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Whisper Statistics Study

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INTRODUCTION

Whisper is computational software designed to assist with validation studies with the Monte Carlo particle transport package MCNP. Historical approaches rely on expert based judgment to select benchmarks while Whisper uses sensitivity/uncertainty (S/U) methods to select relevant benchmarks to a particular application model. Whisper will also derive a calculational margin and margin of subcriticality (MOS) that may be used to generate an upper subcritical limit (USL) for a particular application model.

The default Whisper settings recommends a 100,000 particles per cycle run for 500 active cycles, resulting in 50M active neutron histories per application run. This is computationally intensive and may not be necessary to produce accurate results. A Whisper statistical study was done varying the neutron histories per cycle from 10,000 to the default 100,000. A lower number of neutron histories will allow Whisper to be used on low memory systems such as laptops. The intent of this paper is to present the changes in the Whisper results as the number of neutrons histories run is varied.

DESCRIPTION

The study focused on a variety of MCNP models to adequately cover the material and geometry variable space. The tracked variables, test variables, and constants are listed in Table 1. The neutron histories per cycle that were used are 10000, 25000, 50000, and 100000 (5M, 12.5M, 25M, and 50M active neutron histories, respectively). All calculations were run with MCNP6.1.1 and Whisper 1.1.0.

Table I. Variables Defining the Intended Scope of the Study

Tracked Variables	Test Variables	Constants
• Benchmark Selection • USL • Run Time • Benchmark Weight	• Neutron Histories • Materials • Geometry	• Cycles • .80c libraries • S(α,β) • Temperature

The models used in this study fit into four generic categories dependent on the geometry and materials used. Figure 1 provides a simple diagram and an overview of the four categories. The top left corner of the diagram represents models that have a closer resemblance to benchmarks while the bottom right corner represents models that do not correlate well with benchmarks. While many of the subsequent examples favor the well benchmarked corner, other models run include models containing ^{232}Th or ^{233}U as well as models layering Pu, graphite and water or full glovebox mockups.

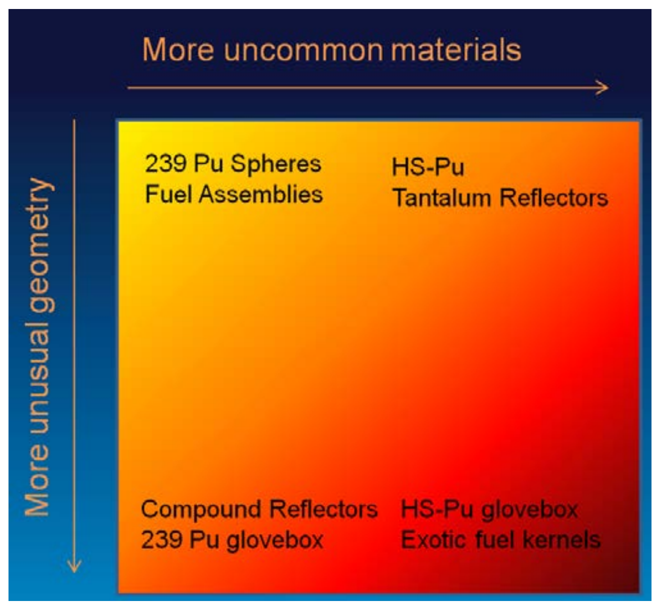

Fig. 1. Material and Geometry Variable Space

Jezebel

The benchmark PU-MET-FAST-001, the Jezebel assembly, is one of the simplest experiments and simplest MCNP criticality models. As such it worked as an extreme case in testing Whisper; the lower number of neutrons per cycle would need to still be effective with this model at a minimum to be expected to work on any others. The Jezebel model used consists of simply a kg Pu(4.5)-Ga bare sphere with radius 6.39 cm. This benchmark also has a detailed model that features the structural apparatus holding the fissile sphere, but for the purpose of this study the simple model was desired.

PURNIMA-I

The benchmark PU-COMP-FAST-004 is a PuO_2 fast reactor with axial molybdenum and radial copper and mild steel reflectors, known also as PURNIMA-I. The MCNP model used also includes the steel grid plates.

