*Transactions of the Korean Nuclear Society Spring Meeting*
*Jeju, Korea, May 12-13, 2016*

# End Plug Welding of SFR Fuel Rodlet for Irradiation Test in HANARO

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## 1. Introduction

A Prototype Generation-IV Sodium-cooled Fast Reactor (PGSFR) is being developed as one of the national long-term nuclear R&D programs in collaboration with the Gen-IV program. As a fuel for SFR, metallic fuel, U-Zr alloy fuel, was selected and is being developed. And U-TRU-Zr fuel development is under way in combination with the pyro-electrochemical processing of spent PWR fuel [1]. To evaluate the SFR fuel performance, the irradiation test in HANARO research reactor was planned and the fuel rodlet to be used for irradiation test should be manufactured under the appropriate Quality Assurance (QA) program. For the fabrication of SFR metallic fuel rodlets, the end plug welding is a crucial process [2,3]. The sealing of end plug to cladding tube should be hermetically perfect to prevent a leakage of fission gases and to maintain a good reactor performance [4]. In this study, the qualification test of the end plug welding of fuel rodlet for irradiation test in HANARO was carried out based on the developed welding technique, welding equipment, welding conditions and parameters [5].

## 2. Requirements of fuel rodlet for irradiation test

Fig. 1 shows the dimensions of SFR metallic fuel rodlet for the irradiation test in HANARO research reactor. The fuel rodelts to be assembled for the irradiation capsule is shown in Table 1. As shown in Table 1, 3 kinds of cladding materials, HT9, FC92B, FC92N and 2 kinds of slug materials, U-10%Zr and U-10%Zr-5%RE are used for the irradiation test.

Table 1. Arrangements of fuel rodlets in capsule.

| Location | ID No. | Fuel Slug | Cladding Material | Barrier Coating |
|---|---|---|---|---|
| Upper | 1 | U-10%Zr | FC92B | |
| | 2 | U-10%Zr-5%RE* | FC92B | Cr |
| | 3 | U-10%Zr | FC92N | |
| | 4 | U-10%Zr-5%RE* | FC92N | Cr |
| | 5 | U-10%Zr | HT9 | |
| | 6 | U-10%Zr-5%RE* | HT9 | Cr |
| Lower | 1 | U-10%Zr | FC92B | |
| | 2 | U-10%Zr-5%RE* | FC92B | Cr |
| | 3 | U-10%Zr | FC92N | |
| | 4 | U-10%Zr-5%RE* | FC92N | Cr |
| | 5 | U-10%Zr | HT9 | |
| | 6 | U-10%Zr-5%RE* | HT9 | Cr |

*RE ; Nd 53%, Ce 25%, Pr 16%, La 6%

The fuel assembly is composed of fuel rodlet and fuel sealing tube. Each fuel rodlet has a lower end plug, a fuel slug, an upper gas plenum, and an upper end plug as shown in Fig. 1. The inside of the fuel rodlet, the gap between the fuel slug and fuel cladding is filled with sodium (Na). The plenum is filled with 1 atmosphere of He gas. After end plug welding, the He leak rate should be less than $5x10^{-8}$ $cm^3/s$.

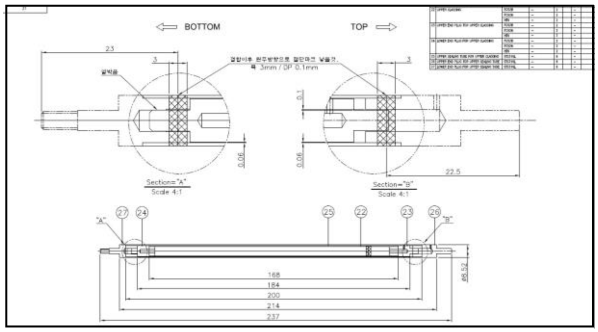


Fig. 1. Drawing of SFR metallic fuel rodlet for irradiation test.

## 3. GTAW for End Plug Welding

Gas Tungsten Arc Welding (GTAW) melts the weld joint by an electric arc generated between the tip of a tungsten electrode and the weld joint. A GTAW system for end plug welding was developed, as shown in Fig. 2.

Fig. 2. Photograph of the GTAW system for end plug welding.

It is composed of a GTAW welder (Model Maxstar 200DX, Miller), a welding chamber, and an arc height controller (Model HAS-01-A-1, Hangil Industry co.). End plug welding is carried out in a He gas atmosphere confined in a welding chamber. The welding chamber accommodates the weld joint and is evacuated to remove air gas, and is back filled with high purity (99.999%) He gas to fill the inner space of the fuel rod.

A welding torch containing a welding electrode is located on top of the welding chamber. The weld joint is positioned directly under the welding electrode. The cladding tube plugged with an end plug is rotated and welding is conducted by the arc generated between the cladding tube and welding electrode. A CCTV camera was used to monitor the alignment of the weld joint and the arc during the welding process. In addition, an arc height controller (Model HAS-01-A-1, Hangil Industry co.) was introduced to adjust the gap between the cladding tube and the tip of the welding electrode.

## 3. End Plug Welding

For the optimal end plug welding conditions to make SFR metallic fuel rod, the performance tests were conducted. The end plugs and cladding tubes material are HT9, FC92B, FC92N, and T92 stainless steel. As a result of the performance welding tests, a good weld shape and weld quality were obtained as shown in Fig. 3.

Fig. 3. Weld shape of fuel rodlet.

## 4. Qualification of End Plug Welding Process

### *4.1 Qualification test procedures*

The qualification test has to be done to prove the weld quality of end plug welding of fuel rodlet. The following qualification test procedures were conducted.

- Welding dummy fuel elements by GTAW
- Visual inspection
- X-ray radiography
- He- leak testing
- Dimension measuring
- Metallographic examination
- Burst test
- Tensile test

### *4.2 Qualification test results*

According to the qualification test procedures, the weld quality evaluation tests were conducted and the following test results were obtained.

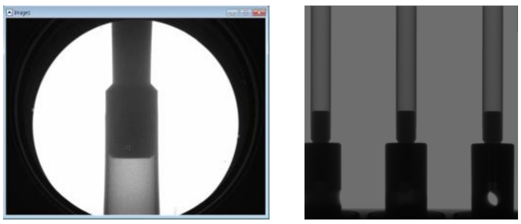

Fig. 4. X-ray radiography result on the weld part.

Fig. 5. Metallographic examination result on the weld part.

Fig. 6. Burst test result.

Fig. 7. Tensile test result.

As shown in Fig. 4 to Fig. 7, the results of visual inspection, X-ray radiography, metallographic examination, burst test and tensile test satisfied the requirements on the weld. And also it was not found any leakage in a helium leak test. As a result of the qualification test, the weld quality of end plug welding of fuel rodlet for irradiation test in HANARO was qualified and the welding process is ready to weld the fuel rodlets under the qualified conditions.

## 5. Conclusions

As a result of the qualification test, the weld quality of end plug welding of fuel rodlet for irradiation test in HANARO was evaluated according to the qualification test procedures and satisfied the requirements on the weld. Consequently the qualified welding process is ready to weld the fuel rodlets.

## ACKNOWLEDGEMENTS

This work has been carried out under the Nuclear Research and Development Program supported by the Ministry of Science, Ict and Future Planning in the Republic of Korea.

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