Nuclear Fuel Test Rod Fabrication for Data Acquisition Test

Chang-Young Joung [a*], Jin-Tae Hong [a], Ka-Hye Kim [a] and Sung-Ho Huh [a]

[a] ***Korea Atomic Energy Research Institute, P.O. Box 105, Yuseong, Daejeon, Korea, 305-600***
Tel: 82-42-868-2519, Fax: 82-42-868-8364, E-mail: joung@kaeri.re.kr

1. Introduction

The centerline temperature resulting from the irradiation properties of nuclear fuel is an important factor for evaluating nuclear fuel properties in-pile, and instrumentation and measurement techniques for the nuclear fuel are necessary to measure the exact temperature. A nuclear fuel test rod must be fabricated with precise welding and assembly technologies, and confirmed for their soundness [1]. Recently, we have developed various kinds of processing systems such as an orbital TIG welding system, a fiber laser welding system, an automated drilling system and a helium leak analyzer, which are able to fabricate the nuclear fuel test rods and rigs, and keep inspection systems to confirm the soundness of the nuclear fuel test rods and rids. The orbital TIG welding system can be used with two kinds of welding methods. One can perform the round welding for end-caps of a nuclear fuel test rod by an orbital head mounted in a low-pressure chamber. The other can do spot welding for a pin-hole of a nuclear fuel test rod in a high-pressure chamber to fill up helium gas of high pressure [2]. The fiber laser welding system can weld cylindrical and 3 axis samples such as parts of a nuclear fuel test rod and instrumentation sensors which is moved by an index chuck and a 3 axis (X, Y, Z) servo stage controlled by the CNC program [3]. To measure the real-time temperature change at the center of the nuclear fuel during the irradiation test, a thermocouple should be instrumented at that position. Therefore, a hole needs to be made at the center of fuel pellet to instrument the thermocouple. An automated drilling system can drill a fine hole into a fuel pellet without changing tools or breaking the work-piece [4]. The helium leak analyzer (ASM-380 model of DEIXEN Co.) can check the leak of the nuclear fuel test rod filled with helium gas.

This paper describes not only the assembly and fabrication methods used by the process systems, but also the results of the data acquisition test for the nuclear fuel test rod.

2. Fabrication of a nuclear fuel test rod

2.1 Design and process

The configuration of a nuclear fuel test rod instrumented with a C-type thermocouple is presented in Fig. 1. This nuclear fuel test rod was deigned and fabricated to develop the fabrication technologies and was used for the data acquisition test. A nuclear fuel test rod is composed of a Zr-4 cladding tube and Zr-4 upper and lower end-caps, alumina dummy pellets instead of UO_2 pellets, a C-type thermocouple, and Swagelok parts. Its size is 9.5mm in out-diameter and 25mm in length. The hole of the alumina dummy pellets was drilled using an automated drilling system to make a hole at the center of the fuel pellet.

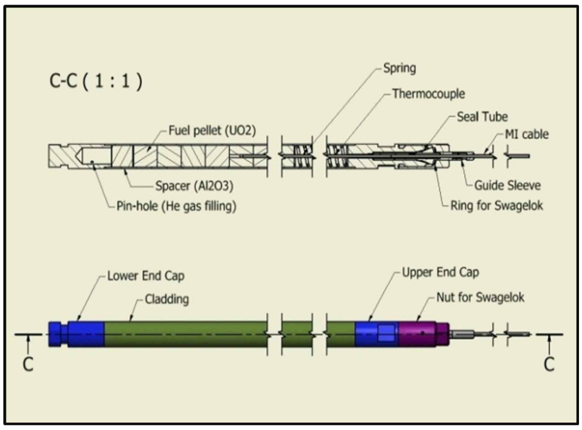

Fig. 1 Configuration of a nuclear fuel test rod for data acquisition test

Joining processes to assemble a nuclear fuel test rod parts are listed in Table 1. To measure the fuel centerline temperature of the nuclear fuel test rod, a C-type thermocouple is installed at the upper end-cap. The thermocouple was sealed with a Swagelok because the MI cable and upper end-cap cannot be welded with hetero-metals.

