Control Rod Position Indicator with High Performance for Reactor Precision Control

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1. Introduction

The Control Element Driving Mechanism(CEDM) of the integrated reactor developed in the future should be capable of precision control of core because it uses fission reaction heat for heating the coolant during start-up and controls the core without boric acid. Therefore, the control rod Position Indicator(PI) should measure fine displacement and maintain displacement measurement performance in frequent movement of the control rod. Also, signals of PI from the safety system shall have high accuracy and resolution. In addition, the signal shall be independent of the control system signal and the signal channel shall be redundant against failure of the measured position signals [1].

In this paper, we describe the results of performance tests for PI by applying a magnetostrictive sensor with high precision and high resolution. The profile type of the sensor was selected so that it can be installed on the outside of the pressure vessel because it must indicate the position of the target(magnet) inside the vessel without penetrating the vessel.

2. Methods and Results

The installation of the magnetostrictive sensor for the performance tests and the results are described. The results of the tests are divided into for accuracy, resolution and influence of step motor.

2.1 Configuration of test instruments

As shown in Figure 1, the magnets that are the targets of the PI sensors are connected to the upper part of the control rod extension shaft that moves up and down using a step motor. On the surface of the pressure vessel, the bracket for adjusting the separation distance between the sensor and the pressure vessel was constructed and installed. The vessel between the sensor and the magnets is made of a non-magnetic material because it detects the position of magnetic force. The magnets were also placed in the vessel in the circumferential direction, considering the direction in which the sensors could be installed in the circumferential direction on the outside of the cylindrical vessel.

In addition, the rod-type sensor was installed as reference sensor on the lower part of the extension rod that can be connected directly to the magnet so that the output (magnet position) values of it can be compared with the PI sensor's of outside the vessel.

The PI and reference sensor are commercial product and specifications are shown in Table 1 [2,3].

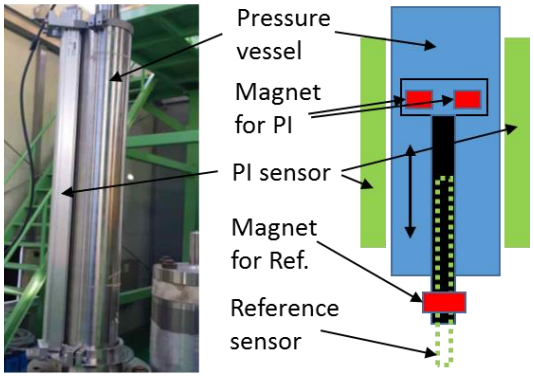

Fig. 1. Configuration of test instruments

Table I: Specification of the magnetostrictive sensors

Use	Position indicator sensor	Reference sensor
Type	Profile type	Rod type
Installed location	Pressure vessel exterior surface	Control rod extension shaft
Output signal	4~20mA	0~10V
Accuracy	±0.01% FS[1)] (Linearity deviation)	±0.01% FS (Linearity deviation)
Sampling rate	1kHz	1kHz
Figure		
Note : 1. Full Scale(measuring length)		

2.2 Accuracy test

As the distance between the magnet and the sensor including the thickness of the pressure vessel, the accuracy of the PI sensor is lower than that of the product specification shown in Table 1. Therefore, to measure the errors of PI sensor, the position values of the reference sensor are assumed to be true values and the errors from the two sensors were identified.

The tests were performed to measure the positions of the magnet moved up and down about 700mm at 1,2mm/s using a step motor for each positions of PI sensors, and the results are shown in Table 2.

Although the error caused by the linear deviation of the reference sensor is assumed to be about 0.5mm, the maximum error of the PI sensor is not more than 2.5mm.

Table II: 2 Result of accuracy test

Position	1		2	
Velocity (mm/s)	1	2	1	2
Maximum error(mm)	1.89	1.89	1.71	1.742.
Average error(mm)	1.05	1.05	0.887	0.897
Standard deviation	0.456	0.488	0.417	0.435

2.3 Resolution test

The figure 2 shows the measured position of the magnets placed from 0mm to 5mm in 1mm for 30 seconds at each position by PI sensors.

To verify the resolution of 1mm, the difference between the mean values of the position data measured for 30 seconds at 1mm and 2mm positions was calculated. The difference for the sensors are 1.01 mm and 1.04 mm respectively. Therefore, it means that resolution of the sensor isn't more than 1.0mm.

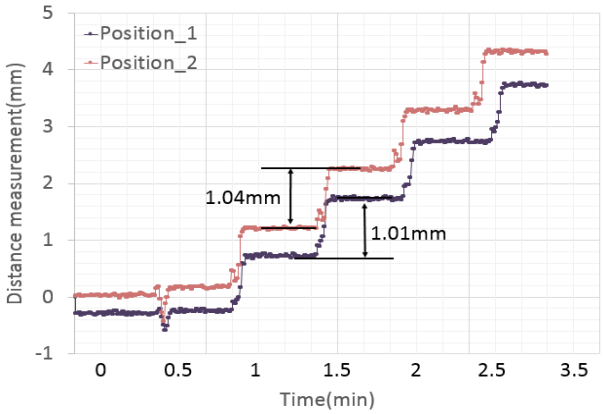

Fig. 2. Result of resolution test

2.4 Effect for magnetic field of step-motor

It is confirmed that the magnetic field of the step-motor installed close to the side of the vessel changes the position value of the PI sensor.

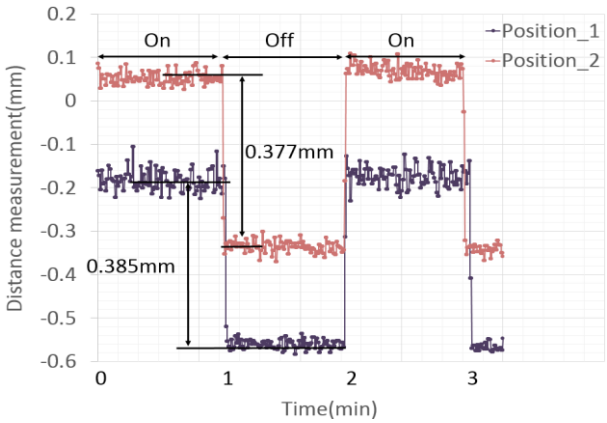

Fig. 3. Bias value according to step-motor on/off

As shown in Figure 3, the position value varies according to the on/off of the step motor. But, the bias values are less than 1 mm and the maximum error value of Table II in the both sensors.

3. Conclusions

For precise measurement of the control rod position (magnet position) inside the pressure vessel, the profile type magnetostrictive sensor with high accuracy and high resolution was applied to detect the position of it from the outside the vessel.

Although all test results were slightly changed with the positions because of different magnet fields from target and step-motor at the positions and the wall of the vessel was placed between the magnet and the sensor, the maximum error value of PI sensor was measured to be less than 2.5 mm, and the resolution could be verified up to 1.0 mm. The resolution is better than commercial nuclear power plant's (over 30mm) [1]. Also, the bias position value from magnetic field of the step motor has been confirmed to be less than 1 mm, but this value is less than the maximum error value.

Therefore, the applying the magnetostrictive sensor to PI sensor of the reactor that requires precision control, is positive even though additional verification as the sensor to provide safety system signals would be necessary.

REFERENCES

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[2] Balluff BTL7-A/E501-M-P-S32/S115KA User's Guide
[3] Santest GYRP/GYFC2 Instruction manual