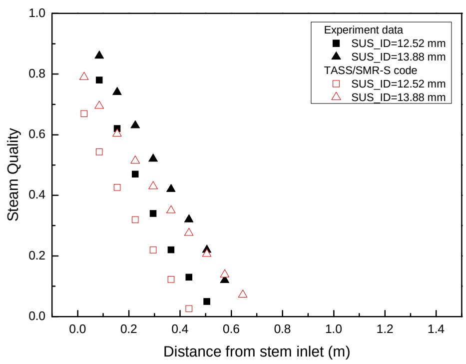

Fig. 4 Steam quality by the tube diameter (6.0 MPa)

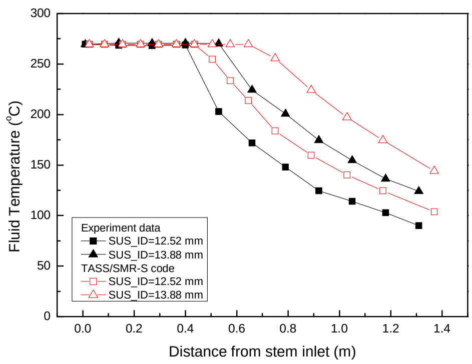

Fig. 5. Temperature by the tube diameter (6.0 MPa)

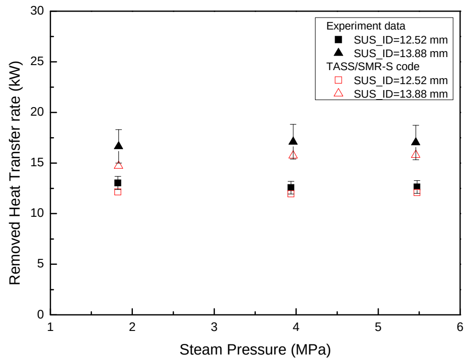

Fig. 6. Heat removal by the tube diameter

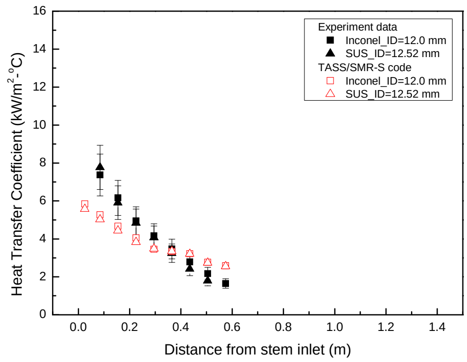

Fig. 7. Local HTC by the tube material (6.0 MPa)

3. Conclusions

The performance by the tube diameter and material effect was evaluated using the TASS/SMR-S code with the POSTECH CHX performance test.

According to the test and calculation results, the CHX performance such as the local HTC and the heat removal is decreased by a decrease in the tube diameter. But the CHX performance is not affected by the tube material.

Also, the TASS/SMR-S code underestimates all trends in comparison with the test results. It is the conservative results in the heat removal of the reactor coolant system (RCS).

Acknowledgement

This study has been performed under a contract with the Korea Ministry of Education, Science and Technology.

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[3] In Sub Jun, "Heat Transfer Characteristics Test Report for the CHX Diameter and Material, 310-TH458-029, 2011