Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

A Numerical Study for Core Subchannel Flow Test of a Sodium-Cooled Fast Reactor

Jonggan Hong[1,*], Sun Rock Choi[1], Seok-Kyu Chang[1], Dong-Jin Euh[1], Hyeong-Yeon Lee[1], Jae Wan Ahn[2]

[1]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Republic of Korea*
[2]*CD-adapco, #1306 JEI Platz Building, 459-11 Gasan-dong, Geumcheon-gu, Seoul, 153-792, Republic of Korea*
[*]*Corresponding author: hong@kaeri.re.kr*

1. Introduction

According to a long-term SFR program approved by the Korean government, a prototype SFR plant will be constructed by 2028. A core subchannel flow test for the SFR has been being progressed at KAERI to evaluate a thermal margin in design codes quantitatively [1,2]. Based on sensitivity and uncertainty analyses, friction coefficient and mixing coefficient are going to be determined experimentally. The friction coefficient determines a distribution of coolant into each subchannel, and the mixing coefficient increases radial heat transfer by a crossflow between neighboring subchannels. Prior to the experiments, a numerical study for the subchannel flow test was performed to investigate the characteristics of the subchannel flow and obtain design parameters for measurement devices.

2. Methods and Results

A non-dimensional analysis shows that correlations related with the friction coefficient and mixing coefficient depend only on *P/D*, *H/D*, and Reynolds number. Thus, a fuel pin assembly for the subchannel flow test using water was designed and fabricated as shown in Table 1 maintaining the *P/D*, *H/D*, and Re in the prototype reactor. The subchannels were divided into three types according to channel shape (Fig. 1). The test assembly consisted of a 37-fuel-pins bundle, a measurement part, an inlet, and an outlet (Fig. 2).

Table 1 Hydraulic specifications of fuel pin assemblies for a prototype reactor and the present test.

	271-pins (Na) Prototype reactor	37-pins (Water) Flow test
Fuel pin diameter (mm)	7.4	8.0
Wire diameter (mm)	0.93	1.0
Wire pitch (mm)	204.9	221.5
Fuel pin length	3400	1500
P/D	1.125	
H/D	27.69	
Reynolds number	37110	
Assembly flow rate (kg/s)	17.6	5.49

The flow distribution and pressure drop of a flow regulator part with a complex shape in the assembly were numerically calculated at mass flow rates of 2, 4, 6, and 8 kg/s. The standard k-epsilon model and high y+ wall treatment were employed and a steady state solution for a water (density: 983.2 kg/m^3, dynamic viscosity: 4.67×10^{-4} kg/m·s) flow was obtained (Fig. 3). There were four high velocity regions before the flow regulator owing to the influence of four inlets. After the flow regulator, however, the velocity distribution became uniform, which confirmed the performance of the flow regulator. The velocity in the axial cross section of the flow regulator ranged from 0 to 0.67 m/s. Consequently, a correlation between the pressure drop and average velocity at the flow regulator was acquired as

$$\Delta P = 2033\, v^2 + 316.9\, v . \qquad (1)$$

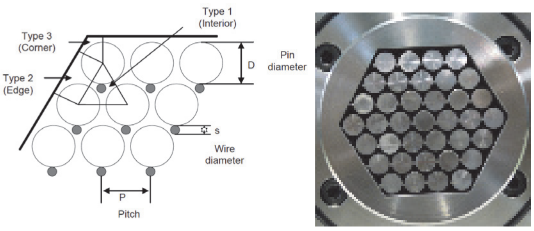

Fig. 1 Schematic diagram and photograph of the subchannels of a fuel pin assembly.

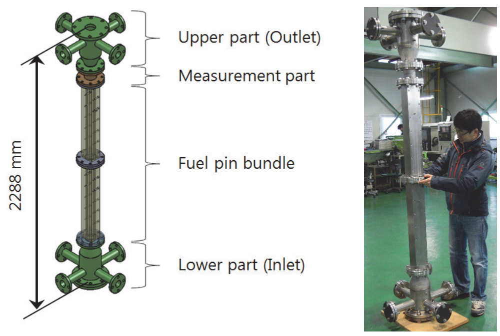

Fig. 2 Schematic diagram and photograph of a fuel pin assembly for the flow test.

