Measuring deformation of Fuel pin in a Nuclear Fuel Test Rig

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1. Introduction

The Nuclear Fuel Test Rig is used to observe changes in the characteristics of the fuel according to the neutron irradiation at HANARO (High-flux Advanced Neutron Application Reactor) [1], which is a research reactor.

Which are the strain and internal temperature of the irradiated nuclear fuel and the internal pressure of fuel due to fission gas, the characteristics of the fuel are measured using various sensors such as a thermocouple, SPND and LVDT.

In this study, two shaped LVDT (Linear Variable Differential Transformer) cores for displacement measurements were designed and manufactured in order to measure the displacement of a fuel pellet and cladding tube using LVDT sensors for measuring electrical signals by converting the physical variation such as the force and displacement into a linear motion. In addition, signals from the manufactured LVDT sensor were collected and calibrated. Moreover, a method for obtaining the displacement in the core according to the sensing signal was planned.

2. Design and manufacture of LVDT core

2.1. Basic principles of the LVDT

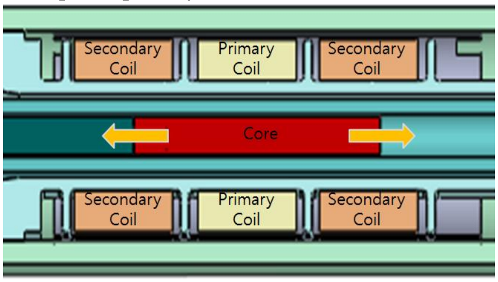

Fig. 1. Key model of the LVDT sensor

LVDT is measuring electric signal that is generated while the magnetic core moves the magnetic field of three coils, as shown in Fig. 1.

2.2. LVDT core for fuel pellet displacement measurement

For measuring the longitudinal displacement of the nuclear fuel pellet, the movement direction of the core must be matched to the longitudinal direction strain of the pellet. Fig. 2 shows a drawing and photograph of the LVDT core for fuel pellet displacement measurements. The core is moving in the same axis and deformation of the sintered body. Core is moved in the longitudinal strain of the pellets.

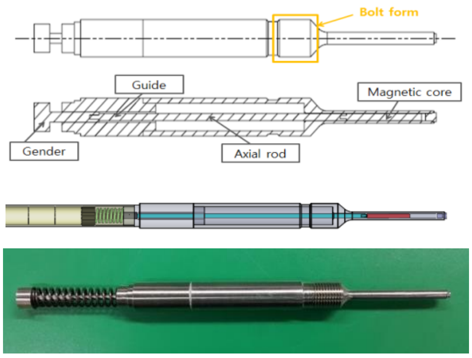

Fig. 2. Manufactured article and drawing of LVDT core for fuel displacement measurement.

2.3. LVDT core for cladding tube length deformation measurements

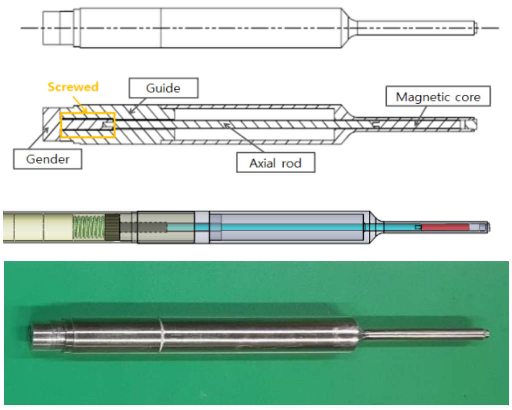

Fig. 3. Manufactured article and drawing of LVDT core for cladding tube length deformation measurements.

The LVDT core for fuel pellet displacement measurements was in direct contact with pellets. However, the LVDT core for the cladding tube length deformation measurements cut off the movement of the core in accordance with the deformation of pellets using a spring between this core and pellets.

3. Signal collect of LVDT core test

3.1. Signal Acquisition Equipment

For the LVDT core to have fine movement, a micrometer transfer jig was prepared. In addition, the voltage value was obtained corresponding to the core position, using an LVDT readout unit, and an LVDT sensor was made by Halden in Norway.

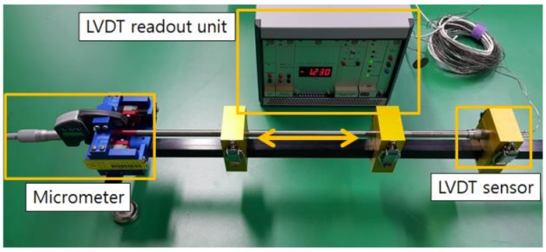

Fig. 4. The micrometer transfer jig, LVDT readout unit and sensor

3.2. Signal Acquisition Experiment

Pellets or a cladding tube are moved by manipulating the micrometer transfer jig, as shown in Fig. 5. The voltage value of the core position is displayed on a readout unit, according to the movement of the core.

