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Development of Gas Filling Technology for Nuclear Fuel Test Rod

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1. Introduction

The inner pressure of a fuel rod resulting from the irradiation characteristics of nuclear fuel is an important factor for evaluating the in-pile nuclear fuel properties. To measure the inner pressure variations during irradiation testing a nuclear fuel test rod of LWR is filled with 22.5bar helium gas [1]. The role of filled helium gas inside a nuclear fuel test rod is to prevent the depression of the cladding tube during the combustion goal of the test fuel and improve the heat transfer coefficient of a gap between pellets and cladding. To conduct the irradiation testing of the nuclear fuel, a test rod must be assembled along with test fuel and several different parts such as end-caps, a cladding, a plenum spring, and sensors, and then filled with high-pressure and high-purity helium gas [2]. Therefore, it is necessary to develop helium gas filling techniques that can achieve exact TIG spot welding at a pin-hole of an end-cap to fill up with helium gas into the nuclear fuel test rod. However, previous spot welding apparatuses do not have repeatability for TIG spot welding because they cannot exactly fix a TIG electrode on a pin-hole of a nuclear fuel test rod in a high-pressure chamber, and they consume a large amount of helium gas. Therefore, a spot welding apparatus composed of a TIG spot welding jig and insertion blocks was developed to easily and accurately conduct TIG spot welding and significantly reduce the amount of gas consumption. In addition, optimum welding conditions using a TIG spot welding jig were established through various weld tests.

This paper describes not only the design properties and filling method of a spot welding system used to fill helium gas into a the nuclear fuel test rod but also some results from weld experiments to verify the gas filling performance of this system.

2. Experimental

The gas filling system shown in Fig. 1 has been configured to fill helium gas inside a nuclear fuel test rod. It consists of three main parts: a high-pressure chamber, a TIG welder, and a TIG spot welding jig. The pressure chamber shown in Fig. 1(a) is connected with a vacuum pump and a gas supply system for high purity gas atmosphere for a TIG spot weld and inserted with the insert blocks to reduce the amount of filling gas. The TIG welder is used to supply power for each weld process conducted in a pressure chamber. It is M-207A model by AMI, Co. The TIG spot welding jig shown in Fig. 1(b) is an apparatus that needs to set a pin-hole position of a nuclear fuel test rod for exact spot welding.

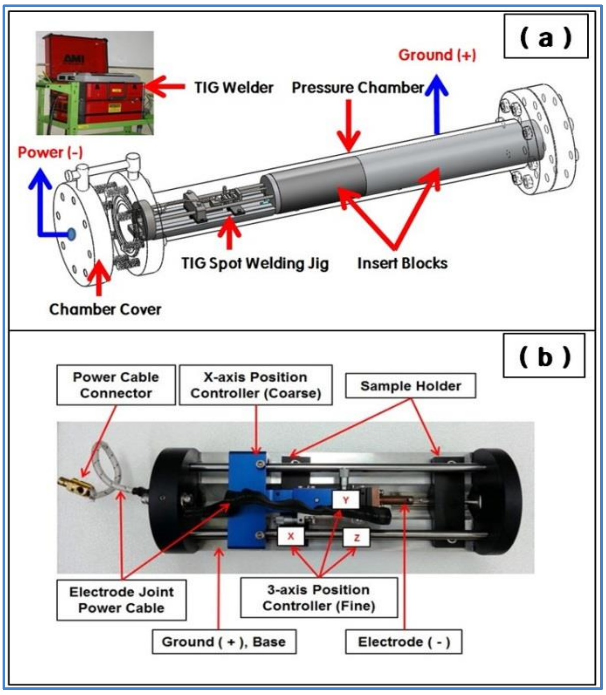

Fig. 1 Gas filling system: (a) The configuration of a spot welding system used to fill helium gas and (b) TIG spot welding jig to hold a nuclear fuel test rod.

During these tests, the weld materials of the nuclear fuel test rod were Zrcaloy-4. To fill helium gas into the nuclear fuel test rod, a TIG spot welding test was conducted using the following test parameters: the welding currents, welding times, chamber pressures, pin-hole sizes, electrode angles, and gaps between a pin-hole and an electrode. To inspect the surface defects, a visual test was carried out to all welded samples. Helium leak tests for nuclear fuel test rods welded to be filled with helium gas were conducted using an ASM-380 model by DEIXEN, Co. (helium detector). A metallographic test was conducted to analyze the weld defects in test specimens. To determine the real applicability of filling helium gas, a dummy fuel test rod instrumented with a C-type thermocouple was fabricated under optimum welding conditions established through the above tests. the soundness was determined through a data acquisition test and heating test in a furnace at 310^{o}C.

