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Analysis of Air-Water Two Phase Flow for K-HERMES-HALF Experiment using RELAP5/MOD3

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1. Introduction

The IVR (In-Vessel corium Retention) through the ERVC (External Reactor Vessel Cooling) is known to be an effective means for maintaining the integrity of the reactor pressure vessel during a severe accident in a nuclear power plant [1, 2]. This measure has been adopted in some low-power reactors such as the AP600, AP1000, and the Loviisa nuclear power plants as a design feature, and in the high-power reactor of the APR (Advanced Power Reactor) 1400 as an accident management strategy for severe accident mitigation. As part of a study on two-phase flow in the reactor cavity under external reactor vessel cooling in the APR1400, K-HERMES-HALF experiment (Hydraulic Evaluation of Reactor cooling Mechanism by External Self-induced flow-HALF scale) had performed at KAERI. This large-scale experiment using a half-height and half-sector model of the APR1400 uses the non-heating method of the air injection. In this research, K-HERMES-HALF test results had been evaluated by using RELAP5/MOD3 computer code to observe and evaluate the two-phase natural circulation phenomena through the annulus gap between the outer reactor vessel and the vessel insulation material.

2. K-HERMES Test Facility

Fig. 1 shows schematic diagram of the K-HERTMES test facility. Since the heating method is very difficult and expensive for a large scale and three-dimensional spherical test section, the non-heating method of an air injection was decided upon in this test. The facility consists of 3 parts, namely, a main test section, an air supply system, and a water recirculation system. The main test section is a half scaled-down reactor vessel and an insulation part which is prepared by utilizing the results of a scaling analysis proposed by F.B. Cheung to simulate the APR1400 reactor and insulation system. By a scaling analysis, the vessel diameter, height, water level, shear key size, and ICI nozzle diameter are linearly scaled-down, which is a half scale. Due to the conical configurations of the insulation material, the minimum gap region between the outer reactor vessel and the insulation is located at 56.6^o based on the vertical axis of the reactor vessel.

The natural circulation flow is discharged through three outlets in the insulation. The area and vertical position of each outlet are adjustable. The flooded water through the outlet is accumulated in the sub-tank and then the water in the sub-tank is transferred to the water reservoir by a water pump. Since the flooded water through each outlet port is independently re-circulated by the water recirculation system, the natural circulation flow in the experimental section has no effect on the water recirculation system. The recirculation flow rate is measured by a water flow meter which is installed on the recirculation water pipe between the pump and the water reservoir. The air flow rate towards each air distributor is controlled and measured by an air control valve and an air flow meter. Because of the higher heat flux in the top region of the vessel, more injectors are arranged in the top region of the lower head vessel.

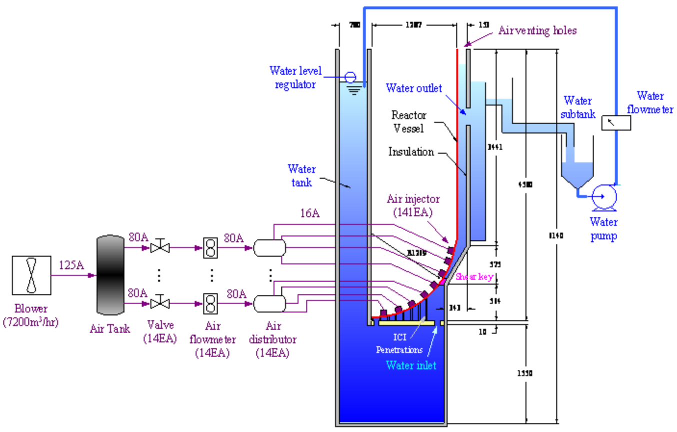

Fig. 1. Schematic diagram of the K-HERMES test facility.

3. Results and Discussion

The RELAP5/MOD3 computer code was used in this evaluation of K-HERMES-HALF test results. Fig. 2 shows the RELAP5/MOD3 results on the water circulation mass flow rate as a function of time. In this condition, the air injection mass flow rate, the water inlet area, the water outlet area and the water outlet position to the water level are 13.0 % of the total air injection mass flow rate, 0.317 m^2, 0.297 m^2, and 0 m, respectively. As the time increases, the water circulation mass flow rate maintains a constant value of approximately 330 kg/s. The mass flow rate through the air outlet hole is very small, because of the air venting. A uniform oscillatory coolant flow was generated in the upper part of the test section.

