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Development of Welding and Instrumentation Technology for Nuclear Fuel Test Rod

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1. Introduction

To measure the irradiation characteristics of the new nuclear fuel developed, a nuclear fuel test rod must be fabricated using various welding and instrumentation technologies. Special sensors such as a T.C (thermocouple), a LVDT (linear variable differential transformer) and SPND (self-powered neutron detector) are installed around the nuclear fuel test rod [1]. The central temperature of the nuclear fuel, the inner pressure of a fuel rod, and the neutron flux resulting from the irradiation properties of nuclear fuels are important factors for evaluating nuclear fuel properties in pile. Therefore, it is necessary to develop various types of welding, instrumentation and helium gas filling techniques that can conduct TIG spot welding exactly at a pin-hole of the end-cap on the nuclear fuel rod to fill up helium gas. The welding process is one of the most important among the instrumentation processes of the nuclear fuel test rod. To manufacture the nuclear fuel test rod, a precision welding system needs to be fabricated to develop various welding technologies of the fuel test rod jointing the various sensors and end-caps on a fuel cladding tube, which is charged with fuel pellets and component parts. We therefore designed and fabricated an orbital TIG welding system and a laser welding system [2].

This paper describes not only some experiment results from weld tests for the parts of a nuclear fuel test rod, but also the contents for the instrumentation process of the dummy fuel test rod installed with the C-type T.C.

2. Design of test fuel rod

To develop the welding and instrumentation technologies for the test rod of nuclear fuels, a dummy fuel test rod was designed and fabricated according to nuclear fuel properties and irradiation conditions. Table 1 lists the properties of the composition parts of a dummy nuclear fuel test rod. The dummy nuclear fuel test rod consists of a cladding tube, top and bottom end-caps, a plenum spring, spacer disks, and Al_2O_3 pellets (dummy fuel). In these experiments, the dummy pellets of the test rod were made of alumina instead of UO_2, while those of the cladding and end-cap were made of Zr-4. Spacers in a conventional fuel rod are usually made of alumina (Al_2O_3) and are located between the plenum spring and pellet as well as the bottom end-cap and pellet. The total length of the dummy nuclear fuel rod including a C-type T.C., the instrumented Swagelok parts of which are about 520 mm. The inside of the dummy nuclear fuel test rod was filled up with helium gas.

Table 1. Properties of the composition parts of a dummy nuclear fuel test rod

Items	Materials	Size
Cladding tube	Zr-4	O.D 9.48mm x I.D 8.33mm, L. 450mm
Top End-cap	Zr-4	Dia. 9.48mm, L. 44mm
Bottom End-cap	Zr-4	Dia. 9.48mm, L. 26mm
Plenum spring	Inconel –X 750	O.D 7.80mm x I.D 4.75mm, L. 112.30mm (1.45mm)
Dummy pellet	Al_2O_3	Dia. 8.2 x 10 mm
Spacer	Al_2O_3	Dia. 8.2 x 5 mm

3. Welding methods

3.1 Round welding for end-cap and sensors

A nuclear fuel test rod is manufactured using various welding technologies jointing between various sensors and end-caps with a cladding tube inserted with fuel pellets and the parts of the nuclear fuel test rod. To precisely weld the end-cap on the cladding tube for the dummy fuel test rod fabrication, round welding tests were conducted by an orbital TIG welding system (AMI –M207A) and a fiber laser system (IPG Fiber Laser Source [QCW150-1500-AC] and Laser Welding Head) according to the welding conditions. These welding systems have been configured to be able to precisely weld an end-cap on a cladding tube. The welding process of the orbital TIG welding system was performed in a low-pressure chamber, and that of the fiber laser welding system was performed under atmosphere conditions purging the helium gas. Using these systems, the performance tests of the round weld were carried out with the welding conditions for the dummy fuel test rod fabrication. The results have shown a good weld-ability at both the orbital TIG welding system and the fiber laser welding system.

3.2 Spot welding for helium gas filling

To perform an irradiation test for a nuclear fuel test rod, the inside of a nuclear fuel test rod must be assembled with test fuels, several parts and sensors, and then filled with helium gas having high-pressure and high-purity. To fill helium gas in the dummy nuclear fuel test rod, TIG spot welding was conducted at a pin-hole drilled with a 0.6mm dia. on the end-cap of the nuclear fuel rod. It was performed to prevent a pin-hole of the end-cap on a nuclear fuel rod from leaking helium gas inside the chamber. Fig. 1 shows a spot welding tool mounted with a dummy fuel test rod and a pin-hole welded by spot welding. The TIG spot welding was carried out using an electrode position control jig to exactly fix a TIG electrode in a high-pressure chamber filled with helium gas according to the pressure conditions and weld variations, such as the welding current, welding time and gap between an electrode and sample. The results have shown a good welding performance at a welding current of 30A, welding time of 0.4sec and a 1mm gap in a helium gas atmosphere (filling pressure: 20bar).

