Validation of WIMS-AECL Code for Coolant Void Reactivity Using DCA Experiments

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1. Introduction

The Deuterium Critical Assembly (DCA), the heavy water moderated and light water cooled pressure-tube type research facility located in Japan, is designed not only for core physics research, but also for the development of the core-related technology for the Advanced Thermal Reactor (ATR). The core structure of the ATR is highly heterogeneous and it is separated from the heavy water moderator by a Calandria tube. Therefore, the neutron behavior is complicated due to arrangement of the core components.

The DCA core structure bears a certain similarity to the advanced CANDU reactor (ACR-700). Therefore, WIMS code is applied to analysis the DCA experiments using slightly enriched uranium fuel of ATR. This will help to improve the lattice cell code for the ACR-700. In this study, the assessment of the core physics characteristics was conducted by using both WIMS-AECL 2-6a code and WIMS-IST code. The analytical results were compared with experimental data (DCA) for 1.2w/o UO_2 fuel (22.5 cm lattice pitch) with 0, 30, 70, 87 and 100 % void fractions.

2. Code Assessment

In the DCA, the core cluster is composed of 28 UO_2 fuel pins and Al clad, and is configured with a square lattice of 121 cells with 22.5 cm pitch. Each cluster consists of three concentric layers of fuel pins counting from the center outward: (i) four pins in the first, (ii) eight in the second, and (iii) sixteen in the third layer. The lattice consists of a coolant, an Al pressure tube, an air gap, an Al calandria tube and a moderator. The heavy water used as the moderator has 99.5mol/o purity. The effective void fraction of the experimental coolant is changed from zero to unity with three intermediate fractions of 0.3, 0.7 and 0.867 accordingly. The important core parameters, such as the infinite & effective multiplication factors and the coolant void reactivity, were analyzed with WIMS-IST and WIMS-AECL 2-6a codes with 2 energy groups and 89 energy groups in both code versions.

In the experiments, the critical heights and material bucklings for various core configurations were measured for the 1.2wt% enriched UO_2 fuel assembly. Material bucklings have been measured by means of the Cu-wire activation technique in DCA as a function of coolant void fraction. The effective multiplication factors and coolant void reactivity were calculated by using the measured bucklings, and the Benoist theory was applied to assess the reliability of these two codes, WIMS-IST and WIMS-AECL 2-6a respectively.

3. Results

3.1 Infinite & Effective Multiplication Factor (k_{inf}, k_{eff})

The infinite multiplication factors are calculated by using both WIMS-IST code and WIMS-AECL 2-6a code for the 1.2 wt% UO_2 fuel with various coolant void fractions. In Figs. 1, the infinite multiplication factors, K_{inf}, increase as an increase of the coolant void fractions. In terms of the sensitivity of the energy groups, there is under 0.6 % deviation between 2 energy groups and 89 energy groups.

The effective multiplication factors are calculated by using the measured buckling in an attempt to compare the reliability of WIMS-IST code and WIMS-AECL 2-6a code. The results of WIMS-AECL 2-6a code agree better with the experimental result, 1.0, than those of WIMS-IST code as shown in Figs. 1,2 and 3. Figure 3 shows the differences between the experimental value, 1.0 and calculated value by using measured buckling. The WIMS-AECL 2-6a code is more accurate than WIMS-IST code. In comparison between two energy groups, the results using 89 energy groups are in better agreement with experimental results than those of the 2 energy groups.

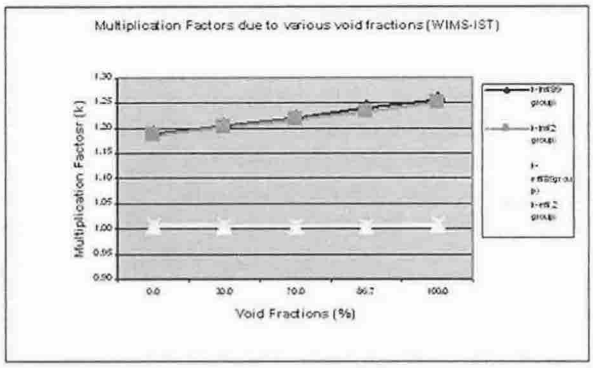

Figure 1. Multiplication Factors (k_{inf}, k_{eff}) with the Various Void Fractions by WIMS-IST Code

