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Performance Tests of Locking Devices and a Prototype Fabrication of an AHR Fuel Assembly

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1. Introduction

Based on the technical experiences in the design and operation for the HANARO, the design of an Advanced HANARO Reactor (AHR) was launched by KAERI. The final goal of the project is to develop a new and advanced research reactor model which is superior in safety and economical aspects.

As a first step for the design of the AHR, a conceptual design of a fuel assembly and a core structure has been carried out [1, 2]. For determining a fuel for the AHR, three typical fuel types of plate, tube and rod fuels, which have been widely used as research reactor fuels, are reviewed from various aspects such as the fuel material and fabrication, reactor physics and thermal-hydraulic characteristics, structural integrity.

To verify the preliminary design of the locking device, the components were fabricated. Then, tests on a loading/unloading, rotational resistance and a vibration with the locking device were carried out. This paper summarizes the results of the performance tests of the locking devices and the prototype fabrication of the AHR fuel assembly.

2. Performance Tests of Locking Devices

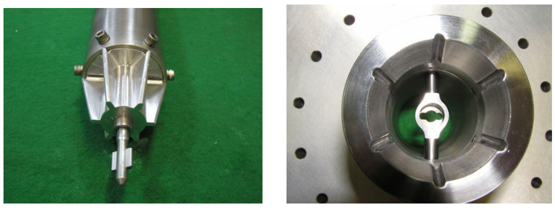
Considering the tubular fuel with stiffeners as a fuel assembly for the AHR, an associated locking device was preliminarily designed to lock the fuel assembly in a fuel channel. A locking device must meet several features such as an easiness of locking of the fuel assembly and the prevention of a rotation of the fuel assembly owing to an effect of the coolant flow. Also, a locking device should be designed to minimize the vibration of the fuel assembly and have a resistance against a fatigue failure. Performance tests on a loading/unloading, rotational resistance and a vibration with the locking device were carried out.

Figure 1 shows the bottom guide and the receptacle cup that were fabricated. To investigate the effect of the conical angle of the contact face on the torsional resistance and the structural stiffness, a bottom guide and a receptacle cup were designed and manufactured with three types of angles. In addition to the surface contact type design, locking devices with six fins for the bottom guide and six grooves for the receptacle cup were designed in order to reinforce the torsional resistance.

2.1 Loading and Unloading Test

To check on the easiness of installation of the fuel assembly and the fixing status of the preliminary designed locking device, loading/unloading tests were performed. The loading/unloading test results show that there was no trouble in a loading and unloading of the fuel assembly for the repeated tests. However, the loose-fitting problem due to the manufacturing tolerances of the contact surfaces between the bottom guide and the receptacle cup were observed for all tested cases.

The test results demonstrate that additional springs or guides on the top of the fuel assembly are needed to suppress the lateral motion of the fuel assembly. Therefore, we have solved this problem by adding a top guide roller at the top part of the fuel assembly so that it reduces the lateral motion of the fuel assembly.



(a) bottom guide (b) receptacle cup

Figure 1. Preliminary design of lower locking devices

2.2 Torsional Resistance Test

An angular moment was imposed by a torque wrench on the fuel assembly. Whether the bottom guide rotates or not was checked by a ruler mark on the receptacle cup whenever the torque ascended stepwise.

In the case of the locking devices without fins, scratch marks at the contact surface were observed. On the other hand, the test results of the locking devices with fins demonstrated that using the locking device with fins on the bottom guide can prevent a torsional motion of the fuel assembly.

2.3 Vibration Test

In order to investigate the effects of the locking device on the natural frequency of the fuel assembly, the modal tests in Figure 2 were performed.

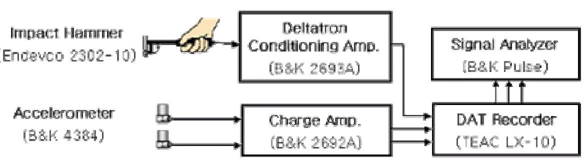


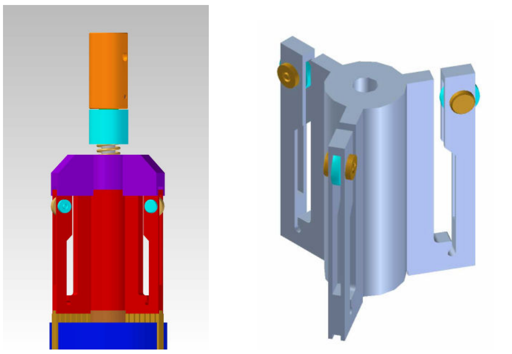
Figure 2. Experimental setup for the modal test of the fuel assemblies loaded at the locking device

The FRFs(Frequency Response Function) were obtained by the modal tests. We observed that the fuel assembly with a surface-contact-type locking device had a higher lateral stiffness than the fuel assembly with a fin-contact-type locking device. Although, vibration characteristics are slightly preferable in the case of the fuel assembly without fins, the locking device with a fin-contact-type is better for preventing an unintentional rotation of the fuel. To increase the first natural frequency and the bending stiffness, the test result suggests that the fin-contact-type locking devices should be designed to have as large a contact area as possible.

