DEVELOPMENT OF TOOLS FOR TREATING AN IRRADIATED FUEL ROD ASSEMBLY IN THE POOL OF HANARO

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ABSTRACT

To inspect a fuel rod during irradiation testing at the test loop of a research reactor, the test rig should be disassembled from the IPS (In-pile test section), and the targeted fuel rod assembly should be disassembled from the test rig and encapsulated in a cask to deliver the assembly to the hot cell. In addition, the fuel rod assembly under inspection in the hot cell should be delivered to the reactor pool and reassembled into the test rig to resume the irradiation test. Because the irradiated fuel rod is highly radioactive, all of the assembly and disassembly operations should be carried out in the reactor pool. Therefore, special tools need to be developed to treat the test rig in the pool of a research reactor. In this study, a new mechanically detachable fuel rod assembly has been developed for intermediate inspection during irradiation test at HANARO. A fuel rod assembly can be divided into two parts, such as an instrumented fuel rod assembly and a non-instrumented fuel rod assembly. In particular, an instrumented fuel rod assembly is assembled at the lower part of the test rig, and a non-instrumented fuel rod assembly is assembled at the bottom of the instrumented fuel rod assembly. The non-instrumented fuel rod assembly is locked in the test rig during irradiation test, and is easily disassembled from the instrumented fuel rod assembly by pushing the anchor button and twisting the non-instrumented fuel rod assembly. In addition, because a test rig is 5.4 meters long and the disassembling operation should be carried out at 6 meters deep in the pool of HANARO, tools to help disassemble and assemble the non-instrumented fuel rod assembly have also been developed. All components were designed to operate mechanically and are made of stainless steel and Al 6061 to minimize the effects from the radioactivity. The performance of the developed fuel rod assembly and tools have been verified through an out pile test.

1. Introduction

KAERI established an independent test loop, the FTL (Fuel test loop), at the HANARO reactor in 2009. A test rig is installed in the IPS of the FTL with several sensors to measure the behavior of nuclear fuel during an irradiation test. However, in addition to monitoring the behavior of nuclear fuel during an irradiation test, users may want to monitor the corrosion behavior of the clad periodically to analyze its lifetime and safety margin. Corrosion of the clad is being assessed by means of interim inspections comprising oxide thickness measurements and photographs of the cladding materials. Because the IPS was designed to allow three pieces of fuel rods to be installed in the test rig, an in-pile inspection of the corrosion growth is not possible, and the corrosion growth should be measured in the hot cell. Thus, the fuel rod assembly needs to be disassembled from the test rig for intermediate examination and reassembled after an intermediate examination.
In this study, a fuel rod assembly is replaced with two fuel rod assemblies, and their assembly

mechanism that can be disassembled between the irradiation periods will be developed. In addition, tools to enable the disassembly operation in the service pool of HANARO will be developed. The performance and reliability of the developed tools will be verified through an out pile test using a mockup.

