LA-UR- 97-285

CONF-970607--16

Title: Comparison of Neutron Lifetimes as Predicted by MCNP and DANTSYS

Author(s):
John S. Hendricks (LANL)
D. Kent Parsons (LANL)
Gregory D. Spriggs (LANL)
Robert D. Busch (UNM)

Submitted to:
American Nuclear Society Meeting
Orlando, FL
June 1–5, 1997

January 22, 1997

Los Alamos
NATIONAL LABORATORY

DISCLAIMER

Comparison of Neutron Lifetimes as Predicted by MCNP and DANTSYS

John S. Hendricks, D. Kent Parsons, Gregory D. Spriggs
Los Alamos National Laboratory, P. O. Box 1663, MS B226, Los Alamos, NM 87545-0001

and Robert D. Busch
University of New Mexico, Dept. of Chem. & Nucl. Eng., Albuquerque, NM 87131-1341

Abstract

The prompt removal lifetime algorithm used in the latest version of MCNP[1] (i.e., version MCNP4B, Feb. 1997) was modified to conform with the neutron-balance definitions described by Spriggs et al.[2] In accordance with the neutron-balance theory, the non-adjoint-weighted removal lifetime is given by

$$\tau_r = \frac{\int \frac{\Phi}{v} d\Omega dr dE}{\int \Omega \bullet \nabla \Phi d\Omega dr dE + \int \Sigma_a \Phi d\Omega dr dE} , \qquad (1)$$

where Φ is the angular neutron flux, v is the neutron velocity, Σ_a is the macroscopic absorption cross section, E is neutron energy, Ω is angle, and r is a spatial vector. The numerator in this expression represents the total neutron population in the system, N, and the denominator represents the total loss rate due to leakage and absorption.

MCNP4B uses three different estimators[3] to calculate the non-adjoint-weighted removal lifetime: 1) a collision estimator, 2) an absorption estimator, and 3) a track-length estimator.

The collision estimate of the prompt removal lifetime for any active cycle is the average time required for a fission source neutron to be removed from the system by either escape, capture [i.e., (*n*,0*n*) reactions], or fission:

$$\tau_r^c = \frac{\sum W_e T_e + \sum (W_c + W_f) T_x}{\sum W_e + \sum (W_c + W_f)} , \qquad (2)$$

where T_e and T_x are the times from the birth of the neutron until escape or collision. W_e is the weight lost at each escape. $W_c + W_f$ is the weight lost to (*n*,0*n*) and fission at each collision,

$$W_c + W_f = W_i \frac{\sum f_k (\sigma_{c,k} + \sigma_{f,k})}{\sum f_k \sigma_{t,k}} , \qquad (3)$$

where W_i is the weight of the neutron entering the collision, f_k is the atomic fraction for nuclide k, σ_c is the microscopic capture cross section, σ_f is microscopic fission cross section, and σ_t is microscopic total cross section for nuclide k.

The absorption estimate of the prompt removal lifetime, τ_r^a, for any active cycle for implicit capture differs from the collision estimator in that,

$$W_c + W_f = W_i \frac{(\sigma_{c,k} + \sigma_{f,k})}{\sigma_{t,k}} \quad . \tag{4}$$

For analog capture, τ_r^a is estimated from

$$\tau_r^a = \frac{\sum W_e T_e + \sum W_c T_c + \sum W_f T_f}{\sum W_e + \sum W_c + \sum W_f} \quad . \tag{5}$$

The absorption estimate differs from the collision estimate in that the collision estimate is based on the expected value at each collision, while the absorption estimate is based on the events actually sampled at a collision. Thus, all collisions will contribute to the collision estimate of the lifetime by the probability of fission (or capture for τ_r^c) in the composite material. Contributions to the absorption estimator will only occur if an actual fission (or capture for τ_r^a) event occurs for the sampled nuclide in the case of analog capture. For implicit capture, the contribution to the absorption estimate will only be made for the nuclide sampled.

The track-length estimate for the prompt removal lifetime for each cycle is accumulated every time the neutron traverses a distance d in any material in any cell:

$$\tau_r^{tl} = \frac{\sum W_i \frac{d}{v}}{W_s} \quad , \tag{6}$$

where W_s is the source weight summed over all histories in the cycle and v is the neutron velocity.

The combined collision/absorption/track-length estimator used in MCNP4B has been compared to deterministic solutions [i.e., Eq. (1)] obtained from the S_n code, DANTSYS.[4] Two different types of systems were analyzed—a bare uranium sphere, and a uranium sphere surrounded by a graphite reflector. The atom densities used in these comparisons correspond to 0.0452, 0.0024, and 0.105 atoms/b-cm for the ^{235}U, ^{238}U, and C, respectively. To make the comparison as meaningful as possible, MCNP was run in the multigroup mode using the same set of cross sections used in DANTSYS (i.e., the original 16-group Hansen-Roach cross sections[5]). The results are presented in Table 1 and Fig. 1.

As can be seen from Table 1, the MCNP and DANTSYS removal lifetimes compare favorably for the bare systems. However, in the reflected systems, the removal lifetime predicted by MCNP begins to deviate somewhat from the DANTSYS result as the reflector becomes thicker. This deviation has not yet been explained.

REFERENCES

1. J. F. BREIMEISTER, "MCNP-A General Monte Carlo Code for Neutron and Photon Transport," Los Alamos National Laboratory report LA-7396-M, Rev. (Sept. 1986).

