Cross Flow Tests of APR+ Core Simulator

Kihwan Kim [a], In-Cheol Chu [a], Hae-Seob Choi [a], Dong-Jin Euh [a], Tae-Soon Kwon [a*]
[a]*Korea Atomic Energy Research Institute, P.O.Box 105, Yuseong, Daejeon, 305-600, Rep. of KOREA*
[*]*Corresponding author: tskwon@kaeri.re.kr*

1. Introduction

An accurate prediction of an APR+ core flow is in demand since the APR+ has 257 fuel assemblies, unlike in the APR1400. The APR+ reactor flow distribution test facility, which was named ACOP (APR+ Core Flow & Pressure Test Facility), was developed to conduct various hydraulic tests [1]. The 257 core simulators were installed in the ACOP to measure the hydraulic characteristics at the inlet and outlet of the fuel assemblies. The simulator was designed with a linear reduced scale of 1/5 to preserve a geometrically similar flow without hindering the dynamic similarity. The cross flow characteristic of the simulator may be regarded as of major importance to evaluate the pressure distribution at the outlet of the fuel assembly. This paper shows a cross flow test for each core simulator which are arranged in a row. The results are also compared with those of the HIPER and core simulators obtained from the CFD code, and are carefully examined.

2. Experimental facility

2.1 Core simulator of APR+

The core simulator was designed to measure the core inlet flow fields and pressure fields at the inlet and exit of the core, respectively. The simulator should have high representative tests in comparison to a realistic HIPER fuel assembly, which is the fuel channel of APR+. Therefore, geometric and dynamic similarity between the simulator and the HIPER fuel assembly was maintained through a scaling analysis. The 1/5 linear scale was adapted and the Euler number was preserved to simulate the effect of pressure drop of the fluid flow as shown in Table 1. A schematic of the core simulator is shown in Fig. 1. The venturi flow meter was installed at the inlet of the core simulator to measure the axial flow rate. The core simulator has four holes on each side of the quadrant to model the cross flow between adjacent core simulators.

2.2 3-FA test facility

As a previous work, the hydraulic characteristics such as the venturi flow meter and pressure drop of the core simulators were validated using the CALIP (Calibration Loop for Internal Pressure drop) test facility.

Table I: Main scaled value of core Simulator

	APR+ (HIPER)	Core Simulator
Core average temperature, ℃	309.6	60
Pressure drop, kPa	150.75	52.50
Exit pressure, MPa	15.51	0.2
Mass flow rate, kg/s	81.78	2.28
Length, mm	4527.5	905.5
Hydraulic dia', mm	12.656	34.612
Flow Area, m^2	2.352E-02	9.409E-04
Reynolds number	4.96E+05	1.79E+05

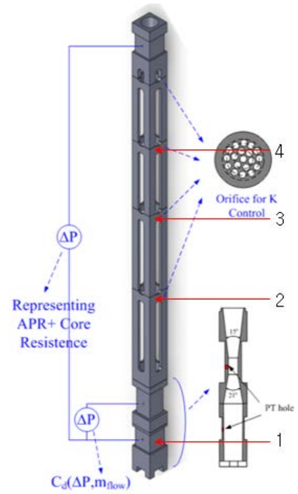

Fig. 1 Schematic of core simulator of APR+

CALIP consists of a main test section, a flow supply system with piping structures, a water reservoir with two heaters, and a data acquisition system. A more detailed description of CALIP is given in [2].

In the 3-FA main test section, the three parallel core simulators are arranged together in a row, as shown in Fig. 2. The two isolation plates are inserted between the neighboring core simulators.

Two ultrasonic flow meters are attached to the downstream of each core simulator to measure the exit flow rate. The total inlet flow rate is measured by two vortex flow meters in the flow supply system.

The cross flow tests were conducted under lower pressure and temperature conditions as shown in Table 1.

