MONACO: A New 3-D Monte Carlo Shielding Code for SCALE

Margaret B. Emmett and John. C. Wagner

Oak Ridge National Laboratory
P. O. Box 2008
Bldg 5700, MS 6170
Oak Ridge, TN 37831-6170

INTRODUCTION

MONACO is a new Monte Carlo shielding code under development at ORNL for the SCALE code package [1]. MONACO currently features the SCALE General Geometry Package (SGGP) and a new set of cross section processing routines. A general automated variance reduction capability based on three-dimensional (3-D) discrete ordinate adjoint data is being implemented. MONACO is based on the MORSE Monte Carlo code, but has been extensively modified to modernize the coding and incorporate the above features. This paper briefly describes MONACO and presents some initial validation results for a deep-penetration benchmark problem.

DESCRIPTION OF WORK

To address a number of long-term goals for the Monte Carlo shielding capabilities in SCALE, a project was recently undertaken to develop a new code, MONACO. Principal goals for this project include: (1) unification of geometric descriptions between SCALE shielding and criticality Monte Carlo codes, (2) implementation of a general 3-D automated variance reduction capability based on proven methodologies, and (3) establishment of a modern code from which to continue future development.

SCALE General Geometry Package

The SGGP, which is also used by the KENO-VI Monte Carlo criticality code, constructs geometric regions and processes them as sets of quadratic equations. Geometric shapes may be specified by using predefined volumes such as cuboids, cylinders, wedges, spheres, and ellipsoids or by using quadratic equations. Other features of this geometry include: cuboidal, hexagonal and dodecahedral arrays, intersecting regions within a unit, and rotation of bodies or holes to any angle and translation to any position. Using the SGGP not only unifies the SCALE criticality and shielding Monte Carlo code geometric descriptions, it enables MONACO users to interactively display their 3-D geometry models using the powerful KENO3D Visualization Tool, which is available in SCALE 5.

Cross-Section Processing

The cross-section package in MONACO uses several new algorithms for efficiently storing and selecting the multi-group data. Several obsolete features in the MORSE cross-section processing routines, such as super-grouping the energy-dependent cross-section information, have not been retained in MONACO. Hence, the cross-section processing routines are now shared by several of the SCALE codes, including KENO.

Automated Variance Reduction

Prior to attempting to implement a general 3-D automated variance reduction capability into MONACO/SCALE, a prototypic code, ADVANTG (Automated Deterministic VAriaNce reducTion Generator) [2], was developed based on existing Monte Carlo (MCNP) and discrete ordinates (TORT) codes and the CADIS (Consistent Adjoint Driven Importance Sampling) methodology [3]. ADVANTG was used to compare the performance of deterministic- and stochastic-based approaches for automated variance reduction, as well as for testing and refining the various aspects of the implementation, and supported the decision to proceed with a deterministic-based automated variance reduction approach for SCALE [2]. This methodology is currently being implemented into MONACO/SCALE.

RESULTS

To support initial validation of the MONACO code system, a series of simple shielding benchmark experiments [4] involving the attenuation of both neutron and gamma point sources through standard cask materials of varying thicknesses was evaluated. For the neutron experiments, the source was a ^{252}Cf spontaneous fission source; for the gamma experiments, a ^{60}Co source was used. The experimental configuration for the case with a 15-cm thick shield is shown in Figure 1. The paraffin block is a 50-cm cube with a conical penetration; the shield block is 80x80-cm with varying thicknesses.

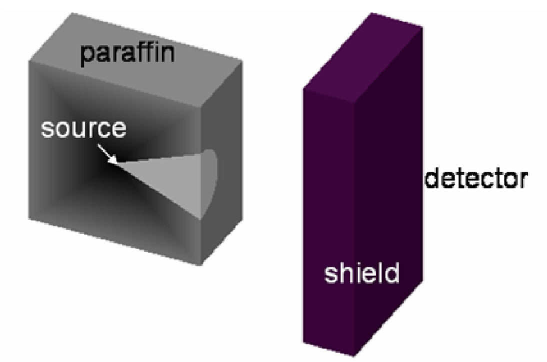

Fig. 1. KENO3D rendering of the benchmark geometry

The calculated results were compared to the experimental data and to results from both the one-dimensional discrete ordinates SAS1 and the three-dimensional Monte Carlo SAS4 shielding modules from SCALE. Tables I and II contain the results for the iron shielding material for neutron and gamma cases, respectively. The MONACO results are in very good agreement with the SAS4 results, which utilize the same cross-section data, and are in good agreement with the experimental results. The trend in the calculated-to-experiment (C/E) ratios for the neutron cases are due to the known deficiencies in the ENDF/B-V data for iron.

MONACO was also tested by running several of the MORSE-SGC sample problems. Results were statistically equivalent. For example, sample problem 6, a gamma only problem that calculates the dose rate for a point, isotropic 4-5 MeV source in an infinite medium of air, produced the following results: at 50 m from the source, MONACO calculated 1.480e-09 and MORSE-SGC calculated 1.478e-9; at 300 m, MONACO calculated 9.12e-10 and MORSE calculated 8.97e-10; and at 1500 m from the source, MONACO calculated 2.66e-11 and MORSE calculated 2.59e-11.

CONCLUSIONS

The initial validation efforts provide a positive indication that MONACO is functioning properly and capable of reproducing experimental results. Much effort is still needed to fully validate MONACO and fully implement the automated variance reduction capability.

REFERENCES

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TABLE I: Comparison of measured and calculated neutron dose rates for iron slabs

Thickness (Cm)	Experiment	SAS1 Calculation	C/E	SAS4 Calculation	C/E	MONACO Calculation	C/E
0	165.3	123.5	0.75	184.5 (1%)	1.12	168.4 (1%)	1.02
5	118.2	123.4	1.04	136.9 (2%)	1.16	110.8 (1%)	0.94
15	62.5	79.4	1.27	69.2 (5%)	1.11	60.5 (3%)	0.97
20	46.3	60.9	1.32	46.6 (3%)	1.01	42.6 (3%)	0.92
25	34.6	46.6	1.35	33.2 (5%)	0.96	29.6 (2%)	0.86
35	19.0	27.5	1.45	15.8 (7%)	0.83	15.3 (3%)	0.81

TABLE II: Comparison of measured and calculated gamma dose rates for iron slabs

Thickness (cm)	Experiment	SAS1 Calculation	C/E	SAS4 Calculation	C/E	MONACO Calculation	C/E
0	1020.0	769.1	0.75	980.0 (1%)	0.96	985.0 (.3%)	0.97
5	255.0	220.6	0.87	243.8 (3%)	0.96	252.0 (1%)	0.99
10	60.0	45.2	0.75	51.6 (4%)	0.86	53.1 (2%)	0.89
15	9.62	8.24	0.87	10.4 (7%)	1.08	9.57 (2%)	0.99
20	1.67	1.41	0.84	1.54 (5%)	0.92	1.57 (4%)	0.94
25	0.34	0.24	0.71	0.29 (6%)	0.85	0.29 (5%)	0.85