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MELCOR Model Development of High Temperature Gas-cooled Reactor

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1. Introduction

The development of safety evaluation tools for High Temperature Gas-cooled Reactor (HTGR) is one of the major challenging issues on the development of licensing technology for HTGR. The safety evaluation tools of HTGR can be developed in two ways - development of new HTGR-specific codes or revision of existing codes. The KINS is considering using existing analytic tools to the extent feasible, with appropriate modifications for the intended purpose. The system-level MELCOR code is traditionally used for LWR safety analysis, which is capable of performing thermal-fluid and accident analysis, including fission-product transport and release. Recently, this code is being modified for the NGNP HTGR by the NRC.

In this study, the MELCOR input model for HTGR with Reactor Cavity Cooling System (RCCS) was developed and the steady state performance was analyzed to evaluate the applicability in HTGR.

2. Development of MELCOR Input Model

MELCOR input model was developed for 600 MWth HTGR design, which is based on General Atomics' GT-MHR (Gas Turbine-Modular Helium Reactor). GT-MHR consists of core with prismatic block made of graphite and UO_2 TRISO-coated particle, Reactor Pressure Vessel (RPV), RCCS and Power Conversion System (PCS) with turbine, compressor, etc.

The design parameters of GT-MHR considered in this study are shown in Table 1.

Table 1: Design Parameters of GT-MHR

Parameters [Unit]	Value
Reactor Power [MWt]	600
Coolant (Helium) Flow Rate [kg/s]	320
Height of Active Core [m]	7.93
Effective Radius of Active Core [m]	2.41
Core Inlet Temperature [°C]	491
Core Outlet Temperature [°C]	850
Core Inlet Pressure [psi]	1,025
Core Outlet Pressure [psi]	7.4

In addition, Figure 1 shows the nodalization of developed MELCOR model.

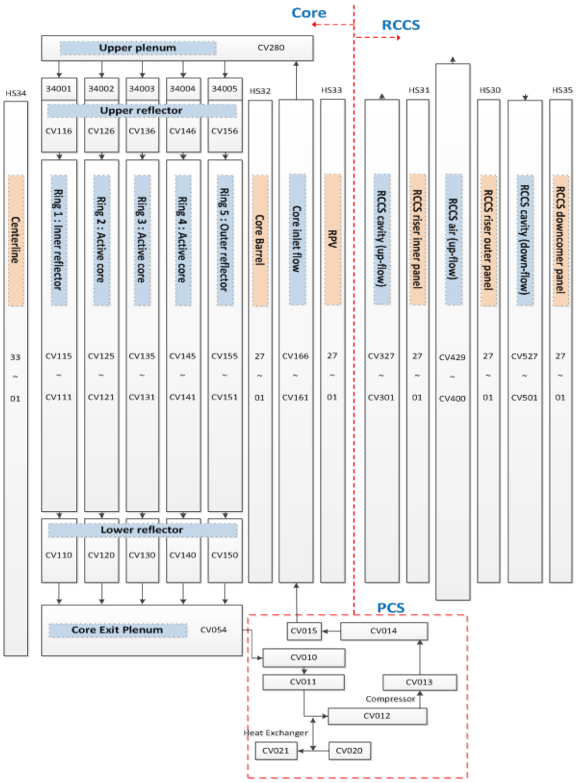

Fig. 1. Nodalization of developed MELCOR model

2.1 Core Model

MELCOR 2.1 was mainly updated on COR package to be applied to HTGR.

Fuel element in core (COR) package of MELCOR 2.1 corresponds to the fuel compact of GT-MHR while cladding element does to graphite block. Cladding is assumed to be a cylinder with radial temperature distribution. Reflector is considered to be Canister-next-to Blade (CB) element.

The core of GT-MHR is composed of upper reflector, active core and lower reflector in axial direction while inner reflector, three rings of active core and outer reflector in radial direction.

Tanaka-Chisaka model is used as the heat transfer model considering conduction and radiation between blocks in radial direction. Graphite oxidation model is included in the existing oxidation model to take radiation heat transfer affected by graphite properties into account. In addition, the effect of bypass flow between blocks can be considered.

The initial temperature condition of CVs (Control Volumes) in core is 764 K. The initial pressure conditions are calculated to be proportionally decreased with height when the pressure of RCCS bottom is 7.025375 MPa.

The developed core model is based on "PMR600" input provided by SNL (Sandia National Laboratory).

2.2 RCCS Model

Riser of RCCS and inner/outer cavity around the riser are modeled as CV for air flow. Inner/outer surface of riser panel and inner panel of downcomer of RCCS are considered as Heat Structure (HS).

The initial temperature condition of all CVs and HSs in RCCS is 316 K. The initial pressure conditions are calculated to be proportionally decreased with height when the pressure of RCCS bottom is 101.31 kPa.

Symmetry condition is used in the downcomer as outermost HS to consider insulation effect. Stainless-steel-304 is adopted for material properties of HS.

3. Analysis Results

Steady state of GT-MHR was simulated with developed input model to validate the calculation capability of MELCOR 2.1 prior to accident analysis.

The coolant temperature at core outlet is 1,120 K as shown in Figure 2. It accurately predicts the target core outlet temperature of GT-MHR in Table 1.

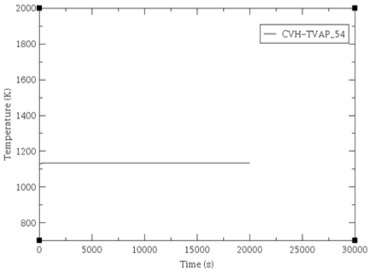

Fig. 2. Coolant temperature at outlet plenum

As shown in Figure 3, the maximum fuel temperature is 1,520 K which is below the operation limit condition. The maximum temperature of GT-MHR in normal operation is allegedly 1,250°C which is predicted in accuracy in this analysis.

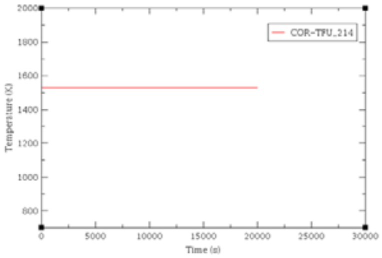

Fig. 3. Maximum fuel temperature

The calculated helium coolant flow rate is 320kg/s and pressure drop through core is 0.051 MPa. Both results predicted the design parameters accurately.

Figure 4 shows the calculated air flow rate in RCCS. It is predicted to be about 2 kg/s while actual expected value is 14.3 kg/s. The error of air flow rate in RCCS could have an influence on accident analysis results since the heat removal through RCCS plays a key role in accident condition. Thus, the cause of error in RCCS flow rate shall be resolved by further validation.

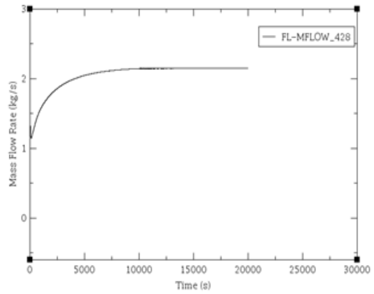

Fig. 4. Air flow rate in RCCS

4. Conclusions

HTGR model with design characteristics of GT-MHR was developed using MELCOR 2.1 code to validate the applicability of MELCOR code to HTGR. In addition, the steady state of GT-MHR was analyzed with the developed model. It was evaluated to predict well the design parameters of GT-MHR.

The developed model can be used as the basis for accident analysis of HTGR with further update of packages such as Radio Nuclide (RN) package.

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