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MUST Code Verification on the Large Scale Benchmark Problem

Jong Woon Kim [a*], Ser Gi Hong [b], and Young-Ouk Lee [a]
[a] *Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong-gu, Daejeon, Korea, 305-353*
[b] *Kyung Hee University, 1732 Deogyeong-daero, Giheung-gu, Gyeonggi-do, Yongin-si, Korea, 446-701*
**Corresponding author: jwkim@kaeri.re.kr*

1. Introduction

The MUST (***M***ulti-group ***U***nstructured geometry ***S***$_N$ ***T***ransport) [1] code has been developed to deal with a complex geometry using unstructured tetrahedral elements as a computational mesh, and has been tested on several test problems.

In this paper, we applied the MUST code to the large scale (a few km size) benchmark problem, which is the DS02 Fat Man problem. Compared to the other test problems, the geometry is rather simple. However, we should consider the ray effects because the epicenter (burst point of the bomb) is modeled as a point source in the air. The source spectra, geometry data, and material compositions for the calculations are available in the DS02 report [2].

The calculated neutron, secondary gamma, and primary gamma doses are compared with the reference results in the DS02 report.

2. Method and results

2.1 Source term

The energy spectra of the prompt radiation produced by the Fat Man are given as 200 neutron groups and 43 gamma ray groups in the DS02 report. To use a coarse group structure, the reference source spectra are re-tallied by MCNP over various group structures. Neutron and gamma leakage spectra with various group structures are shown in Figs. 1 and 2.

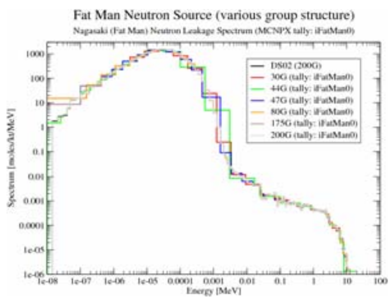

Fig. 1. Neutron leakage spectrum for various group structures.

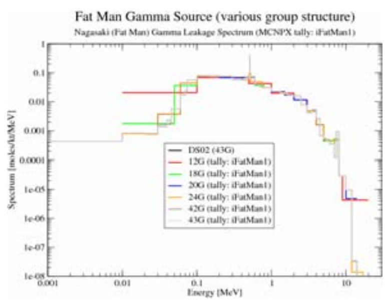

Fig. 2. Gamma leakage spectrum for various group structures.

2.2 Geometry data

A schematic of the Fat Man Test Problem is shown in Fig. 3. Seven altitude-dependent atmospheric profiles with a 50cm thick ground are considered. The height of the burst is 503m above the ground at the center line of the cylindrical geometry.

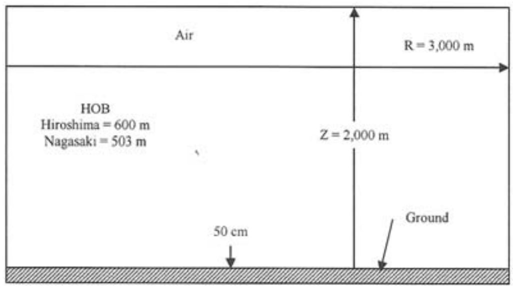

Fig. 3. The schematic of the Fat Man Test Problem.

The MS manager, which is a pre-processing module for the MUST code, is used to deal with geometry input and material assignment. The simple CAD input and computational mesh for this calculation are shown in Figs. 4 and 5.

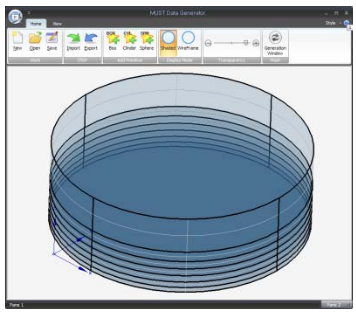

Fig. 4. The geometrical model for the Fat Man Test Problem.

