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Parametric Study of Center-Moved Supports of a Spacer Grid

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1. Introduction

To enhance the fuel safety and to achieve a power uprating, new concept PWR fuel, which is named as a dual cooled fuel, has been studied from 2007. Althought there are some challenging problems about each mechanical component, fuel rod supporting structures is especially dealt with in this paper. A current key issue of fuel rod supporting supports is the narrow gap problem between rods. The gap decreases according to increasing outer diameter of a fuel rod [1]. A few conceptual designs to resolve the narrow gap problem has been suggested. Some of them have been applied for patents. In this paper, a kind of candidates, which is named as a center-moved concave/convex spacer grids, is concerned.

The grid springs in a spacer grid play a role of holding the fuel rods in an appropriate position and preventing fuel rods dropping during normal reactor operation. In the case of the dual cooled fuel, the total mass of a fuel rod is increased. So, the stiffness of grid spring has to be increased than that of conventional grid spring. However, if the stiffnesses of springs are increased too much, fuel rods can bow due to the prohibition of the axial slip of them. So, it is necessary to design an appropriate stiffness.

In this paper, the parametric study is carried out to form a concave/convex shape of the supports to obtain the necessary stiffness.

2. Parameters for a concave/convex spacer grid

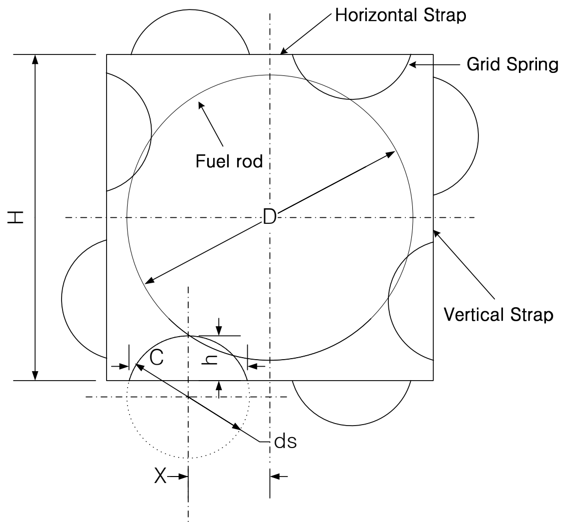

Fig. 1 Schematric drawing of a concave/convex spacer grid.

Fig. 1 shows some parameters which have to decide for a concave/convex spacer grid. Each parameter is below;

- D : the diameter of a fuel rod
- ds : the diameter of a grid spring
- H : the height of a grid cell
- h : the height of a grid spring
- C : the width of a grid spring
- X : the distance between the centers of a fuel rod and a grid spring
- δ : the initial interference between a fuel rod and a grid spring
- t : the thickness of a grid spring (equal to the thickness of straps)

The following equation is constituted to determine the parameters. D, ds, H and t are constants. δ, h and C are to be decided.

$$X = \sqrt{\left(\frac{D}{2} + \frac{H}{2} + ds + \frac{t}{2} - \delta - h\right)\left(\frac{D}{2} - \frac{H}{2} + \frac{t}{2} - \delta + h\right)} \qquad (1)$$

By using Eq. (1), totally 8 models were decided to obtain the relationship between each parameter and stiffness. The 1st model was set as an original basis. The 2th to 4th models increased the value of parameter δ. The 5th to 6th models were to observe the effect of parameter h. The rest models were changed about parameter C.

3. FE models

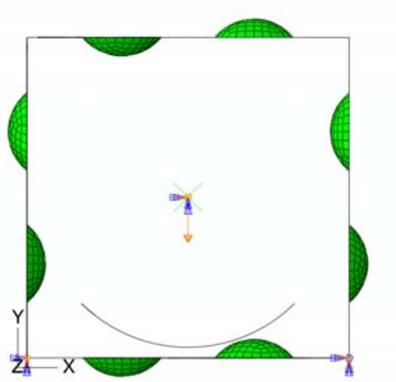

Fig. 2 A finite element model for parametric study.

A 1x1 model was used for parametric study. Shell elements were used for vertical and horizontal straps. A rigid plate was used to simulate a fuel rod.

Analysis was composed of two steps, shrink fit and loading process [2]. During shrink fit, the rigid plate pushes back a grid spring by an initial interference between a fuel rod and a grid spring. After then, the rigid plate moves by 0.4 mm downward to obtain the stiffness of a grid spring.

3. The results of spring characteristic analysis

Table 1 shows the results of spring characteristic analyses about the 8 FE models. These results explain that the spring stiffness is decreased when δ is increased and h and C is decreased.

Table 1 The spring stiffness of all FE models for parametric study.

Model	Stiffness (N/mm)	deviation (N/mm)
1	545.34	basis
2	529.12	- 16.22
3	515.42	- 29.92
4	459.72	- 85.62
5	730.56	185.22
6	984.82	439.48
7	523.65	- 21.69
8	464.68	- 80.66

To compare the influence of each parameter on spring stiffness, all parameters' values are into non-dimensionalized with respect to the diameter of a fuel rod. Table 2 summarizes the variation rates of the spring stiffnesss versus those of the non-dimensionalized values for each model. The variation rate is calculated by using Eq. (2).

$$V.R.\ of\ \ N.D.P. = \frac{\left(P/D - P_0/D \right)}{P_0/D} \qquad (2)$$

Here are,

- V.R. : variation rate
- N.D.P. : non-dimensional parameter's value
- P : parameter's value
- P_0 : original parameter's value
- D : diameter of a fuel rod

Table 2 The variation rates of N.D.P. and stiffness

Model	Par.	V.R. of N.D.P. (%)	V.R. of stiffness (%)
1		Basis	0
2	δ	30	- 2.97
3		50	- 5.49
4		100	- 15.70
5	h	50	33.96
6		100	80.59
7	C	- 23.81	- 3.98
8		- 47.62	- 14.79

* Par. : parameter, V.R. : variation rate

Fig. 3 shows the relationship between N.D.P. and spring stiffness clearly. The spring stiffness in the case of concave/convex spacer grids is almost increased/decreased parabolically while δ, h and C are changed. The change of parameter h is most critical to the spring stiffness. The spring height is found to be a most influencing parameter on the stiffness.

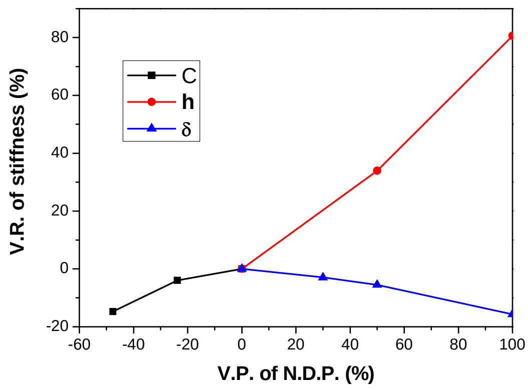

Fig. 3 V.R. of N.D.P. versus V.R. of stiffness

4. Conclusion

Parametric study of a center-moved concave/ convex spacer grids for detail design is performed. The spring stiffness is decreasd as the initial interference between a fuel rod and a grid spring is increased and the height of a grid spring and the width of a grid spring are decreased. Among these parameters, the height of a grid spring is the most influencing parameter on the spring stiffness. Each parameter and the spring stiffness have a parabolic relation approximately.

ACKNOWLEDGEMENTS

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