LVDT Development for High Temperature Irradiation Test and Application

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1. Introduction

The LVDT (Linear Variable Differential Transformer) is used to measure the elongation and pressure of a nuclear fuel rod, or the creep and fatigue of the material during a reactor irradiation test. This device must be a radiation-resistant LVDT for use in a research reactor. Norway Halden has LVDTs for an irradiation test by the own development and commercialized. But Halden's LVDTs have limited the temperature of the use until to 350℃. So, KAERI has been developing a new LVDT for high temperature irradiation test. This paper describes the design of a LVDT, the fabrication process of a LVDT, and the result of the performance test.

2. LVDT Design for High Temperature Irradiation Test

Norway Hadeln has an advanced LVDT application technology. Halden's LVDT is using for fuel stack elongation, cladding elongation, fuel center temperature, fuel rod pressure. Fig.1 is a typical Halden's pressure LVDT. But that LVDT has a temperature limit (~350°C) for usage because of the material characteristics of coating coil and core. Generation IV reactor as SFR or VHTR has the operation condition of high temperature. Therefore, Halden is developing high temperature LVDT (700°C) and JAEA has fabricated the LVDT of MI cable type. As show Fig. 2, JAEA LVDT used ø 0.5mm MI cable for coil but signal output is small because of winding numbers. We have designed a new type LVDT in Fig. 3. The LVDT core is permendur 49 (curie point 940 °C) and The LVDT coil is used a K-type thermocouple of ø 0.25mm. Other characteristic is the single signal MI cable of ø 1.0mm as an instrumented cable. Also, the protection tube is used for the double sealing of an instrumentation cable. The new LVDT is possible to use until about 900 °C after the laser welding[1-3].

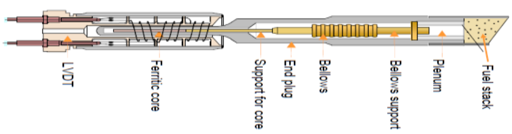

Fig. 1. Typical Halden's Pressure LVDT

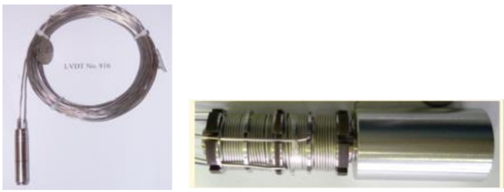

Fig. 2. Halden LVDT (Left) and JAEA LVDT (Right)

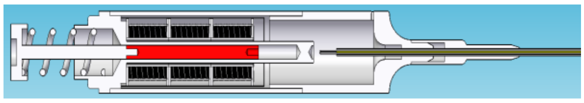

Fig. 3. KAERI's LVDT for High Temperature

3. LVDT Fabrication and Performance Test

For the LVDT fabrication, the bobbin is designed and the coil winding machine was used. The number of coil winding is 166 turns. The winded coil must be stripped ending parts but it is not easy to strip the MI cable of ø 0.25mm. Fig. 4 shows the MI cable stripping machine that was developed and stripped coils. That stripping machine can be stripping MI cable from ø 0.25mm to ø 1.0mm. LVDT parts was assembled and the part of signal cable was sealed by the laser brazing method. Fig. 5 shows the final fabricated LVDT using a miniature connector.

Fig. 6 is the performance test of LVDT. The LVDT is fixed and a core is moved from left to right by the micro head. If a core moves from the center, the output signal changes as showed in the Fig. 7. The linearity of LVDT is very good and the value of sensitivity is 700mV/mm in section from -1.0mm to 1.0mm. Also the signal drift showed very stable value to 0.1mV/24h.

Fig. 4. MI Cable Stripping (Left) and Winded Coils on Bobbin (Right)

Fig. 5. Final Fabricated LVDT that MI Cable is connected to Miniature Connector.

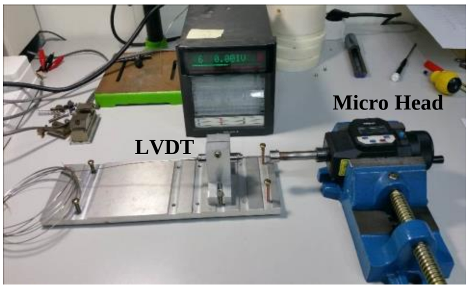

Fig. 6. Performance Test of High Temperature LVDT

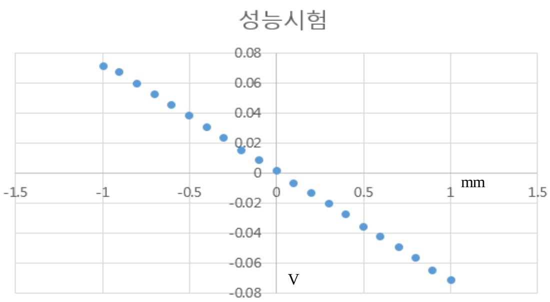

Fig. 7. Output Characteristics of High Temperature LVDT

4. LVDT Application for HARNRO Irradiation Test

The instrumented fuel for irradiation test has double instrumented sensors. Fig. 8 shows an instrumented fuel rod for HARO irradiation test. The upper part was equipped with an elongation LVDT or a pressure LVDT. The lower part was equipped with a thermocouple for the centerline temperature measurement. As the Fig. 9, these fuel rods are assembled in a Rig.

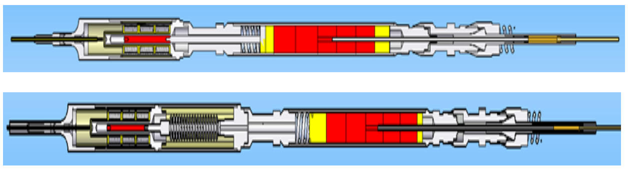

Fig. 8. Irradiation Test Fuel Rod Equipped with Elongation LVDT and Pressure LVDT Centerline Temperature Sensor that Lower part is instrumented with centerline temperature sensor.

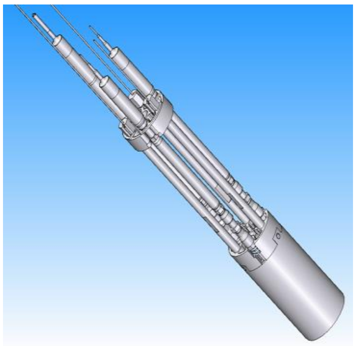

Fig. 9. Irradiation Rig Design of Equipped with Elongation LVDT and Pressure LVDT

5. Conclusions

The high temperature LVDT for HANARO irradiation testing was newly designed and fabricated. The designed LVDT uses thermocouple cable for coil wire material and one MI cable as signal cable. This LVDT for a high temperature irradiation test can be used until a maximum of 900°C. Welding is a very important factor for the fabrication of an LVDT. We are using a 150W fiber laser welding system that consists of a welding head, monitoring vision system and rotary index. The fabricated LVDT shows good linearity compared to the Halden LVDT. The developed LVDT for the irradiation test will be utilized for the elongation measurement of a pellet.

Acknowledgements

This work was supported by the National Research Foundation Grant (NRF-2013M2A8A1035822) from Ministry of Science, ICT and Future Planning (MSIP) of Republic of Korea

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