Shielding Benchmark Calculation on a Multilayer One-dimensional Cylindrical Geometry with AETIUS and ANISN - Revisited

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1. Introduction

In the previous paper [1], we compared neutron, photon, and total flux distributions along the radial direction on a multilayer one-dimensional cylindrical geometry with AETIUS, ANISN [2], and MCNPX.

The three results should have been the same or similar. Two of the calculation results (for AETIUS and MCNPX) were well matched, although the AETIUS result was slightly less than that of MCNPX. However, the result for ANISN was different from the other two.

In the previous paper, we concluded that the causes of this difference were related to the use of different cross sections. For ANISN, we used the BUGLE-96 cross sections, which are collapsed with PWR-specific neutron and gamma flux spectra, whereas AETIUS and MCNPX do not use it.

In this paper, we identify what caused these differences.

2. Methods and Results

2.1 Brief overview of AETIUS

We have been developing a discrete ordinates code called AETIUS (An Easy modeling Transport code usIng Unstructured tetrahedral mesh, Shared memory parallel). AETIUS is programed using f90 and uses Gmsh [3] as a pre- and post- processing program. The overall calculation flow of AETIUS is shown in Fig. 1.

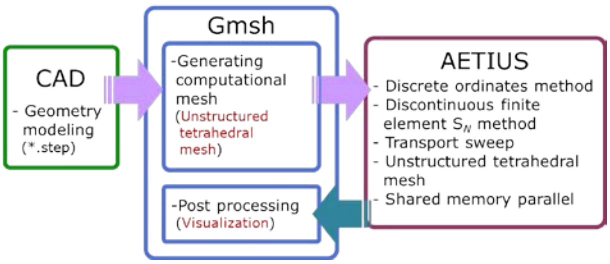

Fig. 1. Overall calculation flow of AETIUS.

2.2 Brief overview of previous results

The layout of the shielding benchmark Test Problem used in the calculation is shown in Fig. 2, and the calculated total (neutron+photon) flux comparison is shown in Fig. 3.

As shown in Fig. 3, we can see that the results for AETIUS and ANISN are different, and we concluded that this difference was due to the use of different cross sections.

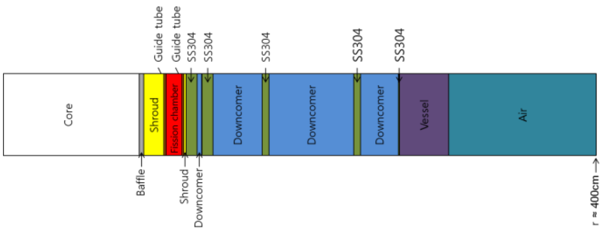

Fig. 2. Layout of shieling benchmark Test Problem (a multilayer one-dimensional cylindrical geometry) [1].

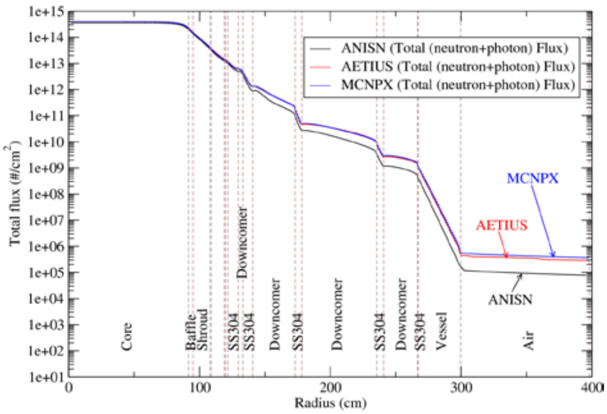

Fig. 3. Comparison of three total (neutron+photon) fluxes along the radial direction [1].

2.3 Numerical Test

For ANISN and AETIUS, we used identical macroscopic cross sections processed by GIP (Group-organized cross section input program) [4] with BUGLE-96 [5]. GIP is a program used to prepare group-organized microscopic and/or macroscopic cross sections for use by DORT, ANISN, or related codes.

This time, as shown in Fig. 4, we extracted the AETIUS cross sections from the output of GIP so the same cross sections were used by ANISN and AETIUS.

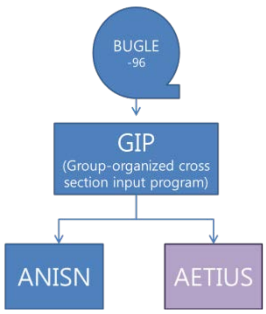

Fig. 4. Cross section preparation for ANISN and AETIUS.

The results calculated using the same cross sections were compared and are shown in Fig. 5. Although using identical cross sections, the results for AETIUS and ANISN were still inconsistent.

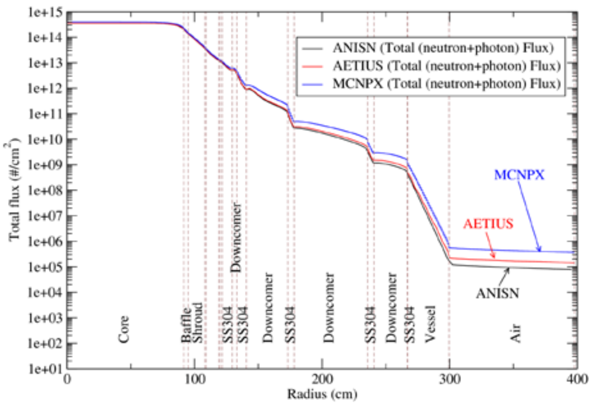

Fig. 5. Comparison of three total (neutron+photon) fluxes along the radial direction with identical cross sections.

