Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, May 29-30, 2014

Design Improvement of Iso-Kinetic Flow Sampling Device at Subchannel in a Wire-Wrapped 37-pin Fuel Assembly for a Sodium Cooled Fast Reactor

Dong-Won Lee*, Hyungmo Kim, Yung-Joo Ko, Seok-Kyu Chang, Hae Seob Choi, Dong-kin Euh, Hyeong-Yeon Lee
[1]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Republic of Korea*
**Corresponding author: dongwon888@kaeri.re.kr*

1. Introduction

Securing the structural integrity of a fuel assembly during reactor operation is of utmost importance in order to prevent reactor severe accident like the Fukushima nuclear power plant through a flow characteristics tests with test assembly scaled down from a prototype reactor of a sodium-cooled fast reactor (SFR) [1]. Flow distribution of each subchannel is a crucial factor for the core thermal design and experimental tests for the design code verification and validation in a temperature limitation analysis were conducted [2]. To evaluate uncertainty is very important to ensure reliability at the results of the fuel assembly. Therefore the sub-channel analysis method is commonly used for the thermal hydraulic analysis of a SFR, a wire wrapped sub-channel type. In KAERI, two sub-channel analysis codes (SLTHEN, MATRA-LMR) are considered to utilize for the design of the prototype reactor. In this study, design improvement of iso-Kinetic flow sampling device at sub-channel in a wire-wrapped 37-pin fuel assembly for a sodium cooled fast reactor is conducted for decreasing misalignment sensitivity.

2. Iso-Kinetic sampling design concept

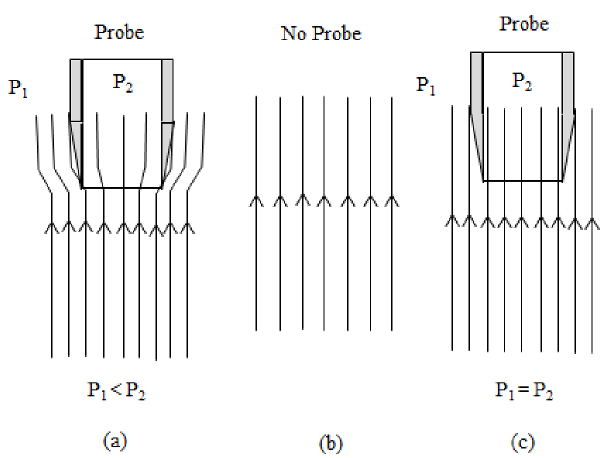

Fig. 1 Iso-Kinetic concept

Iso-kinetic sampling method was used to measurement of the flow distribution in each sub-channels, traditionally. This is a method that can extract the flowrage from measuring sub-channel by positioning the sampling probe at the exit of fuel rod. A basic concept to measure flow distribution is shown in Fig. 1. Fig. 1(a) shows the difference between internal pressure and exit pressure when liquid flows steadily upward. So the amount of flow rate at the exit of the bundle is different from that inside the probe. If liquid flows like Fig. 1 (b) when probe do not exist, it is basic theory like Fig. 1(c) by controlling the pressure difference between the inlet of the probe and outside of the probe.

To measure flow rate of the subchannels, a sampling probe has been developed by KAERI. A design of the iso-kinetic and extraction probe is shown in Fig. 2. Iso-kinetic sampling illustrates a schematic of the iso-kinetic extraction method and the sampling subchannels. In Fig. 2 (a), the sampling probe is positioned at the exit of the sampling sub-channel, and the flow rate is extracted through the probe for the measurement of the flow distribution. The sampling probe which is enclosed with a flexible bellows can be accurately moved to any sampling positions by a 3-D traversing system. The entrance projection of the sampling probe is identical to the flow cross section of the measuring sub-channel.