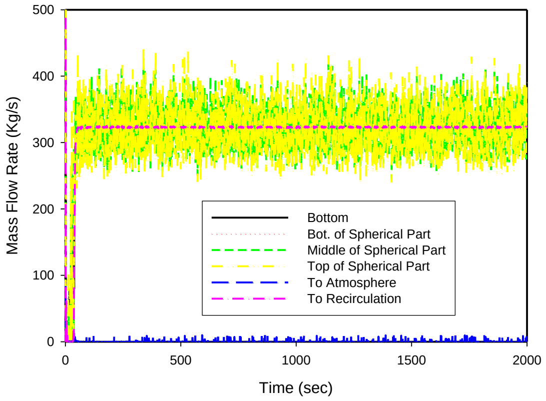

Fig. 2. RELAP5 results on coolant mass flow rate as a function of time.

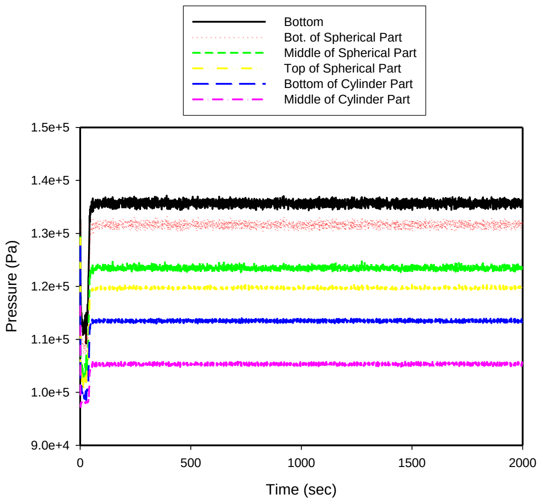

Fig. 3. RELAP5 results on the local pressure as a function of time increase.

Fig. 3 shows the RELAP5/MOD3 results on the local pressure as a function of time. As the time increases, the local pressure maintains a constant value with a small oscillation. The local pressure in the bottom of the test section maintains approximately 1.35 bars. Fig. 4 shows a comparison of the RELAP5/MOD3 results with the experimental results on the water circulation mass flow rate as a change of air injection mass flow rate. The RELAP5/MOD3 results are very similar to the experimental results. Increase in the air injection mass flow rate leads to an increase in the water circulation mass flow rate. Fig. 5 shows a comparison of the RELAP5/MOD3 results with test results on the local void fraction. Increase in the air injection mass flow rate leads to increases in the local pressure and a pressure difference between the lower and the upper parts, which results in an increase in the water circulation mass flow rate. In general, the RELAP5/MOD3 results are very similar to the experimental results.

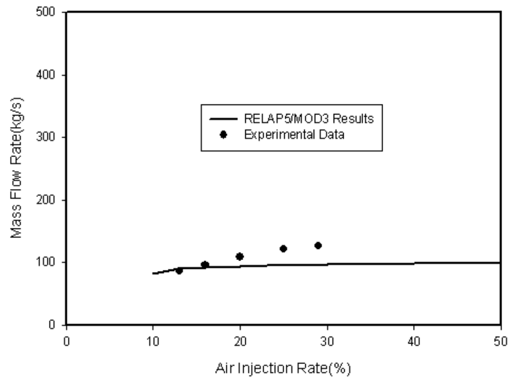

Fig. 4. A comparison of the RELAP5/MOD3 results with test results on the water circulation mass flow rate.

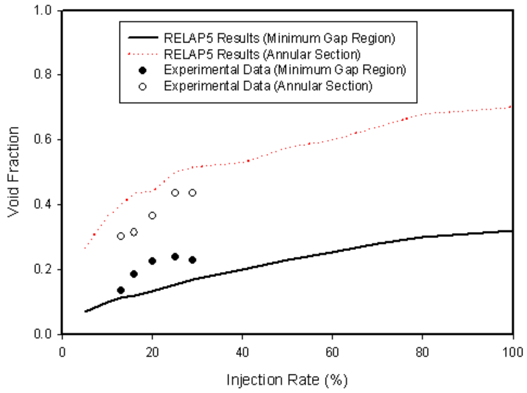

Fig. 5. A comparison of the RELAP5/MOD3 results with test results on the local void fraction.

4. Conclusion

The K-HERMES-HALF experiment has been analyzed to verify and evaluate the experimental results using the RELAP5/MOD3 computer code. In general, the RELAP5/MOD3 results on the water circulation mass flow rate and the local void fraction are very similar to the experimental results.

ACKNOWLEDGMENTS

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