Performance Test Results on Cross Flow Characteristics in a Three Full Scale Fuel Assemblies

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1. Introduction

To evaluate the reactor thermal margin of APR+, the reactor core flow distribution including both axial and lateral directional hydraulic resistances of fuel assemblies should be quantified. The 3-Ch cross flow (3-FA) test facility has been constructed with three full-size fuel assemblies [1] to investigate the cross flow characteristics and to get benchmark data for the core simulators of the reactor core flow distribution test facility (ACOP). ACOP will use 257 core simulators and each core simulator should have the same core flow characteristics of the APR+ fuel assembly.

Using the 3-FA test facility, the performance tests have been performed. The axial and lateral directional hydraulic resistances of fuel assemblies have been measured and the test results have been compared to the CFD calculation results.

2. Description of Test Facility

The 3-FA test facility was designed to operate at the low pressure (1.0 MPa) and low temperature (100 ^{o}C) conditions. The test facility simulates the hydraulic characteristics in the reactor core. The Euler Number is conserved 1/1 so that the ratio of pressure drop to the dynamic pressure of the core is conserved and the fluid velocity in the test facility is reduced accordingly.

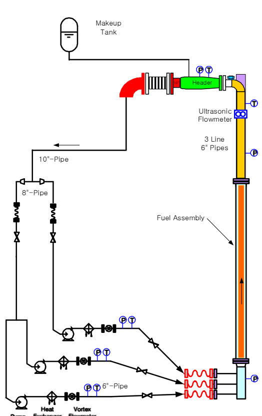

Fig. 1. Schematic diagram of the 3-FA test facility

The 3-FA test facility consists of a main test section, three loops, upper and lower piping structures, a common header, and a makeup tank (Fig. 1). The main test section comprises 3 full-size APR+ fuel assemblies and each assembly can be separated by the movable isolation plate. The isolation plates can be withdrawn to give open space for the cross flow to adjacent assemblies.

Three pumps provide circulation water through the fuel assemblies. The pump speed is controlled by an inverter and can deliver sufficient water to a fuel assembly to cover at least 120 % of the nominal flow rate of the APR+ reactor. Heat exchangers are used to provide the desired water temperature and the system pressure is maintained by the makeup tank.

At the inlet of the test section, three vortex flow meters have been installed and three ultrasonic flow meters will measure the flow rates at the outlet of the test section. There are 42 pressure taps at the back part of the test section for the measurement of axial and lateral differential pressures and 84 differential pressures are measured (Fig. 2). In addition, characteristics of the flow vibration near the grid spacer will be measured by the LASER vibrometer through the four windows installed at the front part of the test section.

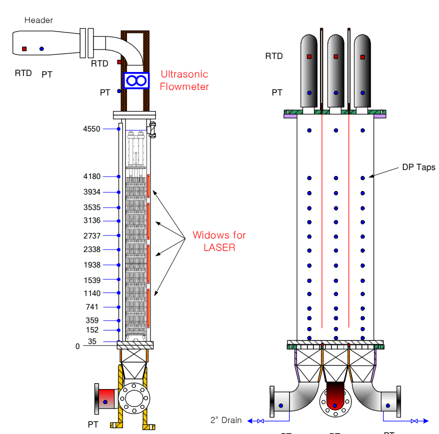

Fig. 2. Locations of the instruments

3. Performance Test Results

Several cross flow test have been performed to check the performance of the test facility. A cross flow test has been performed to get data on the axial K factor distribution. The isolation plates, which were located between adjacent two fuel assemblies, were fully inserted so that the each channel was completely separated and the 100 % flow rate was provided for each channel. K factors were calculated based on the following equation;

$$K = 2\rho \frac{A^2}{m^2} \Delta P \quad (1)$$

where, ΔP is the measured pressure drop for the given section, m is mass flow rate, A is the flow area, and ρ is density of water. Table 1 shows the calculated axial K factors. The calculated K factor for the given section is used to calculate the sectional axial flow rate as well as the cross flow rate for other tests.

