Evaluation of Reactor Physics Characteristics for the Modified CANDU6 Fuel

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1. Introduction

The regional overpower protection (ROP) system in CANDU6 reactor is to prevent OID (Onset of Intermittant Dryout) caused by the slow loss of regulation (SLOR) and is performed at the evaluated ROP trip setpoint. The evaluated trip setpoint is getting lower as plant operating time goes on. Recently the modified fuel is being developed as one of solutions for lower ROP set point in CANDU6 reactor. The standard 37 element fuel bundle of CANDU6 has the same size fuel pins. The center pin of the modified fuel is smaller than the others in order to improve the operating and safety margin. In this study the main reactivity coefficients were calculated to evaluate the effect on reactor physics characteristics by the modifying diameters of center pin.

2. Methods and Results

The physics parameters are evaluated under the 9 cases which has different diameter of central fuel element and the various conditions of temperature and density. The WIMS-IST, a two-dimensional multigroup neutron transport code, is used to evaluate the physics parameters [1].

2.1 Lattice Cell Model

The horizontal section of fuel bundle is shown in Fig. 1. The reference lattice cell is modeled according to the design parameters of the Wolsong-1 physics design manual [2]. The fuel pin is divided into three regions which have two fuel regions and one cladding region [3]. For the sensitivity calculation, the 9 cases are considered by varying the diameters of central fuel pins. The diameter is varied by changing ±20% of reference diameter at intervals of 5%. The same value for the fuel density is assumed because the mass of uranium is reduced in proportion to the volume reduction. The effective nominal temperature of fuel, coolant and moderator is 687°C, 288°C, and 69°C, respectively. The density of coolant and moderator at nominal condition is 0.807589 g/cm^3 and 1.085089 g/cm^3, respectively. Those cases are calculated in condition of fresh fuel.

2.2 Parametric Study of Center Fuel Pin Size

Temperature coefficients of fuel, coolant, and moderator are calculated to compare the effects of the different fuel pin sizes. The material properties for the evaluation are as follows. The fuel temperature is varied by 25°C, 687°C and from 100°C to 900°C at intervals of 100°C. The temperature and density of the coolant and moderator is changed by each matching value. The coolant temperature is changed every 40°C from 60°C to 300°C and the moderator temperature is varied by adding 10°C from 29°C to 75°C. To calculate the void reactivity the coolant density is changed from 0.1 to 0.9 g/cm^3 at interval of 0.1 g/cm^3.

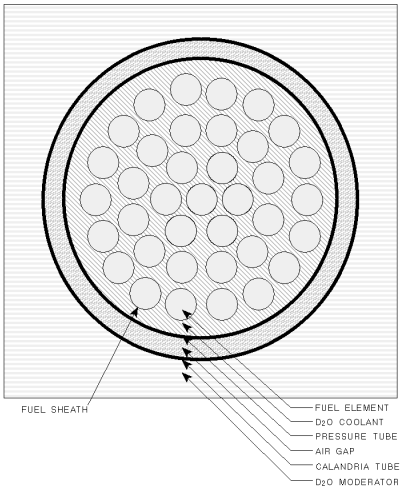

Fig. 1. Standard 37 Element Fuel Bundle

2.3 Results

1) Temperature Coefficients

The reactivity change due to changing the temperature of fuel, coolant and moderator is shown in Figure 2. The properties of natural uranium fuel and moderator, density and quantity, are the same in all cases. So, the fuel temperature coefficients are little affected by the change of center pin size. The maximum difference is not over 0.69%. There is no effect of changed diameter for the moderator temperature coefficient. The quantity of coolant is different from each case to reduce the volume of fuel element. The maximum difference is 1.96%.

2) Void Reactivity

Because the quantity of coolant in the decreasing cases is a little more than the standard, the void reactivity in the decreasing cases is more different than the increasing cases as shown in Figure 3. The difference of void reactivity for the 9 cases is below 1.5%.

Table 1 shows the evaluated value of void reactivity under the full voiding and reactivity change. In the present results the difference between standard and modified fuel with 20% reduced diameter is about 0.22 mk. Figure 3 shows the difference between the results of lattice calculation and core calculation. Considering the difference between 2D and 3D calculation, the maximum void reactivity may be not over 4 mk.

