Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Assessment of MARS Code Applicability for the HTTR Benchmark Problem

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1. Introduction

MARS code has been developed for multidimensional best estimate analysis of commercial LWRs and advanced reactors. Recently, many features for HTGR (High Temperature Gas-cooled Reactor) model, such as direct contact heat transfer, radiation heat transfer and convective heat transfer, have been installed in MARS code. Since the assessment works have been focused to the commercial LWR during the past many years, there are assessment needs for the HTGR application [1]. This study, as a part of works for the MARS code applicability assessments, calculates the cooling capability of RCCS (Reactor Cavity Cooling System) - an IAEA Benchmark Problem for HTTR (High Temperature engineering Test Reactor).

2. Methods and Results

2.1 Test Facility

A mockup test facility was constructed to investigate the HTTR RCCS phenomena, for which MARS code assessments are made. An outline of the experimental apparatus simulating the water cooling panel system of the HTGR is shown in Figure 1.

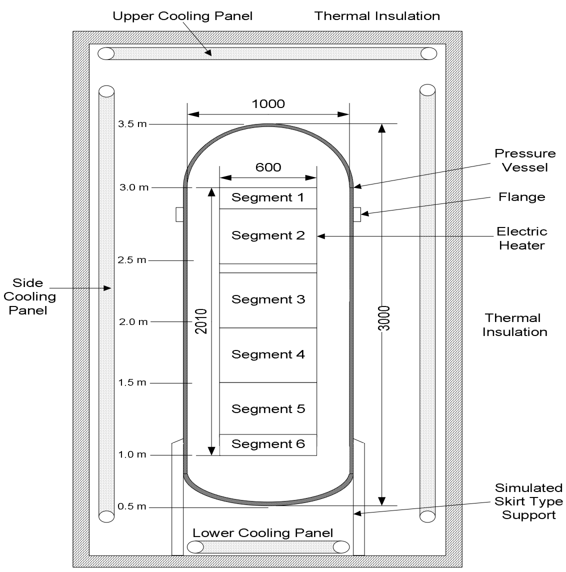

Figure 1. Schematic of HTTR RCCS mock-up.

The experimental apparatus consists of a pressure vessel containing electric heaters with the maximum heating rate of 100 kW, cooling panels and thermal insulation surrounding the pressure vessel, and systems for helium gas supply and vacuum [2].

2.2 Benchmark problem

The IAEA held in common research information that Co-ordinate Research Project (CRP) on "Heat Transport and Afterheat Removal for Gas Cooled Reactors Under Accident Conditions", which were performed at IWGGCR (International Working Group on Gas Cooled Reactors) and have been published the TECDOC-1163, which synthesizes research results for the exiting HTGR [2]. The TECDOC-1163 is put on various benchmark problems with respect to the afterheat removal for the RCCS. In this study, this problem assesses whether the decay heat from the core can be removed sufficiently during accidents by the RCCS.

2.3 System Modeling

In order to simulate benchmark problem of HTTR RCCS Mockup, for which experimental results together with the simulated results are available, system from the core vessel to the RCCS is modeled as one-dimensional coordinate as shown in Figure 2.

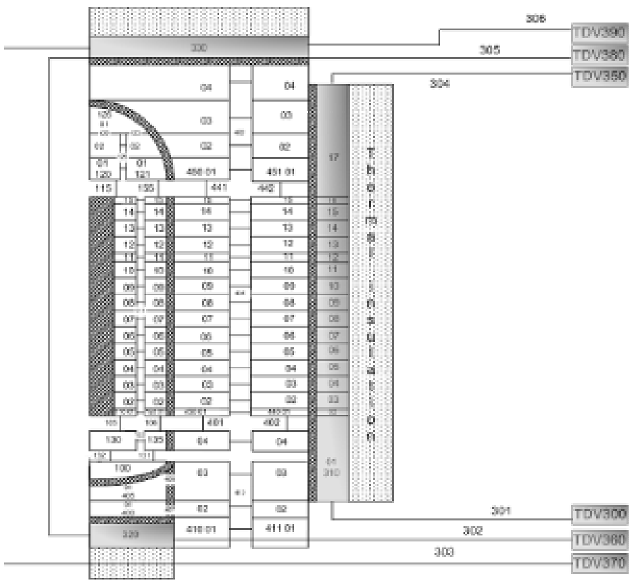

Figure 2. Nodalization for HTTR RCCS mock-up.

