Verification of FRBurner module of CBZ code system: Fast reactor core burn-up calculation based on OECD/NEA benchmark report

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New module of reactor physics code system CBZ for fast reactor burn-up calculation which is designed for our future work demand. We verify the accuracy of this new module and show 2 kinds of correction effect, such as heterogeneous assembly model effect and transport theory effect.

Keywords: Verification, fast reactor, burn-up, sodium void worth, Doppler coefficient, correction effect.

1. Introduction

CBZ is a general-purpose reactor physics code system and FRBurner module is designed for fast reactor burn-up calculation. We are going to verify its accuracy so that we can make sure our tool could give reasonable result for various types of fast reactor core. We choose one OECD/NEA benchmark work [1] as our reference because it provides 4 cores with 3 kinds of fuel and 2 kind of sizes. They are MET-1000, MOX-1000, MOX-3600 and CAR-3600. Number represents the size of core. English abbreviation indicates the fuel type of each core. Many institutes give various result about these 4 cores.

2. Methodologies and Result

Effective neutron multiplication factor k_{eff}, effective delayed neutron fraction β_{eff}, sodium void worth $\Delta\rho_{void}$ and Doppler coefficient $\Delta\rho_{Doppler}$ for 4 cores are compared with reference under heterogeneous lattice model with transport theory(this methodology is the most rigorous one of FRBurner module). Figure 1 shows bias for each core of these 4 terms. Maximum value of bias for k_{eff}, β_{eff}, $\Delta\rho_{void}$, $\Delta\rho_{void}$ are 0.81%, 4%, 9% and 9% respectively.

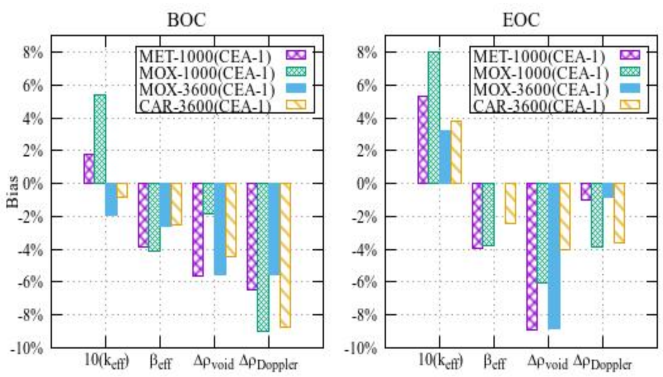

Fig. 1. Bias comparison

As for correction, we separate sodium void worth into non-leakage component and leakage component, furthermore, we decompose non-leakage part into yield, absorption and scattering components. Heterogeneous lattice model leads to large impact on k_{eff}, non-leakage component of sodium void reactivity and Doppler coefficient. Maximum value of difference for k_{eff}, non-leakage $\Delta\rho_{void}$, leakage $\Delta\rho_{void}$ and $\Delta\rho_{Doppler}$ are 0.69%, 9%, 2% and 10% respectively. Transport theory leads to unneglectable impact on keff and leakage component of $\Delta\rho_{void}$, especially for MET-1000. Maximum value of difference for k_{eff}, non-leakage $\Delta\rho_{void}$, leakage $\Delta\rho_{void}$ and $\Delta\rho_{Doppler}$ are 0.54%, 0.2%, 2% and 0.7% respectively. Besides, effects of methodologies on β_{eff} are not shown at here due to they are negligible.

3. Conclusion

Firstly, we confirm that FRBurner module fits our needs, and it gives reasonable result towards various types core. Secondly, correction effects indicate we should preform heterogeneous lattice model and transport theory calculation. Especially for heterogeneous lattice model.

Reference

[1] Bernnat, Wolfgang, et al.(2016). Benchmark for Neutronic Analysis of Sodium cooled Fast Reactor Cores with Various Fuel Types and Core Sizes(Report Number: NEA/NSC/R(2015)9).