3. Results and discussions

To develop TIG spot welding technologies using the helium gas filling system, TIG spot welding tests were conducted for the specimens, and the optimum spot welding parameters such as a welding current of 60A, a welding time of 0.8s., a pin-hole size of 1 mm, an electrode angle of 60^o, and a welding gap of 0.134 mm were obtained. TIG spot welding tests on filling a rod with helium gas were carried out as follows: First, a nuclear fuel test rod was fixed to a newly developed TIG spot welding jig according to the position of the electrode (-) on a pin-hole of the end-cap (+), and then putt into the chamber. Second, after vacuuming the chamber, a nuclear fuel test rod is filled with helium gas according to the pressure parameters. Finally, the TIG welder programed using the weld parameters is turned on. Surface and microstructure photographs of specimens welded at (a) 40 A and 0.4 s and (b) 60 A and 0.8 s are shown in Fig 2. A pin-hole of the specimen shown in Fig. 2(a), was not sufficiently filled with a fusion zone at 40 A and 0.4 s under identical parameters (a chamber pressure of 22.5 bar, a pin-hole size of 1 mm, an electrode angle of 60^o, and a welding gap of 0.134 mm), whereas that of the specimen shown in Fig. 2(b) was completely filled with a fusion zone at 60 A and 0.8 s.

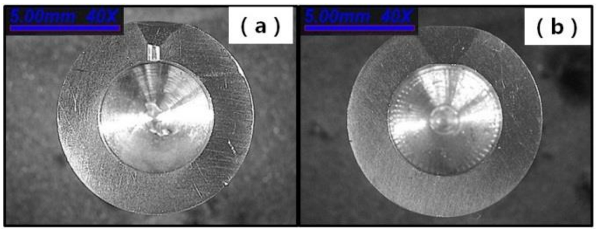

Fig. 2 microstructure photographs of specimens welded according to currant and time parameters; (a) 40 A and 0.4 s, and (b) 60 A and 0.8 s.

The dummy fuel test rod shown in Fig 3 was fabricated using the production conditions with the instrumentation techniques of the C-type T.C for measuring the centerline temperature, and it was then filled with helium gas of 22.5 bar using a gas filling system. In this gas filling process, its pin-hole was welded at a welding current of 60 A, a welding time of 0.8 s, a pin-hole size of 1mm, an electrode angle of 60^o, and a welding gap of 0.134 mm. To confirm the real applicability of the nuclear fuel test rod instrumented with sensor data acquisition, and heating tests were carried out in 310^{o}C furnace similar to the in-pile temperature of a PWR. In this test, the data acquired from a dummy fuel test rod instrumented with a C-type thermocouple were able to be measured in real time. The surface of a dummy fuel test rod heated in a furnace was slightly discolored through oxidation, but the dummy fuel test rod was conformed to the soundness through helium leak tests before and after the heating test. The amount of helium gas remaining in the dummy fuel test rod will be measured through a rupture test in an autoclave of a hot cell.

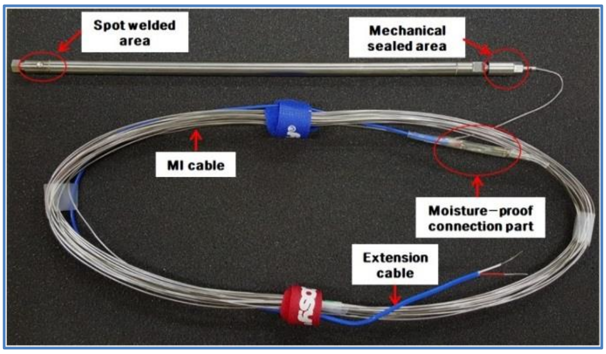

Fig. 3 Dummy fuel test rod heated at 310^{o}C.

3. Conclusions

A gas filling system was developed to fill helium gas into a nuclear fuel test rod instrumented with sensors. It is configured for welding a nuclear fuel test rod by applying a TIG welder using a pressure chamber. To develop TIG spot welding technologies using the helium gas filling system, TIG spot welding tests were conducted for end-cap specimens, and the optimum spot welding parameters such as a welding current of 60A, a welding time of 0.8s., a pin-hole size of 1 mm, an electrode angle of 60^o, and a welding gap of 0.134 mm were obtained. A dummy fuel test rod filled with helium gas was fabricated using the production conditions with the instrumentation techniques, and the data acquisition test and heating test for the dummy fuel test rod were carried out in a furnace. The soundness of the dummy fuel test rod was confirmed through an analysis of acquainted data signals and helium leak values.

Acknowledgement

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