In the ANISN calculation, we used options related to buckling (*dy*: cylinder or plane height for buckling correction, *bf*: buckling factor, normally 1.420892) [2]. We changed them all to zero and compared the recalculated ANISN and AETIUS results (see Fig. 6).

It can be seen that the two results are closer to each other than before, and the results are in agreement except for the vessel and air regions.

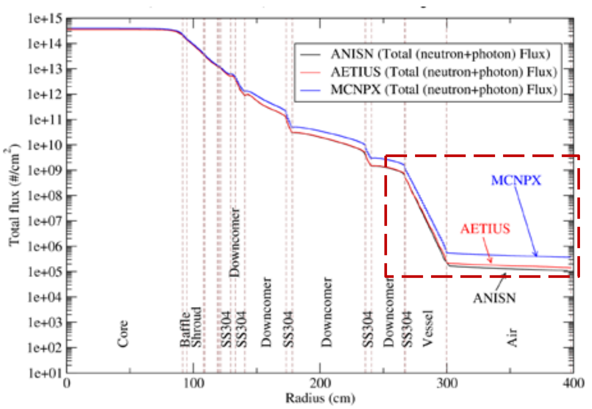

Fig. 6. Comparison of three total (neutron+photon) fluxes along the radial direction with identical cross sections and the buckling options set to zero in the ANISN calculation.

Figure 7 is an enlarged view of the dotted box section in Fig. 6. Data points of ANISN are marked with circles. This shows that the flux distribution is linearly connected (see dotted circle in Fig. 7) at the boundary where the material is changed from vessel to air.

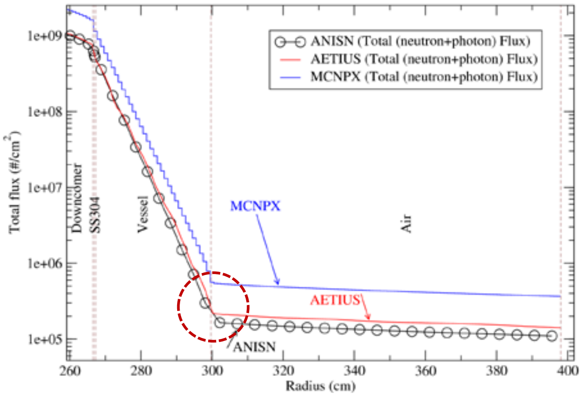

Fig. 7. Enlarged view of the dotted box section in Figure 6.

In order to see the details of the flux drop in the material boundary, the ANISN calculation was performed again after dividing the vessel and the air regions into 40 meshes (4 times more than before) and 60 meshes (3 times more than before), respectively, and the results were shown in Fig. 8.

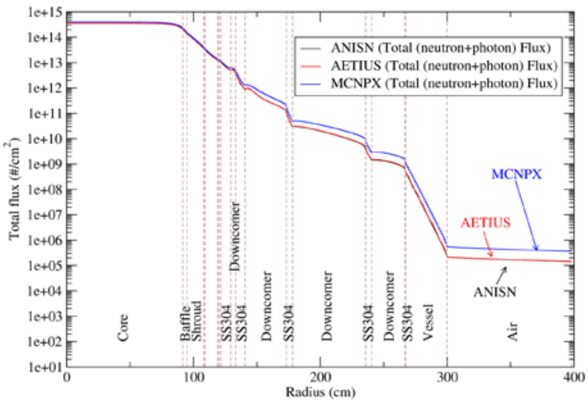

Fig. 8. Comparison of three total (neutron+photon) fluxes along the radial direction with identical cross sections, with buckling options set to zero in the ANISN calculation, and refined vessel and air regions in the ANISN calculation.

The final comparison was shown in Fig. 8: it can be seen that AETIUS and ANISN now give the same results.

3. Conclusions

ANISN and AETIUS were calculated using the identical cross sections provided by the GIP.

The buckling-related factors (*dy* and *bf*), which were not considered in the AETIUS calculation in the 1-D cylinder problem, was used in the ANISN calculation.

The correct flux distribution can be obtained by using fine mesh at the material boundaries, where the density varies greatly. In the ANISN calculation, we believe that the number of meshes used in the vessel and air regions was insufficient. In the case of AETIUS, this phenomenon was not noticeable because it uses the $DFES_N$ (Discontinuous Finite Element S_N) method. ANISN, on the other hand, is expected to use a continuous spatial difference method such as the diamond differencing scheme.

As shown, ANISN and AETIUS give the same result when the same cross section is used, the buckling-related factor is not used, and fine mesh is used for the vessel and air regions in the ANISN calculation.

REFERENCES

[1] J. W. Kim, J. H. Song, and Y. Lee, "Shielding Benchmark Calculation on a Multilayer One-dimensional Cylindrical Geometry with AETIUS, ANISN, and MCNPX," Transaction of the Korean Nuclear Society Spring Meeting, Jeju, Korea, 2017.

[2] W. W. Engle, Jr., A Users Manual for ANISN: A One Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering, Oak Ridge National Laboratory, K-1693, 1967.

[3] C. Geuzaine, J. -F. Remacle, "Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities," Int. J. Numer. Meth. Eng. 79 (11) 1309-1331, 2009.

[4] W.A. Rhoades and M.B. Emmett, DOS: The Discrete-Ordinates System, Oak Ridge National Laboratory, ORNL/TM-8362, 1982.

[5] BUGLE-96, Coupled 47 Neutron, 20 Gamma-Ray Group Cross Section Library Derived from ENDF/B-VI for LWR Shielding and Pressure Vessel Dosimetry Applications, Oak Ridge National Laboratory, DLC-185, 1996.