Systems are composed of three parts: reactor, reactor cavity cooling system, and water cooling panels. Heat transfer between each system is modeled using heat structures. The heater segments are divided into 15 volumes to the axial direction to simulate the core. The reactor cavity between the heater segments and the pressure vessel, the pressure vessel and water cooling panels are modeled as two annulus components in the direction of radius, and each annulus components is connected by the multiple junction. This modeling features enable to simulate the natural convection phenomena in the annulus. The thermal power of heater segments surface is fixed to the boundary condition of interior for the heat structure to simulate the decay heat.

In order to simulate the radiation heat transfer, enclosure concept was applied; the problem was considered as two enclosures. One is composed of outer surface of the core and the inner surface of the reactor pressure vessel, the other is composed of the outer surface of the reactor pressure vessel and the outer surface of the water cooling panel. To compute radiation heat transfer between two surfaces, a view factors (which is also called a configuration or shape factor) were calculated using NEVADA (Net Energy Verification And Determination Analyzer) tools [3].

2.4 Results

Figure 3 shows the experimental and the calculated surface temperature profiles of the core vessel, the pressure vessel and the water cooling panel for benchmark problem I of the vacuum case (vacuum in a pressure vessel at 1.3 Pa). The open symbol and close symbol denote the experimental data and the analytical results, respectively.

As shown in figure 3, the calculated results for temperature of the flange at the height of 2.8 m show slightly high values but the analytical results generally show good agreements with experimental data.

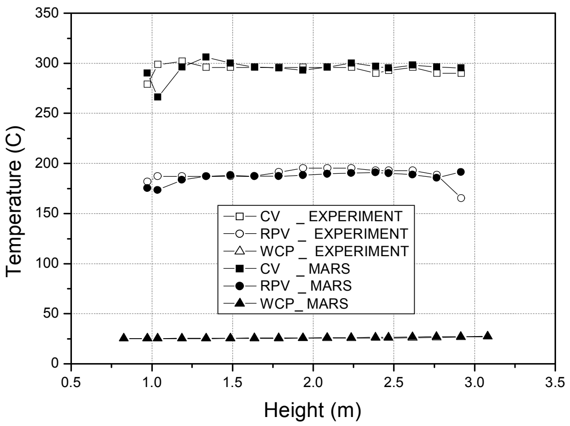

Figure 3. Temperature distribution (Benchmark problem Ⅰ).

The experimental pressure vessel temperature shows large drop at top. However that in the MARS assessment shows slight increase. This is caused by the flange modeling in MARS. While in the actual case, heat is lost in the flange, the MARS code neglects it. The MARS input data seems to be modified to deal with heat loss at the flange section. Temperatures on the cooling panels show almost uniform values near 26℃~33℃, close to the temperature of the cooling water.

Also, heat transfer inside pressure vessel occurs dominantly radiation heat transfer. Other T/H parameters calculated as follows: the flow rate of the water is 2.778 kg/s, the inlet and outlet temperatures are 26℃, 33℃ respectively, total heat removal rate by the RCCS is 31.2 kW and radiation heat transfer rate is 20.6 kW, natural convection rate is 10.6 kW. Radiation heat transfer rate occupies about 66% of total heat transfer rate.

3. Conclusion

The IAEA Benchmark Problems for HTTR RCCS Mockup test were calculated in order to assess MARS code applicability to the gas-cooled reactor safety analyses. The calculated results show good agreements in temperature with a maximum deviation around 4.2%. Deviation was evaluated to be originated from the simplification of complicated geometry and from the modeling capability of heat transfer characteristics in the HTGR components such as flange and support legs. Especially, it was found that the radiation heat transfer in the reactor cavity plays an important role in the afterheat removal phase by the RCCS. Thus, it is concluded that MARS code can be successfully to calculate the RCCS cooling capability of HTGR.

REFERENCES

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[3] TAC Technology, Net Energy Verification And Determination Analyzer, NEVADA Software Package User's Manual 1997.