Nuclear Calculation Evaluation of CANDU Fuel Channel Deformation

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1. Introduction

As the operational time increases, pressure tubes and calandria tubes in CANDU core encounter inevitably a geometrical deformation along the tube length. A pressure tube may be sagged downward within a calandria tube by creep from irradiation. Fuel pin bundle shape may also be changed by irradiation creep. The worst case from safety point of views must be the irregular deformation of fuel bundle in sagged tube. When a pressure tube at high temperature contacts with a calandria tube wall at low temperature, hydrogen spread and blister by gradient of temperature may also be formed. Then, a crack course damage of pressure tube can occur. This event can bring about a problem that is serious in integrity of pressure tube. A measurement of deflection state of in-service pressure tube is, therefore, very important for the safety of CANDU reactor.

In this study, effects of fuel channel deformation on nuclear safety parameters are to be analyzed. With results from analysis, methodology improvement for the correction for channel deformation will be studied. In this paper, comparisons of MCNP and HELIOS results for the deformation of CANDU fuel channels are provided as the primary step research.

2. Models and Methodology

CANDU fuel channel is analyzed by WIMS code package as a design tool. However, WIMS code cannot describe irregular bundle geometry of eccentric array. Therefore, two kinds of computer codes are used, one is MCNP as a probabilistic analysis and the other is HELIOS as a deterministic analysis. Calculation models are sagged fuel bundle by 0.6 cm deviation from the center position of concentric channel. The maximum expansion of fuel channel is also assumed for the creep ballooning. Based on the operational experience, expansion of pressure tube is said to be about 5% by creep phenomenon.

3. Nuclear Calculation Evaluation on Sagged Fuel Channel

3-1. Probabilistic Analysis

At the first step, hypothetical sagging phenomena were analyzed by MCNP. The distances of deviation from center were assumed as 0.5cm, 1cm, 1.5cm, 2cm and 2.5cm. Fig.1 shows that there was strong correlation between sagged distance and k-eff.

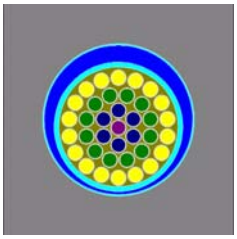

Fig.1. MCNP Model of a Sagged PT

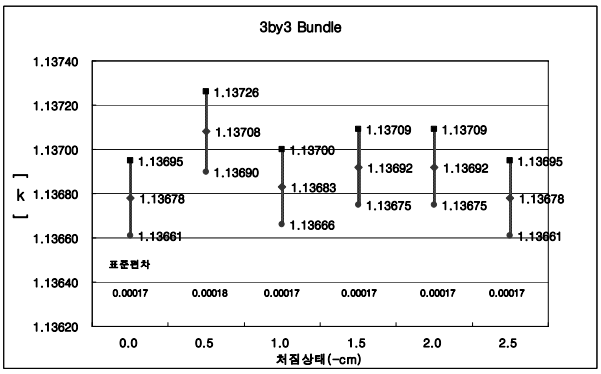

Fig.2. Comparison of k-eff of Sagged Channels

Based on realistic assumption, the maximum sagging distance is 0.6 cm. Table 1 shows that error level in k-eff is less that standard deviation.

Table1. MCNP Results

	K
Standard Channel	1.13695 ±0.00034
0.6cm Sagged Channel	1.13655 ±0.00033
Δ k	0.00040

3-2. Deterministic Analysis

In order to eliminate probabilistic error, the same calculation was repeated by HELIOS.

Table.2.HELIOS Results

	k
Standard Channel	1.13583
0.6cm Sagged Channel	1.13556
Δ k	0.00027

From HELIOS, difference in k-eff was also very small by 27pcm which is normally less than the calculation uncertainty. Differences in k-eff along the depletion of fuel were also small. It may be said that the sagging effect to nuclear calculation is negligible.

4. Nuclear Calculation Evaluation on Pressure Tube Expansion

5% volume expansion of pressure tube by creep phenomenon was assumed, i.e. more coolant area was assumed as more moderator in the fuel channel. Differences in k-eff from MCNP is 544pcm whereas 579pcm from HELIOS as shown in Table 3. Fig.3 shows the effect of sagging and tube expansion. Tube expansion may have considerable effect in nuclear design parameters whereas sagging effect may not.

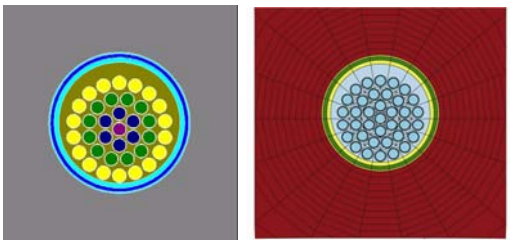

Fig.3. MCNP, HELIOS modeling of PT by Creep

Table.3. MCNP, HELIOS Results

	MCNP	HELIOS
	k	k
Normal Channel	1.13695 ±0.00034	1.13583
0.6cm Sagged Channel & 5% Expanded Pressure Tube by Creep	1.13151 ±0.00034	1.12986
Δ k	0.00544	0.00597

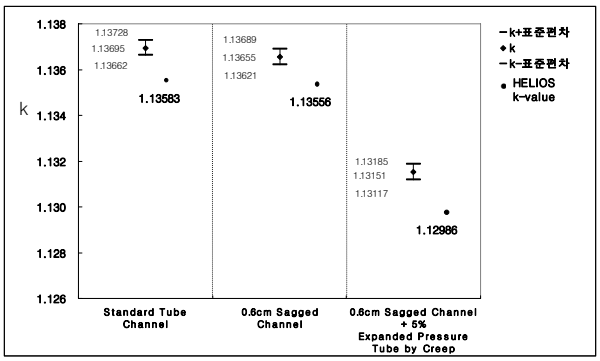

Fig.4. Comparison in K-eff of MCNP and HELIOS

5. Conclusions

From the initial study on the fuel channel deformation of CANDU plant, it was found that sagging phenomena do not give considerable effect on nuclear calculation, however, tube expansion effect from creep may be considerable. This finding is the same from both computer code MCNP and HELIOS.

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