Table 1: Axial *K* factors

	Ch-1	Ch-2	Ch-3
Lower end fitting	0.0030	0.0027	0.0030
Grid 1	0.0005	0.0008	0.0005
Grid 2	0.0014	0.0014	0.0014
Grid 3	0.0015	0.0015	0.0015
Grid 4	0.0015	0.0015	0.0015
Grid 5	0.0017	0.0017	0.0017
Grid 6	0.0017	0.0017	0.0017
Grid 7	0.0017	0.0018	0.0018
Grid 8	0.0018	0.0018	0.0018
Grid 9	0.0017	0.0017	0.0017
Grid 10	0.0016	0.0016	0.0016
Inconel	0.0011	0.0012	0.0012
Upper end fitting	0.0004	0.0004	0.0004

A commercial CFD code of CFX version 12 has been used to evaluate the flow characteristics of the 3-FA test facility [2]. The simulation type is steady state and the turbulent flow is simulated numerically using the k-ε model. At the downstream exit, the usual Neumann-conditions are applied for the fully-developed flow. The tetra-prism mesh was generated by using ICEM code.

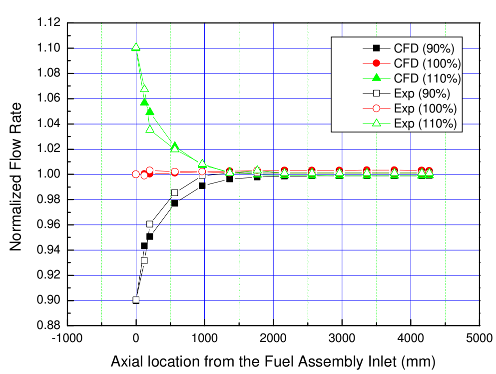

Fig. 3 Comparison of normalized flow rates between the Test-1 result and the calculation

Figure 3 compares the normalized flow rates between the Test-1 result and the calculation (Test-1 condition: Isolation plate was fully withdrawn and 90%, 100%, and 110% flow rates were provided for each channel). The results show that the cross flow characteristics are similar for both cases. The most of cross flow mixing were occurred within the 1/3 region from the entrance of fuel assembly. And the cross flow is not significant at the downstream of the fuel assembly, where a sufficient uniform flow condition is reached.

Figure 4 compares the normalized flow rates between the Test-2 result and the calculation (Test-2 condition: Isolation plate was fully withdrawn, and 95%, 110%, and 95% flow rates were provided for each channel). The results show that, for the symmetric flow rate condition, the cross flow mixing occurs within the 1/6 region from the entrance of fuel assembly.

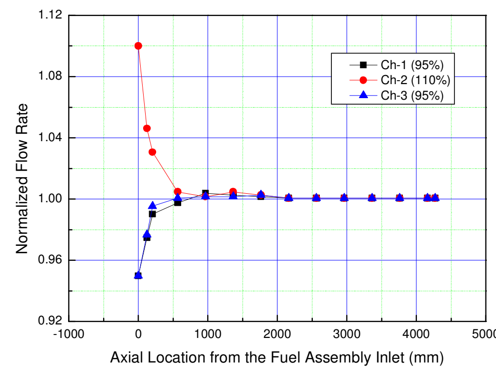

Fig. 4. Comparison of normalized flow rates between the Test-2 result and the calculation

4. Conclusions

Seversal tests have been performed to check the performance of the 3-FA test facility. The tests have been performed at the reduced temperature and pressure conditions. The test results show that the facility works properly and can be used to create the valuable test data for the cross flow characteristics of the APR+ fuel assembly. The test results will be used for the design verification of the core simulator of the ACOP.

Acknowledgement

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REFERENCES

[1] C. K. Park et al., Design and Construction of 3-Ch Cross Flow Test Facility, KNS Spring Meeting, Taebaek, Korea, May 26-27, 2011.
[2] J. H. Bae et al., Numerical Simulation for a Core Simulator of ACOP, KNS Spring Meeting, Taebaek, Korea, May 26-27, 2011.