Fabrication of the Instrumented Fuel Rods for the 3-Pin Fuel Test Loop at HANARO

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1. Introduction

The 3-Pin Fuel Test Loop(hereinafter referred to as the FTL) facility has been installed at HANARO(High-flux Advanced Neutron Application Reactor) and the 3-Pin FTL is under a test operation. The purpose of this paper is to fabricate the instrumented fuel rods for the 3-Pin FTL. The fabrication of these fuel rods was based on experiences and technologies of fuel rods for an instrumented fuel capsule [1]. This paper presents the design, assembling and welding of fuel rods and the results of qualification tests.

2. Design of the instrumented fuel rods

The three instrumented fuel rods of the 3-Pin FTL have been designed as shown in Fig. 1. As shown Fig. 1, the one fuel rod(180°) was designed to measure the centerline temperature of the nuclear fuels and the internal pressure of the fuel rod, and others(60° & 300°) were designed to measure the centerline temperature of the fuel pellets.

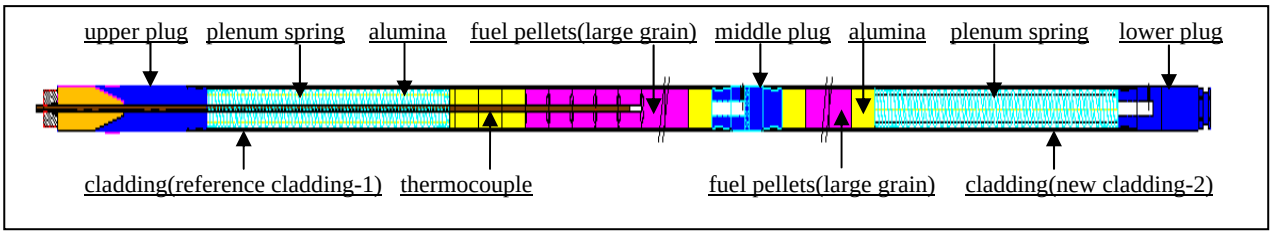
In the instrumented fuel rods, the C-type thermocouples were used to measure the centerline temperatures, a pressure transducer and a LVDT(Linear Variable Differential Transformer) were used to measure the internal pressure of the fuel rod. The fuel rods contains of cladding, fuel pellets, plugs, alumina, plenum spring and sensors. The claddings were made of the reference material 1 & 2 and new material 1 & 2.

3. Fabrication of the instrumented fuel rods

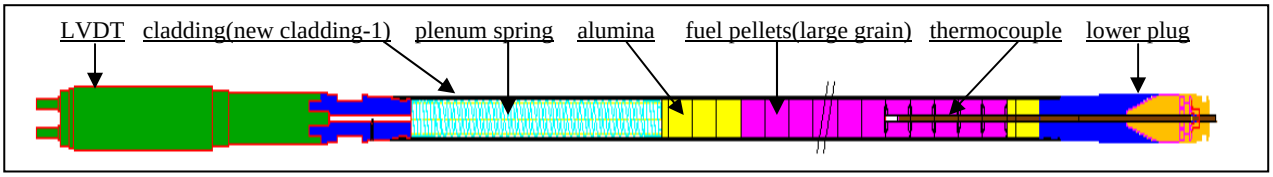
The major procedures of fabrication are followings: (1) the assembling and weld of fuel rods with the pellet mockups and the sensor mockups for the qualification tests, (2) the qualification tests of weld, (3) the assembling and weld of instrumented fuel rods with the nuclear pellets and the sensors for the irradiation test, and (4) the helium leak test and the dimensional measurement of fuel rods.

3.1 Assembling and weld

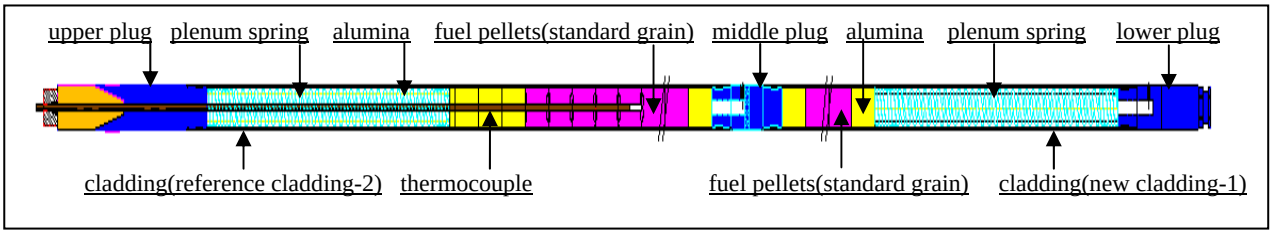
The UO_2 pellets(2.0 w/o, large grain and standard grain) fed into cladding. Some pellets were drilled at center(Ø1.47 mm) to install a thermocouple(Ø1.2 mm) as shown in Fig. 2.



