An Evaluation for Natural Circulation Flow through ERVC in the SMART

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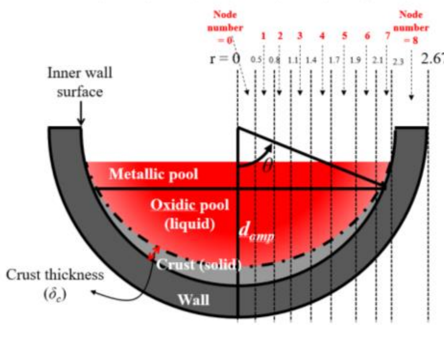
1. Introduction

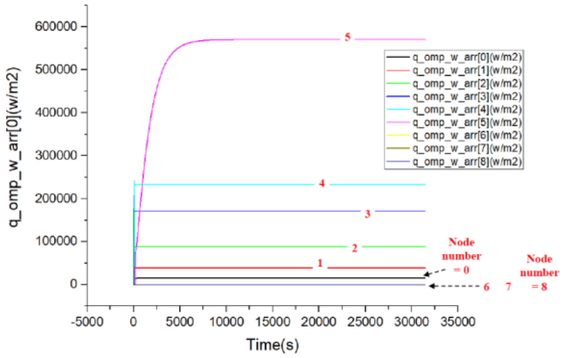
KAERI (Korea Atomic Energy Research Institute) is developing the SMART (System-Integrated Modular Advanced Reactor) 365 MW_{th} in which the IVR (In-Vessel corium Retention) through ERVC (External Reactor Vessel Cooling) is adopted as a severe accident mitigation system to maintain the integrity of the reactor vessel [1]. The preliminary evaluation using the SPACE 2.19a was performed to calculate a natural circulation flow rate through the annular gap between the outer reactor vessel wall and the insulation of the reactor vessel with assuming the severe accident conditions [2, 3]. In particular, the corium thermal power was assumed as 0.56% of the thermal power of the SMART based on the previous work [4]. A new thermal power of the corium based on the current SMART design is calculated using the SIMPLE (Severe In-vessel Melt Progression in Lower plenum Environment) code [5]. Therefore, it is necessary to reevaluate that the ERVC can sufficiently remove the thermal load from the corium to the outer reactor vessel during the severe accident.

2. Corium Thermal Power

The SIMPLE code was used to calculate the thermal power of the corium during the severe accident in the SMART [4]. The calculated heat fluxes on the vessel wall inner surfaces are shown in Fig. 1. The predicted angles of the oxide pool and metallic pool are 34.03^o and 43.34^o, respectively (Fig. 1(a)). We decided to use the maximum heat flux 0.58 MW/m^2 at node 5 and the corium layer angle 45^o as the wall boundary condition of the SPACE analysis for the conservative evaluation of the ERVC (Fig. 2) [6].



(a) Node system used in the SIMPLE analysis



(b) Calculated heat fluxes on the vessel inner wall

Fig. 1 SIMPLE calculation results.

3. SPACE Analysis

3.1 Input Models and Calculation Assumptions [2]

Input models and calculation assumptions (Fig. 2 and Table 1) were developed based on the current design parameters of the ERVC in the SMART. The coolant supplied by the IRWST (TFBC106) circulates from the cavity water pool (Node C100) through the gap between the outer reactor vessel and insulation (Nodes. C30 - C90). The water inlet is a single face 11. The cross flow faces of No. 63 and 93 are the water circulation outlet and steam outlet, respectively. The spherical and cylindrical reactor vessels are simulated using the heat structure numbers 100 and 200, respectively. The generated steam is vented into the containment atmosphere (TFBC 104). In all calculations, the initial conditions are assumed to be ambient pressure with no coolant flow rate. In addition, a sensitivity calculation was conducted by changing the heat flux from 0.58 MW/m^2 to 0.72 MW/m^2 and 0.43 MW/m^2 for seeing the calculated natural circulation flow rates according to the heat flux variation.

