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A Study of On-Off Holddown Spring Design for Fuel Assembly Bowing Resistance

Seong-Soo Kim*, Joon-Kyoo Park, Sang-Youn Jeon, Jung-Min Suh
KEPCO Nuclear Fuel, Daejeon, 305-353, Korea
**Corresponding author:ssookim@knfc.co.kr*

1. Introduction

The holddown spring is one of the major components of a Fuel Assembly (FA) for Pressurized Water Reactor (PWR), because it holds the FA firmly over the up-lift force in startup and Hot Full Power (HFP) conditions and allows the FA length change that is caused by irradiation growth and thermal expansion of guide tubes [1]. However, the FA might be bent if there is an excessive spring force loaded from holddown springs. As a result of this, it makes a serious problem and affects its reliability when loading / unloading the FA or inserting a Rod Cluster Control Assembly (RCCA). To solve the problems, an On-Off holddown spring was newly developed as shown in Fig. 1.

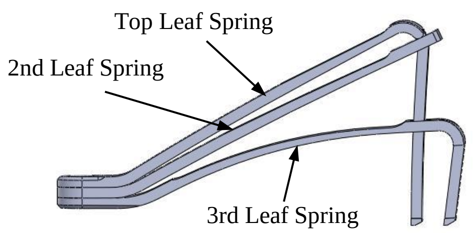

Fig. 1. On-Off Holddown Spring Design

The On-Off holddown spring is designed optimally to secure a minimum margin of holddown spring force in HFP condition by operating only two springs and to be able to generate a margin of holddown spring force comparing to that of a conventional type in startup condition by operating the all springs together as shown in Fig. 2.

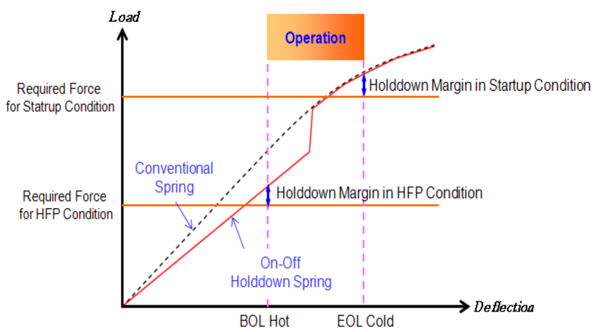

Fig. 2. On-Off Holddown Spring Characteristics

In this study, FA bowing resistance for the On-Off holddown spring is evaluated using the holddown spring characteristics, which are verified by load vs. deflection test.

2. Load vs. Deflection Test

The purpose of test is to obtain the load vs. deflection curve for the On-Off holddown spring.

2.1 Test Configuration

The configuration of the test is shown in Fig. 3. A top nozzle, eight holddown spring sets, a loading device, and top nozzle fixtures are used for On-Off holddown spring test.

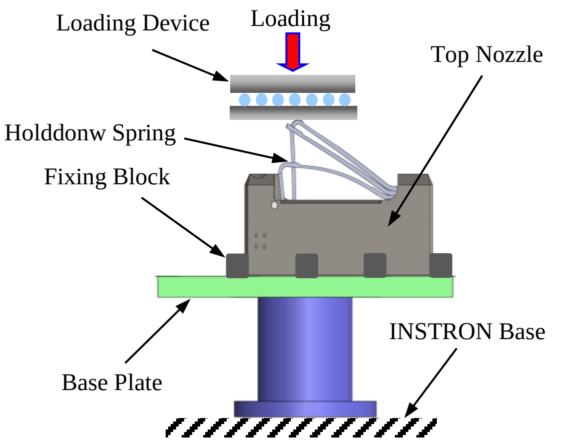

Fig. 3. On-Off Holddown Spring test Configuration

2.2 Test Procedure

The test was performed at room temperature in air condition utilizing the INSTRON universal testing machine. The setup of the test is shown in Fig. 4. The holddown springs were individually placed on the INSTRON universal testing machine. Load as a function of axial movement was applied to the top surface of the holddown spring. The holddown springs were deflected to the maximum compressed height and the deflections were removed slowly to reduce the dynamic effect.

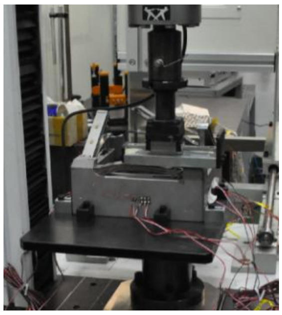

Fig. 4. On-Off Holddown Spring test Setup

2.3 Test Results

The average load vs. deflection curve for eight On-Off holddown spring sets is shown in Fig. 5. The average load vs. deflection curve was compared with the test results of the conventional holddown spring (17x17 FA). It shows that the On-Off holddown spring can generate the design-intended holddown spring force in operating condition that secures a minimum margin of holddown spring force in HFP condition and a margin of holddown spring force in startup condition comparing to them of a conventional type.

