Modified H type Spring Design for Dual Cooled Fuel Rods

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1. Introduction

From 2007, spacer grids have been designed for dual cooled fuels through the project, 'development of design technology for dual cooled fuel structure'. Because the diameter of a dual cooled fuel is bigger than conventional ones about 1.67 times, the gap between the fuel rod and strap is further narrow at the cell center of a strap. So most candidates of spacer grids have supports such as springs and dimples in the corner. In these cases, the fuels are supported by supports in diagonal direction. And then the fuels could be moved in arbitrary directions. Spacer grid designers could have problems to control the stiffness of supports, too soft or too stiff. For resolving these weak points, new supports located in the center of a strap are designed. This concept is derived from our patent[1]. In this paper, we describe new designed supports and spring characteristic analysis. The stiffness of the new candidate of a spring could be predicted by this methodology[2]. Analysed spring stiffness is almost the same as the conventional springs.

2. Spring design

To use relatively large area in the corner of a cell, high bridges and low concave spring are used as shown in Fig. 1. Solid lines are neutral lines of an unit strap which is composed of a base plate, one spring and two dimples. Dashed lines are outer edge of a fuel rod.

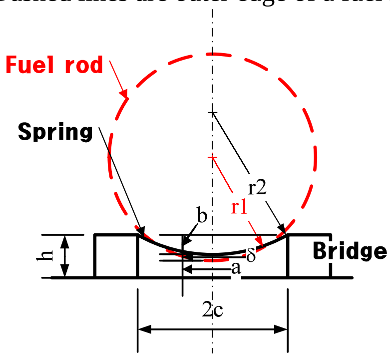

Fig. 1 The schematic drawing of newly designed spring (neutral line).

$$r_2^2 - (r_2 - b)^2 = c^2 \qquad (1)$$

$$a = (p - r_1)/2 \qquad (2)$$

$$h = a + b + \delta \qquad (3)$$

there are,

r_1 : the radius of a dual cooled fuel rod

r_2 : the radius of a spring surface

p : the pitch of unit cell

δ : initial interference

h : the height of a bridge

The height of a bridge is determined by using Eq. (1) ~ (3). Through Eq. (1), we could calculate 'b' because 'r_2'and 'c' are fixed constants to satisfy that the deformed spring shape could contact with a fuel without any empty space after being pressed by a fuel rod and the manufacturing constraints. Because 'p' and 'r1' are determined to follow compatibility constraints with a conventional fuel assembly[3], 'a' is determined by using Eq. (2). For Eq. (3), initial interference between a spring and a fuel rod is related to spring force. So this value is decided from the weight of a dual cooled fuel rod.

Fig. 3 shows a unit cell which consists of four unit straps. A fuel rod is supported by two springs and four dimples. The lines show neutral lines of springs and dimples except for the circular line of a fuel rod. In this case, the diameter of fuel rod includes the thickness of a inner strap to show whether the dimples contact with a fuel rod or not. Then, the surfaces of dimples are just contacted with the outer surface of a fuel rod and the surfaces of springs are pushed by initial interference.

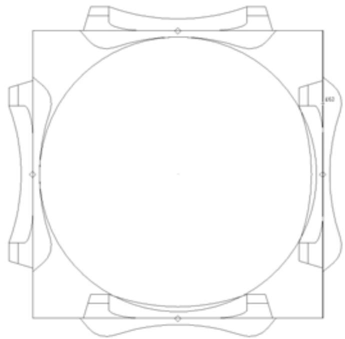

Fig. 3 A dual cooled fuel rod and an unit cell with newly designed springs and dimples.

3. FE model

A newly designed spring was converted into a finite element model. A static analysis to predict the stiffness of this spring was performed. Used methodology has been previously verified by experimental spring characteristic results[2].

Fig. 4 shows a FE model of newly designed spring and boundary conditions. The outer longer edges of an unit strap were clamped in the all translational directions. The reference point of a rigid plate was constrained in the X and Z directional degree of freedom. A dual cooled fuel rod was simulated by a rigid plate and an unit strap was divided by S3R(3-node triangular general-purpose shell) and S4R(4-node general-purpose shell, reduced integration with hourglass control) elements. The used materials of the unit strap are the elastic-plastic properties of Zry-4 which are measured by tensile test. The reference point of the rigid plate was just moved in the normal direction of the unit strap, Y axis. During the rigid plate was moved downwards until 2 mm with the increment of 0.001 mm, reaction forces at the reference point were obtained.

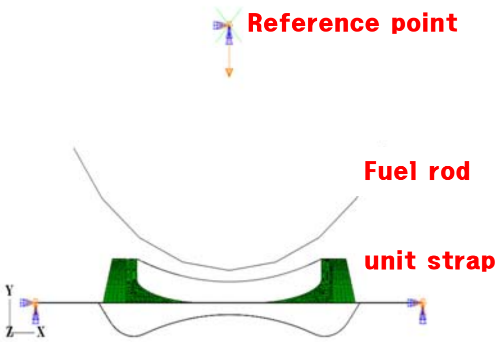

Fig. 4 The FE model to predict spring characteristics (neutral plane).

4. The results of spring characteristic analysis

Fig. 5 shows the characteristic curve of newly designed spring. The spring deforms plastically at 0.2 mm deformation. The stiffness of this spring is obtained for the linear range by using linear fitting method. The reaction force increases rapidly at 0.7 mm deformation after the rigid plate contacts with the base plate of an unit strap.

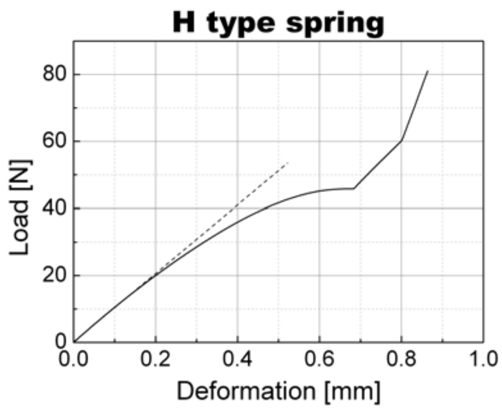

Fig. 5 The characteristic curve of newly designed spring.

Table 1 summarizes the stiffnesses of the new spring and previously designed ones (cantilever and hemi-sphere type)[2, 4]. New spring stiffness is lower than a hemi-sphere type spring and higher than a cantilever type spring. Because conventional spring stiffness is 98.4 N/mm, this new spring stiffness is almost same. Loading force is reaction force when the springs are deflected by initial interference. The spring force has to be larger than 5.2~6.36 N in the case of a dual cooled fuel. A newly designed H type spring satisfies the required spring force condition sufficiently.

Table 1 Spring characteristics of springs to support a dual cooled fuel rod

Model	Cantilever	Hemi-sphere	H type
Interference [mm]	0.32	0.2	0.3
Loading force [N]	8.9	83.0	28.5
Stiffness [N/mm]	30.3	599.2	100.17

5. Conclusions

A new spring has been designed to support a dual cooled fuel rod. This spring is located in the center of a strap. This is different from the previously designed cantilever, hemi-sphere and circular insertion type spring. We could guess the movement of fuel rods and control to aim one direction by using this new designed supports. The stiffness of a new spring is lower than that of a hemi-sphere spring about 6 times and higher than that of a cantilever spring about 3 times. The spring force is 28.5 N which sufficiently satisfies the required spring force to support dual cooled fuel rods. Since new designed strap has more empty space than the previous designs, less pressure drop is also occured.

ACKNOWLEDGEMENTS

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