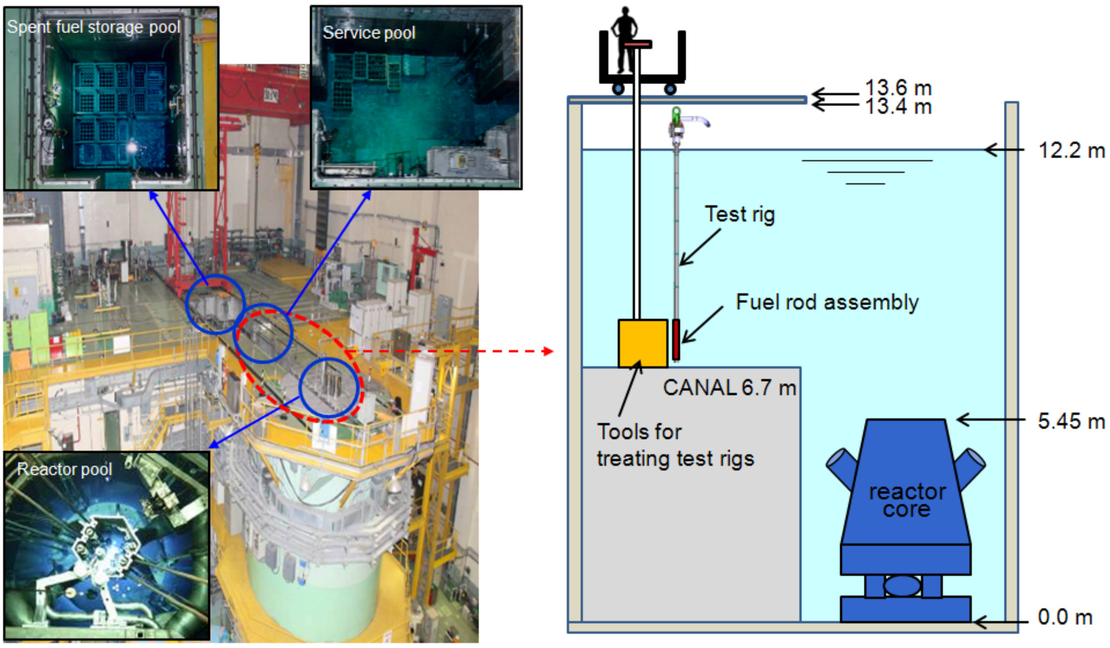


Fig 1. Reactor pool of HANARO and space for treating test rigs

2. Design change of a fuel rod assembly

The design of the test rig used in the FTL is shown in Fig 2. A fuel rod assembly is assembled at the bottom of the test rig, as marked with the circle. In addition, the design of the fuel rod assembly was is changed to be divided into two parts, i.e., an instrumented fuel rod assembly and a non-instrumented fuel rod assembly, to make intermediate inspection possible during the irradiation test.

