Fuel Rod Drag Force Prediction for Mid Grid Spring Design

Su-Pil Ryu*, Joo-Young Ryu, Dong-Geun Ha, Kyoung-Bo Eom, Sang-Youn Jeon, Jung-Min Suh
KEPCO NF Co., 989beon-gil 242, Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: spryu@knfc.co.kr*

1. Introduction

Spacer grids are arranged in a nuclear fuel assembly as shown in Fig. 1. It carries out support of fuel rods, maintaining distance between the fuel rods and protecting the fuel assembly from the external loads during shipping and handling [1]. Fuel rod drag force occurring when the fuel rod is loaded into the skeleton assembly influences the fuel rod performance. If the drag force is too large, it is possible to exceed the scratch acceptance criteria of the fuel rod. In the opposite case, the grid may not support the fuel rod properly. A grid spring is important parameter to decide the fuel rod drag force and composes the biggest part of the grid design change. So predicting the fuel rod drag force according to the change of the grid spring height can reduce design period of the fuel assembly.

Predicting the fuel rod drag force according to the change of the grid spring height was studied for KSNP type nuclear fuel assembly. A mid grid which accounts for most was selected as a prediction subject. The spring height of the mid grid was changed in the reduced direction. Structural analyses for the mid grid spring were performed in ANSYS v.14.0 and the mechanical tests were carried out in the test equipment owned by KEPCO NF.

2. Load-Deflection Analysis

2.1 Analysis Model

To perform the structural analysis, reaction force and displacement of the mid grid spring were applied by transverse displacement control of the fuel rod in contact with the spring as shown in Fig. 2. Fixed supports were assigned to the adjacent fuel rod and welding area which is end cell corners of the grid. And interference phenomenon of the slot with intersectional grid was expressed. Zirconium alloy was applied to the mid grid cell and the fuel rods both.

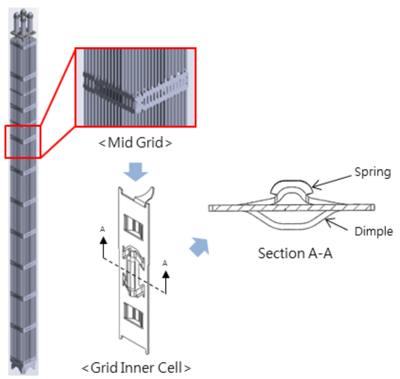

Fig. 1. General configuration of mid grid inner cell in a nuclear fuel assembly.

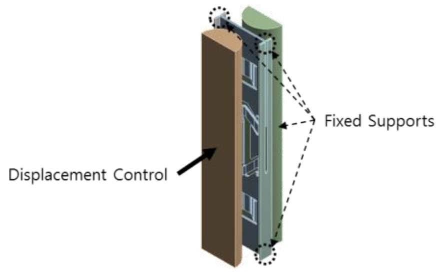

Fig. 2. Boundary and loading conditions.

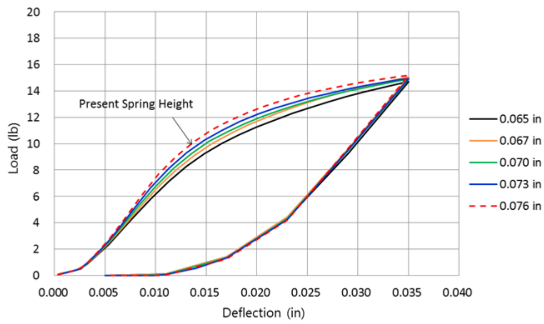

Fig. 3. Load-deflection analysis result of mid grid spring.

2.2 Load-Deflection Analysis

Nonlinear structural analyses were performed in ANSYS for the each model. The load-deflection curves for the spring height of the mid grid from 0.065 in to 0.076 in are represented in Fig. 3. The tendencies of the load-deflection characteristic are similar. It represents the spring forces for the each spring height are able to derive through the test result for the present spring height of the mid grid.

3. Load-Deflection Test

The load-deflection curve of the present mid grid spring was measured using INSTRON test machine of KEPCO NF as shown in Fig. 4. The black curve means the design curve which considers the change of the spring characteristic by weld bead of the end plug during the fuel rod loading. Table I shows the derived spring forces for the each spring height through the test result of the present spring height.