3. PROTOTYPE OF THE FUEL ASSEMBLY

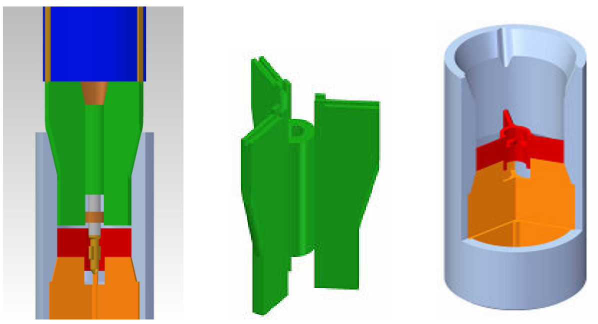
Based on the results of the performance tests of the preliminary designed locking devices, a prototype of the fuel assembly and the top/bottom locking devices of the ARR were designed. The flow analysis and pressure drop analysis for the coolant inlet channel were also considered in the design of the locking devices.

Figure 3 represents the schematic of the designed top locking devices. In order to prevent a fluid induced vibration in the lateral direction of the fuel assembly, a top guide with 3 top guide rollers were designed on the top part of the fuel assembly



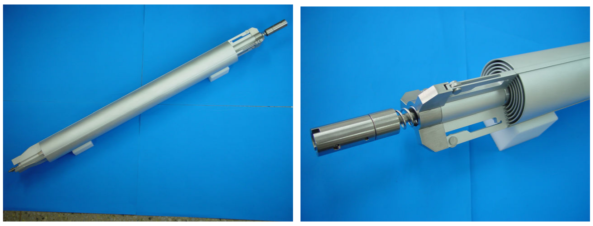
(a) top locking device (b) top guide and roller
Figure 3. Conceptual design of the top locking device

Figure 4 represents the schematic of the designed bottom locking devices. To reduce the flow resistance due to the coolant flow, the direction of the three wings of the spider and the bottom guide was designed to coincide with that of the flow straightener.

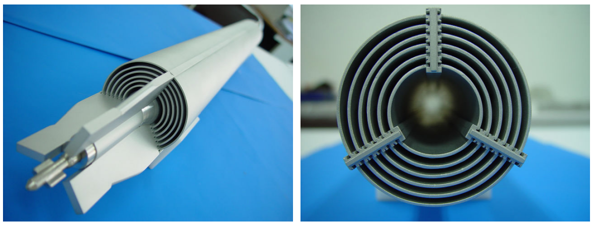


(a) bottom locking device (b) bottom guide (c) spider / straightener
Figure 4. Conceptual design of the bottom locking

Based on the conceptual design and the performance test results, two-dimensional and three-dimensional drawings and a technical specification for the assembly and swaging were documented to fabricate the prototype of the fuel assembly. Figure 5 shows the prototype of the fuel assembly for the AHR.



(a) fuel assembly (b) top locking device



(c) bottom locking device (d) fuel element and stiffeners
Figure 5. Prototype of the AHR fuel assembly

4. Conclusion

The conceptual designs of the fuel assembly and locking devices for the AHR ware carried out. To verify the preliminary design of the locking device, performance tests on a loading/unloading, rotational resistance and a vibration with the locking device were carried out.

For this purpose, the components of the preliminary designed locking devices were fabricated and its locking performance was investigated. The test results show that using the locking device with fins on the bottom guide can prevent a torsional motion of the fuel assembly. It is observed that the fixing status of the locking device in the lateral direction is incomplete and a lateral motion of the fuel assembly can occur due to the manufacturing tolerances of the contact surface between the bottom guide and the receptacle cup. This observation demonstrates that additional springs or guides on the top of the fuel assembly are needed to suppress the lateral motion of the fuel assembly. Based on the performance test results, the design concept of the locking devices was reflected in the design of the fuel assembly and its prototypes were fabricated. In a future study, the fuel assembly and locking devices will be verified by performing the pressure drop, vibration and endurance tests in a coolant.

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