The conceptual design of the fuel assembly for a new research reactor

Jeong-Soo Ryu†, Yeong-Garp Cho, Doo-Byung Yoon, Ho-Jin Dan,
Hee-Tack Chae, and Cheol Park
Korea Atomic Energy Research Institute, Deokjin, Yuseong, Daejeon, Korea
jsryu@kaeri.re.kr†

1. Introduction

HANARO (Hi-flux Advanced Neutron Application Reactor), is an open-tank-in-pool type research reactor with a thermal power of 30MW. The HANORO has been operated at Korea Atomic Energy Research Institute since 1995. Based on technical experiences in design and operation of the HANARO, the design of a new research reactor (ARR) was launched by KAERI in the 2002. The final goal of the project is to develop a new and unique research reactor model which is superior in safety and economical aspect.

Following results about the tubular fuel and the locking device were obtained from the previous study [1-2]. The stiffener supporting the tubular fuel was proved to improve vibration characteristics such that not only the natural frequency increased but also the beam-type mode was prevented. Fin and groove pairs were verified essential to the locking device in order to resist the torsional moment by coolant flow. Also, Separation and wake of flow can occur at the coolant inlet section between the receptacle and the fuel channel unless carefully designed.

In this study, integrating these results and reflecting other reference reactors, the fuel assembly was conceptually designed and its prototype was fabricated. The flow analysis and pressure drop analysis for the coolant inlet channel were also considered in the design of the locking devices so that generated heat effectively cools down and the fuel assembly is protected against the external force. We will confirm and coordinate the crucial design factors by investigating the locking performance, pressure drop and vibration characteristics of the newly designed fuel assembly and locking devices in near future.

2. Parts of the fuel assembly

The fuel assembly is comprised of three groups of parts; the tubular fuel, the bottom locking device, and the top locking device. In following subsections, each group is described.

2.1 The tubular fuel with stiffeners

Three stiffeners divide cross-section into three equal parts and the standard fuel assembly consists of six curved plates for each trisection as shown in Fig. 1. Each fuel plate is made of U-Mo for fuel core and Al1060 for cladding material, and the height of core fuel is 700 mm. Coolant passes through about 2.5 mm gap waterway between fuel plates.

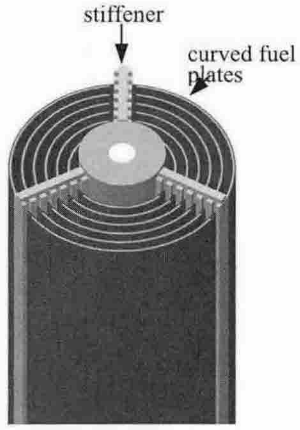

Fig. 1 Curved fuel plates and stiffeners

The stiffener has grooves to fix the fuel plates by swaging of which method was applied to the fuel assembly of the BR2 reactor. We successfully applied swaging technique to manufacture the tubular fuel as shown in Fig. 1. Stiffeners are not directly connected to the spacer tube because it is difficult to manufacture the stiffener and the central tube as a whole part. Top and bottom shape of the stiffener also be adequately designed to connect to the top guide and the bottom guide. Reflecting design of the HANARO reactor, the spacer tube comprises four rods. Especially the bottom part of the spacer tube is designed to avoid separation and wake of the coolant flow.

