Fabrication Process of a Nuclear Fuel Test Rig in HANARO

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1. Introduction

To evaluate the performance of newly developed PWR nuclear fuels, an adequate test rig installed in a pressure vessel of IPS, as a part of FTL (Fuel Test Loop) should be fabricated to meet the irradiation purposes. Generally, a nuclear fuel test rig is designed to measure the central temperature of a nuclear fuel pellet and the internal pressure of a fuel rod during an irradiation test. In special cases, it is also designed to measure the swelling or elongation of the fuel rod. The test rig should be designed and fabricated to endure highly heated (300℃) and pressurized (15.5 MPa) coolant. In addition, it is important to maintain its structural soundness and sealing performance for the flow induced vibration. In this study, the fabrication process of a nuclear fuel test rig that includes a detachable fuel rod assembly has been developed.

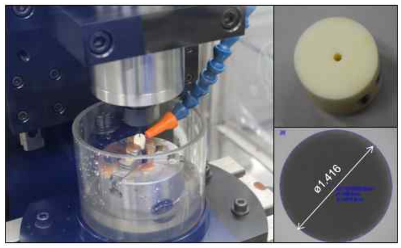
2. Fabrication Process of a Test Rig

The fabrication of fuel rods and assembly of a test rig are described in this section. The fabrication process consists of assembling fuel rods and their supporting structure, sealing of the pressure boundary, and installation of the test rig in the IPS.

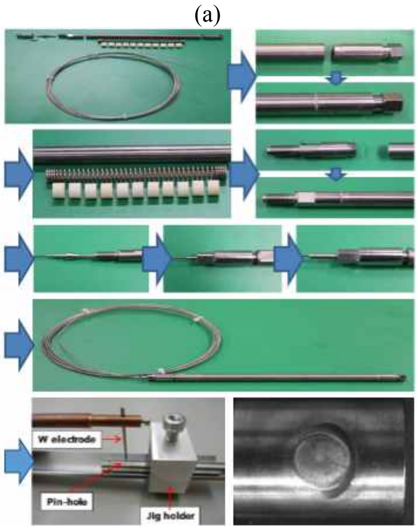
2.1 Fuel rod

Generally, a nuclear fuel test rig consists of instrumented fuel rods in which thermocouples or LVDTs are installed. In this study, a detachable fuel rod assembly is considered to enable the intermediate examination, and the uninstrumented fuel rod is also included [1].

Fig. 1 shows the fabrication process of the instrumented fuel rod. As shown in the figure, it needs to drill off fuel pellets and sintered alumina pellets to install a thermocouple in the instrumented fuel rod. Because the diameter of the C-type thermocouple used in nuclear fields is 1.2 mm, the pellets need to be drilled off with a diameter of 1.4±0.05 mm [2]. After cogging one end of a cladding with an end cap by the laser welding method, a plenum, pellets, and a thermocouple are inserted in the cladding. Then, the other end is clogged with another end cap by the laser welding. The instrumentation feed through part of an end cap is then sealed through a laser welding process. Finally, the hole of the end cap in the helium gas chamber (filled with 2 MPa) is sealed out by the TIG spot welding. The uninstrumented fuel rod uses the same fabrication process without drilled pellets and a thermocouple.



(a)



(b)

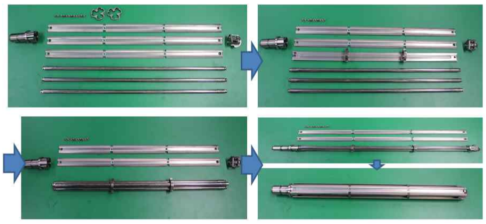
Fig. 1. Fabrication process of an instrumented fuel rod (a) drilling of a sintered alumina pellet (b) assembly of a fuel rod.

