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Improvement of Measurement Accuracy of Coolant Flow in a Test Loop

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1. Introduction

To verify the performance of a newly developed nuclear fuel, irradiation test needs to be carried out in the research reactor and measure the irradiation behavior such as fuel temperature, fission gas release, neutron dose, coolant temperature, and coolant flow rate. In particular, the heat generation rate of nuclear fuels can be measured indirectly by measuring temperature variation of coolant which passes by the fuel rod and its flow rate. However, it is very difficult to measure the flow rate of coolant at the fuel rod owing to the narrow gap between components of the test rig. In nuclear fields, noise analysis using thermocouples in the test rig has been applied to measure the flow velocity of coolant which circulates through the test loop[1~3]. Hong developed a coolant flow simulator and carried out experiment to measure the flow velocity using the noise analysis technique[4,5]. However, because measurement accuracy is less than 60%, it needs to enhance hardware to eliminate external noise.

In this study, hardware of the coolant flow simulator is updated to improve measurement accuracy by protecting and strengthening source signals. Ground pattern of the PCB in the control board is enhanced to protect source signals from external noise and some critical components are wrapped with aluminum foil. In addition, heating unit is added to increase signal strength of source signals by heating up the coolant.

2. Improvement of coolant flow simulator

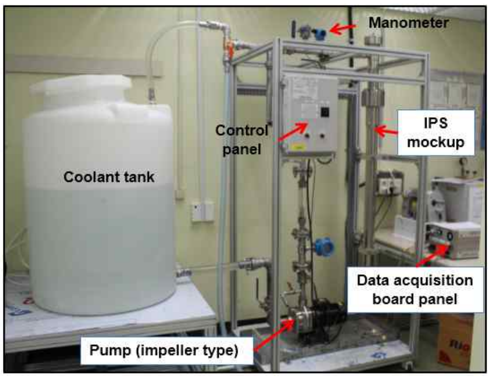

Fig. 1. IPS coolant flow simulator

Hong developed a coolant flow simulator as shown in Fig. 1. However, because external noise was not completely removed and the signal strength of source signals is too weak, it was difficult to extract fluctuation signals from the source signals and applying the noise analysis technique shows bad accuracy in measuring flow velocity of coolant.

In this chapter, updated hardware to heat coolant and to eliminate external noise is described.

2.1 Heating unit

Because thermocouples are used to obtain signal data from the coolant, the source of fluctuation signal to measure the flow velocity is heat energy. It means that previous study didn't get sound fluctuation signal because experiment was carried out by circulating coolant with room temperature.

Therefore, a heating unit is added in the pipeline of the coolant flow simulator to heat the coolant up to a designated temperature. In addition, to enhance the measurement sensitivity, K-type thermocouples are changed from encapsulated type to bare type (PP-K-24, Omega co., ltd.).

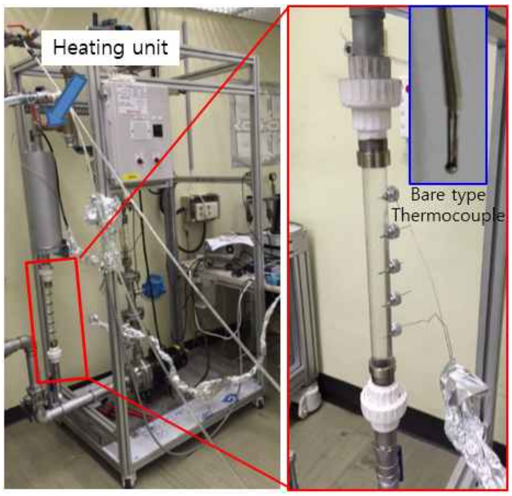

Fig. 2. Heating unit and test channel for flow measurement

2.2 Elimination of external noise

External noise except for the fluctuation signals obtained from coolant flow prevents accurate measurement of flow velocity using the noise analysis technique. In the coolant flow simulator, antenna noise generated from the frame of equipment and power source noise generated from power cables disturb fluctuation signals of coolant. Therefore, ground pattern is enhanced at the power input terminal of the control board. In addition, the frame of the equipment, the controller of the heating unit, signal cables, and control board enhance earth connection, as shown in Fig. 3.