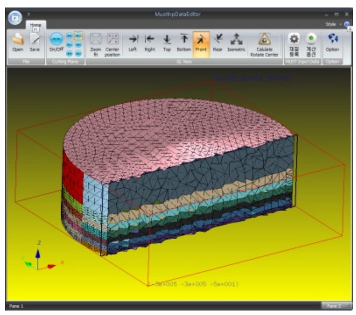

Fig. 5. The calculational mesh for the Fat Man Test Problem.

2.3 Tests and Results

Two calculations are performed with neutron and gamma sources separately.

The neutron and secondary gamma doses are calculated with the neutron source. The secondary gamma is produced by neutron reaction with air and ground. This process is simulated using coupled a 47 neutron/20 gamma multi-group cross section library.

The primary gamma dose is calculated with the gamma source. Detail parameters for the calculation are listed in Table I.

Table I: The calculation parameters

Source terms	
Height of burst [meter]	503
Energy yield [kt]	21
Total neutrons [moles/kt]	0.26400
Total gamma rays [moles/kt]	0.09022
Geometry	
No of mesh element	82,680
Air zone (Radius/Height)	3km/2km
Ground zone (Radius/Height)	3km/50cm
Cross sections	
P_N order	P_3
Library	Coupled 47 neutron group /20 gamma group
Solver	
Quadrature order	8×8 Chebyshev-Legendre
Others	
Dry air atmospheric density is used.	
Doses are compared at a height of 1m above the ground.	
Gmsh [3] is used for 3D isodose post-processing.	
Reference: DS02 report	

The calculated doses at a height of 1m above the ground are compared with the DS02 results, and are shown in Fig. 6. In this benchmark calculation, only prompt doses are considered because source spectra, which are given in DS02 (Figs. 1 and 2), are for the prompt radiations.

In Fig. 6, the calculated neutron and primary gamma doses match up with the reference results. However, the secondary gamma shows small differences.

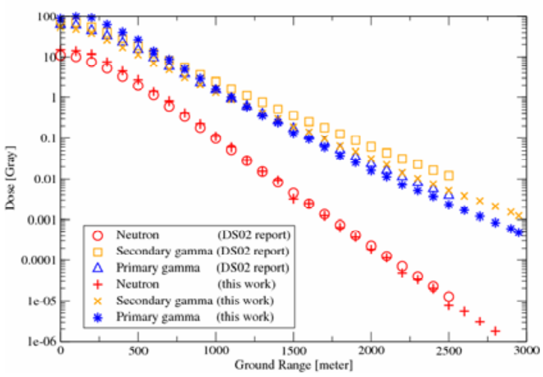

Fig. 6. Comparisons of doses vs. ground range.

The isodose surface of a neutron is shown in Fig. 7. Considering the height of burst is 503m above the ground and the scattering mean free path is large compared with the space meshing, ray effects can occur. However, the dose profiles shown in Fig. 7 vary smoothly with distance and altitude because the first collision source method [4] is applied.

The isodose surface of the secondary gamma is shown in Fig. 8. Small ray effects can be observed even though the first collision source method is used. However, considering the secondary gamma rays are generated by neutron collisions and absorption in the air and ground, these small ray effects are understandable.

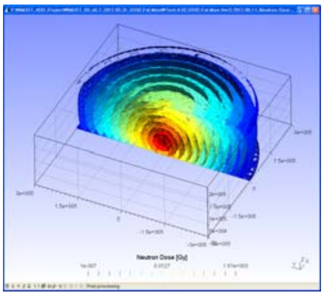

Fig. 7. Neutron isodose profile.

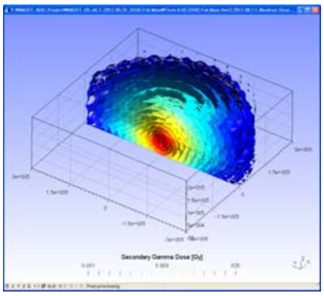

Fig. 8. Secondary gamma isodose profile.

3. Conclusions

The large scale benchmark problem, that is the DS02 Fat Man problem, is solved with the MUST code and the results are compared with DS02 reference results.

The neutron and primary gamma doses match up well with the reference results. For the small dose differences in the secondary gamma, we need more sensitivity calculations with finer energy group structures.

Acknowledgement

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REFERENCES

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