2.2 Supporting structure

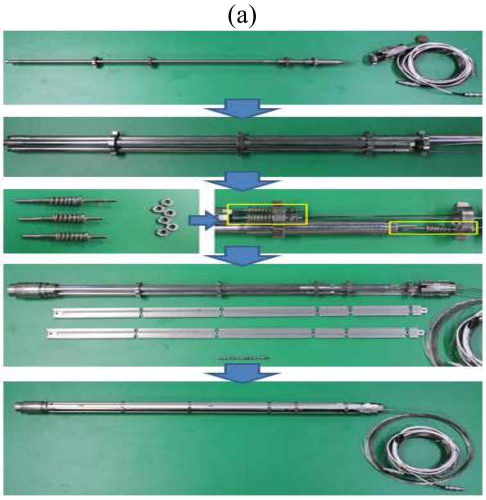
The test rig in this study is designed to accommodate six fuel rods (ø9.5 x L420). Because the fuel rods should be fixed in the test rig during the irradiation test, several supporting components are assembled into two fuel rod assemblies. One is an instrumented fuel rod assembly that accommodates three instrumented fuel pins, and the other is an uninstrumented fuel rod assembly that accommodates three uninstrumented fuel pins. The instrumented fuel rod assembly is assembled into a long supporting structure which fixes the fuel rod assembly at the irradiation position, and guides the flow of the coolant. Fig. 2 shows the assembly process of a fuel rod assembly and its supporting structure.

2.3 Sealing of pressure boundary part

During the irradiation test of nuclear fuels in the test loop, coolant with 300℃ and 15.5 MPa circulates through the test loop. Therefore, the test rig installed in the test rig should be sealed out to prevent the leakage of the coolant. The instrumentation feed through part is very difficult to seal out because 16 instrumentation cables pass through a small sealing plug. In this study, the instrumentation feed through part is sealed out using the induction brazing method with BNi-2 and a special vacuum chamber [3]. Fig. 3 shows the sealing process of the instrumentation feed through part. Then, helium leak test and hydraulic pressure test are carried out to verify its sealing performance.



(a)



(b)

Fig. 2. Fabrication process of fuel rod assembly and supporting structure (a) uninstrumented fuel rod assembly (b) instrumented fuel rod assembly and supporting structure.

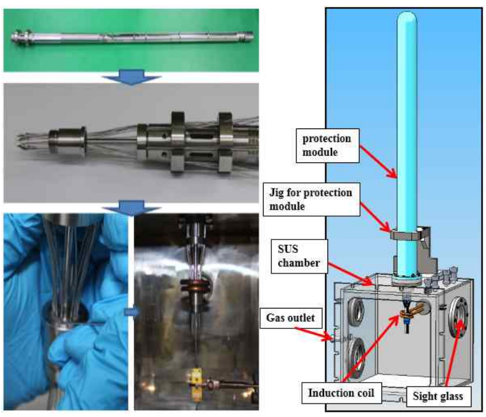


Fig. 3. Sealing process of the instrumentation feed through part using a vacuum induction brazing.

2.4 Installation of the test rig in the IPS

The fabricated nuclear fuel test rig is necessary to be installed in the IPS of the test loop to carry out the irradiation test. The test loop in HANARO has an independent coolant circulation system, and the IPS uses a double pressure vessel whose inner diameter is 46 mm. To circulate the coolant in the IPS, a flow divider is installed in the double pressure vessel. The test rig is then installed in the double pressure vessel, as shown in Fig. 4.

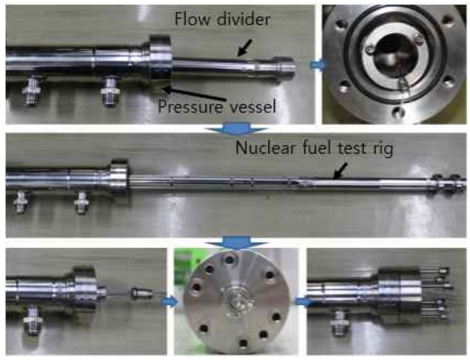


Fig. 4. Install of a nuclear fuel test rig in the pressure vessel.

3. Conclusions

The fabrication process of a nuclear fuel test rig that includes a detachable fuel rod assembly has been introduced in this study. Key techniques to fabricate a nuclear fuel test rig have been developed and used in fabricating a test rig mockup. Therefore, to fabricate a new test rig, the tooling of the components and making sub-assemblies that do not include nuclear fuels are outsourced, and the key assembly and sealing processes are carried out in the controlled area using the developed techniques. The developed technique will be used in fabricating a test rig to carry out an irradiation test in the FTL.

ACKNOWLEDGEMENTS

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