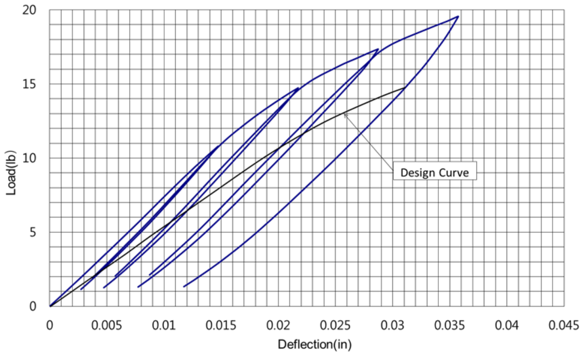

Fig. 4. Load-deflection test result of mid grid spring.

Table I: Spring Height vs. Spring Force

Spring height (in)	Spring force (lb)
0.065	5.4
0.067	6.5
0.070	8.1
0.073	9.7
0.076	11.1

4. Prediction of Fuel Rod Drag Force

4.1 Estimation of Fuel Rod Drag Force

It is possible to determine the fuel rod drag force by using the Eq. (1) when the fuel rod is loaded into the skeleton assembly [2].

$$F_{DF,i} = N_{CP} \times \mu_j \times F_{Spring\ ,i} \qquad (1)$$

where, $F_{DF,\,i}$: Fuel rod drag force (i = Spring height)
N_{CP}: The number of contact point between mid grid and fuel rod
μ_j: Friction coefficient (j = 0.1 ~ 1)
$F_{Spring,\,i}$: Spring force of mid grid

Fig. 5 shows the candidate prediction curves of the fuel rod drag forces for each friction coefficient.

4.2 Fuel Rod Drag Force Test

The friction coefficient which is an unknown parameter is possible to determine by using correlation of the spring force and the fuel rod drag force. The fuel rod drag force of KSNP type fuel assembly was measured by fuel assembly fabricating equipment as shown as Fig. 6. The average drag force of the mid grid through the test is 25.6 lb.

4.3 Prediction of Fuel Rod Drag Force

The friction coefficient between the mid grid and the fuel rod was derived by substitution the drag force test result to the Eq. (1). That is 0.58. By these processes, the final prediction curve of the drag force according to

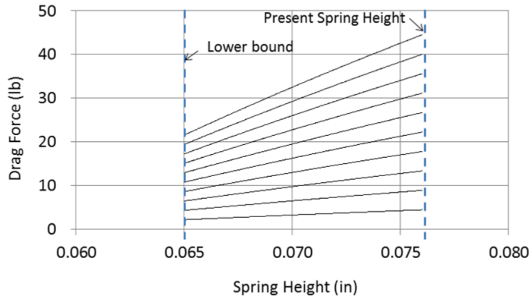

Fig. 5. Candidate prediction curves of fuel rod drag force.

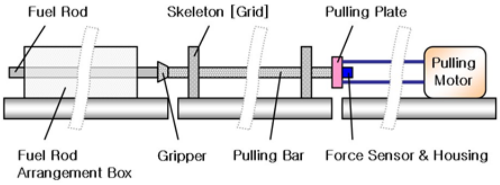

Fig. 6. Schematic diagram of fuel rod drag force test.

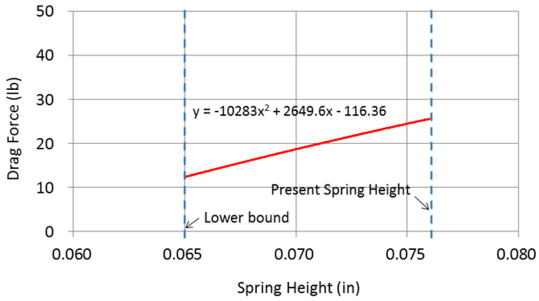

Fig. 7. Prediction curve of fuel rod drag force.

the spring height of the mid grid was derived as shown in Fig. 7.

5. Conclusions

In this study, the prediction curve of the fuel rod drag force according to the mid grid spring height was derived.

The load-deflection analyses were performed for the each mid grid spring height. The mid grid spring force and the fuel rod drag force were measured through the mid grid load-deflection test and the fuel rod drag force test, respectively. The friction coefficient was derived by using correlation of the mid grid spring force and the fuel rod drag force. And then the final prediction curve of the drag force according to the mid grid spring height was determined.

In the case of the mid grid spring height change, the fuel rod drag force can predict for changed spring height by using the prediction curve. And it is expected to be able to reduce the design period of the nuclear fuel assembly.

REFERENCES

[1] Si-Hwan Kim, Incore Fuel Management, Hyungseol, 2010
[2] D. Halliday, Fundamentals of Physics 8E, Wiley, 2009