HEU Cylinder

The benchmark HEU-MET-FAST-050 is a heterogeneous tungsten-diluted HEU cylinder. It is arranged by alternating disks of U(96) and tungsten in two separate stacked cylinders. The approach to critical is by bringing the two cylinders close together. The steel structure holding the assembly is also modeled.

Pu-Be Sphere

This model uses a Pu(0)-Be sphere with a plutonium concentration of 0.36 g/cc, surrounded by 12-inch water reflection. The concentration of the sphere makes this an intermediate energy system, with 53% of fissions caused by intermediate energy neutrons (40% are from thermal neutrons, 7% from fast).

Heat Source Pu Sphere

This model comes from a critical mass solution curve for a mixture of 65 wt% ^{238}Pu and 35wt% ^{239}Pu. The data cited is from the 200g/L concentration.

Flooded Graphite Mold

This model uses a graphite mold with multiple slots/spaces. The spaces would be filled with fissionable material and the remainder of the spacing would be filled with water. The mold is also suspended in a sphere of water to represent infinite water reflection. This model was used with Pu239, U233, and Th232.

RESULTS

The following examples of typical results show how the suggested USL varies as a function of the number of neutron histories as well as the number of benchmarks Whisper used in its calculations and the highest correlation coefficient between the application model and the selected benchmarks.

Jezebel

Table II. Jezebel Model Results

N/Cycle	USL	# BM's	High ck
100	0.98078	42	1
50	0.98075	44	0.9998
25	0.98062	44	0.9994
10	0.98053	46	0.9995

Standard deviation of the USLs: 1.01E-04

PURNIMA-I

Table III. PURNIMA-I Model Results

N/Cycle	USL	# BM's	High ck
100	0.97387	69	0.9883
50	0.97387	69	0.9888
25	0.97371	69	0.9885
10	0.97381	69	0.9883

Standard deviation of the USLs is 6.54E-05.

HEU Cylinder

Table IV. HEU Cylinder Model Results

N/Cycle	USL	# BM's	High ck
100	0.9756	172	0.9998
50	0.97538	181	0.9993
25	0.97521	178	0.9988
10	0.97442	178	0.9982

Standard deviation of the USLs is 4.45E-04.

Pu-Be Sphere

Table V. Pu-Be Model Results

N/Cycle	USL	# BM's	High ck
100	0.9525	190	0.7752
50	0.9526	190	0.7758
25	0.9526	190	0.7783
10	0.95254	190	0.7821

Standard deviation of the USLs is 4.24E-05.

Heat Source Pu Sphere

Table VI. Heat Source Pu Model Results

N/Cycle	USL	# BM's	High ck
100	0.96443	96	0.9291
50	0.96438	98	0.93
25	0.96423	93	0.9279
10	0.96455	95	0.9298

Standard deviation of the USLs is 1.15E-04.

Flooded Graphite Mold

Table VII. Pu239 Flooded Mold Model Results

N/Cycle	USL	# BM's	High ck
100	0.979	64	0.9538
50	0.97905	64	0.9544
25	0.97883	64	0.9532
10	0.97865	64	0.9514

Standard deviation of the USLs is 1.57E-04.

Table VIII. U233 Flooded Mold Model Results

N/Cycle	USL	# BM's	High ck
100	0.94339	126	0.7679
50	0.9434	126	0.7673
25	0.9433	126	0.7694
10	0.94348	126	0.7712

Standard deviation of the USLs is 6.38~~9~~E-05.

Table IX. Th232 Flooded Mold Model Results

N/Cycle	USL	# BM's	High ck
100	0.93521	142	0.0092
50	0.93524	137	0.0092
25	0.93525	136	0.0092
10	0.93549	141	0.0093

Standard deviation of the USLs is 9.76E-05.

CONCLUSIONS

While variations in benchmark weight averaging up to percent ranges and subsequent benchmark ordering variations have been observed, this has not translated into significant changes in the recommended USLs. Typical standard deviation of the USL is on the order of~~r~~ E-04 or E-05. Therefore, if the USLs are rounded to 3 digits, there is no change in recommended USLs for the range of neutron histories tested. However, Whisper should not be used in cases where the correlation coefficient is too low. The U233, Th232 and Pu-Be results all fall into this category. While none of these rose enough to give a false positive, the ck value did go up in all three cases. Therefore, if a model is close to the correlation cutoff, it should be run again with more particles.