Comparison of Monte Carlo Critical Spectra from B_1 Buckling Search and Albedo Search Methods – Preliminary Results

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1. Introduction

Since the Monte Carlo method overcomes limitations in multi-group approximation and geometry description, it is gaining increasing use in reactor physics problems. Recently, a new leakage-corrected method was suggested by the authors, in which the critical spectrum is obtained by albedo-based leakage correction in the Monte Carlo method [1].

In this paper, the critical spectrum based on the albedo-based leakage-corrected method will be compared with the critical spectrum by conventional B_1 method (with condensed cross sections) and reference critical whole-core assembly spectrum. These two methods are implemented in our local MCNP5 (version 1.50).

2. B_1 Critical Buckling Search Method

To apply B_1 method in continuous-energy problem, group-wise condensed and homogenized parameters are generated by Monte Carlo in the HELIOS 45 group structure. Then the multi-group B_1 equations[1] are formulated as :

$$\Sigma_g \psi_g - \sum_h \Sigma_{0,h\to g}\psi_h \pm iBJ_g = \chi_g, \quad (1)$$

$$3\alpha_g(B)\Sigma_g J_g - 3\sum_h \Sigma_{1,h\to g} J_h = \mp iB\psi_g, \quad (2)$$

where

$$\alpha_g = \begin{cases} \frac{1}{3}x^2\left(\frac{\arctan(x)}{x-\arctan(x)}\right) & \text{for } x^2 = (B/\Sigma_g)^2 > 0, \\ \frac{1}{3}x^2\left(\frac{\ln((1+x)/(1-x))}{\ln((1+x)/(1-x))-2x}\right) & \text{for } x^2 = -(B/\Sigma_g)^2 > 0 \end{cases},$$

and the notations are in Ref. [2]. In 1st-order scattering term in Eq.(2), a widely used approximation[3] is used. The solutions of Eqs. (1) and (2) are obtained as

$$\vec{\psi} = A^{-1}\vec{\chi}, \quad (3)$$

$$k = \sum_g \nu\Sigma_{fg}\psi_g, \quad (4)$$

where $A_{gh} = \Sigma_g\delta_{gh} - \Sigma_{0,h\to g} + B^2 D_{gh}$.

The iteration to find an appropriate $B^2(k=1)$ and associated critical spectrum using material buckling relation $k = k_\infty/(1+M^2B^2)$ is performed using the above B_1 algorithm until $|k-1| < \varepsilon$.

3. Leakage-Corrected Albedo Search Method

An alternative method to find critical spectrum is suggested by authors[1]. In this new method, the steady-state transport equation is solved with extended albedo boundary condition for eigenvalue $k_{eff,i}$ with given albedo α_i :

$$\vec{\Omega}\cdot\nabla\psi(\vec{r},\vec{\Omega},E) + \sigma_t(\vec{r},E)\psi(\vec{r},\vec{\Omega},E) = \int d\vec{\Omega}'\int dE'\sigma_s(\vec{r},E'\to E,\vec{\Omega}'\cdot\vec{\Omega})\psi(\vec{r},\vec{\Omega}',E') + \frac{\chi(E)}{k_{eff,i}}\int d\vec{\Omega}'\int dE'\nu\sigma_f(\vec{r},E')\psi(\vec{r},\vec{\Omega}',E'). \quad (5)$$

$$\psi(\vec{r},\vec{\Omega}',E) = \alpha_i\psi(\vec{r},\vec{\Omega},E), \text{ for } \vec{n}\cdot\vec{\Omega}' = -\vec{n}\cdot\vec{\Omega} < 0, \vec{r}\in\Gamma, \quad (6)$$

where i is the iteration index. In Eq. (6), the weight of Monte Carlo particle passing albedo surface is multiplied by α_i . Then α_i is updated by the secant method as

$$\alpha_{i+1} = \alpha_i - \frac{k_{eff,i}(\alpha_{i-1}-\alpha_i)}{k_{eff,i-1}-k_{eff,i}}, \quad (7)$$

and Eqs.(5) and (6) are solved iteratively until $k_{eff,i}$ becomes 1.0. Since Eq.(7) only requires k_{eff}, the whole albedo-search iteration procedures are embedded in inactive generations.

4. Numerical Results

The critical whole core (based on the SMART reactor [4, 5]) shown in Fig. 1 is considered. In the reference whole-core calculation, assembly-wise neutron spectra are obtained for C1 and C2 assemblies. Other calculational conditions are shown in Table I.

