Comparison of the Reactor Physics Characteristics between the Standard and Modified 37-Element Fuel for CANDU6

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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 periodically evaluated ROP trip setpoint. The evaluated trip setpoint is getting lower as plant operating time goes on. Recently the modified fuel (37M) is being developed as one of solutions for lower ROP set point in CANDU6 reactor. The standard 37 element fuel bundle(37R) of CANDU6 has the same size fuel pins. But the center pin of the modified fuel is smaller than the others in order to improve the heat-transfer properties relative to 37R designs. The radius reduction increases the flow area around the center pin and decreases the mass of uranium. This study is performed to evaluate the impact of the design change on the reactor physics parameters.

2. Methods and Results

The physics parameters according to the burnup are evaluated under the various conditions of temperature and density.

2.1 Lattice Cell Model

The WIMS-AECL version 3.1, a two-dimensional multigroup neutron transport code is used to evaluate the physics parameters[1]. The WIMS-AECL 3.1 is improved for the resonance treatment to consider the resonance self-shielding effect and is possible to use the ENDF/B-VII libraries. The resonance cross sections of uranium isotopes in ENDF/B-VII libraries are modified. Figure 1 shows the end view of fuel bundle.

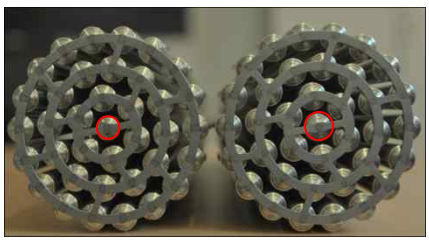

Fig. 1. End view of 37M(left) and 37R(right)

The center pin diameter of the modified 37-element fuel is reduced 12%. The mass of uranium is reduced 0.6%. The reference lattice cell for each fuel type is modeled according to the fuel design parameters[2]. The center pin of fuel bundle is divided into five regions which have four fuel regions and one cladding region[3]. The others are divided into eight regions for fuel regions to consider resonance self-shielding. 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 0.8080042 g/cm^3 and 1.0851822 g/cm^3, respectively. Those cases are calculated in 50 burnup steps.

2.2 Reactor Physics Parameters

Temperature coefficients of fuel(FTC), coolant(CTC), and moderator(MTC) and coolant density coefficient are calculated to compare the effects of the different fuel types. The material properties for the evaluation are shown in the table 1. The temperature and density of the coolant and moderator is changed independently. To calculate the coolant void reactivity the 0% and 100% voiding conditions are assumed.

Table 1. Reference and perturbation conditions used in WIMS calculations

	Temperature [°C]			Density [g/cm^3]
Material	Fuel	Coolant	Moderator	Coolant
Reference	687	288	69	0.8080042
Perturbation	650 700 750	270 295 305	65 75	0.0001

2.3 Results

Table 2 presents the results of lattice calculations for the standard and modified 37-element fuel bundles.

Table 2. Results of physics parameters at mid-burnup for each fuel type.

Fuel Type	Standard 37-element	Modified 37-element	Difference
Mid-Burnup [MWH/kg-U]	3604.8	3627.8	-
CVR [mk]	13.41	13.51	0.1
FTC [mk/°C]	0.0078	0.0071	-0.0007
CTC [mk/°C]	0.0414	0.0408	-0.0006
MTC [mk/°C]	-0.0459	-0.0460	-0.001

1) Coolant Void Reactivity (CVR)

WIMS predicts a small increase in coolant void reactivity for 37M of relative to37R. Because the coolant quantity of modified fuel is a little more than the standard fuel, the void reactivity of modified fuel is bigger as shown in Figure 2. The difference of CVR between two fuel types is below 0.2 mk for the range of calculated burnup. The relative error of void reactivity is approximately 0.75% at mid-burnup.

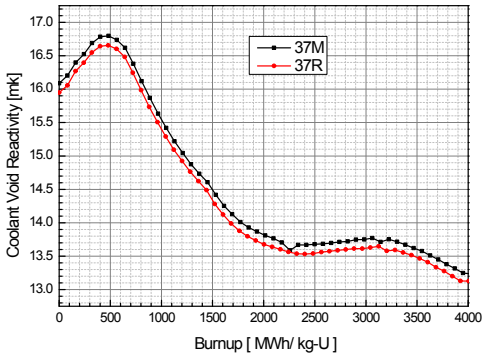

Fig. 2. Reactivity change due to coolant voiding

2) Temperature Coefficients

The temperature coefficient of fuel, coolant and moderator is shown in Figure 3. The fuel temperature coefficient of 37M because of the uranium mass reduction is lower than 37R. The coolant and moderator temperature coefficients are not affected by the reduction of center pin diameter.

3. Conclusions

The impacts of the fuel design change on the reactor physics parameters are small with the difference below the recommended uncertainty of code. Therefore to reduce the diameter of center pin is expected only to improve the thermal hydraulic condition because of increasing the flow area around the center region. In further study the physics parameters are going to be re-evaluated with 3-dimensional code, RFSP and analyzed the effect of the modified fuel in several points of view.

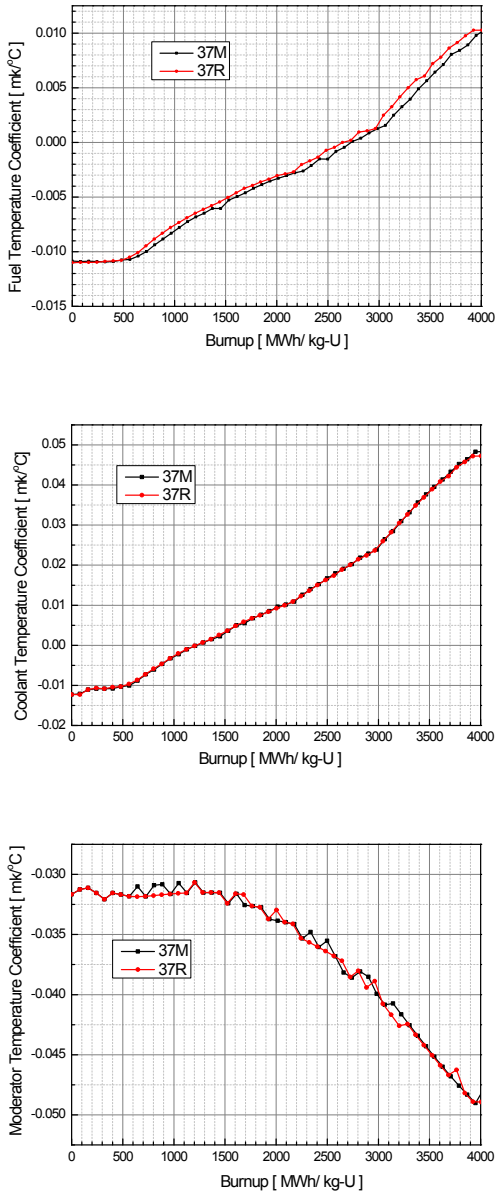

Fig. 3. Temperature coefficient of fuel(top), coolant(middle) and moderator(bottom)

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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.