Preliminary Analysis of the Fuel Bundle Stiffness by ANSYS for SFR

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1. Introduction

In SFR (Sodium-cooled Fast Reactor) the temperature of the fuel pin is higher than that of the hexagonal duct, so the thermal expansion rate of the fuel bundle is higher than that of the duct. The neutron fluence and the fuel pin pressure are also increased according to the burnup. So the radial expansion and bowing of a fuel pin bundle would occur, and then fuel bundle would interact with a duct. This phenomenon is called bundle-to-duct interaction (BDI) [1]. Under the BDI condition, excess cladding strain and hot spots would occur. Therefore BDI as well as the core mechanics [2] should be considered to evaluate the FBR fuel integrity.

The analysis codes such as ETOILE [3], SHADOW [4], and MARSE [5], have been developed to evaluate the BDI behavior.

The ANSYS [6] based model is also being developed to analysis the bundle duct interaction for SFR in Korea. In this paper, the fuel pin/bundle model for analyzing the bending deflection and oval deformation was described. The preliminary analysis of the fuel bundle stiffness was performed by the developed model.

2. Methods and Results

In this section, a fuel pin/bundle model, and the bundle stiffness analysis are described.

2.1 Fuel Pin/Bundle Model

One fuel pin was modeled by three-dimensional beam element. This beam element can express the fuel pin bending. The PIPE20 element in ANSYS was used for the bending defection of the fuel pin/bundle.

In a wire-wrap fuel assembly, the spacing of fuel pin is maintained by the wire-wrap. So the deformation of each fuel pin strongly depends on the contact points between the wire-wrap.

The expansion and oval deformation are modeled by truss elements. The LINK8 element in ANSYS was used for the fuel deformation.

The truss elements are attached at the points of fuel-to-fuel or fuel-to-duct contact points. The number of possible contact points is 12 per one wire-wrap length. The CONTACT52 element in ANSYS was used for the contact point.

Figure 1 shows the finite element model for the typical FBR bundle of 271 pins. It is expected that the ANSYS model can simulate the fuel bundle design very well.

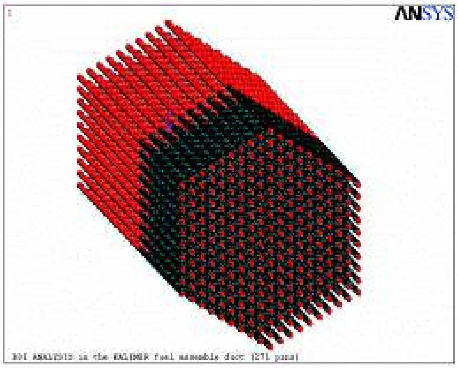

Fig. 1. Finite element model for BDI (271 fuel rods)

2.2 Bundle Stiffness Analysis

To evaluate the BDI behavior of fuel bundles in SFR during irradiation, a complicated computation should be carried out on a fuel subassembly containing 271 pins.

However, a lot of computing time is needed to analyze the BDI in the ANSYS calculation, because numbers of nodes are more than 100,000 for the 271 pins.

In this paper, in order to check its applicability to a large bundle analysis, the bundle stiffness of 37 rods and 127rods were preliminary analyzed.

The key geometric parameters for ANSYS application are shown in Table 1.

Table I: Key parameter

Outer diameter of cladding [mm]	8.5
Inner diameter of cladding [mm]	7.2
Outer diameter of spiral wire [mm]	1.4
Wrapper pitch of spiral wire [mm]	200~400
Number of fuel pins	37, 127

The pin outer diameter is 8.5 mm, the pin inner diameter is 7.2 mm. The wire wrapping pitch is 203, 304, and 400 mm. The pin pitch is 9.7 mm and the wire diameter is 1.4 mm. The gas plenum in a fuel pin located at the upper part of the cores, the fuel pin is fixed only at the lower end.

Figure 2 shows the stiffness according to the length of wire-wrap pitch.

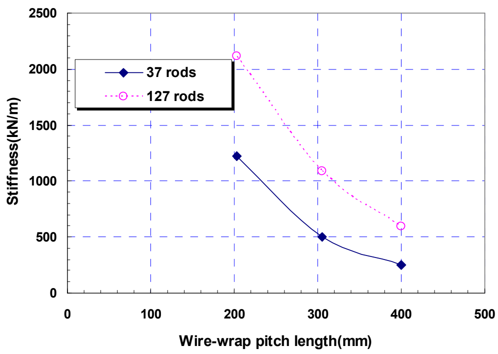

Fig. 2. Stiffness according to the length of wire-wrap pitch

In the case of 37 fuel rods, the calculated stiffness was about 1200 kN/m for 200mm of wire-wrap pitch length. On the other hand, the calculated stiffness was about 300 kN/m for 400mm of the wire-wrap pitch length.

In the case of 127 fuel rods, the calculated stiffness was about 2100 kN/m for 200mm of wire-wrap pitch length. However, the calculated stiffness was about 600 kN/m for 400mm of the wire-wrap pitch length.

It was expected that the stiffness of the fuel bundle was decrease by the increase of the length of wire-wrap pitch.

It shows that the compulsive force of the bundle against the compressive force of the duct increase with the decreasing of length of wire-wrap pitch.

It also shows that the stiffness of the bundle increase with the number of the fuel rods. So these kinds of relation such as the stiffness vs. number of fuel rods should be considered in the design of 271 fuel rods.

Figure 3 shows the stiffness according to the wire-wrap turn number for 37 rods.

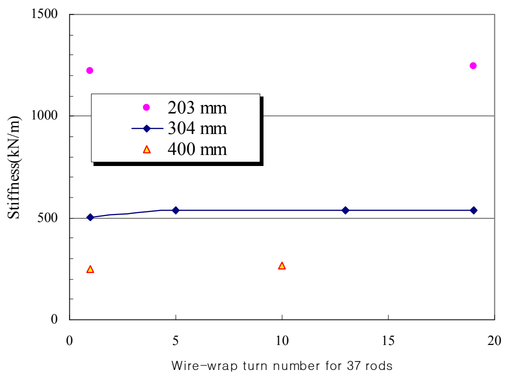

Fig. 3. Stiffness according to the wire-wrap turn number for 37 rods

In the case of 5 wire-wrap turn for 400mm of wire-wrap pitch, the calculated stiffness was about 550 kN/m, which is more or less larger than that of 1 wire-wrap turn.

On the other hand, the calculated stiffness 19 wire-wrap turn for 400mm of wire-wrap pitch was about same as that of 5 wire-wrap turn.

It shows that the effect on BDI by the wire-wrap turn number is less severe than that by the length of the wire-wrap pitch.

3. Conclusions

The ANSYS model is being developed for the prediction of BDI. The code calculates the fuel bundle stiffness, and the mechanical interactions of fuel bundles.

According to the preliminary design concepts of the fuel assembly, the BDI should be controlled by the design of the wire-wrap pitch, wire-wrap tension, wire-wrap turn number, wire-wrap thickness etc.

In order to check of the applicability of the ANSYS model, the stiffness by the length of wire-wrap pitch and the the stiffness according to the wire-wrap turn number were calculated.

It was calculated that the stiffness of the fuel bundle was decrease by the increase of the length of wire-wrap pitch.

There are lots of uncertainties in the modeling, so this analysis model will be developed continuously, and this preliminary analysis model and results will be helpful for the establishment of the preliminary design concepts of the fuel assembly.

Acknowledgements

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