Table 1 joining processes for a nuclear fuel test rod

Joint parts	Methods
Seal tube = Upper end-cap	Mechanical sealing
End-cap = Cladding	TIG welder (round welding)
Seal tube = MI cable	Laser welder (round welding)
Swagelok nut = Guide sleeve	Laser welder (spot welding)
Helium filling (22.5bar.g)	TIG welder (spot welding)

The Swagelok is assembled with component parts such as a seal tube, a nut for the Swagelok, a ring for the Swagelok, and a guide sleeve. The welding of End-cap/Cladding for a the nuclear fuel test rod was performed by the orbital TIG welding system programed according to welding parameters (current of each step: 40A-38A-36A-34A-32A, time of each steps: 5). The welding points of Seal tube/MI cable and Swagelok nut/Guide sleeve were welded with round welding by a fiber laser welding system according to each established welding condition. The helium gas filling (22.5bar.g) in a nuclear fuel test rod was performed with the spot welding (conditions: 60A, 0.4sec) using a high press chamber of an orbital TIG welding system.

2.2. Soundness confirmation

The soundness confirmation of the nuclear fuel test rod sealed by a mechanical sealing and sealed by spot welding to fill up helium gas was fulfilled by helium leak tests and microstructural analyses. In these specimens, no leak and defects were found out. The welding areas of the nuclear fuel test rod welded by TIG welding and laser welding underwent a visual inspection and microstructural analyses. No defects were detected in these specimens.

3. Data acquisition test results

The data acquisition system was composed of a muffle furnace to make the in-pile temperature conditions and a notebook computer installed with a NI-9213 module and a cDAQ-9174 chassis. Fig. 2 shows a data acquisition program programmed by NI Labview. This program was used to acquire and memorize the temperature values from a thermocouple instrumented in a nuclear fuel test rod during out-pile testes. The data acquisition test was carried out with a nuclear fuel test rod fabricated from above processes, and conducted in a muffle furnace of 310 ℃ like an in-pile temperature of a PWR. In this test, the data acquainted from a nuclear fuel test rod instrumented with a C-type thermocouple through a data acquisition system were able to be measured and memorized in real time, and a nuclear fuel test rod tested in a muffle furnace was conformed to the soundness.

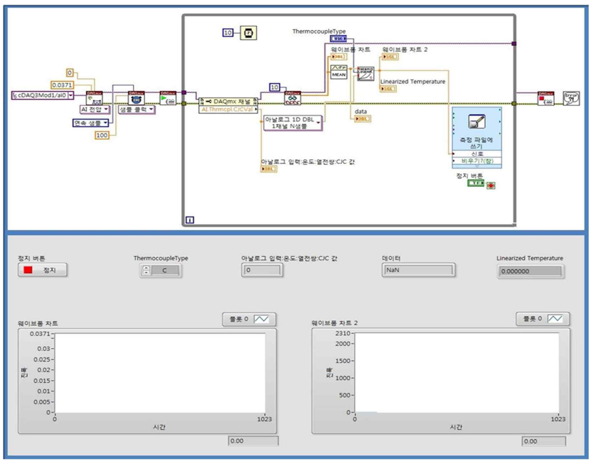

Fig. 2 Data acquisition program programmed by NI Labview

4. Conclusions

A nuclear fuel test rod for the data acquisition test was fabricated using the welding and assembling technologies acquired from previous tests. The soundness was confirmed through microstructural analyses and a helium leak test. The data acquisition test was carried out using a nuclear fuel test rod through a data acquisition system, which was composed of a muffle furnace to make in-pile temperature conditions and a notebook computer controlled by the data acquisition program. The data acquainted through a data acquisition system were able to be measured and memorized.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (2012M2A8A5010535)

REFERENCES

[1] B.G. Kim, J.M. Sohn, K.N. Choo, “Development Status of Irradiation Devices and Instrumentation for Material and Nuclear Fuel Irradiation Tests in HANARO”, Nuclear Engineering and Technology, Vol 42., No. 2, pp. 203-210, 2010.

[2] C.Y. Joung, S.H. Ahn, J.T. Hong, K.H. Kim, “Development of TIG Welding System for a Nuclear Fuel Test Rig” “Transactions of the Korean Nuclear Society Spring Meeting”, Gwangju, Korea, May 30-31, 2013.

[3] KAERI, TR-5268/2013, “The Fabrication of Precision Laser Welding System for Nuclear Fuel Test Rig”, 2013.

[4] H.Y. Jeong, J.T. Hong, S.H. Ahn, C.Y. Joung, “Fabrication of an instrumented fuel rod mock-up using a precise drilling machine”, “Jou. of Korean Soc. of Mechanical Technology, vol. 14(5), PP. 97-102, 2012. ,