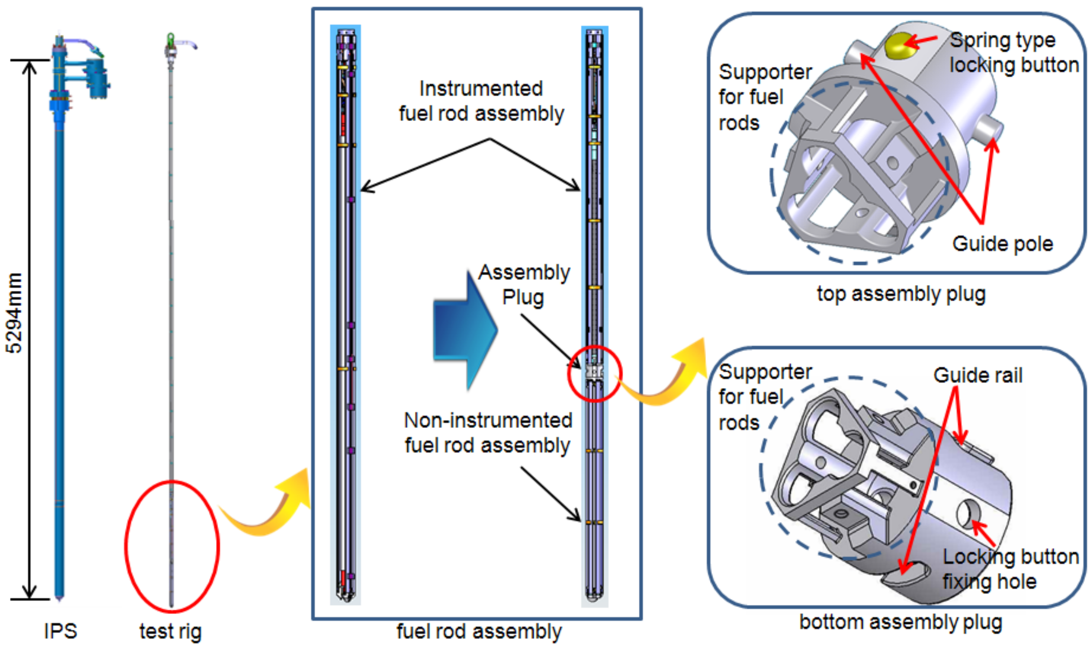


Fig 2. Modeling of the IPS and fuel rod assembly

If a fuel rod assembly instrumented with LVDTs and thermocouples is installed on the test rig and irradiated in the reactor, it is difficult to disassemble for the intermediate examination owing to the damage to the MI cables. Therefore, the instrumented fuel rod assembly was designed to be fixed on the test rig until the end of the irradiation period. Because a non-instrumented fuel rod assembly is not affected by sensors or cables, it should be easily disassembled and assembled with a simple operation to carry out an intermediate inspection. Therefore, the non-instrumented fuel rod assembly was designed to be assembled at the bottom of the instrumented fuel rod assembly. In addition, both assemblies were designed to be assembled by bayonet-type assembly plugs at each end. Fig 3 shows the disassembly mechanism of the fuel rod assemblies. When the locking button on the top assembly plug is pushed in, the non-instrumented fuel rod assembly can be rotated clockwise according to the guide rail of the bottom assembly plug, and disassembled from the top assembly plug.

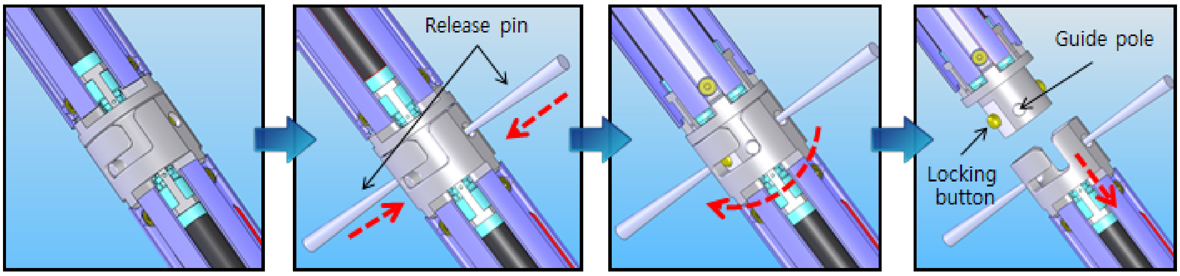
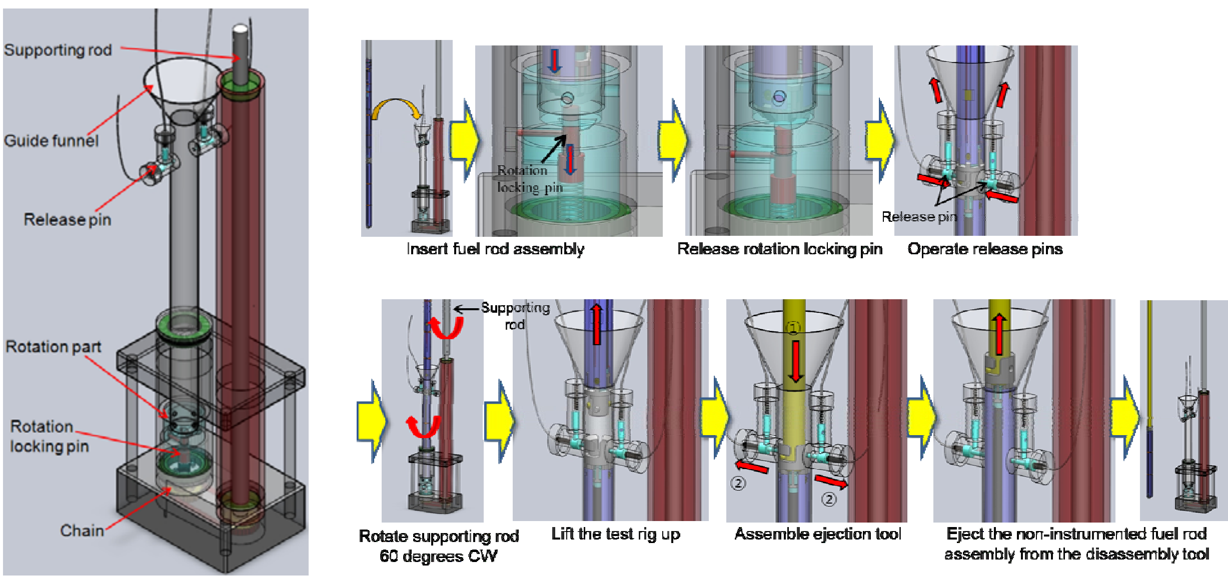