Table 1. Comparison of reactivity change for temperature coefficient and void reactivity under full voiding condition between standard pin size and -20% size. (unit : mk)

	WIMS-IST (2D)		WIMS-IST/ RFSP-IST (3D)*
Case	-20% OD	Standard 37-element	Standard 37-element
Fuel (900°C)	-2.1769	-2.1765	-2.4726
Coolant (300°C)	0.414978	0.414956	0.3751
Moderator (75°C)	-0.2555	-0.2555	-0.2860
Void Reactivity (full Voiding)	17.541	17.317	20.2

* reference [3].

3. Conclusions

There is nearly no difference of the reactor physics characteristics due to the partial change of fuel bundle. Therefore to reduce the diameter of center fuel element is expected only to improve the thermal hydraulic condition because of increasing the quantity of coolant through center region. In further study the physics parameters are going to be re-evaluated with 3-dimensional code, RFSP-IST and analyzed the effect of the modified fuel in several points of view.

REFERENCES

[1] S.R. Douglas, WIMS-AECL Release 2-5d Users Manual, AECL, COG-94-52(Rev.4) FFC-RRP-299, 2000.
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[3] McArthur Randall D., a WIMS Utilities Model of 37-Element Fuel for Wolsong Nuclear Power Plants: Wolsong 1, 59-03311-220-001, Rev.2, 2008.

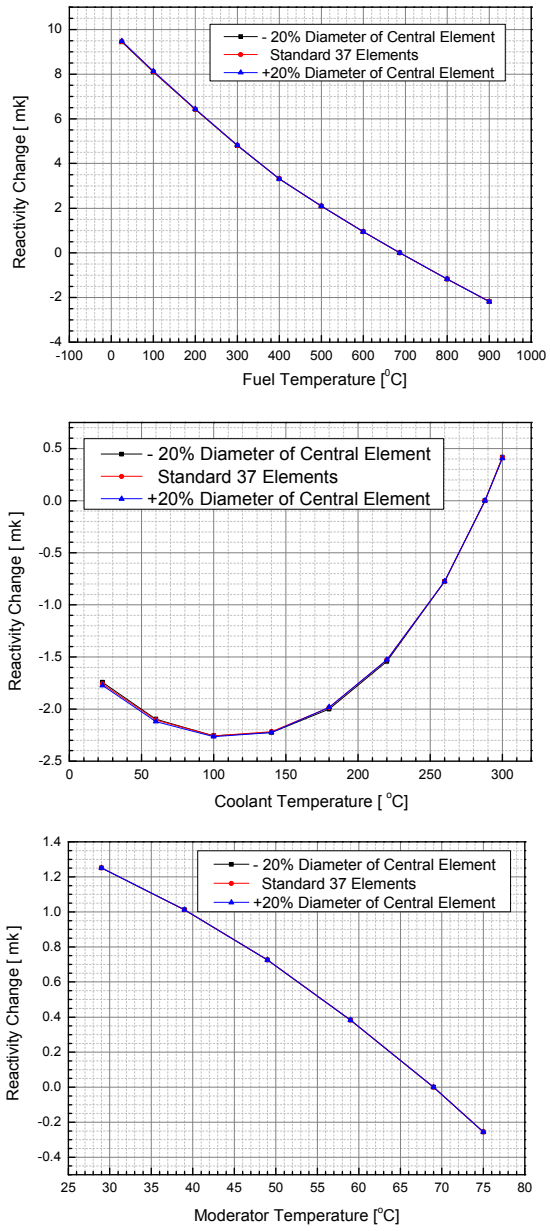

Fig. 2. Reactivity change due to change the temperature of fuel(top), coolant(middle) and moderator(bottom)

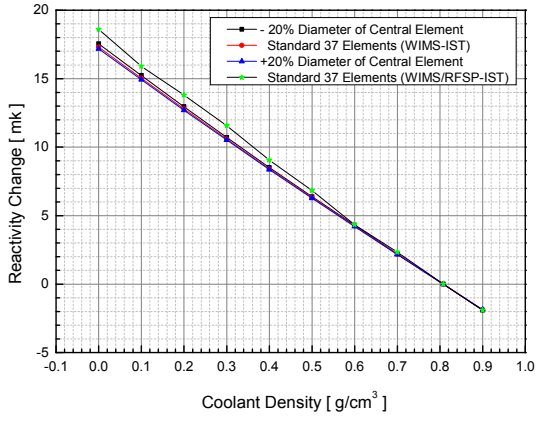

Fig. 3. Reactivity change due to coolant voiding