# Evaluation of Mechanical Integrity for Helical Coil Hold-Down Spring of PLUS7™ Fuel

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## 1. Introduction

Nuclear fuel assembly is subject to hydraulic forces generated by primary coolant flow during reactor operation. These forces may be sufficient to overcome the fuel assembly weight thereby allowing the fuel assembly to lift off of its support.

Toprovideapositivehold-downmarginagainstthe upwardcoolantflowforces,helicalcoilspringsorleafspring sareinstalledinthefuelassemblies.

An advanced fuel for Korean Standard Nuclear Power Plants (KSNP), PLUS7 fuel has developed to get the thermal margin increase, failure free and high seismic resistance, etc. And the new designed helical coil hold-down spring was introduced into PLUS7 fuel assembly.

Thepurposeofthispaperistoevaluatethemechanicalinte grityfor thehelicalcoilhold-downspringofPLUS7fuelasse mbly.

## 2. Study on the Spring Design Parameters

Therequired springforceformaintaining the positiveh old-downmargincanbecalculatedasfollows:

$$S_f = \frac{F_l + F_B - W}{4} \quad (1)$$

where, $S_f$ : Required spring force
$F_l$: Hydraulic lift force on fuel assembly
$F_B$: Buoyant force of the fuel assembly
W: Fuel assembly weight

The standard equation [1] for spring rate is as follows:

$$K = \frac{S_f}{\delta} = G \times \frac{d^4}{8ND^3} \quad (2)$$

where, δ: Spring deflection
d: Coil diameter
D: Spring diameter
G: Torsional Modulus of Coil Spring
N: Number of Coil Turn

From these two equations (1) and (2), the spring design parameters, D, d, and N are determined.

## 3.Evaluation of Mechanical Integrity

Thehold-down springshould be designed to maintain the mechanical integrity and its functions in reactor duringthedesignlife(about 5years). In this section, the mechanical integrity of hold-down spring was evaluated.

### *3.1 Shear Stress Analysis*

The analyses of spring shear stress were performed by ANSYS FEM Code [2] and standard spring equation [3] as follows:

$$\tau = K_w \frac{8FD}{\pi d^3} \quad (3)$$

where, F: Spring force for specified condition
$K_W$: Wahl Correction Factor

$$= \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

where, C: Spring Index = D/d

The results of ANSYS analyses were shown in Figure 1 and 2.

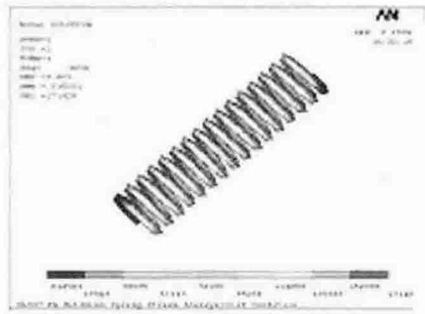

Figure 1. Von-Mises's yielding stress at cold condition

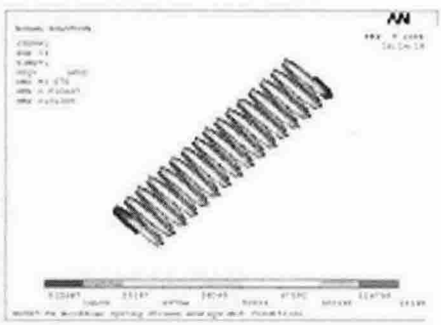

Figure 2. Von-Mises's yielding stress at hot condition

According to the von-Mises theory [4], the yielding stress in torsion is as follows:

$$\tau = \frac{\sigma_o}{\sqrt{3}} \qquad (4)$$

Where, $\sigma_o$: von Mises's yielding stress

As shown in Table 1, the results of ANSYS analyses were almost same as those of standard spring equation and PLUS7 hold-down spring satisfies the shear stress requirement.