2.2 The Bottom locking device

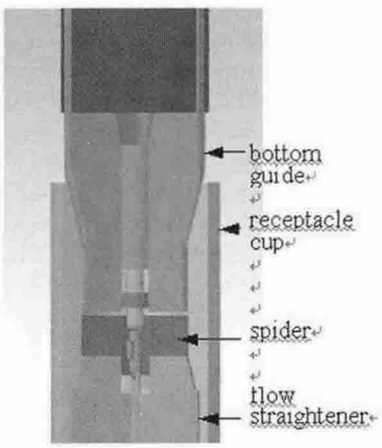

Fig. 2 Bottom parts of the locking device

The bottom locking device consists of the bottom guide, the receptacle, the spider, central rod tip, and flow straightener as shown in Fig. 2. The bottom guide is designed to match the receptacle cup and the stiffener at its both ends. Based on the results of flow analysis and pressure drop analysis, the thickness and configuration of the receptacle have been changed to increase the flow section area of the coolant inlet. To reduce the wake phenomena at the coolant inlet section, the flow straightener that has three wings was designed at the bottom of the locking device as shown in Fig. 2. In addition, to reduce the flow resistance due to the coolant flow, the direction of three wings of the spider and bottom guide was designed to coincide with that of flow straightener in plane. Thinking of wear owing to contact between parts, material of the bottom guide, the spider and the receptacle cup is set to Al6061, SS304 and SS304, respectively. As shown in Fig. 2 the receptacle supports spider where the fuel assembly is installed, and also it holds the flow straightener which forms the fluid channel.

2.3 The top locking device

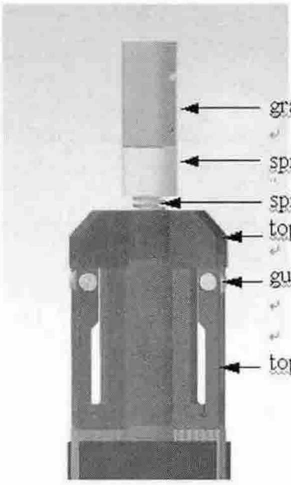

Fig. 3 Top parts of the locking device in the fuel channel

Considering an aluminum matrix in core region, a top part supporter of the fuel assembly has to be constructed not to wear out easily. Instead of the top guide spring used in the HANARO, the top guide is designed to support the fuel assembly. Although the top guide designed in this study is similar to that of the BR2, there is a different feature. Only one beam-type spring works in the BR2, but three beam-springs in this design support the fuel assembly so that the fuel assembly is protected against external force directionally unbiased. Because the top guide roller allows small vertical displacement of the fuel assembly, the wear problem can moderate.

The grapple head, the spring cover and the top guide cover are also major components of the top of the fuel assembly as shown in Fig. 3. Spring connected to the central rod plays important role in securing required space and hooking the fuel assembly into the locking device. To inherit the loading method of the HANANO, shape of the grapple head is maintained but position of the spring is moved at top of the fuel assembly. When the central rod tip of the fuel assembly is inserted into the spider and the receptacle cup, plane degrees of freedom are restrained and vertical motion is suppressed. As a result, a simple support condition due to the top guide and the roller is imposed on the top part of the fuel assembly.

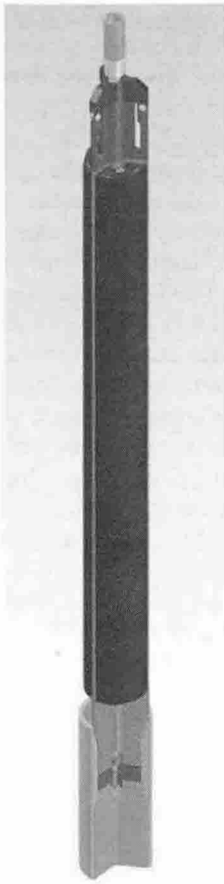

Fig. 4 fuel assembly

3. Conclusion

Integrating the results from previous works and the experience by operating the HANARO, we designed the fuel assembly including the top and the bottom locking device.

To safely hold the fuel assembly in the fuel channel, the top guide with rollers was devised. For the bottom locking device, we introduced three pairs of fins and grooves to resist torsional moment. Coolant flow analysis made us revise the receptacle and the flow straightener. Two-dimensional and three dimensional drafts and technical specification for assembly and swaging were documented, and we fabricated the prototype of the fuel assembly and the fuel channel.

Locking performance, pressure drop characteristics and vibration characteristics of the prototype of the fuel assembly will be tested in the near future. Through these tests, the fuel assembly will be tuned and modified to have better performance.

REFERENCES

[1] Ryu, J.-S., Cho, Y.-G., Yoon, D.-B., and Park, C., "The conceptual design for fuel assembly and reactor structures of a new research reactor," Technical Report, KAERI/TR-2661/2004, Korea Atomic Energy Research Institute, 2004

[2] Ryu, J.-S., Yoon, D.-B., Cho, Y.-G., and Park, C., "Tests of locking devices for the conceptual design of ARR fuel assembly," 2004 spring proceeding of Korean Nuclear Society, 2004