A Comparative Analysis of Neutron and Gamma Coupled Transport Calculations using DANTSYS, MUST and MCNP

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1. Introduction

In this study, a comparative analysis of the neutron and gamma coupled transport calculation using MUST[1], TWODANT[2] and MCNP[3] was addressed for a cylindrical shielding problem with same multi-group cross section library both for TWODANT and MUST. This work was done as a part of the verifications of the MUST code which has been developed at KAERI for neutral particle transport analysis for complicated geometrical problems. TWODANT and MUST solves the multi-group transport equation with discrete ordinates approximation but TWODANT uses finite difference spatial difference methods with only regular meshes while MUST uses the discontinuous finite element methods (DFEM)[4] and the sub-cell balance methods [5] with tetrahedral meshes to treat unstructured geometries.

2. Modeling and Results

2.1 Problem Model

To remove the errors coming from the geometrical complications, we considered a cylindrical shielding problem that consists of the inner source region and the outer shield region. The configuration is given in Fig. 1.

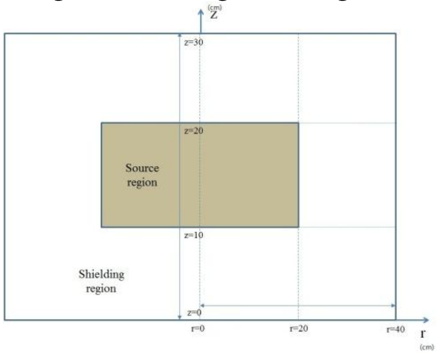

Fig. 1. Configuration of the test problem

The interior source region is source region and its material is SS316. A fixed neutron source is uniformly distributed in this source region. Material of this region is SS316. This source region is located at the center of the problem and its radius and height are 20cm and 10cm, respectively. The outer shield region has no source and its material is the natural lead. Its radius and height are 40cm and 30cm, respectively. The source strength of 1000neutrons/cm^{3}sec is uniformly distributed in the energy range from 1.74MeV to 17MeV. Source region is located in the center of the problem. The number of tetrahedral meshes used in MUST is 19434. Fig. 2 shows this tetrahedral mesh division. For TWODANT, we used the R-Z geometry option. As shown in Fig. 1, the numbers of coarse meshes of TWODANT are 2 and 3 in R and Z directions, respectively. Each coarse mesh in R direction is subdivided into 40 fine meshes while the one in Z direction into 20 fine meshes. The spatial discretization option of MUST is DFEM and the S_N order used in TWODANT is 10. The chebyshev-regendre quadrature of 4 azimuthal and 4 polar directions per octant was used in MUST. The TWODANT and MUST calculations used a same 30 group neutron/12 group gamma coupled cross section library (P_3 anisotropy of scattering) which is generated using TRANSX. This library is based on ENDF/B-VII.r0. For MCNP, the number of source particles is 10^7 which gives reasonably low standard deviations of the flux and current tallies. The cross section libraries for MCNP are based on ENDF/B-VII.

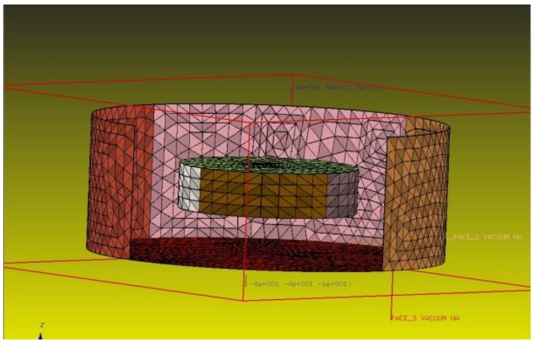

Fig. 2. Tetrahedral Mesh division used in MUST

2.2 Comparative Analysis

In this section, the results of the MUST, TWODANT, and MCNP calculations are inter-compared. Fig. 3 shows the neutron spectra calculated with MUST and TWODANT in the shield region. As shown in Fig. 3, two codes give very good agreements.

Fig. 4 shows the leakage rates through the top boundary face calculated with MUST and TWODANT. These leakage rates show good agreement. Fig. 5 compares the leakage rates calculated with MUST and MCNP. There are larger discrepancies in two energy groups (1.84E-01~3.03E-01Mev, 3.03E-01~5.00E-01Mev) than in the MUST and TWODANT comparison while the discrepancies in the other groups seem to be reasonably small. These relatively larger discrepancies are due to the inaccuracies of the 30 group neutron cross sections in the resonance range of iron which occupies the largest part of SS316.