Table1. Shear Stress Analysis Results

| | Hot Condition | Cold Conditon |
|---|---|---|
| ANSYS | 75,857 psi | 98,974 psi |
| Equation | 75,837 psi | 97,485 psi |
| Design Criteria | 89,000 psi | 100,500 psi |

*3.2 Flow Induced Vibration Test*

To investigate the dynamic characteristics of helical coil hold-down spring, the hydraulic flow test was done in the Vibration Investigation of Small-scale Test Assemblies (VISTA) hydraulic test loop at flow rates in excess of normal reactor operation. Results of test show that the magnitude of peak to peak amplitude for the helical coil spring is very small and the PLUS7 helical coil hold-down spring has an acceptable flow induce vibration response based on the lateral vibration amplitude of helical coil hold-down spring at in-core flow rate.

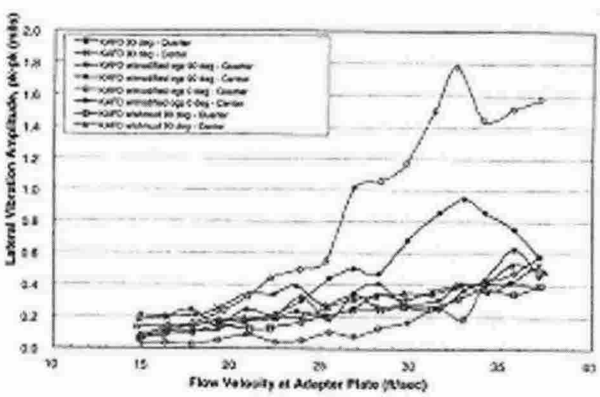

Figure 3. Lateral Vibration Amplitude

*3.3 Fatigue Analysis*

Allowable alternating stresses for hot or cold operation are determined using the modified Goodman diagram. The modified Goodman diagram is constructed using the shear yield and shear endurance limit of helical hold-down spring material. From this figure, the allowable alternating stress is approximately 7.44ksi(cold) and 14.242 ksi(hot) for the PLUS7 fuel based on the calculated shear stress.

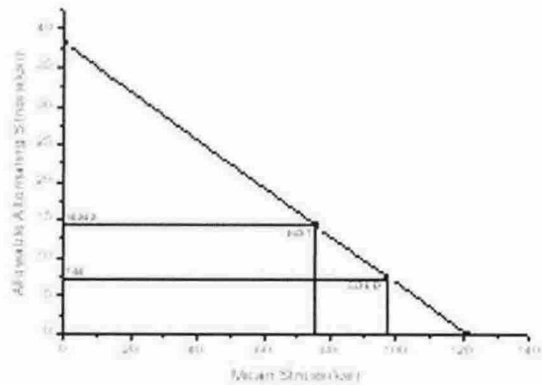

Figure 4. Modified Goodman Diagram

The alternating stress due to the amplitude generated by flow induced vibration can be calculated as follows:

$$\tau = K_w \frac{8(\Delta F)D}{\pi d^3} \qquad (5)$$

where, $\Delta F = K \times \delta$

where, K: Spring Stiffness

$\delta$: Amplitude

The calculated maximum alternating stresses are 2.1 ksi and 1.9 ksi at cold and hot condition, respectively. These stresses are maintained at a level that provides a relatively large alternating stress margin with respect to the fatigue stress limits.

## 4. Conclusion

Based on the results of shear stress analyses, hydraulic test, and fatigue analysis, the helical coil hold-down spring of PLUS7 fuel assemblies will be maintained the mechanical integrity and its functions during the design life of 3 ~ 5 years.

## REFERENCES

[1] Shigley, J. E, Mechanical Design, Third Edition, Mc Graw-Hill Book Co., 1977.
[2] Swanson Co., ANSYS/8.1, 2004
[3] A.M. Wahl, Mechanical Spring, Mc Graw-Hill Book Co., 1963.
[4] George E. Dieter, Mechanical Metallurgy, Mc Graw-Hill Book Co., 1988.