Design Improvements of a Fuel Capsule for Re-irradiation Tests

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1. Introduction

The development of an advanced reactor system such as the next generation nuclear plant and other generation IV systems require new fuels, claddings, and structural materials. To characterize the performance of these new materials, it is necessary for us to have leading-edge technology to satisfy the specific test requirements of the recent R&D activities such as the high-fluence- and high-burnup-related tests. Thus, new capsule assembling technology and re-instrumentation technology has been developed to meet the demands for the high burnup test at HANARO since 2003. In 2003, a mockup of the capsule assembly machine was designed and fabricated [1, 2]. The performance test which started in 2004 was undertaken to determine and present the main performance characteristics of the capsule assembly machine (CAM) including the special tools. In 2005, a series of analyses using a finite element analysis program, ANSYS [3] and full scale tests in air were performed to improve the design of the capsule's components for an effective utilization of the CAM[4]. The handling tools were fully qualified through the performance tests in 2006[5]. KAERI is now reviewing the water flow area in the top region of a fuel capsule main body for re-irradiation tests and optimizing the design of the central region area of a capsule to be joined with special bolts.

2. Methods and Results

Since the structural integrity of an assembled capsule under the HANARO operational conditions must be assured before an application in the reactor, some limitations on the experimental and analytical requirements were reviewed and solved.

2.1 Description of a Fuel Capsule for Re-irradiation Tests

The typical HANARO fuel capsule is about 5m in height and consists of a main body of 56mm in outer diameter and about 1 m in length, three test fuel pins of 11.7mm in outer diameter and about 20 cm in length, a bottom guide assembly, a guide tube and a protection tube made of STS 304 stainless steel tube. Figure 1 is the schematic view of the HANARO fuel capsule for re-irradiation tests.

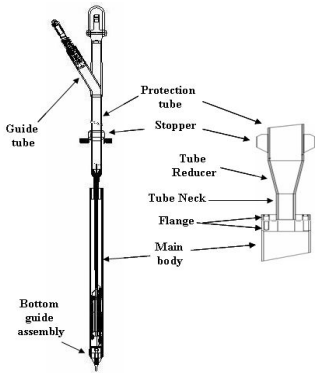

Figure 1. Schematic view of the HANARO fuel capsule

A new capsule assembly technique was developed in which special built bolts are used to assembly capsule's components. For an effective assembling process by bolting, each of the flanges was designed to be welded on both sides of the bottom of a protection tube and the top of a capsule's main body, and the two flanges are connected with four stainless steel bolts by using a remote working tool [4].

2.2 Design Improvements and Optimization

Through the detailed analysis and tests of the thermal hydraulics and of the structure-related stress, along with a vibration analysis, the design concept of a fuel capsule was optimized and found to be structurally integrated and reconciled with HANARO's hydraulic conditions [6]. Particularly, the components such as the top end plug of the capsule main body were designed for a specimen to be effectively cooled and exposed in neutron environment during irradiation test. The minimum cooling water flow area of the top end plug of the current capsule is about 800 mm^2, which was obtained by using a mockup fuel capsule in the out-of-pile test facility, which has the same flow tubes as those in the HANARO reactor. Therefore, a new design change of the components such as an end plug, locking bolts, and guide pins was proposed as shown in Figure 2 and Table 1. Particularly, sufficient access to the top of a capsule's main body and space for an in-situ

bolting by a remote tool was considered for the assembling process.

Table 1. Key Design Parameters of a Capsule

Case	Previous Design(mm)	New Design(mm)
Locking Bolt	STS 304, M8 x P1.25, PCD 47, 4Ea	STS 304, M6.35 x P1.27, PCD 46, 3Ea
Guide Pin	OD6, PCD 47	OD5, PCD 48
Protection Tube Flange	STS 304, OD58	STS 304, Flange OD55/ID41xT15 Flange Cover OD58/ID55xT15

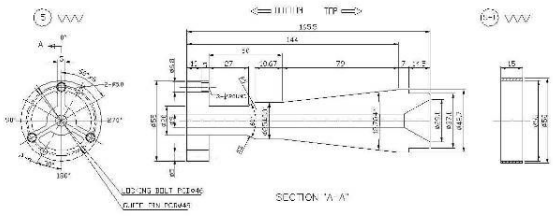

Figure 2. Improved design of the tube neck and reducer of a fuel capsule

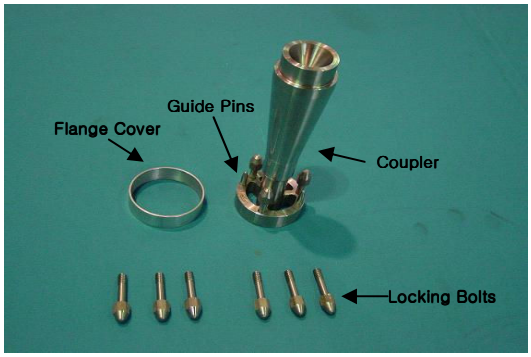

Figure 3. Photos of fuel capsule components

3. Conclusion

From the design improvements of the fuel capsule for re-irradiation tests, the major findings from this study are delineated as below.

1. The previously designed protection tube with the introduction of a long tube reducer was optimized to be reconciled with the HANARO's required hydraulic test conditions.
2. Based on the new design concept, a capsule mock-up was manufactured for the performance tests under water. After the completion of a series of out-pile experiments, this capsule will be used for the fuel experiments related to advanced fuel development programs.
3. Test data prepared by this study is to be used for the design and fabrication of the HANARO capsule.

ACKNOWLEDGEMENTS

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