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Generation of Few-group Cross-sections by MCNP5 and Their Comparison with Deterministic Code for the Small Sodium-cooled Fast Reactor

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1. Introduction

In recent sodium-cooled fast reactor (SFR) design, MgO reflector is being investigated as an alternative to enhance the neutron economy of the initial low-enriched uranium core [1, 2]. However, noticeable neutron spectrum softening is observed in outmost layer of fuel assemblies. This phenomenon would induce some discrepancies in the conventional few group homogenization and condensation procedure.

In our previous work [3], few-group cross-sections (including high-order scattering) obtained by the MCNP5 [4] code were compared with those by the TRANSX/TWODANT [5, 6] code for a 300 MWe SFR TRU burner core and considerable discrepancies were reported. In this paper, similar approach is performed for the small SFR with an MgO reflector.

2. Description of the Small MgO Reflector SFR

The heterogeneous MCNP5 and the corresponding simplified R-Z TRANSX/TWODANT models are shown in Figs. 1 and 2, respectively.

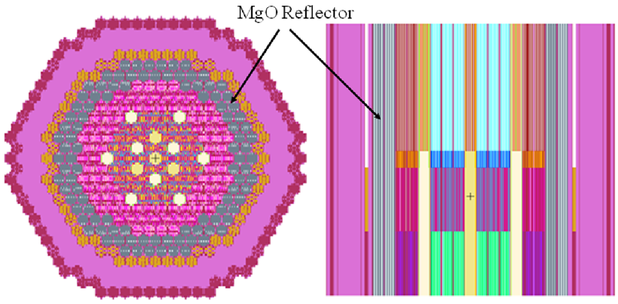


Fig. 1. MCNP5 model of the small MgO reflector SFR

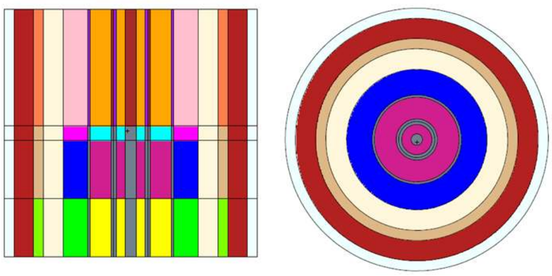
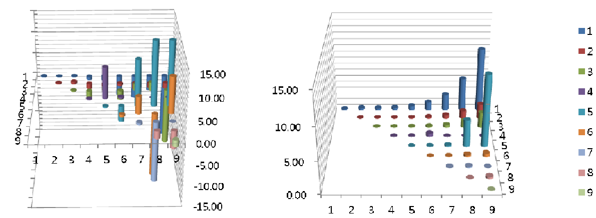


Fig. 2. R-Z TRANSX/TWODANT model of the small SFR

Nine-group cross sections are generated by using the continuous-energy MCNP5 calculations and the results are compared those from the multi-group deterministic calculations by TRANSX/TWODANT. The TRANSX code generates 150-group self-shielded cross sections for each region and then collapses the multi-group data into a 9-group structure by using the neutron spectrum calculated by the TWODANT code. The ENDF/B-VII.0 nuclear data are used for both MCNP5 and deterministic calculations in the current work.

3. Numerical Results

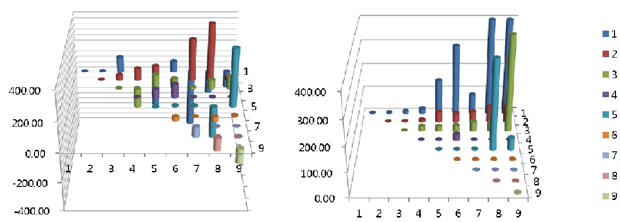
Figure 3 shows both the relative differences of the P_0 scattering cross-sections of U-238 in the outer region between the two methods. MCNP5 standard deviations of the P_0 scattering cross-sections are also shown in Fig. 3.



