Design Improvement of Double Pressure Vessel in the In-pile Test Section

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1. Introduction

To carry out an irradiation test of nuclear fuels, a nuclear fuel test rig should be fabricated and installed in the in-pile test section (IPS), which is installed in the reactor hall. While carrying out an irradiation test, sealing out coolant which passes through the test rig is one of the most important issues. In 2008, KAERI carried out a commissioning test for the newly developed loop and test rig. As a result of the commissioning test, it turned out that there is a probability of leakage of coolant, and the mechanical designs of several components need to be improved. In particular, although the double pressure vessel is assembled with the IPS head by two o-rings and six bolts, 15.5 MPa of highly pressurized coolant leaks through the gap between the vessel and IPS head. Because the temperature of the coolant in the test loop is 300℃, and the pool of HANARO is 40℃, the double pressure vessel is necessary to insulate them. Therefore, a new design to prevent the leakage of coolant needs to be developed. In this study, EB welding technique is considered to assemble the double pressure vessel and the IPS head, and their mechanical design is modified to enable the welding process.

2. Design Improvement of Double Pressure Vessel

To enable the EB welding, the assembly part of the double pressure vessel and the IPS head need to be redesigned. In this section, new designs for the EB welding process and the results of the welding experiments are described.

2.1 Design Changes for EB Welding

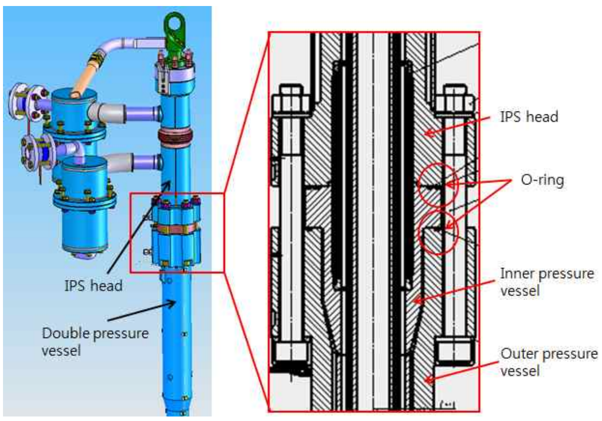
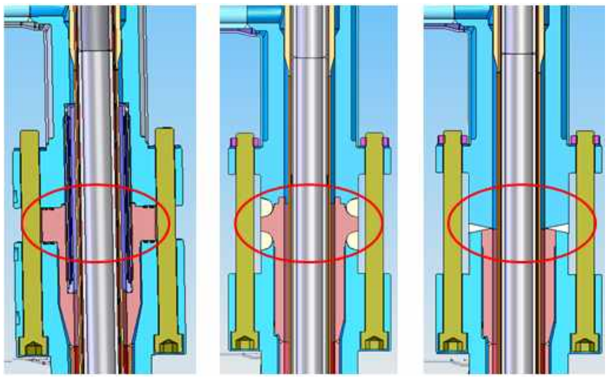


Fig. 1. Former design of the IPS.

Fig. 1 shows the former design of the IPS. Although two o-rings are applied and fixed with six bolts, an o-ring is not strong enough to seal out a high temperature and highly pressurized coolant. Therefore, welding is considered to seal out the coolant. However, the thickness of the double pressure vessel and IPS head is 21 mm, and it is difficult to weld those parts by the conventional welding techniques. Fig. 2 shows the heritage of the design change. Fig. 2(b) shows the design for TIG welding. As shown in the figure, two steps of welding are necessary, and it generates a large heat affected zone. In addition, it is difficult to weld the part owing to the small working space. The EB weld has long penetration depth, and can be a good solution to join those parts. As shown in Fig. 2(c), the design is changed to carry out a butt weld for the two pressure vessels and the IPS head with a single step. Six bolts should be assembled after the welding process to prevent damage while transporting the assembly.

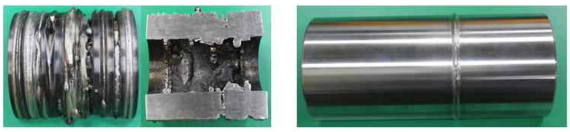


(a) (b) (c)

Fig. 2. Welding design for the double pressure vessel (a) Former design (b) TIG welding design (c) EB welding design

2.2 EB Weld of Double Pressure Vessel and IPS Head

Prior to fabricating the mockup, the welding parameter needs to be adjusted to achieve 21 mm of penetration depth, as shown in Fig. 3. In addition, the optimal welding parameters are listed in Table I. The test results show that weld nugget is completely penetrated throughout the whole specimen.



(a) (b)

Fig. 3. Test specimens for EB weld (a) checking the penetration depth (b) simulating the butt welding

NDE was carried out using the specimen shown in Fig. 3(b). As shown in Fig. 4, the double pressure vessel and the IPS head are welded completely without a defect or void.

Table I: Weld and Travel Setting for EB weld

ITEM	Cleaning	Tracking	Welding	Deburring
Voltage (kV)	150			
Focus current (mA)	2175	2175	2130	2225
Weld current (mA)	8	15	50	25
Distance (mm)	544	544	544	544
Velocity (mm/min)	1200			
Pressure (Torr)	<<$5.0x10^{-6}$			

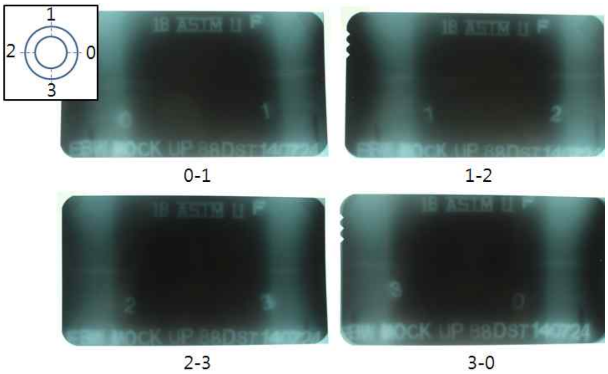


Fig. 4. Result of NDE for the EB welded part

2.3 Cross section test

To check the penetration depth of the welded nugget, the specimen of Fig. 3(b) is cut in the axial direction, and post processes such as polishing and etching were carried out on the cross section. Fig. 5 shows the cross section of the welded part. As shown in the figure, nugget is fully penetrated through the double pressure vessel assembly.

Fig. 5. Cross section of the EB welded part

2.4 Hydraulic Pressure Test

During the irradiation test, 15.5 MPa of pressurized coolant circulates in the test loop including the IPS. Therefore, the welding part also should endure the pressure of the coolant up to 15.5 MPa. The design pressure of the double pressure vessel and the IPS head is 17.5 MPa, and the welded part should endure 21.9 MPa according to ASME III & V. Fig. 6 shows the experimental setup for hydraulic pressure test of the pressure vessel. 21.9 MPa of coolant is induced in the vessel and is maintained for 20 minutes. The test results show that there is no leakage or pressure drop of the coolant.

Fig. 6. Hydraulic pressure test of the EB welded part

3. Conclusions

In this study, an improved design for sealing out the coolant at the pressure boundary between the double pressure vessel and the IPS head has been developed. An EB weld is applied to seal out the pressure boundary, and its sealing performance is verified by NDE, a cross section test, and a hydraulic pressure test. From the verification test results, the improved design can be used in fabricating the IPS for a nuclear fuel irradiation test.

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