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Performance Evaluation of the KAERI Designed Spacer Grid Shapes for PWRs(II)

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1. Introduction

In PWR fuel assemblies (FAs), spacer grids (SGs) are very important structural components for laterally and vertically supporting the nuclear fuel rods (FRs). Based on design experiences and by scrutinizing the design features of foreign advanced nuclear fuels and the foreign patents of SGs, KAERI has devised 18 kinds of SG shapes and has been applying for domestic and foreign patents since 1997. Mechanical/structural and T/H performance evaluation is carried out on two KAERI devised SG shapes, which are assumed to be the most effective candidates for the SG of the next generation nuclear FA in ROK, and also on two commercial SGs for the sake of a comparison.

2. Performance Evaluations

The performance evaluation on two KAERI devised SGs and two commercial SGs were performed in detail. One of the KAERI devised SGs is a SG assembly with an optimized H-shape spring [1] as shown in Fig. 1. The spring shape was modified based on the H-shape spring [2] of which the main feature is a conformal contact shape at the contact part between the spring/dimple and the FR. To improve the performance of the H-shape spring, we adopted the systematic optimization design technique and obtained an optimized spring shape including the contact contour [3]. The other is the Doublet-type SG [4]. This SG is also modified based on the initial Doublet-type SG [5] of which the main feature is a support of the FR with a line contact.

We also selected two commercial SGs as references. One is widely used in the current commercial FA, which is designated in this paper as Ref. A. The other is a cutting-edge SG designated as Ref. B [6], whose shape of the supporting parts is similar to that of the KAERI devised SG with an Opt. H spring.

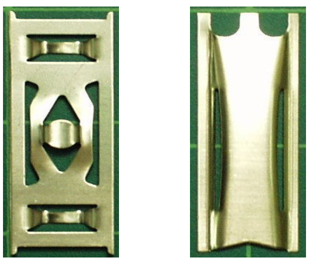

Figure 1 KAERI's SG springs(Left: Opt. H; Right: Doublet).

2.1 Patent-right of KAERI designed spacer grids

We have acquired US and ROK patents for the H-shape spring [2], optimized H-shape spring [1], and the initial Doublet-type SG [5]. Recently, we have also acquired US patent for the Doublet-type SG [4] and now it is under review for EC and ROK patents.

2.2 Spring Characteristics

Force-deflection tests on four kinds of SG springs were performed up to the plastic range of the springs. The tests were performed for springs which were deflective by up to 1.0 mm. Test results in Ref. 7 showed that the stiffness of the KAERI devised SG springs were within the recommended stiffness range while that of Ref. A SG was not within the range. In addition, the elastic ranges were larger and the plastic sets were less for the KAERI devised springs when compared to those of the commercial SG springs.

2.3 Fuel Rod Vibration Characteristics

To investigate the FR support and vibration characteristics, a modal test of a single dummy FR supported by five SGs has been performed. The objective of this test is to compare the maximum deflection of each SG shape when the same input force is applied to the FR. Three levels of input forces of 0.5, 0.75, and 1.0 N were used in the test. Similar tendencies were obtained for the other input forces. According to the result of 0.5 N, the maximum deflections for the springs are as follows; for the Doublet spring 0.08 mm, for the Opt. H spring 0.11 mm; and for Ref. B 0.128 mm. Test results are shown in Ref. 8 in detail. Because the maximum deflection is small, it means that the SG has a better vibration resistance to external forces and this leads to a greater resistance to fretting wear damage. From the results we can draw a conclusion that the vibration characteristics for resisting a fretting wear for the KAERI devised springs are superior to that of Ref. B.

2.4 Fretting Wear Characteristics

The fretting wear resistance test under a high temperature and high pressure condition was performed at AECL of Canada [7] in early 2004. The AECL wear resistance test at a reactor operation temperature to derive the FR wear coefficient for the PWR FR/the Opt. H SG was performed by using a sliding and impact wear tester. Table 1 shows the AECL wear test results of the Opt. H and Ref. B SG springs. According to Table 1, the wear resistance of the Opt. H SG spring is superior to that of the Ref. B SG spring, i.e. smaller wear coefficients (K) and also smaller maximum wear depths when compared to the Ref. B SG spring.

Recently another fretting wear test under room temperature conditions was performed at KAERI as the number of fretting cycles was increases to around 10^7. Test results are shown in Refs. 8-10 in detail.

Table 1 AECL results at spring (based on the Opt. H's value).

	Opt. H	Ref. B
Mean FR wear coefficient (K)	1.00	4.39
Max. FR wear mark depth	1.00	2.44

2.5 CHF Characteristics

The critical heat flux (CHF) Freon test for the Opt. H was performed at KAERI. The test results as shown in Fig. 2 show that the CHF performance for Opt. H SG is enhanced by up to 16.4 % when compared with the SG without a mixing vane.

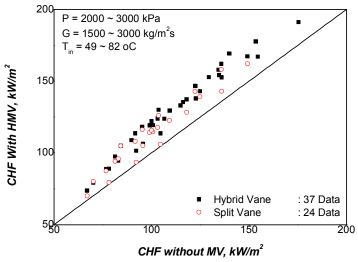

Figure 2 CHF enhancements.

2.6 Spacer Grid Buckling Strength

The buckling strength test was performed by using a pendulum type impact tester for the Opt. H spacer grid and Ref. B spacer grid. And also a finite element analysis on the buckling strength of the spacer grid assemblies was performed. Table 2 shows the test and analysis results. According to Table 2, the Opt. H spacer grid could meet the 0.3g seismic criteria for both 16x 16 type and 17x17 type.

Table 2 Spacer grid buckling strength under Room Temperature

		Buckling strength (kN)		
		Analysis(A)	Test(B)	Ratio(A/B)
16x16 type	Opt. H	23.5	25.5	0.922
	Ref. B	25.7	27.7	0.928
17x17 type	Opt. H	28.2	30.6*	0.92
	Opt-Opt. H	31.2	33.9*	0.92

* estimated value using conversion factor 1/0.92

3. Conclusion

The mechanical/structural and T/H performance evaluation for two KAERI devised SG shapes which are assumed to be the most effective candidates for the SG of the next generation nuclear fuel assembly in ROK were carried out. Also the same tests for two commercial SGs were carried out as well. The results of the comparisons show that the performances of the KAERI devised candidates are superior or comparable to those of the commercial SGs from the aspects of the spring characteristics, fretting wear resistance, fuel rod vibration characteristics, and the CHF characteristic of the SGs. And also the Opt. H spacer grid could meet the 0.3g seismic criteria for both 16x 16 type and 17x17 type.

Acknowledgements

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