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Simulation of CS28-1 experiment by using CANDU severe accident code, CAISER

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1. Introduction

Based on the background that the acceptable standard of fission product release is definitely defined in the severe accident legislation, the necessity of accurate severe accident analysis code for a CANDU reactor is raised in Korea. Hence, the severe accident code development for a CANDU reactor, named as CAISER (Candu Advanced Integrated SEveRe accident code) has started in KAERI from last year with 5 years plan. The modeling of the core degradation phenomena happening in the fuel channel has been introduced in the previous paper [1]. The governing equations for the main components in a fuel channel, which are a fuel, cladding, a pressure tube and a calandria tube, has been developed. All kinds of heat transfer including the oxidation heat generation was considered in the energy equation. The 3-dimensional nodal systems afford to calculate the detailed temperature distribution in a fuel channel. The melting and relocation process, including the fuel rod slumping, has modeled in a mass conservation equation. The pressure tube and the calandria tube are nodalized with 2-dimensional nodal system, one is in the azimuthal direction, and the other is in a flow direction.

With a purpose of verification of the CAISER code, the CS-28 experiment was calculated by using the CAISER code. Since there is no severe accident experiment in the world for CANDU reactor, although the CS-28 experiment does not treat the melt and relocation process in severe accident condition, we can validate the code for the heatup phase, which is related to the all kinds of heat transfer in a fuel channel. The temperature distribution in fuel rods, a pressure tube and a calandria tube has secured and compared with the experimental data.

2. CS28-1 experiments

The CS28-1 experiment [2] is one of the three experiments of the CS28-x series of experiments (CS28-1, CS28-2, and CS28-3) using a full scale horizontal fuel channel with a 28-element fuel bundle. Figure 1 illustrates the cross-section of test fuel channel in the CS28-1 experiment. The superheated steam at about 700 °C was injected into the inlet of the test section with a mass flow of 15 g/s. The test fuel channel is submerged in a water of 40°C, and the 28-element fuel bundle of 1.8m length is installed in the test fuel channel. The fuel bundle consists of three rings of FES (Fuel Element Simulator): 4 elements in the inner, 8 elements in the middle, and 16 elements in the outer ring. Since heater is installed inside FES, the power of test bundle was controlled with time in the experiment, which increase with time step by step, as shown in Fig.2.

The surface temperature of the fuel element simulators (FES) is raised to have an oxidation reaction, which generates a hydrogen gas with the exothermal heat generation.

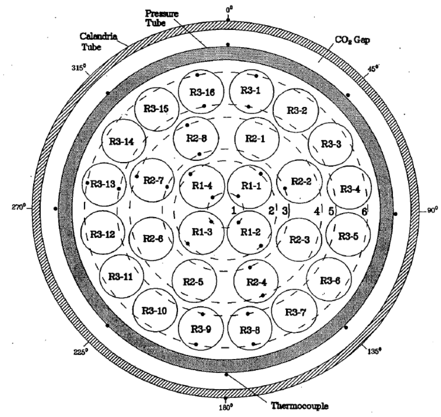


Fig.1 Cross-sectional view of CS28-1 experimental test section.

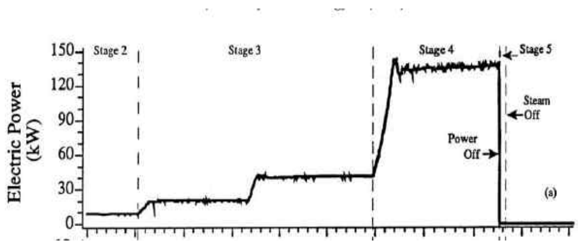


Fig.2 Electric power to the heater in CS28-1 experiment.

3. Simulation results for CS28-1 experiments

In order to simulate CS28-1 experiment, the cross-section of fuel channel has been nodalized with 3 by 6 node system, which is shown in Fig. 3. The pressure tube and calandria tube has also a number of azimuthal nodes. The fuel channel has 12 nodal numbers in a flow direction. The FES is modeled by the fuel and cladding in CAISER code, while the material property is corrected to reflect the electric heater in the experiment.

Figure 4 shows the comparison results between the experimental data and the numerical simulation results of CAISER code. The FES temperature is compared for the inner, middle and outer ring rods (Fig. 4(a)). The temperature is shown to increase with the increase of electric power, and it increases steeply by the exothermal oxidation reaction above 1200K. The FES temperature at inner ring has the highest temperature, while the FES temperature at outer ring has the lowest temperature, since the heat sink of fuel bundle is located at the outside of fuel channel, which is cold water surrounding the fuel channel. It is revealed that the the FES temperature distribution which is calculated by CAISER is in line with the experimental data.

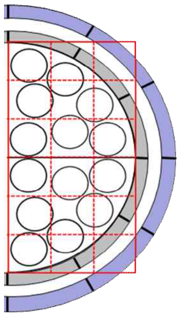
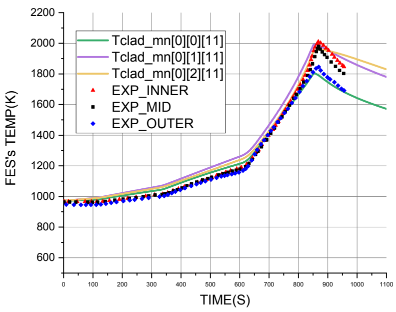
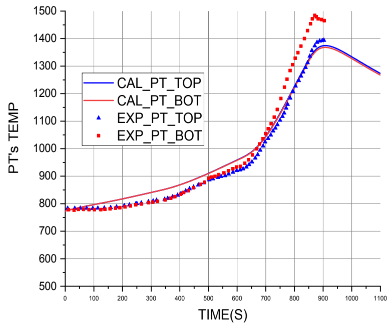


Fig. 3 CS28-1 nodal system in CAISER code

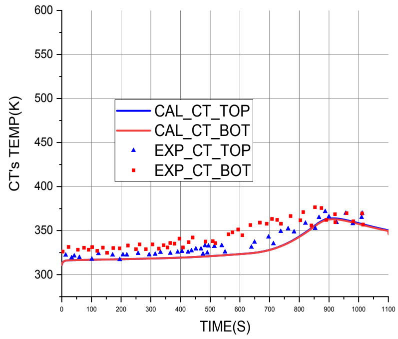
From the Fig. 4(b), it is shown that the pressure tube temperature of bottom region is higher than that of top region. Since the fuel rods experience the slumping in a high temperature condition, the fuel rods moves to the downward direction, which results the decrease of convective heat transfer from fuel rods, and the high coolant temperature in the bottom region, and it results to the high temperature of pressure tube in the bottom region.



(a) FESs temperature evolution



(b) A pressure tube temperature evolution



(c) A calandria tube temperature evolution

Fig. 4 Comparison of temperature distribution with the experimental data.

However, in the CAISER simulation, the coolant temperature has a temperature distribution only in a flow direction. That is, the coolant temperature is same on the cross-sectional plane. Hence, the pressure tube temperature is almost same between the top and bottom region.

On the other hand, figure 4(c) shows the calandria tube temperature is well predicted by the simulation of CAISER code.

3. Conclusions

The CS28-1 experiment was simulated by using CAISER code, and compared with the experimental data. It is revealed that the FES temperature distribution is in line with the experimental data. However, the temperature distribution of the pressure tube shows little difference in an azimuthal direction, which is different with the experimental data, because the coolant temperature in CAISER code has 1-dimensional distribution in a flow direction. The effect of the local coolant temperature distribution on the cross-sectional section should be considered in a future.

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