

Preliminary Evaluation of a Water-Cooled RCCS in NSTF Facilities

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1. Introduction

KAERI has developed the GAMMA+ code [1] to predict thermo-fluid transients in the VHTR. The validation of GAMMA+ code with several benchmark problems [2,3] was accomplished to support a reliable CFD and system-level code development for next generation VHTR design. The performance of RCCS (Reactor Cavity Cooling System) is very important to the VHTR design because it is safety-grade system to remove the decay heat. ANL (Argonne National Laboratory) had planned the experiments simulating the heat transfer of the water-cooled RCCS in NSTF Facilities.

As one of the benchmark problems, the simplified model simulating the water-cooled RCCS is postulated to support a system code validation. This study shows the evaluation results of GAMMA+ code for the benchmark problem. This V&V analysis of the NSTF intends to obtain the code-to-code or code-to-experiments data providing a higher credibility and accuracy of GAMMA+ code for the VHTR design.

2. Problem and Modeling Methods

In this section, some of the modeling methods of GAMMA+ code used to simulate the benchmark problem are described.

2.1 Benchmark Problem

Fig. 1 shows the benchmark problem of the water-cooled RCCS which is composed of eight water tubes in air cavity box. The heater power of 72 kw is removed by tube water flow of 2.55 kg/s at the inlet temperature of 24.31 °C and outlet pressure of 0.263 MPa.

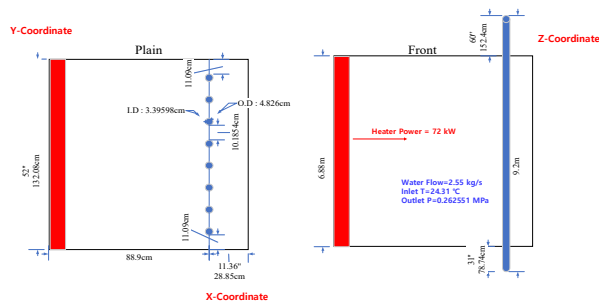


Fig. 1. Simplified Model Simulating the Water-Cooled RCCS in NSTF Facilities.

2.2 Fluid and Wall Block System Model

Fig. 2 shows the fluid and wall block system of the water-cooled RCCS for GAMMA+ evaluation. 3-D fluid (10x8x20) in the air box and 1-D fluid (26 cells) in the water tubes are used. 3-D wall block plates are modeled at each six face of the box. With circumstantially dividing four parts of tube, 3-D model of tube is also used to consider the radiation between tubes and plates. For the sensitivity study of heat loss to the air environment, various emissivity values of outer surface plates are applied.

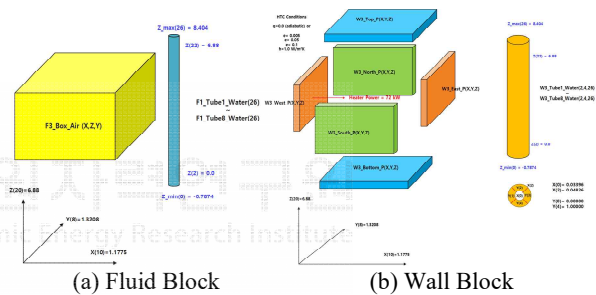


Fig. 2. Fluid and Wall Block System Model for GAMMA+.

2.3 Radiation Model

Generated heater power at west plate is dominantly transferred to the water tubes by radiation heat transfer between outer surfaces of tubes and inner surfaces of plates in the box. Radiation model is considered separately in four regions such as box inside plates, west/east plate to eight tubes, south/north plate to tube1/tube8 and surfaces between adjacent tubes. Fig. 3 shows the radiation modeling between adjacent tubes. As circumstantially dividing four parts of tube, quarter surface area of tube is considered in the radiation of adjacent tubes.

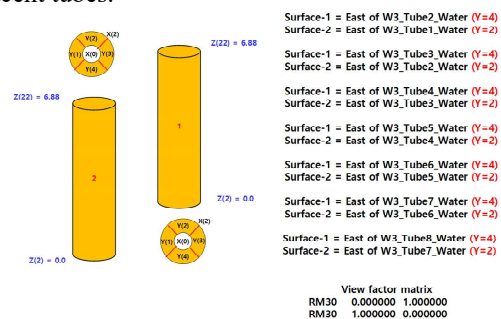
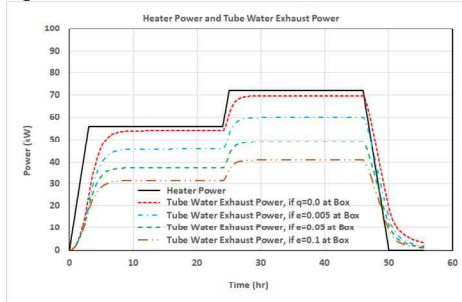


Fig. 3. Radiation Modeling between Adjacent Tubes.

