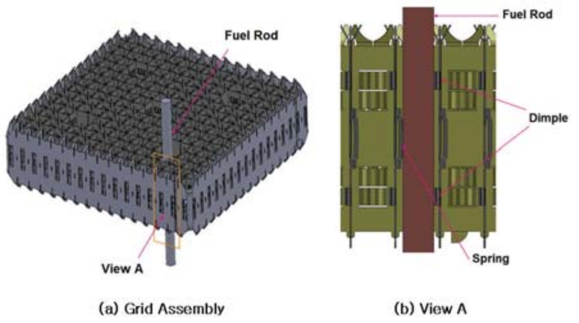
Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

A Fatigue Analysis Method for Grid Spring with Impact Force

Kyoung Joo Kim [a*], Kyong Bo Eom [a], Kyeong Lak Jeon[a], Jea Hoon Kim [b]
[a]*Korea NuclearFuel Co., Deajeon, 305-353, Korea*
[b]*Chungnam National University, Deajeon, Korea*
[*]*Corresponding author: Kyoungjoo@knfc.co.kr*

1. Introduction

The springs and dimples which support the fuel rods are exposed to axial flow within a reactor [1]. Fatigue on springs and dimples in the grid cell is caused by stress cycles, due to flow induced fuel rod vibration. The grid cell configurations of the fuel rod and spring/dimple are shown in Fig. 1. A pure vibratory stress condition exists only after the springs have relaxed after several months of operation, and then the fuel rods are free to move within the grid springs and dimples. Before that gap forms between the fuel rod and spring/dimple, the fuel rod will rub against the springs and dimple. After the gap has formed, the fuel rod will rub and/or impact against the spring and dimple. Therefore, the spring and dimple are required to be evaluated for fatigue failure. Stress analysis on the grid inner strap cell under load using finite element analysis is performed to obtain the stress intensity values of the spring and dimples which are used in the fatigue analysis.



(a) Grid Assembly (b) View A

Fig. 1. Grid Assembly

2. Methods

2.1 Stress Analysis

The purpose of this analysis is to obtain SID (Stress Intensity Distribution per unit pound) on the spring and dimples using FEA.

The fuel rod sections and the grid cell including spring and dimples, were modeled using SolidWorks[2]. The models were imported into the ANSYS[3] pre-processor and then meshed using element type SOLID92, which is suitable for large, nonlinear displacements. For the top and bottom welded corners, all degrees of freedom were fixed so as to simulate the weld. The upper left edge and all of the right edges were constrained by symmetric boundary conditions. All nodes of the fuel tube section were coupled in the same direction as the load application direction. The TARGE170 and CONTAC173 elements were used for the contact surfaces. Fig. 2 shows the meshed elements and the applied boundary conditions. This model consists of 10860 nodes and 5067 elements. The unit pound was applied on the spring and dimple to obtain SID.

Material non-linearity, geometrical non-linearity, and contact analysis were considered in solving. SID per unit pound for the grid spring and dimples was obtained and is presented in Fig. 3. The maximum stress intensity value is 37.74 ksi per unit pound on grid spring.

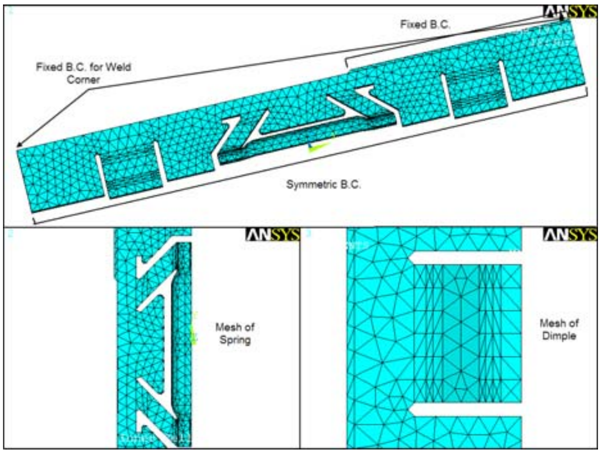


Fig. 2. Grid Inner Cell Mesh and Boundary Conditions

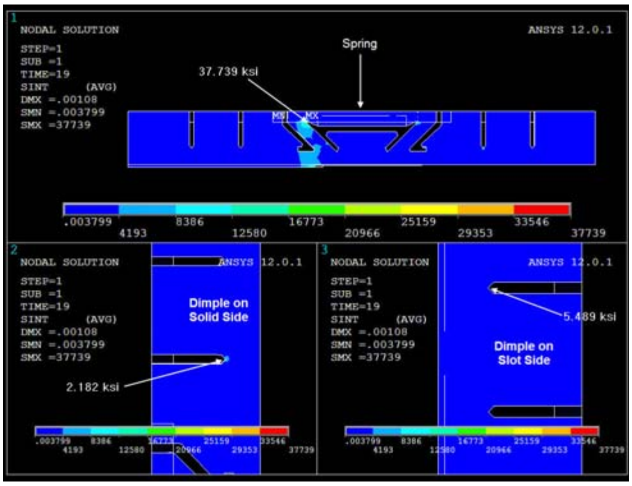


Fig. 3. Grid Cell Stress Intensity Distribution

2.2 Fatigue Test

The purpose of this test is to obtain SLR (Stress-to-Load Ratio) on the grid spring, which is to be used in adjusting SID from FEA.