(a) Discrepancies (b) MCNP5 standard deviation

Fig. 3. Difference in P_0 scattering cross-sections of U-238 in outer region and associated MCNP5 standard deviations

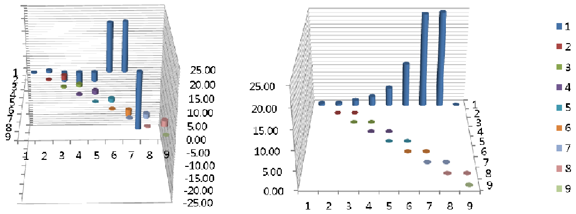
The relative differences and associated standard deviations of P_1 scattering cross-sections in the outer region U^{238} are shown in Fig. 4.



(a) Discrepancies (b) MCNP5 standard deviation

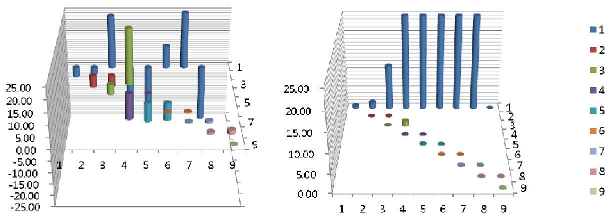
Fig. 4. Discrepancies in P_1 scattering cross-sections of U-238 in outer region and MCNP5 standard deviations

Figures 5 and 6 show the relative differences and MCNP5 standard deviations of P_0 and P_1 scattering cross-sections of O^{16} in the reflector region .



(a) Discrepancies (b) MCNP5 standard deviation

Fig. 5. Discrepancies in P_0 scattering cross-sections and MCNP5 standard deviations of reflector region O^{16}



(a) Discrepancies (b) MCNP5 standard deviation

Fig. 6. Discrepancies in P_1 scattering cross-sections and MCNP5 standard deviations of reflector region O^{16}

The relative differences and MCNP5 standard deviations of total and capture cross-sections of O^{16} in the reflector region are provided in the Table I.

Table I. Total and (n,γ) cross-sections of reflector region O^{16}

Group	σ_t	Diff.	σ_γ	Diff.
1	1.083E+00[a] 1.080E+00[b]	-0.31[c]	1.127E-08 1.128E-08	0.11
2	1.728E+00 1.726E+00	-0.12	2.070E-08 2.070E-08	0.00
3	3.449E+00 3.437E+00	-0.36	3.521E-08 3.529E-08	0.22
4	4.484E+00 4.472E+00	-0.26	5.749E-08 5.744E-08	-0.08
5	3.606E+00 3.605E+00	-0.03	8.950E-08 8.933E-08	-0.19
6	3.759E+00 3.759E+00	0.01	1.504E-07 1.505E-07	0.07
7	3.818E+00 3.818E+00	-0.01	2.495E-07 2.496E-07	0.02
8	3.839E+00 3.839E+00	0.00	4.058E-07 4.059E-07	0.03
9	3.852E+00 3.853E+00	0.03	8.082E-06 1.053E-05	30.29

[a] : MCNP5 results of heterogeneous model
[b] : TWODANT/TRANSX code results
[c] : Relative difference between MCNP5 model and TWODANT/TRANSX code results [%]

3. Conclusions

For U^{238} in the outer region, P_0 within group scattering cross-sections in fast energy range show a good agreement (less than 1 % discrepancies), while within-group scattering cross-sections in relatively low energy region (8th and 9th group) and down-scattering cross-sections showed considerable discrepancies (e.g., 7 to 8 group cross-section shows -14.34 % discrepancies with 0.16 % MCNP5 standard deviation). Similar but much larger discrepancies are observed in the P_1 scattering cross-sections.

Similar tendencies have been observed for O^{16} in the reflector region. The deterministic conventional TRANSX/TWODANT approach underestimates P_0 down-scattering cross-sections while overestimates P_1 within-group scattering cross-sections. It is considered that the current 150-group structure needs to be improved for an accurate modeling of the MgO reflector in SFR.

To fix the problems, the 3-D deterministic analyses will be performed with the few-group data generated by MCNP5 in the future.

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