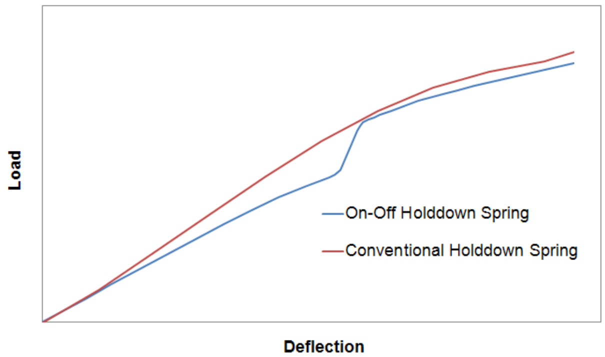

Fig. 5. Load vs. Deflection Curves

3. Analysis of FA Bowing Resistance

The test results for the On-Off holddown spring were used to evaluate FA holddown forces per operating cycles. FA holddown forces are calculated in consideration of thermal expansions of reactor and FA, and FA growth and holddown spring relaxation caused by irradiation. And then FA holddown margins were obtained by subtracting the required forces from the FA holddown forces in each condition. It is important for holddown spring to reduce the FA holddown margins because excessive FA holddown margins cause FA bowing. Fig. 6 shows the rate increase of FA bowing resistance as percent which were obtained by subtracting the margins of On-Off holddown spring from them of the conventional holddown spring (17x17 FA) as the equation 1.

$$B.R(\%)=\frac{(\text{Conventional Spring Margin})-(\text{On-Off Spring Margin})}{(\text{Conventional Spring Margin})} \quad (1)$$

Where, B.R is the FA Bowing Resistance.

It is shown that the rates of FA bowing resistance for On-Off holddown spring are increased by 71% in beginning of cycle (BOC) 3 for HFP condition and 49% in BOC 3 for startup condition respectively against them of the conventional holddown spring. Because the conventional holddown spring is much stiffer than the On-Off holddown spring, it is much affected on its spring rate reduction for high temperature and irradiation. As a result, the holddown margin reduction ratio between the On-Off holddown spring and the conventional holddown spring is gradually increased though three cycles and it positively affects the rate increase of FA bowing resistance as shown in Fig. 6.

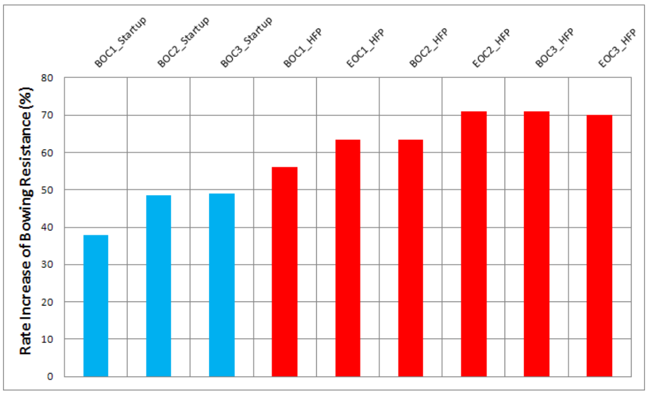

Fig. 6. Rate Increase of FA Bowing Resistance

4. Conclusions

The On-Off holddown spring was newly designed to secure a minimum margin of holddown spring force in HFP condition and a margin of holddown spring force in startup condition comparing to that of a conventional type. In this study, FA holddown margins for the On-Off holddown spring were evaluated using the holddown spring characteristics, which are verified by load vs. deflection test, as follows:

- The load vs. deflection curve for the On-Off holddown spring shows that the On-Off holddown spring can generate the design-intended holddown spring force in operating condition as the On-Off holddown design concept.

- The rates of FA bowing resistances for On-Off holddown spring are increased by 71% in HFP and 49% in startup condition in comparison with them of the conventional holddown spring.

- It shows that FA's reliability will be dramatically improved by applying the On-Off holddown spring because it is able to prevent FA from bowing which is caused by an excessive spring force loaded from holddown springs.

REFERENCES

[1] S.S.Kim, Evaluation of an On-Off Holddown Spring Design and Its Characteristics, Water Reactor Fuel Performance Meeting, T1-014, 2011.