Implementation of SP3 method calculation capability to FRBurner module of CBZ code system

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We add SP_3 method calculation capability into CBZ code system and verify the accuracy of this new function by calculating the OECD/NEA benchmark problem [1].

Keywords: SP_3 method, perturbation theory, reactivity.

1. **Introduction** The simplified P_N (SP_N) method is one extension of diffusion theory which considers angular neutron flux, so it could provide high accuracy result comparing to diffusion theory, besides, it cost shorter computing time than transport theory. In this work, we add SP_3 calculation function into a fast reactor burn-up calculation module FRBurner in CBZ which is a general-purpose reactor physics code system. The original SP_3 equations are [2] :

$$-D_g\nabla^2(\phi_g^0+2\phi_g^2)+\Sigma_{r,g}\phi_g^0-\sum_{g'\neq g}\Sigma_{s,g'\to g}\phi_{g'}^0=\frac{\chi_g}{k_{eff}}\sum_{g'}\nu\Sigma_{f,g'}\phi_{g'}^0 \qquad (1)$$

$$\frac{27}{14}D_g\nabla^2\phi_g^2-\frac{5}{2}\Sigma_{t,g}\phi_g^2+\Sigma_{r,g}\phi_g^0-\sum_{g'\neq g}\Sigma_{s,g'\to g}\phi_{g'}^0=\frac{\chi_g}{k_{eff}}\sum_{g'}\nu\Sigma_{f,g'}\phi_{g'}^0 \qquad (2)$$

The perturbation theory is one important method to analyze small changes of reactor, such as reactivity. As perturbation theory needs adjoint flux, we derive the explicit expression of adjoint equations corresponding to Eqs. (1) and (2),

$$-D_g\nabla^2\phi_g^0+\Sigma_{r,g}(\phi_g^0+\phi_g^2)-\sum_{g'\neq g}\Sigma_{s,g\to g'}(\phi_{g'}^0+\phi_{g'}^2)=\frac{1}{k}\nu\Sigma_{f,g}\sum_{g'}\chi_{g'}(\phi_{g'}^0+\phi_{g'}^2) \qquad (3)$$

$$-2D_g\nabla^2\phi_g^0=-\frac{27}{14}D_g\nabla^2\phi_g^2+\frac{5}{2}\Sigma_{t,g}\phi_g^2 \qquad (4)$$

2. **Result** Results about coolant void reactivity given by diffusion and SP_3 theory are compared with transport theory, and differences are shown in figures 1 and 2. Although systematical underestimation on leakage component is observed, the total reactivity still reasonable. As for other components such as non-leakage component, there is no significant difference.

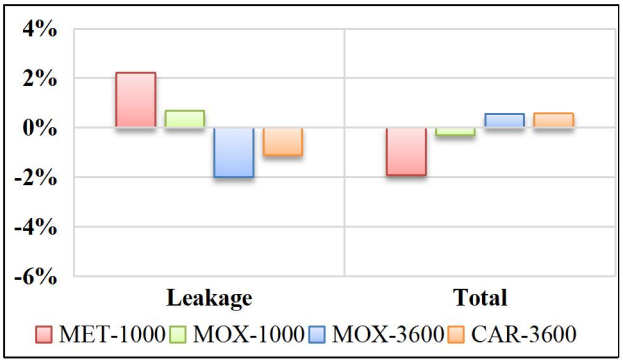

Fig.1 Difference between diffusion and Transport theory(0-D Homogenized model)

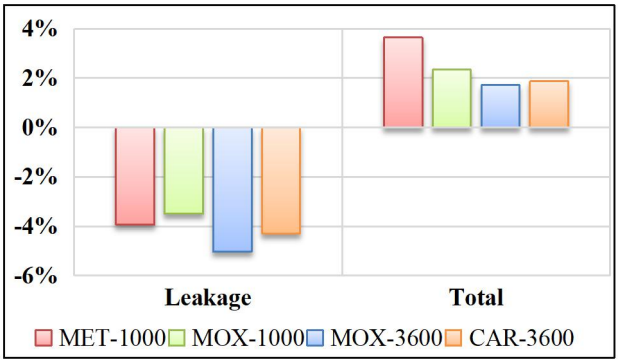

Fig.2 Difference between SP_3 and Transport theory (0-D Homogenized model)

3. **Conclusion** In this work, we implemented SP_3 method in CBZ and find that SP_3 theory systematically underestimates the leakage component of sodium void reactivity.

References [1] Bernnat, Wolfgang, et al.(2016). (NEA/NSC/R(2015)9). [2] Kenichi TADA, et al. (2008). 45:10, 997-1008.