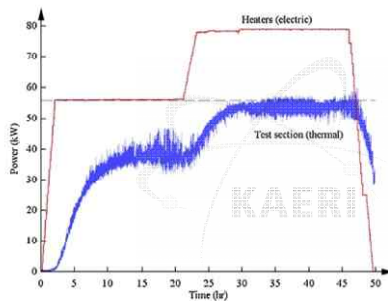
3. Results

3.1 Effects of Heat Loss to the Environment

Benchmark problem does not provide some detailed conditions such as heater power history and insulation of air box. As shown in Fig. 4 (a), it is assumed the heater power is supplied like step-by-step ramp similar to the experimental data [4] of Fig. 4 (b). Sensitivity calculations are done to examine the effects of heat loss as changing emissivity at outer surface of box. It shows that the higher emissivity produces the higher heat loss, and the actual exhaust power through the water tubes highly depends on the heat loss to the air environment.



(a) Calculated Data



(b) Experimental Data [4]

Fig. 4. Sensitivity Study of Heat Loss to the Environment on Exhaust Power through the Tubes.

3.2 Exhaust Power through Each Tube

Fig. 5 shows the behavior of exhaust power through each water tube with the adiabatic conditions at outer surface of box. The behavior of water exhaust power corresponds to the heater power change. South and north side tube (tube1 & tube8) get the higher power (33%) than other inside tubes.

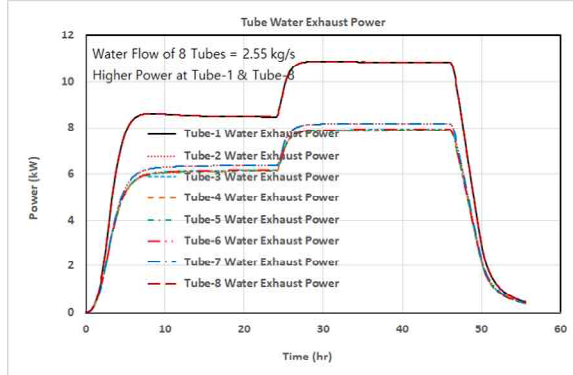


Fig. 5. Behavior of Exhaust Power through Each Tube.

3.3 Maximum Temperature

Fig. 6 shows the behavior of maximum temperature at box inside surfaces. South and north plates have a higher temperature (735 °C) than the west heater plate (581 °C). Thus, side water tubes (tube1 and tube8) adjacent to south/north plates have the higher temperature (49 °C) than other tubes (44 °C).

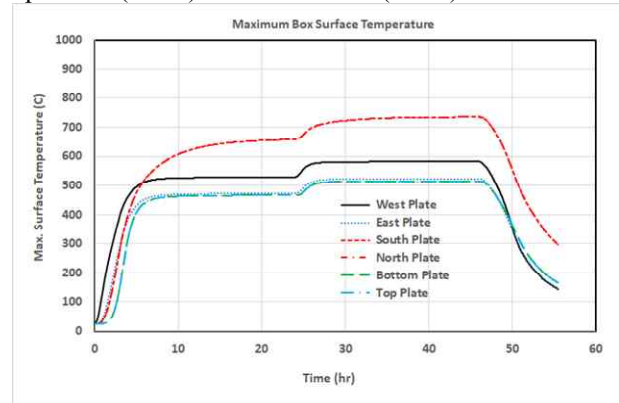


Fig. 6. Maximum Temperature at Box Inside Surface.

4. Conclusions

This study preliminarily evaluates the heat transfer for the simplified model of a water-cooled RCCS. It demonstrates the heat loss to the environment highly affects the actual heat removal through the water tubes. Heater power is more transferred to side region (tube1 & tube8) than other inside tubes because the high temperature plates (south/north) are adjacent to side tubes. In the future, comparing these results with other CFD calculation or experimental data could provide the reliable V&V data for GAMMA+ code.

ACKNOWLEDGEMENTS

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