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Assessment of Lattice Characteristics for ZED-II Using WIMS-CANDU

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1. Introduction

An investigation on the effect of the lattice characteristics to Zero Energy Deuterium (ZED)-II reactor in AECL has been performed. Since the neutronic behavior of the ZED-II lattice is similar to that of the CANDU reactor, the feasibility study is performed using ZED-II experimental data so as to use the analysis of the CANDU reactor safety analysis.

The assessment of the core physics characteristics of ZED-II reactor has been conducted using WIMS-CANDU code and WIMS-AECL code with ENDF/B-VI nuclear data libraries of 69- and 89- neutron energy groups, respectively. The compared parameters are the effective multiplication factors for the fresh and mid burn-up simulating natural uranium fuel (MOX) using the critical buckling derived from the experiments.

The calculation results show that there is a little larger over-prediction from the critical experiment in WIMS-CANDU calculation when compared to WIMS-AECL values.

2. Experiments in ZED-II

The experiment in ZED-II was performed to validate the lattice code WIMS-AECL for the CANDU reactor physics analysis and to design the advanced CANDU reactor ACR. The experiment determines the material buckling and buckling-change-on-voiding of the UO_2 fuel with D_2O unvoided and air voided as a coolant in the test channels. Also, the experiment was performed to study the effect of the channel temperature on the reactivity and D_2O and CO_2 gas were used to heat the channel as a coolant. The reactor is made critical by pumping heavy-water moderator into the calandria and the power is controlled by adjusting the moderator level.

The ZED-II experiment used two kinds of fuels; natural uranium fresh fuel and MOX (mixed oxide) fuel calibrated to simulate the mid-burn up of the natural uranium fuel life in a CANDU reactor. The MOX fuel pellets contain the uranium depleted to 0.323wt% U^{235} and 0.2wt% Pu^{239} in heavy element. Also, a poison 0.013wt% Dy^{164} was required to get a buckling similar to that of a mid burn-up fuel. The geometry of 37-element test fuel assembly of ZED-II is as shown in Figure 1.

The buckling was measured by the flux-map, the substitution and high temperature experiment;

- in the flux-map experiment, the buckling was derived by measuring the reactivity of Cu-wire in the reference lattice and voided & flooded seven-rod substitution lattices

- in the substitution experiment, the buckling was derived by measuring the moderator critical height for the reference lattice followed by one-, three-, seven-rod substitution lattices

- in the high-temperature experiment, the buckling was derived by measuring the moderator critical height in the test channel including the heater, heater leads, heater shroud, thermocouples and support rods, using D_2O and CO_2 gas coolant of temperature ranging from 25°C to 300°C.

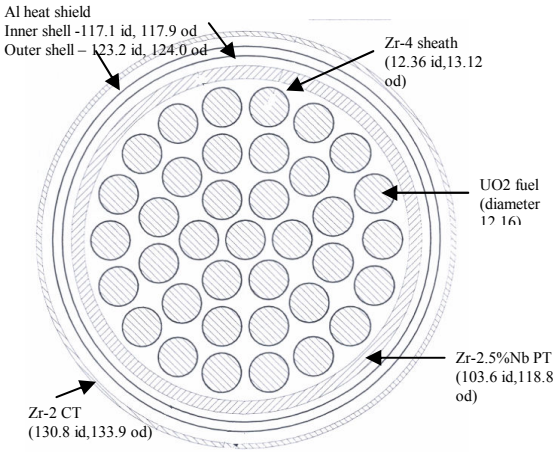

Figure 1 Cross section of a test assembly
(All dimensions in mm)

3. Calculation method

In order to investigate the lattice characteristics for ZED-II reactor, the cell calculation was performed for 37-element ZED-II fuel using lattice codes such as WIMS-CANDU and WIMS-AECL and using the critical buckling derived from the experiment and compared with the experimental data. The nuclear data libraries in WIMS-CANDU and WIMS-AECL are adopted with the 69- and 89-energy groups of ENDF/B-VI, respectively.

The fuel assembly for a WIMS calculation was modeled as a square lattice including a fuel pellet, clad, coolant, pressure tube, air gap, calandria tube and a moderator. The transport calculation was performed by the collision probability option (PIJ) and B1 method

was not used to calculate the effective cell flux using WIMS-AECL because the present WIMS-CANDU does not consider the end-region effect with the B1 method simultaneously. However the Benoist diffusion coefficient model was used to generate the cell average diffusion coefficients.