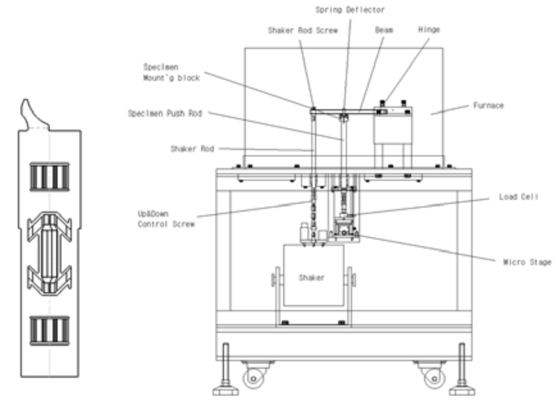
The stress amplitude at failure is obtained by applying the test failure cycle to an S-N curve. The stress amplitude at test failure cycle is divided by the applied peak-to-peak load in the test to find the SLR.

The test was run in a furnace at an air temperature of 600°F. The test vibration frequency was 65 Hz.

Fig. 4 shows the specimen and fatigue test apparatus.

All tested specimens showed no signs of failure or cracking on spring, but were assumed to fail on spring at the end of the test cycle. Fig. 5 shows fatigue test result.

The grid spring fatigue test results are summarized in table I. The largest SLR was calculated to be 6.05 ksi/lb at the spring.



(a) Spring and dimple specimen (b) Fatigue test apparatus

Fig. 4. Specimen and Fatigue test apparatus

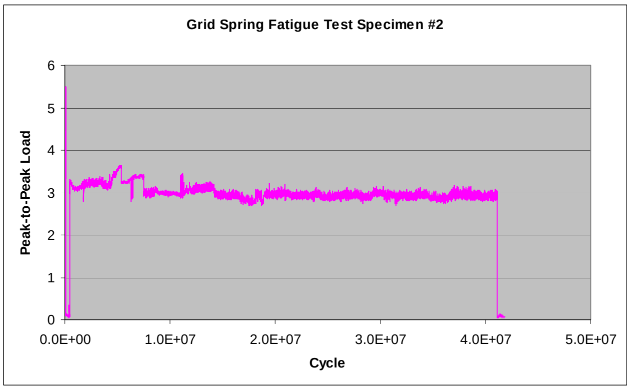


Fig. 5. Grid Spring Fatigue Test Result of Specimen #2

Sample		Test duration (cycles)	Stress at # cycles (ksi)	Spring pk-pk load (lb)	Stress-to-load ratio (ksi/lb)
ID	condition				
#2	No failure	41,100,480	18.16	3	6.05
#4	No failure	41,596,201	18.15	3.59	5.05
#5	No failure	44,374,723	18.09	3.52	5.14

Table I : Grid Spring Fatigue Test Results

2.3 Fatigue Analysis

Based on previous experience, it is believed that the stress level from FEA is usually exaggerated. Therefore, it is nacessary to evaluate the true SID by adjusting the SID from the FEA using the experimentally determined SLR.

The adjustment factor (F) is defined by the SLR from the test divided by the SID from the FEA which, in this paper, was 0.16 (6.05/37.74), thus obtaining the final SID.

Then, the fatigue usage factor is determined by operating cycles to failure cycles for each stress level. The failure cycles are conservatively obtained by applying the stress range (x2) to the S-N curve. The final SID multiplied by the oscillating fuel rod force on the grid spring and dimple from the fuel assembly loop test is the stress range.

The fatigue usage factor calculated on the grid spring in this paper was 1.55E-4.

3. Conclusions

This paper describes the process of obtaining the grid spring and dimple fatigue life (usage factor) using final SID, attuned by the adjustment factor through FEA and testing. The key steps of the process are as follows.

1. The SID is obtained by FEA using the unit load applied and the SLR is obtained by testing at the grid spring and dimple.
2. The adjustment factor is obtained by dividing the SLR by the SID. This means that the final SID is obtained.
3. The fatigue usage factor is determined by operating cycles to failure cycles for each stress level.

Acknowledgments

This work is funded by the Korea Ministry of Knowledge Economy (R-2005-1-391), and the authors express their gratitude.

REFERENCES

[1] Nam-Gyu Park, Joon-Kyu Park, Kyong-Bo Eom, Shin-Ho Lee, and Kyu-Tae Kim, Modal Parameter Identification Method for Fuel Tube with Spacer Grids, Korean Nuclear Society, Vol.2, 2007.
[2] SolidWroks Corporation, SolidWorks office (SolidWorks Essential: Parts and Assembly, 2009
[3] ANSYS Tutorial v12.0