(a) a fuel rod to measure the centerline temperature of the nuclear fuel (60°)



(b) a fuel rod to measure the internal pressure of fuel rod and centerline temperature of the nuclear fuel (180°)



(c) a fuel rod to measure the centerline temperature of the nuclear fuel (300°)

Fig. 2. Schematic diagrams of instrumented fuel rods for the 3-Pin FTL

Fig. 2. Fuel pellets (left: before drilling, right: after drilling)

The weld of pinhole was performed after welds of between cladding and plug were performed. Fig. 3 shows the results of the claddings and middle plug weld and a pinhole weld. The fuel rod was filled with helium gas of a gauge length of 22.5 kg/cm^2. The all weld processes were performed in helium gas chamber by using TIG(Tungsten Inert Gas) welding method.

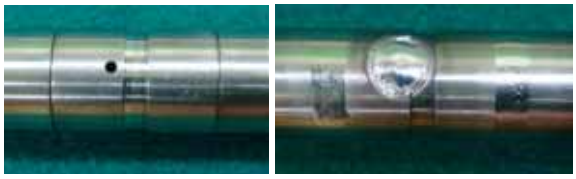


Fig. 3. Cladding and middle plug weld and pinhole weld (left: before weld, right: after weld)

3.2 Qualification tests of welding

The qualification tests, such as dimension measurements, electric resistance measurements of sensors, tensile tests, metallography examinations and helium leak tests were performed to verify the quality of weld. The dimension and electric resistance measurements were performed at before and after of weld.

The three different specimens(reference cladding-1 & 2, new cladding-1) were prepared for the tensile tests. The tensile tests were performed at room temperature. In all specimens, the fractures were occurred at not welding zones as shown in Fig. 4.

Fig. 4. tensile test of claddings after weld

The five specimens were prepared for metallography examinations. The cross sections of weld of between a cladding and a plug, and a pinhole are shown in Fig. 5. In all specimens, depth of welding zone is larger than the thickness of a cladding(0.57 mm).

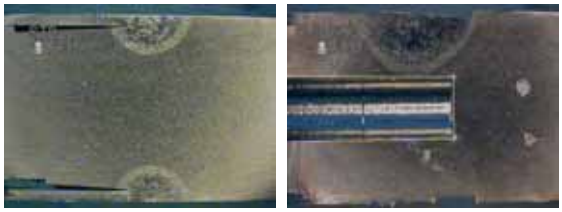


Fig. 5. Photograph of cross section of weldments (left: between cladding and plug, right: pinhole)

3.3 Fabrication of the instrumented fuel rods

The three instrumented fuel rods were fabricated as shown Fig. 6. In the helium leak test of the fuel rods, the helium gas was detected less than 5x10^{-9} mbar·l/sec.

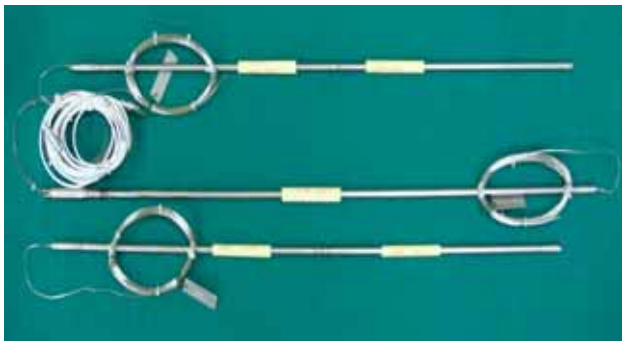


Fig. 6. The instrumented fuel rods for the 3-Pin FTL

4. Conclusion

Satisfactory results were obtained for all the qualification tests of the instrumented fuel rods for the 3-Pin FTL. Therefore the three instrumented fuel rods for the 3-Pin FTL have been fabricated successfully. These will be installed in the In-Pile Section of 3-Pin FTL. And the irradiation test of these fuel rods is planned from the first half of the 2009 for about 3 years at HANARO.

Acknowledgement

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[1] J.M.Sohn, “Design of the Instrumented Fuel Capsule(05F-01K) for the Dual Instrumented Fuel Rods Irradiation Test at HANARO”, Korea Nuclear Society, 2005.10