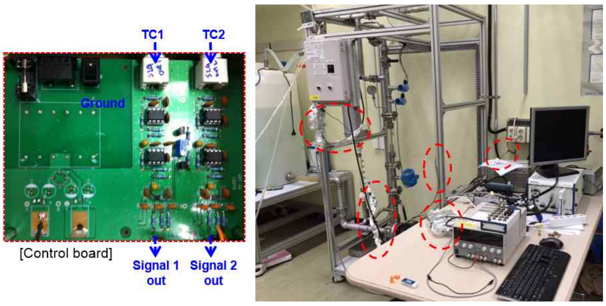

Fig. 3. Enhancement of ground pattern and earth

3. Measurement of coolant flow rate

After heating the coolant up to 40℃, several experiment to measure and calibrate the flow velocity using noise analysis technique has been carried out. Signals generated from the two thermocouples instrumented with a distance of 200 mm are delivered to the control board. Then, the signals are amplified and filtered by eliminating DC components, power ripple, and other external noise. Finally, fluctuation signals are extracted and registered into PC for 600 sec. with a 0.005 second sampling time. Time shift between the two fluctuation signals can be calculated by a cross correlation method as shown in Fig. 4. Thus, the flow velocity of coolant can be obtained by dividing the distance between thermocouples with the time shift.

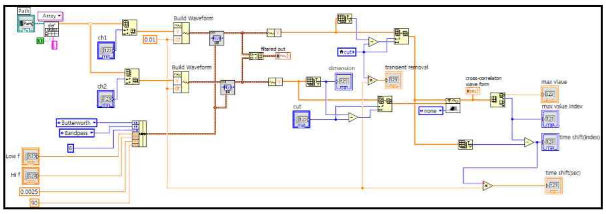

Fig. 4. Program for cross correlation

Table I shows the result of experiments which measure the flow velocity using the noise analysis technique by changing the input flowrate from 10 liter/min. to 60 liter/min. Measured flowrate using the noise analysis technique shows good agreement with the reference input flowrate, which average error of the experiment is 4.26% (max. 9.27%). From the test results, the accuracy of flow measurement increases tremendously while the measurement error of previous study was 49.3%.

Table I: Measured flow rate by cross correlation

Input flow (liter/min.)	Δ t (sec)	Measured flow rate (liter/min.)	Error (%)
10	0.345	10.93	9.27
20	0.195	19.33	3.34
30	0.135	27.93	6.92
40	0.095	39.68	0.79
50	0.075	50.27	0.53
60	0.060	62.83	4.72

4. Conclusions

In this study, to improve the measurement accuracy of coolant flow in a coolant flow simulator, elimination of external noise are enhanced by adding ground pattern in the control panel and earth around signal cables. In addition, a heating unit is added to strengthen the fluctuation signal by heating the coolant because the source of signals are heat energy.

Experimental results using the improved system shows good agreement with the reference flow rate. The measurement error is reduced dramatically compared with the previous measurement accuracy and it will help to analyze the performance of nuclear fuels.

For further works, out of pile test will be carried out by fabricating a test rig mockup and inspect the feasibility of the developed system.

REFERENCES

[1] T. Valerio, "A new method to measure rig coolant flowrate," F-Note 222, OECD Halden Reactor Project, 1992.
[2] T. Valerio, "Flow-rate measurements in IFA-596/597 via cross correlation technique," F-Note 644, OECD Halden Reactor Project, 1993.
[3] C. Hartmann, J. K. Liverud, B. Volkov, and K. W. Eriksen "Volume flow measurements from temperature noise measurements," FC-Note-2751, OECD Halden Reactor Project, 2012.
[4] J. T. Hong, C. Y. Joung, S. H. Heo, and K. H. Kim, "Development of Coolant Flow Simulation System for Nuclear Fuel Test Rigs," Trans. Korean Soc. Mech. Eng. A, Vol. 39, No. 1, pp. 117~123, 2015.
[5] J. T. Hong, J. B. Kim, C. Y. Joung, S. H. Ahn, and S. H. Heo, "Measurement of Coolant Flow in a Nuclear Fuel Test Rig," Int. J. Preci. Eng. Manuf., Vol. 16, No. 9, pp. 1993-1998, 2015.