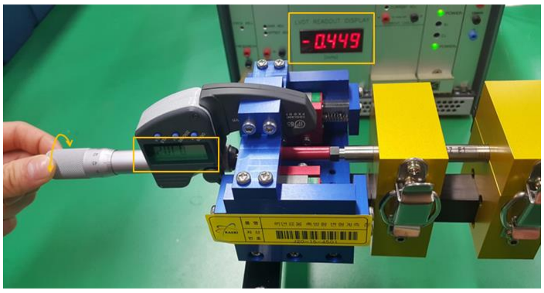

Fig. 5. *Signal Acquisition Experiment*

4. Management of signal

4.1. Data calibration

Signal of the voltage value corresponding to the position is made visible as a graph, as shown in Fig. 6. Data ware obtained through repeated experiment repeated.

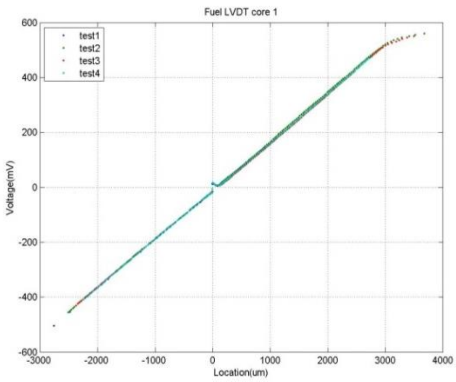

Fig. 6. Repeated graph

However, the collected data will incur error owing to the experimenter operating manually and the decimal place of the displayed value is limited.

Data was obtained through a repeated converge linear-equation suing a trust-region algorithm and NLS (Non-Linear Least Square) [2] using MATLAB. The NSL of the equation can be expressed following Eq. 1.

$$P_{est} = argmin_p \sum_{i=1}^{T} \left[\sqrt{(x-x_i)^2 + (y-y_i)^2} - \hat{d}_i\right]^2 \quad (1)$$

The calibration graph is shown in Fig. 8.

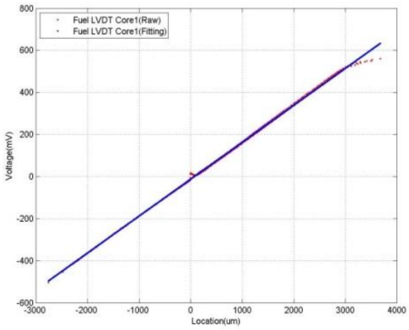

Fig. 7. Calibration graph

4.2. Displacement anticipation

The calibrating linear graph is expressed through a prediction equation such as Eq. 2.

$$V = a \times \delta + b \quad (2)$$

In Eq. 2 above, the amount of movement of the core according to the output voltage variation can be derived following Eq. 3.

$$\Delta\delta = \frac{(\Delta V - b)}{a} \quad (3)$$

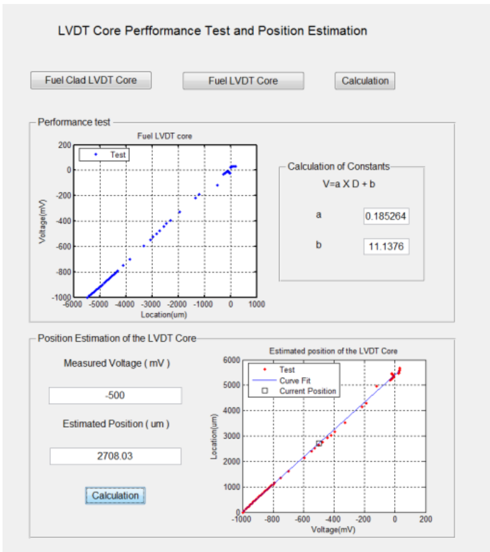

Fig. 8. Performance test program

Based on the above equations, a program was coded using MATLAB, as shown Fig. 8.

Performance test program processed data of signal acquisition experiment and derived constant term a and b of Eq. 2. Then it anticipated displacement using variation of the measuring voltage value between the initial position and moving position of the core.

5. Conclusions

In this study, an LVDT core for measuring the longitudinal displacement of fuel pellets and clad was designed and produced. A signal processing method for the prepared core was investigated. A derived equation can used to predict the change in the position of core.

A following study should be conducted to test the output signal and real variation of out-pile system. For further work, a performance verification is required for an in-pile irradiation test.

REFERENCES

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[2] J.K. Lee, Y.J. Kim, and S.C. Kim, "Efficient Localization Algorithm for Non-Linear Least Square Estimation", Jou. Of Korean Soc. Of Information and Communications, Vol. 40(1), 2015