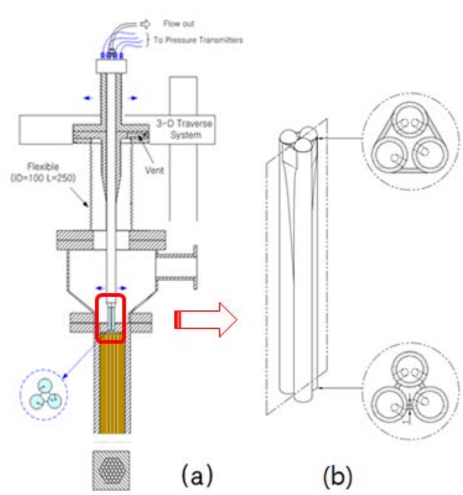

Fig. 2 Design of the Iso-Kinetic and extraction probe

The sampling probe has pressure taps for measuring the pressures of the sampling subchannel and neighboring subchannels. The exit pressure of the sampling line is controlled to compensate the pressure loss owing to the insertion of the sampling probe by comparing the pressures of the sampling sub-channel and neighboring subchannels [3].

3. Iso-kinetic uncertainty analysis

3.1 Evaluation of misalignment uncertainty

The iso-kinetic sampling device has been designed for the measurements of the flow distribution. An iso-kinetic sampling measurement uncertainty at extraction through the internal probe for the measurement of the flow rate is composed of combined expanded systematic uncertainty and random uncertainty. The experimentation condition error was 0.32%, the X-axis probe misalignment error was 2.5%, the Y-axis probe misalignment error was 0.9% and flowmeter & DA equipment error was 0.2%. As shown above, the misalignment error was the highest factor of uncertainty . Fig. 3 shows the experimentation of uncertainty measurement due to misalignment.

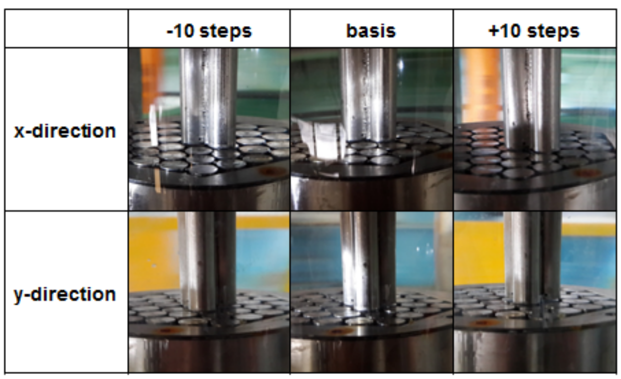

Fig. 3 experimentation of uncertainty measurement

From Fig. 3, the measurement of the flow distribution at sub-channel in wire wrapped 37-pin fuel assembly was conducted by misalignment step dimension. A one step dimension is 85.7 (μm/step). The measurement of the flow distribution at sub-channel in wire wrapped 37-pin fuel assembly has been conducted over the range of ±10 steps. The result of the experimentation is shown in Fig. 4.

The horizontal experimental cases are less than ± 0.4 mm and the vertical experimental cases are less than 0.4 mm. Therefore, the flow sensitivity of horizontal misalignment is less than 2.5%, and the flow sensitivity of vertical misalignment is less than 0.9%. So reducing misalignment error is necessary through design improvement of iso-kinetic flow sampling device in order to reduce total uncertainty.