Table 1. Basic Analysis Conditions [2]

- Coolant injection area : 0.5 m^2 - Steam exit area : 0.5 m^2 - Coolant circulation port area : 0.5 m^2 - Steam exit level : 9.8 m from bottom head - Coolant circulation port level : 4.8 m from bottom head - Gap between external wall and insulation : 0.1 m - Heat flux on the external wall : 0.58 MW/m^2 - Water level : 4.9 m from bottom head - Injected coolant temperature : 50 ℃

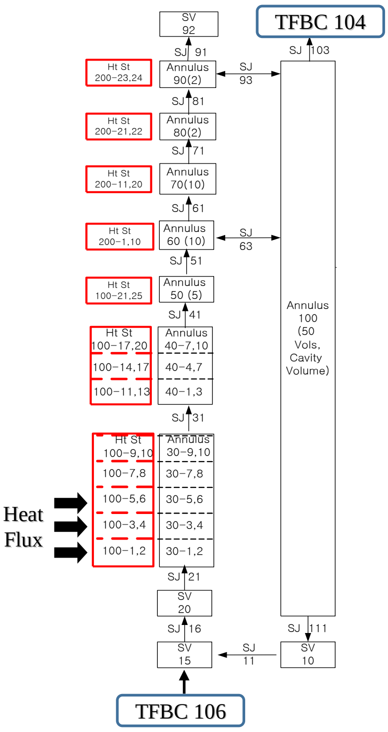
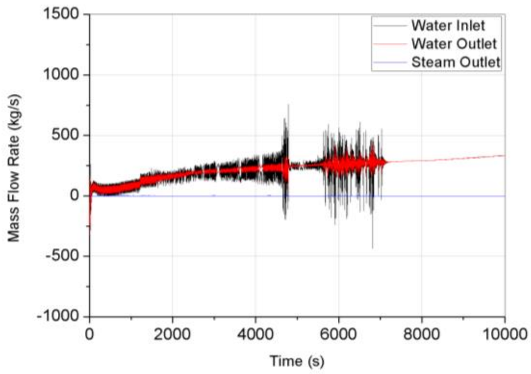


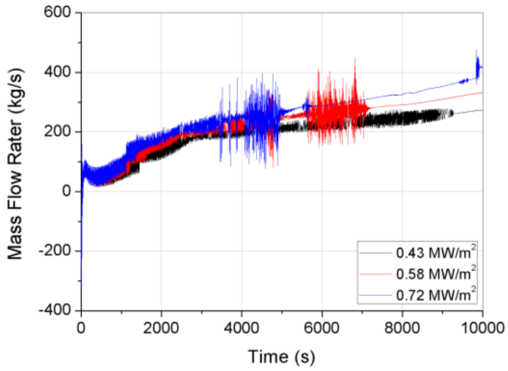
Fig. 2. Nodalization for the SPACE analysis [2]

3.2 Discussion on the Calculation Results

The predicted natural circulation flows through the annular gab are shown in Fig. 3. Fig. 3(a) shows that the natural circulation flow of approximately 460 kg/s is developed at 10,000 s through the annulus gap at the wall heat flux 0.58 MW/m^2 after passing the period of an oscillating flow. Fig. 3(b) shows that the natural circulation flow rates at 10,000 s are developed to approximately 420 kg/s and 510 kg/s at the wall heat flux of 0.43 MW/m^2 and 0.72 MW/m^2, respectively. The CHF test results regarding the IVR-ERVC showed that the calculated natural circulation flow rates of approximately 460 kg/s at the heat fluxes 0.58 MW/m^2 can sufficiently cool down the reactor vessel without the CHF occurrence [4]. From the sensitivity calculation results, we judged that the calculated natural circulation flow rates are a reasonable result.



(a) Natural circulation flow rate at heat flux 0.58 MW/m^2



(b) Natural circulation flow rate at the water outlet according to various heat fluxes

Fig. 3. SPACE Analysis Results

4. Conclusions and Further Work

KAERI performed an evaluation for the IVR-ERVC of the SMART through predicting the natural circulation flow rate through the annular gap using the SPACE code. In this calculation, the predicted corium thermal power 0.58 MW/m^2 by the SIMPLE code was used as the wall boundary condition of the SPACE analysis. From the calculated natural circulation flow and the CHF test data, we can conclude that the reactor vessel integrity can be maintained by the operation of the IVR-ERVC system during the severe accident. As a further work, a structural integrity analysis for the reactor vessel of the SMART will be conducted.

ACKNOWLEDGMENTS

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