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Study on the Static Characteristics of Holddown Spring for OPR1000 Fuel Assembly

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1. Introduction

The top nozzle assembly of the fuel assembly for OPR1000 consists of a flow plate, a holddown plate, four holddown springs and so on. The coil-type holddown springs have to provide sufficient forces to prevent fuel assembly lift-off from the core plate of the nuclear reactor due to hydraulic loads during normal operation and anticipated operational occurrences. The coolant flow generates flow-induced vibration of the coil-type holddown springs which causes fatigue failure. The holddown spring should not cause the fatigue failure occurred by the hydraulic vibration and a resonance.

In general, the coil-type holddown springs are designed by the theoretical method [1]. In addition, most static characteristics such as spring constant and shear stress can evaluated using the traditional method. It, however, is difficult to exactly evaluate the lateral stiffness to find out the vibration characteristic of the holddown spring in various assembled condition.

In this paper, the FE (Finite Element) model is proposed to predict the lateral stiffness as an analytical method and the FE analysis results are compared with the results of the static test.

2. Static Test

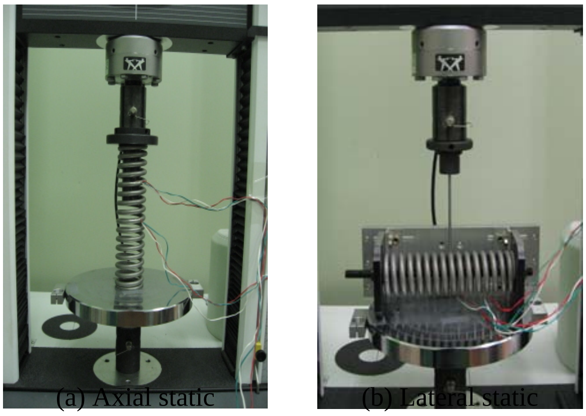
2.1. Axial static test

The holddown springs were basically tested to calculate the axial stiffness, and then to verify the validity of FE model. The setup of axial static test is shown in Figure 1(a). Each spring was placed on the Instron universal testing machine and compressed to the deflection length which corresponds to BOL(Beginning of Lifetime)hot condition.

2.2. Lateral static test

The lateral stiffness of holddown spring is required to predict the lateral vibration characteristics in various assembled conditions.

The lateral stiffness was determined for each of the four test springs at compressed heights corresponding to as-assembled, BOL cold and BOL hot conditions. The setup of lateral static test is shown in Figure 1 (b). The spring was positioned in the clamping device. Stops were machined in the base plates of the clamping device to prevent movement of the spring ends. The coil center position was displaced in 0.02 inch/min increment to a maximum of 0.25 inch.



(a) Axial static (b) Lateral static

Figure 1.Test set up

3. Test and Analysis Results

3.1 Axial static test and analysis result

A 3D modeling was generated using Solidworks 2009[2]. Then, a general purpose FE program COSMOS [3] was used in the FE analysis. Total number of nodes and elements used in FE analysis was 25,670 and 12,265. The used material property was linear isotropic elastic material. Applied mesh element was parabolic solid element.

For the boundary conditions, the bottom flat face of spring ends was fixed and top flat face was displaced to the test assembled conditions.

The results are summarized at Table 1. The axial stiffness for each test spring was calculated by the simple linear regression analysis method. The FE analysis results agree relatively well with the test and theoretical method results considering an error of measurement.

Table 1. Axial Spring Stiffness comparison

	Test [lbs/in]	Theory[3] [lbs/in]	FE [lbs/in]
#1	156		
#2	158	159.15	158.401
#3	160		
#4	158		

3.2 Lateral static test and analysis result

The plot of the load versus lateral deflection results is given in Figure 2. The spring stiffness was calculated by simple linear regression analysis. The spring stiffness shows the tendency to increase according as the compressed heights are increased.

For the boundary conditions, the bottom face of spring was fixed, and the top face was constrained laterally to stimulate the test conditions as shown Figure 3.

Table 2. shows the lateral spring stiffness compassion. The FE analysis result is in agreement with the test results. The analysis results show the tendency to increase according to compressed heights as the test results.

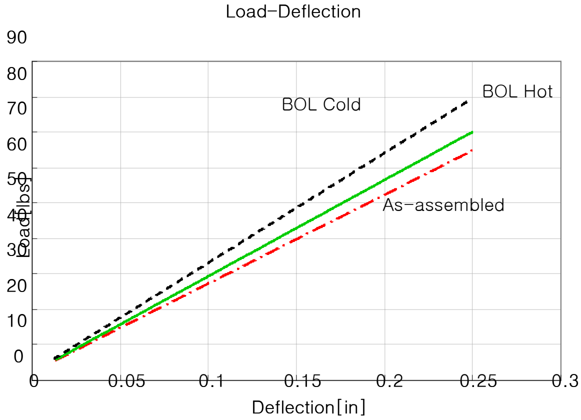


Figure 2. Load versus Lateral Deflection

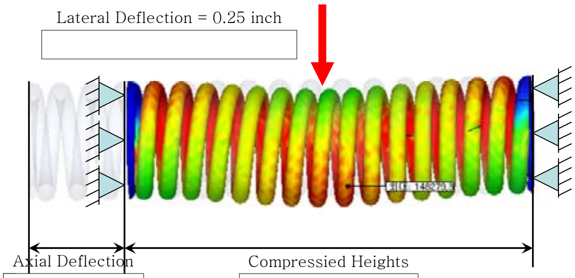


Figure 3. FE Analysis result

Table 2. Lateral Spring Stiffness comparison

	Assembled Condition		
	As-assembled [lb/in]	BOL Hot [lb/in]	BOL Cold [lb/in]
#1	263	275	281
#2	243	257	294
#3	271	289	328
#4	268	303	355
Average	261.25	281	314.5
FEM [lb/in]	254.020	260.332	282.46
Error [%]	2.8	7.9	11.34

4. Conclusion

In this paper, the FE analysis method was presented to predict the holddown spring characteristics and then the results were compared with the test results.

In conclusion, The FE analysis results agree relatively well with the test results. It is valid method that to verify the holddown spring design parameter using presented FE analysis. Also the presented FE analysis can be used to predict the vibration characteristics of holddown spring.

ACKNOWLEDGE

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