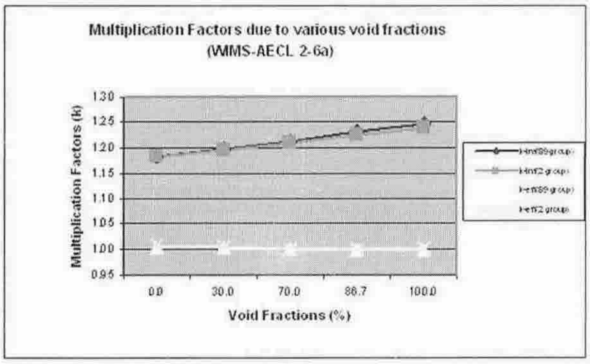

Figure 2. Multiplication Factors (k_{inf}, k_{eff}) with the Various Void Fraction by using WIMS-AECL 2-6a Code

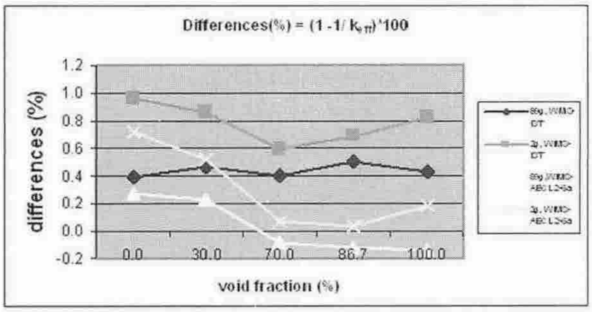

Figure 3. Differences between Criticality and Calculated k_{eff} with Measured Buckling

3.3. *Coolant Void Reactivity*

The coolant void reactivity is calculated with various void fractions as shown in Fig.4 in unit of \$ (β_{eff} = 0.72%). In DCA, the void reactivity is negative due to the small lattice pitch and light water coolant, while that of a conventional CANDU reactor is positive.

As to the sensitivity study for energy groups, the difference of the coolant void reactivity between the 2 energy groups and 89 energy groups is insignificant. As a result of the void reactivity, WIMS-AECL 2-6a code is closer to the experimental results than those of WIMS-IST code with both energy groups.

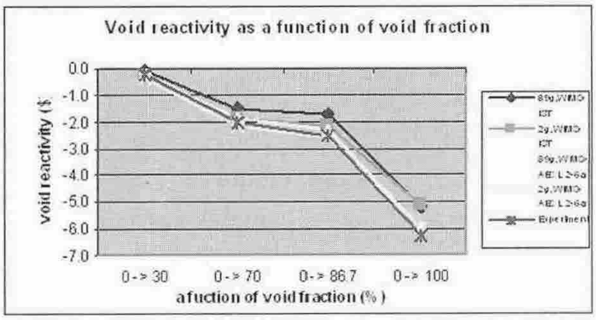

Figure 4. Void Reactivity Change with Void Fraction

4. Conclusions

In this study, the infinite multiplication factor, effective multiplication factor and the coolant void reactivity are investigated by a comparison between WIMS-IST and WIMS-AECL 2-6a codes with the experimental results of DCA. The conclusions of the present study are summarized as follows:

(1) The infinite multiplication factors are calculated by using both WIMS-IST code and WIMS-AECL 2-6a code with various coolant void fractions for the 1.2 wt% UO_2 fuel. The results show that the infinite multiplication factors increase slightly as an increase of the coolant void fraction.

(2) The effective multiplication factors are evaluated with the measured buckling for comparing the reliability between WIMS-IST code and WIMS-AECL 2-6a code with experimental results of DCA. As for the 1.2 wt% UO_2 fuel, the WIMS-AECL 2-6a code agrees relatively well with the experimental value, 1.0, better than the WIMS-IST code. In terms of the energy groups, the 89 energy groups are in better agreement rather than the 2 energy groups.

(3) The coolant void reactivity becomes more negative due to spectrum hardening as the void fraction increases,. With regard to the energy groups, the difference of the coolant void reactivity between 2 energy groups and 89 energy groups is insignificant for both codes. However, the void reactivity of WIMS-AECL 2-6a code agrees well with the experimental results, better than those of WIMS-IST code with both energy groups.

In conclusion, the results of WIMS-AECL 2-6a code with the 89 energy groups are in better agreement with the experimental results in terms of the effective multiplication factors and coolant void reactivity.

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