2. G. D. SPRIGGS, R. D. BUSCH, K. J. ADAMS, D. K. PARSONS, L. PETRIE, and J. S. HENDRICKS, "On the Definition of Neutron Lifetimes in Multiplying and Non-Multiplying Systems," Los Alamos National Laboratory report, to be published (1997).

3. J. S. HENDRICKS, "Monte Carlo Lifetimes," Los Alamos National Laboratory research note XTM:RN(U)-97-001 (Jan. 15, 1997).

4. R. E. ALCOUFFE, "DANTSYS: A Diffusion Accelerated Neutral Particle Transport Code System," LA-12969-M, Los Alamos National Laboratory (1995).

5. G. E. HANSEN and W. H. ROACH, "Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies," LAMS-2543, Los Alamos National Laboratory (Dec. 1961).

Table 1: Non-Adjoint-Weighted Prompt Removal Lifetime

Case	Core Radius (cm)	Refl. Thick. (cm)	k_{eff}		Lifetime (ns)	
			DANT	MCNP[a]	DANT[b]	MCNP[c]
1	6	–	0.7151	0.7145	4.06	3.89
2	7	–	0.8226	0.8223	4.74	4.55
3	8	–	0.9240	0.9240	5.40	5.19
4	9	–	1.0188	1.0178	6.03	5.77
5	10	–	1.1071	1.1060	6.61	6.33
6	11	–	1.1888	1.1880	7.16	6.87
7	12	–	1.2642	1.2630	7.68	7.35
8	7	1	0.8770	0.8768	6.23	5.95
9	7	3	0.9485	0.9475	10.6	9.95
10	7	5	0.9967	0.9972	20.2	18.4
11	7	10	1.0714	1.0716	325	275
12	7	20	1:1445	1.1423	22,900	16,800
13	7	30	1.1815	1.1805	148,000	107,000
14	7	40	1.2022	1.2043	407,000	290,000
15	7	80	1.2290	1.2270	2,090,000	1,480,000
16	7	150	1.2341	1.2379	4,630,000	3,250,000
17	7	200	1.2343	1.2380	5,560,000	3,900,000

a. Uncertainty = 0.001 for Cases 1–14 and 0.003 for Cases 15–17.
b. Calculated using the *k*-eigenfunctions.
c. Using 16-group Hansen-Roach. Uncertainty of lifetimes is less than 0.1%.

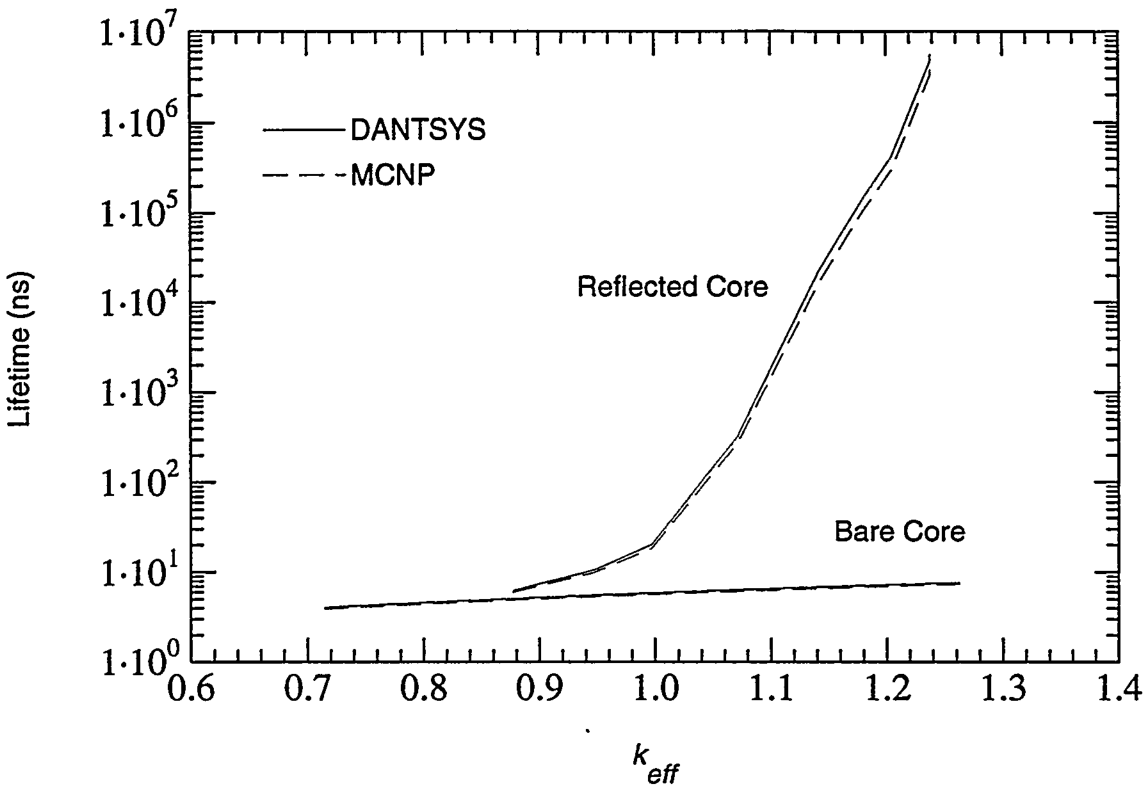

Fig. 1. Comparison of non-adjoint-weighted removal lifetime predicted by MCNP and DANTSYS.