The water flow in all parts of the test assembly was analyzed numerically at a mass flow rate of 4.345 kg/s. The flow regulator was substituted with a porous media using Eq. (1) to simplify the numerical calculation. The standard k-epsilon model and high y+ wall treatment were employed and a steady state solution was obtained.

Fig. 4 shows the velocity distribution of each subchannel at a cross section in the fuel pin bundle. It was found that the velocity field could be categorized according to channel shape. The discrepancy of the flow rate between the subchannels with the same channel cross section was small (Fig. 5). As the area of the subchannel increased, the flow rate increased clearly. The average flow rate was 0.04 kg/s in the type 1-subchannel, 0.09 kg/s in the type 2-subchannel, and 0.03kg/s in the type 3-subchannel.

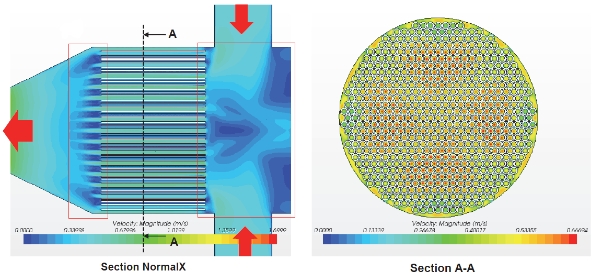

Fig. 3 Velocity distribution of flow regulator.

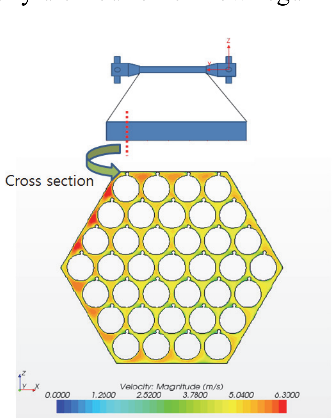

Fig. 4 Velocity distribution of subchannels.

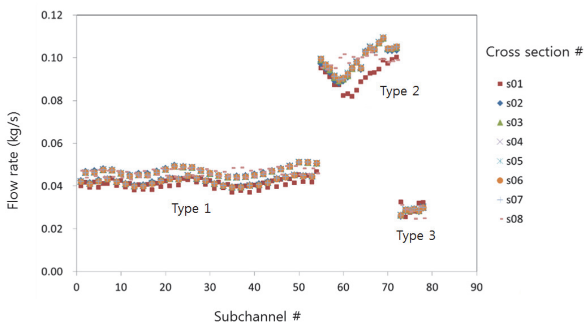

Fig. 5 The flow rates of subchannels categorized according to the channel shape.

The pressure drop between two pressure taps in the fuel pin bundle was found to be about 64 kPa by the numerical calculation. This numerical result will be helpful for selecting a differential pressure gauge used in the experiment because it is hard to estimate the pressure drop in the fuel pin bundle due to the its complex structure.

3. Summary

Prior to an experiment for a subchannel flow concerned with friction coefficient and mixing coefficient, a numerical analysis of the water flow in a test assembly was successfully conducted. The performance of the flow regulator installed in the upstream region of the assembly was confirmed numerically. It was shown that as the subchannel area increased, the average flow rate increased as expected. Also, the numerical results will provide reasonable design specifications in selecting the measurement devices and completing the construction of an experimental setup for the subchannel flow. Based on the results of this work, an experimental test for the SFR core subschannel flow is going to be conducted.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST). (No. 53123-13)

REFERENCES

[1] W. S. Kim, Y. G. Kim, and Y. J. Kim, A Subchannel Analysis Code MATRA-LMR for Wire Wrapped LMR Subassembly, Annals of Nuclear Energy, Vol. 29, p. 303, 2002.
[2] W. S. Yang, An LMR Core Thermal-Hydraulics Code Based on the ENERGY Model, Journal of the Korean Nuclear Society, Vol. 29, p. 406, 1997.