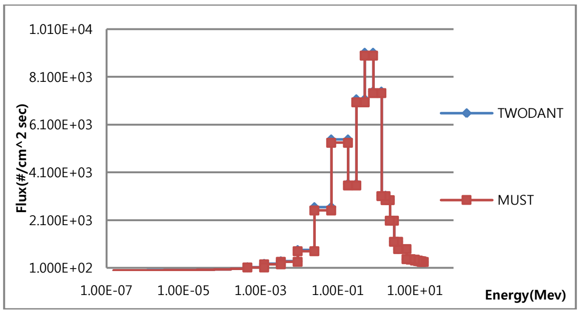

Fig. 3. Neutron spectra in the shield region

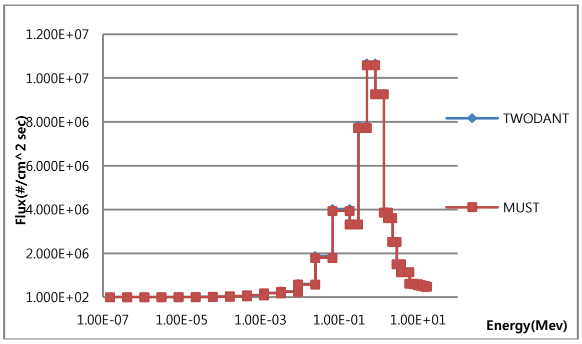

Fig. 4. Neutron leakage spectra through the top boundary face (MUST/TWODANT)

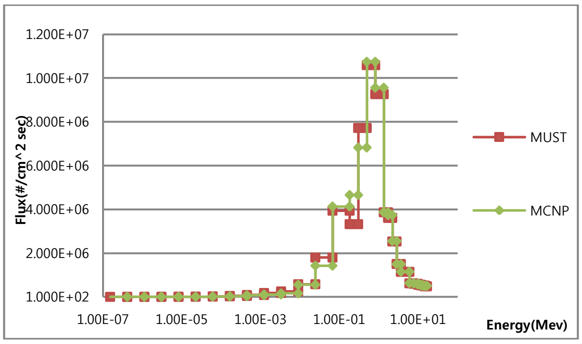

Fig. 5. Neutron leakage spectra through the top boundary face (MUST/MCNP)

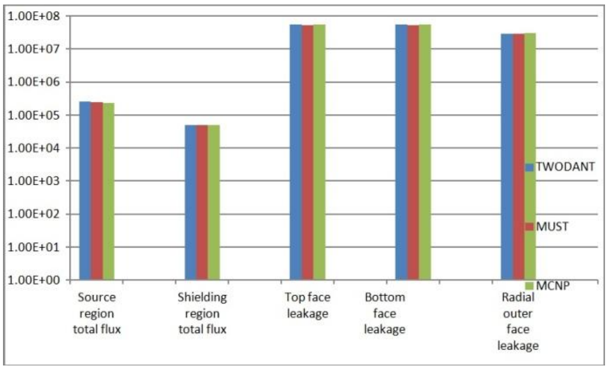

Fig. 6. Total neutron fluxes leakage rates and through boundary faces for zones

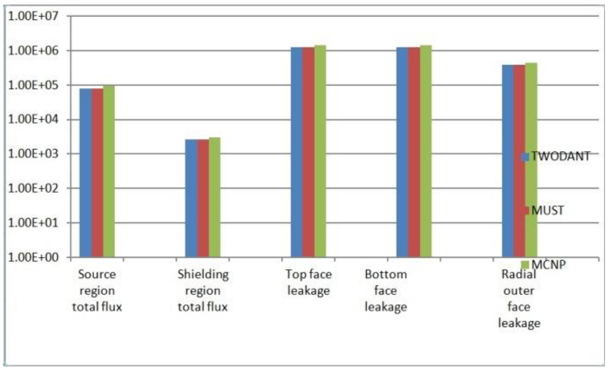

Fig. 7. Total gamma fluxes leakage rates and through boundary faces for zones

Fig.6 and Fig. 7 compare the total fluxes (energy integrated) and the leakage rates through the boundary faces for neutron and gamma, respectively. These figures show that three codes considered here shows very good agreements in the region-wise total fluxes and the leakages.

3. Summary and Conclusions

A benchmark calculation for the MUST code was done for a cylindrical shielding problem. The calculations were done with TWODANT and MCNP for comparison. The spectra both in the source and shield regions and the leakage spectra through the boundary faces were inter-compared. The results showed that MUST and TWODANT with a same multi-group cross section library give very good agreements in all the quantities while MUST and TWODANT give relatively larger discrepancies for the resonance energy ranges of iron due to the inaccuracies of the present multi-group cross section library. Also, it was found that the total leakage rates through the boundary faces were reasonably accurate in comparison with MCNP. In the future, we will analyze the effect of the multi-group energy group structures on the spectra.

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