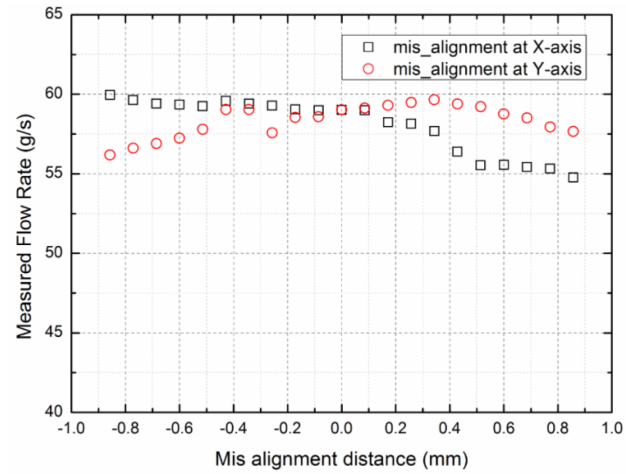

Fig. 4 The result of the uncertainty experimentation

3.2 Improvement for misalignment uncertainty decrease

The previous experimental device showed that the value of uncertainty was fairly high. One of the reasons was flow instability at the end of fuel assembly due to wrapped wires. Thereafter, the distance between probe bottom surface and the end of fuel assembly needs for flow instability, but if the distance between bottom surface of probe and the end of fuel assembly was far, distorted flow rate rather than original flow rate would be measured from sampling probe. To solve the problem, it was designed that the improved devices with flow divider and modified sampling probes were adopted to measure the subchannel flowrate as realistic as possible. The concept of the flow divider and modified probe was shown in Fig. 5.

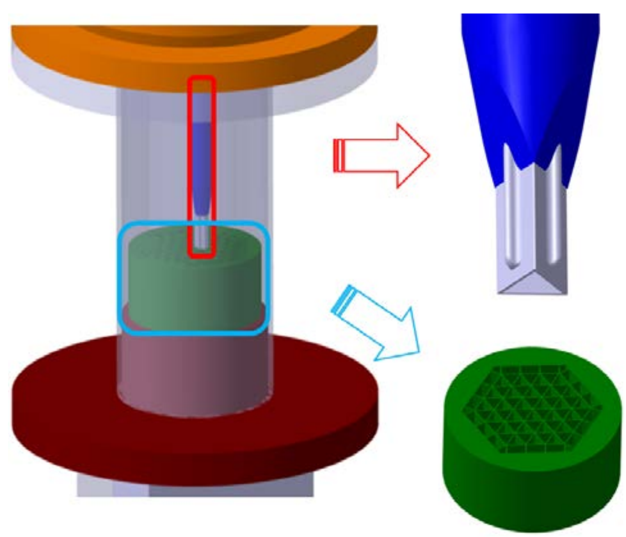

Fig. 5 The concept of the flow divider and changed Iso-Kinetic

As shown in Fig. 5, flow divider entered over the exit of the fuel bundle. Besides subchannel flow mixing prevented by using flow divider, probe was designed according to the previous concept. The installation of the new measuring system was currently underway and test operation will soon start..

4. Conclusions

The subchannel flow characteristics analysis method is commonly used for the thermal hydraulic analysis of a SFR, a wire wrapped subchannel type. In KAERI, two subchannel analysis codes are considered to be utilized for the design of the prototype reactor. In this study, the X-axis probe misalignment error is 2.5%, the Y-axis probe misalignment error is 0.9% and flowmeter & DA equipment error is 0.2%. As shown in above results, the misalignment error was the highest factor in uncertainty analysis. To solve the problem, design improvement of iso-kinetic flow sampling device at subchannel in a wire-wrapped 37-pin fuel assembly is practiced for decreasing misalignment sensitivity error. Therefore, the experimental test results for the improved sampling device can be compared to those for the previous sampling device and the improvement in terms of uncertainties between the two sampling devices can be quantified..

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2013K1A3A7A03078195).

REFERENCES

[1] Kim, Y.I, Lee, Y.B., Lee, C.B, Hahn, D.H., 2013, Sodium cooled fast reactor development in Korea, FR-13, 4-7 March, Paris.

[2] S.-K. Cheng and N. E. Todreas, Hydrodynamic Models and Correlations for Bare and Wire-Wrapped Hexagonal Rod Bundles – Bundle Friction Factors, Subchannel Friction Factors and Mixing Parameters, Nuclear Engineering and Design, Vol.92, p. 227, 1986

[3] S.K. Chang, D.J. Euh, H. Bae, H.Y. Lee, and S.R. Choi, Design of the Wire Wrapped 37-Pin Fuel Assembly for Measurements of the Flow Characteristics in a SFR, The Sixth Korea-China Workshop on Nuclear Reactor Thermal-Hydraulics(WORTH-6), April 11-13, 2013, Busan, Republic of Korea.