Table I. Calculational Condition

	B1	Leakage-corrected albedo	Reference whole core
Cross-section library	ENDF/B-VI.6 continuous-energy library		
Histories per generation	50,000	50,000	250,000
Inactive generations	100	1200*	100
Active generations	600	600	600

*including albedo-search procedure

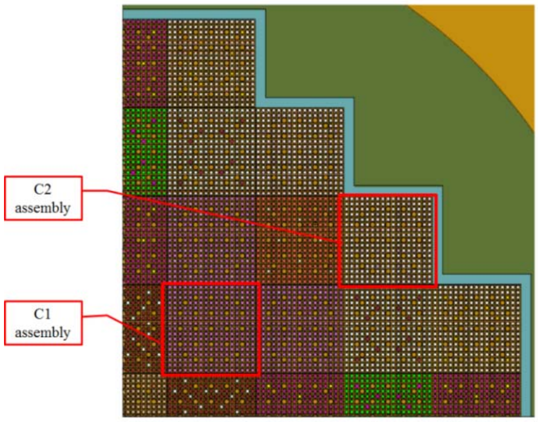

Fig.1. The whole-core reference model

The neutron spectra of C1 assembly are shown in Fig. 2, while their differences against reference assembly spectrum are shown in Fig. 3. Corresponding results for C2 assembly are shown in Figs. 4 and 5.

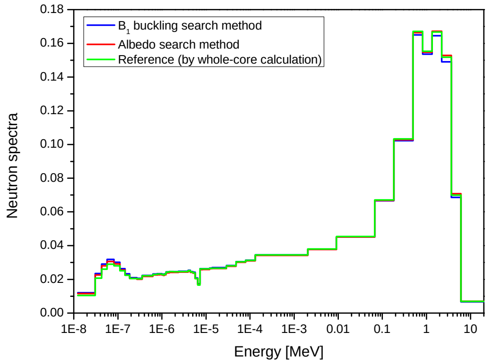

Fig.2. Neutron spectra of C1 assembly

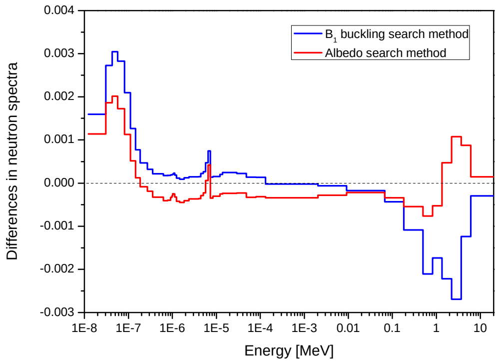

Fig.3. Differences in neutron spectra of C1 assembly

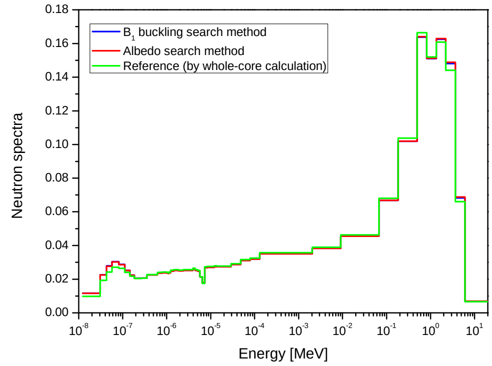

Fig.4. Neutron spectra of C2 assembly

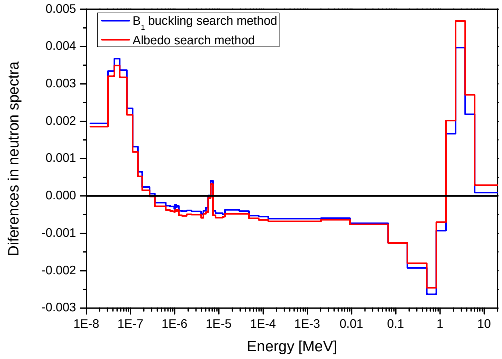

Fig.5. Differences in neutron spectra of C2 assembly

5. Conclusions

In this paper, the critical spectra obtained in Monte Carlo simulation based on two different methodologies are compared. The leakage-corrected albedo search method shows better results in critical spectrum for C1 assembly because there is no space-energy separation. However, in C2 assembly (peripheral assembly whose two interfaces are surrounded by reflector), both of the two methods show poor results due to the lack of dissimilar boundary information. However, in the leakage-corrected albedo search method, incorporation of the dissimilar boundary information is possible in an additional albedo search and is in plan as a future study.

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