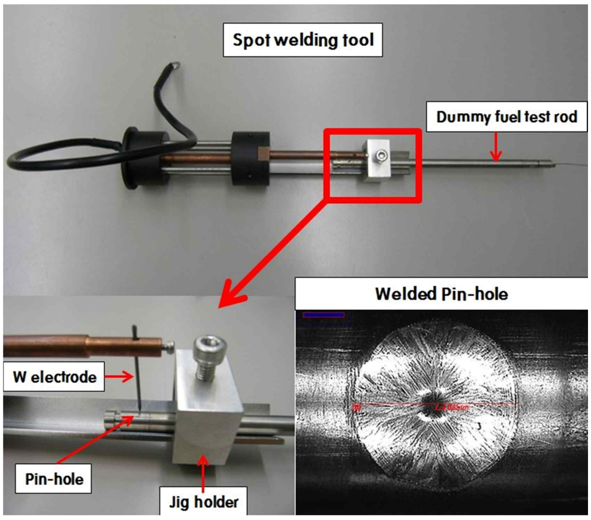

Fig. 1 The spot welding tool mounted with a dummy fuel test rod and a pin-hole welded by spot welding

4. Thermocouple instrumentation

The central temperature of the fuel pellets during the irradiation test is acquainted from a C-type T.C instrumented at the nuclear fuel test rod. The T.C is installed at the top or bottom of the end-cap to measure the central temperature of a nuclear fuel test rod. Its hot junction is the point jointing a positive wire (5%Re+W) and a negative wire (26%Re+W). It is sealed by a mechanical sealing method [3] using a Swagelok part because the MI cable and fuel cap cannot be welded using hetero-metal. The Swagelok composition parts of the fuel test rod and a cross sectional photo of the sealed T.C Swagelok part are shown in Fig. 2. The sealing point in the cross sectional photo is the mechanical contact area compressed by the strength forced between a seal tube and an end-cap. The dummy fuel test rod was fabricated according to the production conditions obtained through some tests, such as the mechanical sealing test and welding test to develop the instrumentation techniques of the T.C for the nuclear fuel test rod. Its soundness was confirmed by helium leak tests and microstructural analyses.

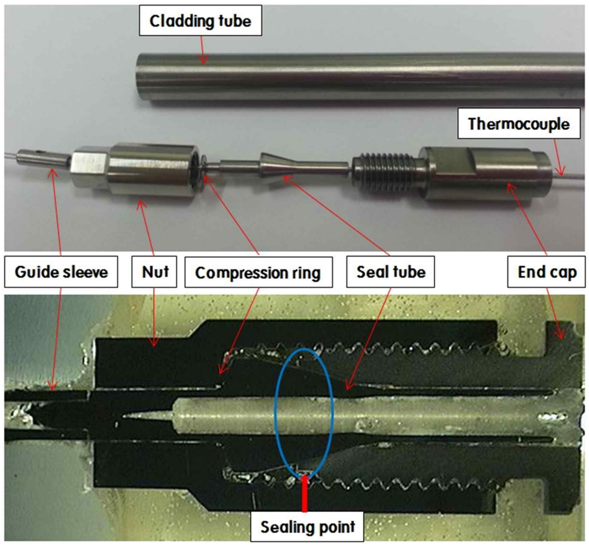

Fig. 2 The Swagelok composition parts of the fuel test rod and a cross sectional photo of the T.C Swagelok part

5. Conclusions

A dummy nuclear fuel test rod was successfully fabricated with the welding and instrumentation technologies acquired with various tests. In the test results, the round welding has shown a good weld-ability at both the orbital TIG welding system and the fiber laser welding system. The spot welding to fill up helium gas has shown a good welding performance at a welding current of 30A, welding time of 0.4sec and gap of 1 mm in a helium gas atmosphere. The soundness of the nuclear fuel test rod sealed by a mechanical sealing method was confirmed by helium leak tests and microstructural analyses.

Acknowledgement

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REFERENCES

[1] KAERI, TR-3633/2008, "Fabrication report on the instrumented fuel rods for the 3-pin Fuel Test Loop at HANARO", 2008.
[2] C.Y. Joung et al., "Development of TIG Welding for a Nuclear Fuel Test Rig" KNS Spring Meeting, 2013.
[3] KAERI, AR-559/2000, "A Review on the Welding Technology for the Sealing of irradiation Test Fuel Element", 2000.