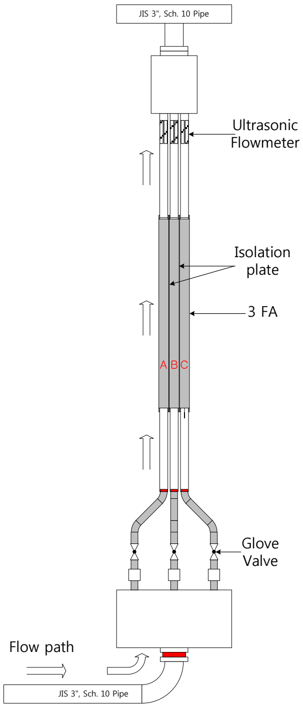

Fig. 2 Schematic of 3-FA test facility in the CALIP

The 90%, 100%, and 110% flow rates with respect to the reference value are provided to each core simulator, A, B, and C, respectively. The cross flow rates along the axial distance can be measured by changing the three kinds of isolation plates in the test section, as shown in Fig. 3. The location of the isolation plate coincides with the 2 through 4 positions of core simulator in Fig.1.

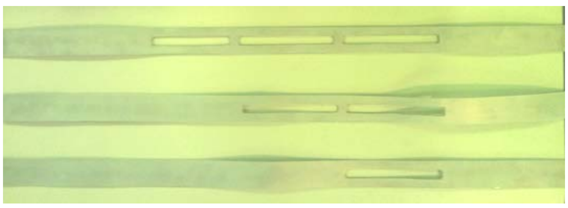

Fig. 3 Isolation plate with various holes

3. Test results

Fig. 3 shows the results of the cross flow ratio along the axial location for each core simulator. It was noted that the axial location of the HIPER fuel assembly is used to show together the results of the HIPER fuel assemblies and core simulators calculated using a commercial CFD code of CFX version 12 [3]. The test results show very similar to those of the HIPER fuel assemblies. However, there are some discrepancies at the 2nd point of the core simulator when comparing the CFD core simulator results, since the gap thickness of the isolation plate affects the fluid flow between the core simulators.

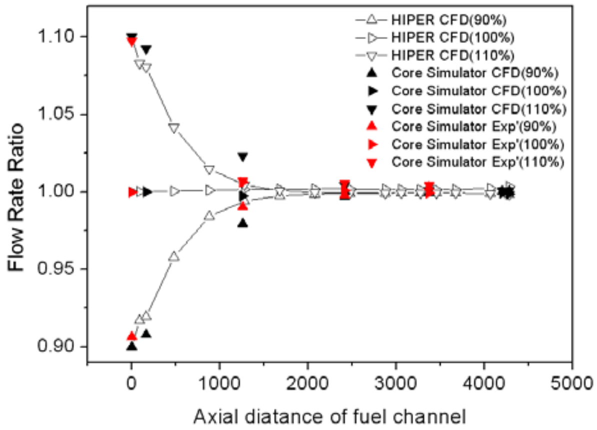

Fig. 3 Cross flow ratio of 3-FA test when compared with the results of the CFD code

The overall cross flows are decreased with an increase in the axial distance, which means that most of cross flow mixing is intensified when passing the entrance region. This tendency is reasonable from the view point of performance and its compatibility to the ACOP facility.

4. Conclusions

An experimental study was conducted to evaluate the cross flow characteristics of 3-core simulators using the CALIP test facility. The results are carefully examined and verified through a comparison with other reported results. For a separate channel mass flow rate of 90%, 100% and 110%, the results shows good agreement with those of the HIPER fuel assembly obtained from CFD codes. In the overall evaluation, the used core simulator to simulate the cross flow has a promising design for application to the ACOP facility.

Acknowledgement

The authors would like to gratefully acknowledge the financial support of Ministry of Education, Science and Technology.

REFERENCES

[1] D. J. Euh. et al., Development of a Test Facility to Simulate the Reactor Flow Distribution of APR+, Transactions of the KNS Spring Meeting, May 26-27, 2011, Taebaek, Korea.
[2] Y. J. Ko. et al., Design and Performance Verification of Fuel Assembly and Steam Generator Simulators for SMART Reactor, The 14th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-14), Sep. 25-30, 2011, Toronto, Ontario, Canada.
[3] J.H. Bae. et al., Cross Flow Characteristics in a Three Fuel Assemblies, Proceedings of ICAPP'12, Paper 12055, June 24-28, 2012, Chicago, USA.