The conceptual design of the standard and the reduced fuel assemblies for an advanced 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 operating at Korea Atomic Energy Research Institute since 1995. Based on the technical experiences in design and operation for the HANARO, the design of an Advanced Research Reactor (ARR) was launched by KAERI in 2002. The final goal of the project is to develop a new and advanced research reactor model which is superior in safety and economical aspects.

This paper summarizes the design improvements of the conceptually designed standard fuel assembly [1] based on the analysis results for the nuclear physics. It includes also the design of the reduced fuel assembly in conjunction with the flow tube as the fuel channel and the guide of the absorber rod.[2] In the near future, the feasibility of the conceptually designed fuel assemblies of the ARR will be verified by investigating the dynamic and the thermal behaviors of the fuel assembly submerged in coolant.

2. Components of the fuel assembly

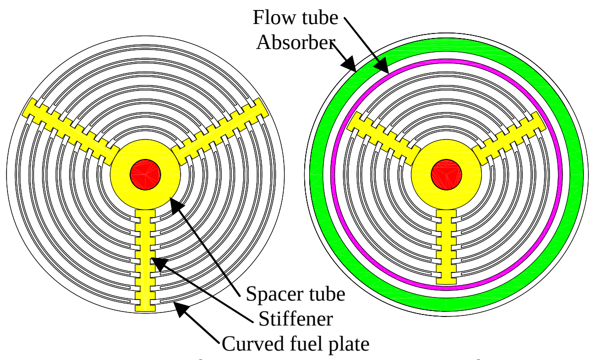
The designed fuel assembly consists of three subassemblies; the tubular fuel with stiffeners, the top locking device, and the bottom locking device.

2.1 The tubular fuel with stiffeners

The fuel assembly consists of curved fuel plates as shown in Fig. 1. The number of plates for each trisection is 7 for the standard fuel assembly in Fig. 1(a) and 5 for the reduced one in Fig. 1(b). Each fuel plate will be made of U-7Mo or U_3Si_2 for the fuel meat and Al1060 for the cladding material. The longitudinal length of fuel meat is 700 mm.

Three stiffeners were designed to divide cross-section into three equal regions. The stiffener has grooves to fix the fuel plates. The swaging procedure and tools were developed and successfully applied for fixing the fuel plates on those stiffeners. Because it is difficult to manufacture the stiffener and the spacer tube as a whole part, they are independently fabricated and then assembled. Top and bottom shape of the stiffener were adequately designed to connect to the top and the bottom guides of the fuel assembly. Considering the manufacturing and assembling tolerances of the HANARO fuel assembly, the spacer tube is comprised of four tubes.

The reduced fuel assembly is similar to the standard fuel assembly except for including a space for installing the absorber and the flow tube as shown in Fig. 1(b). The cross-sectional diameter of the reduced fuel assembly is smaller than that of the standard fuel assembly and the number of fuel plates is adjusted to five.



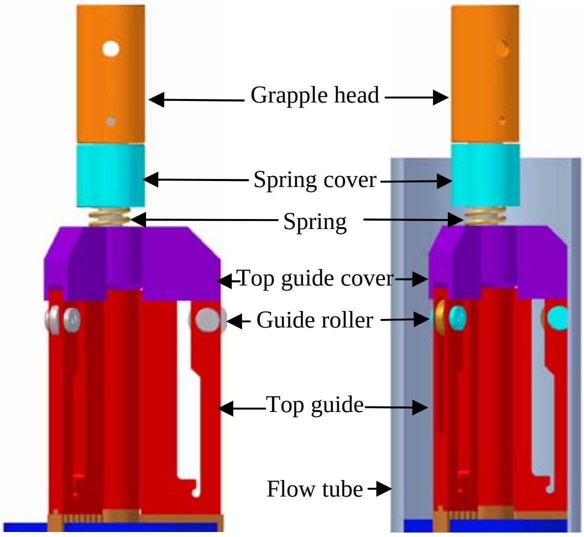
(a) Standard fuel (b) Reduced fuel

Fig. 1 Cross sections of the fuel assemblies

2.3 The top locking device

The fuel assembly has to be constructed not to wear out easily. The grapple head, the spring cover and the top guide cover are also major components of the top locking device as shown in Fig. 2. Instead of the top guide spring used for the fuel assembly of the HANARO, the top guide is designed as three beam-type springs to support the fuel assembly of the ARR. It is designed that three wings of the top guide support the fuel assembly so that the fuel assembly can be protected against fluid induced vibration. In addition, guide roller is designed to reduce the wear between the top guide and the fuel channel.