Fig 3. Disassembly mechanism of the fuel rod assembly

3. Development of disassembly tools and sequence of disassembly process

To prevent operators from being exposed to radioactive rays, all of the disassembly and reassembly processes of the irradiated fuel rod assembly should be carried out in the service pool of HANARO. Thus, the disassembly tool and the disassembly process of the fuel rod assemblies were designed as shown in Fig 4. All components were designed to operate mechanically, and their materials were designated with stainless steel and aluminum to minimize the effects from the radioactivity and corrosion.
The disassembly tool can be divided into a rotation part, a release pin part, and a support part. The rotation part helps the test rig find the exact position to disassemble the non-instrumented fuel rod assembly, and rotates the non-instrumented fuel rod assembly when locking buttons on the assembly plug are released. The release pin part operates the release pins to push the locking buttons in. When the release pins are fastened, the locking buttons are pulled out. The support part supports the disassembly tool, preventing it from falling over, and delivers a rotation force through the chain at the bottom of the tool. That is, rotating force acting on the rotation part is generated by rotating the support rod.



(a) disassembly tool (b) sequence of disassembly process
Fig 4. Modeling of the disassembly tool and sequence of disassembly process

Fig 5 shows the developed disassembly tool using the above design concept. To check the accuracy and basic performance of the disassembly tool, a preliminary disassembly experiment was carried out using a mockup of the test rig according to the sequence of the disassembly process.
The experiment was repeated ten times. After the experiment was repeated three times, the wire connected with a release pin was loosened owing to the small joining force of the screw. Therefore, their joining design was replaced with Ni brazing. After repairing the wire problem, there was no more issue in operating the disassembly tool during ten additional tests.

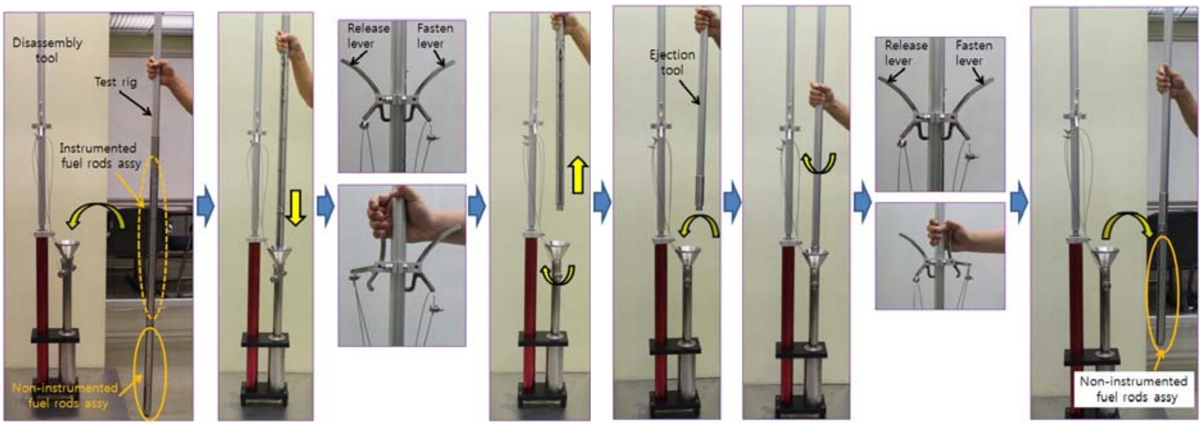


Fig 5. Sequence of preliminary disassembly experiment in a laboratory

4. Conclusion

In this study, a fuel rod assembly that can be disassembled and reassembled during irradiation test has been developed to make an intermediate examination of fuel rods possible. In addition, the disassembly process and a tool that can be operated in the reactor pool have been developed and tested in air. From the results of a preliminary disassembly experiment in air, all functions such as the docking of the test rig into the disassembly tool, the release of locking buttons, and the disassembly of the non-instrumented fuel rod assembly perform well with good reliability and repeatability. The test results show that the disassembly tool can be used in the reactor pool to disassemble a non-instrumented fuel rod assembly for intermediate inspection.
In the future, a delivery tool needs to be developed, which accommodates the disassembled non-instrumented fuel rod assembly in the cask and delivers it to the hot cell.

Acknowledgement

This research has been carried out as a part of the nuclear R&D program funded by the Ministry of Science, ICT and Future Planning in Korea.

5. References

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