The comparisons for k-effective were performed with the modeling of a uniform lattice containing the fresh natural uranium fuel and MOX fuel by using the buckling derived from the experiment.

4. Results and discussion

The following tables show the k-effective values calculated using WIMS-AECL and WIMS-CANDU provided with the 89- and 69-goups libraries respectively, based on the ENDF/B-VI nuclear data file. The buckling derived from the experiment was used as an input.

Table 1 show that WIMS-AECL and WIMS-CANDU over predicts the k-effective multiplication factors for the fresh fuel, by 1.84mk and 3.88mk in the cooled D_2O coolant and by 5.07mk and 7.31mk in the void coolant, respectively, using the critical buckling. For the MOX fuel WIMS-AECL and WIMS-CANDU over predicts the k-effective by 0.4mk and -3.8mk in the cooled D_2O coolant and by 1.4mk and -3.2mk in the void, respectively using the critical buckling.

Table 2 shows that WIMS-AECL and WIMS-CANDU over predicts the k-effective in the D_2O and CO_2 gas coolant using the critical buckling, except the case of WIMS-CANDU for the water coolant of temperature from 25°C to 100°C.

Table 1 Buckling and k-effective for FNU and MOX at room temperature

Fuel Type	Coolant	Buckling (m^{-2})	WIMS-AECL	WIMS-CANDU
FNU	D_2O	3.572	1.00184	1.00388
	air	3.884	1.00507	1.00731
	change	0.312	0.00323	0.00343
MOX	D_2O	0.520	1.00037	0.99524
	air	1.178	1.00139	0.99682
	change	0.658	0.00102	0.00128

* Data corresponds to a moderator purity of 99.569wt% D_2O and a moderator temperature of 23.43°C.

Table 2 Buckling and k-effective for in the heat experiment

Channel temp(°C)	Coolant density (g cm^{-3})	Buckling (m^{-2})	WIMS-AECL k-effective	WIMS-CANDU k-effective
D_2O water coolant				
25	1.104	3.336	1.00667	0.99706
50	1.095	3.301	1.00717	0.99750
100	1.063	3.227	1.00855	0.99895
150	1.016	3.162	1.00995	1.00045
200	0.956	3.115	1.01115	1.00175
250	0.881	3.079	1.01250	1.00312
300	0.781	3.063	1.01387	1.00457
Void coolant				
25	0.0012	3.679	1.01165	1.00014
50	0.0012	3.662	1.00940	1.00071
100	0.0012	3.629	1.01052	1.00185
150	0.0012	3.596	1.01165	1.00294
200	0.0012	3.564	1.01274	1.00401
250	0.0012	3.533	1.01380	1.00505
300	0.0012	3.502	1.01487	1.00610

* Data corresponds to a moderator purity of 99.710wt% D_2O, a moderator temperature of 24.69°C and a coolant purity of 99.74wt% D_2O.

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References

[1] J. R. Askew, "The Calculation of Resonance Captures in a Few-group Approximation", United Kingdom Atomic Energy Authority, AEEW-R 489, 1966.
[2] J. R. Askew, F. J. Fayers and P. B. Kemshell, "A general description of the lattice code WIMS", J. of the Brit. Nucl. Energy Soc. 5, 4(1966).
[3] J. V. Donnelly, "Description of the Resonance Treatment in WIMS-AECL", Atomic Energy of Canada Limited Report, AECL-10550, 1993.
[4] J. V. Donnelly, "WIMS-CRNL: A User's Manual for the Chalk River Version of WIMS", Atomic Energy of Canada Limited Report, AECL-8955, 1986.
[5] R. J. J. Stamm'ler and M. J. Abbate, Methods of Steady-State Reactor Physics in Nuclear Design, Academic Press, London.
[6] G. I. Bell and S. Glasstone, Nuclear Reactor Theory, Van Nostrand Reinhold Company, New York, 1070.
[7] S. Q. Bogado Leite, "An assessment of WIMS Method for Computing Collision Probability in one-Dimensional Annular Systems", Progress in Nuclear Energy, Vol. 36, No. 4, pp. 367-378, 2000.
[8] R. J. J. Stamm'ler, J. Blomstrand and Z. J. Weiss, "Equivalence relations for resonance integral calculations", Journal of Nuclear Energy, Vol. 27, pp. 885-888, 1973.