The shape of the grapple head is identical with that of HANARO fuel assembly. The spring located at the top of the locking device plays important role for providing a required force for hooking the fuel assembly into the bottom locking device. When the fuel assembly is inserted into the spider, only horizontal degrees of freedom are restrained. As a result, a simply supported condition due to the top guide and the roller is imposed on the top part of the fuel assembly.



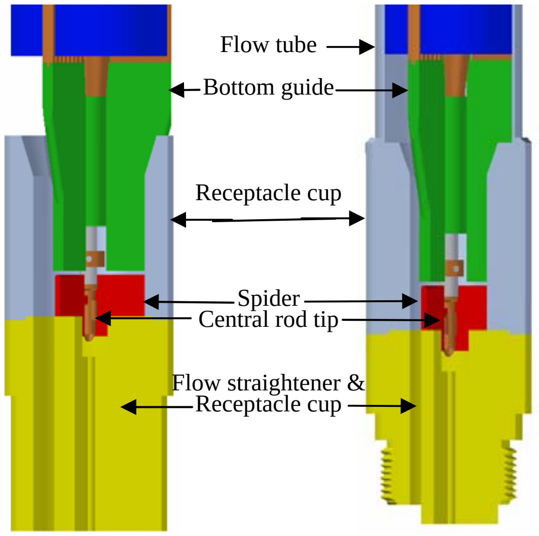
(a) Standard fuel (b) Reduced fuel

Fig. 2 Top parts of the locking device in the fuel channel

2.2 The bottom locking device

The bottom locking device consists of the bottom guide, the receptacle, the spider, the central rod tip, and the flow straightener as shown in Fig. 3. Based on the analysis results of flow pattern and pressure drop, the thickness and configuration of the receptacle have been changed to increase the flow area of the coolant inlet. In order to reduce the wake phenomena at the coolant inlet section, the flow straightener of three wings was designed at the bottom of the locking device. 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. Considering the possibility of wear that could occur due to the contact between parts, the materials of the bottom guide, the spider and the receptacle cup were selected as Al6061, SS304, and SS304, respectively. As shown in Fig. 3, the receptacle is designed to support the spider where the central rod tip of the fuel assembly is installed.

The receptacle of the standard fuel assembly is welded on the bottom grid of the reactor core. In case of reduced fuel assembly, as shown in Fig. 3 (b), the bottom of the receptacle is a part of flow tube which is installed in the grid plate by the thread joint.



(a) Standard fuel (b) Reduced

Fig. 3 Bottom parts of the locking device

3. Conclusion

The conceptual design of the standard fuel assembly for the ARR was improved. In addition, the conceptual design of the reduced fuel assembly was carried out. Since the core coolant causes a problem of the flow-induced vibration, the top guide with rollers, the bottom guide, and the flow straightener were designed to safely hold the fuel assembly during operation. As a further work, the dynamic and the thermal behaviors of the fuel assemblies will be investigated by performing various analysis and experiment.

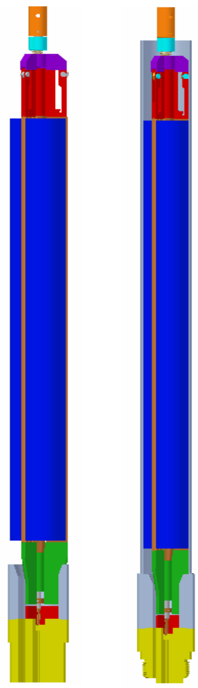


Fig. 4. Fuel Assembly

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[2] Ryu, J.-S., Dan, H.-J., Cho, Y.-G., Yoon, D.-B., and Park, C., "The conceptual design for fuel assemblies for an advanced research reactor," Technical Report, KAERI/TR-2909/2005, Korea Atomic Energy Research Institute, 2005.