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KENO Monte Carlo Code Capabilities

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INTRODUCTION

SCALE [1] (Standardized Computer Analyses for Licensing Evaluation) is a computer code system that is widely used and accepted around the world for criticality safety analyses. It is a modular code system that utilizes individual programs for performing one or more of the required calculations for a desired analysis result. One primary objective in the initial development and ongoing enhancements to SCALE is to provide easy-to-use calculational tools for performing accurate safety analyses of nuclear facilities and packages using current computing techniques.

The Monte Carlo codes KENO V.a and KENO-VI in SCALE are widely used to calculate the multiplication factor of fissile systems, as well as the flux distributions throughout the system. KENO V.a and KENO-VI differ in their treatment of the geometric modeling of the problem. KENO-VI is not an updated version of KENO V.a., but rather provides more general geometric modeling capabilities. As such, both codes are maintained and improved continuously. KENO V.a contains simpler geometric modeling capabilities and therefore runs much faster, while still allowing complex geometries to be modeled using simple geometric shapes. KENO-VI allows more complex geometric modeling and runs longer than KENO V.a. Current versions of both codes in SCALE 5.1 employ a multigroup scheme to treat the energy dependence of the transport equation; however, much effort has recently been devoted to add a continuous-energy scheme to treat the energy dependence of the transport equation in these codes for SCALE 6.0.

ENERGY TREATMENT OF THE TRANSPORT EQUATION

The multigroup cross-section treatment in solving the transport equation allows the KENO codes to execute and calculate the desired parameters much faster than codes that use the continuous-energy treatment. When the multigroup cross sections are generated using proper weighting functions, the results are typically very accurate. However, for certain problem types, generation of an accurate weighting spectrum with the use of one-dimensional transport codes may not be possible. Therefore, continuous-energy capability within the KENO codes is desired.

Continuous-energy treatment capability using the AMPX-generated,[2] KENO-specific continuous-energy cross sections has been implemented in the KENO codes. In an effort to allow SCALE users to easily run their existing KENO cases, changes to the input structure have been minimized. To execute the continuous-energy versions of KENO V.a and KENO-VI using CSAS (Criticality Safety Analysis Sequence), the SCALE user simply has to specify the continuous-energy cross-section library in the library input record. A new parameter has been added to the KENO parameter data to allow binning of integral values such as fluxes and absorptions in one of the existing SCALE multigroup cross-section-library energy-group structures or in a user-specified energy-group structure.

Testing of continuous-energy capability in KENO is ongoing. In that regard, preliminary continuous-energy cross-section libraries using the ENDF/B-VI.7 and ENDF/B-VII.0 data have been generated for KENO. Calculated k_{eff} values using both of these continuous-energy libraries and the ENDF/B-VI.7-based multigroup library for selected benchmark problems [3] are listed in Table I.

VISUALIZATION TOOLS

As part of recent development efforts to improve SCALE's ease of use, the SCALE project team at Oak Ridge National Laboratory has developed an integrated graphical visualization package for KENO V.a and KENO-VI in SCALE. This package uses the SCALE Graphically Enhanced Editing Wizard (GeeWiz)[4] as the visualization control center that provides users access to the point-and-click input menus for KENO input setup, KENO3D [5] interactive three-dimensional geometry visualization tool, Javapeño [6] interactive two-dimensional data-plotting code, and HTML-formatted [7] KENO output.

GeeWiz and KENO3D are compatible with KENO V.a and KENO-VI and run on Windows personal computers. Javapeño is a Java application that runs on multiple computing platforms, including Windows, Unix, Linux, and Macintosh. GeeWiz, KENO3D, and Javapeño provide pull-down menus, toolbars, and context-sensitive help to guide users. GeeWiz and KENO3D are compatible with the CSAS/KENO V.a, CSAS6/KENO-VI, TSUNAMI-3D/KENO V.a, TRITON/KENO V.a, TRITON6/KENO-VI, and STARBUCS/KENO V.a/ KENO-VI sequences in SCALE.

GeeWiz serves as a control center for execution of the SCALE automated sequences that use KENO V.a or KENO-VI, including CSAS, CSAS6, and TSUNAMI-3D. GeeWiz provides input menus and context-sensitive help to guide users through the setup of their input. It includes a direct link to KENO3D to allow users to view the components of their geometry model as it is constructed. Once the input is complete, the user can click a button to run SCALE and other buttons to view the standard and HTML output and run Javapeño. KENO3D has also been upgraded and interfaces directly with GeeWiz. GeeWiz provides a simple user interface with toolbar buttons to access the primary functions of the program.

KENO3D provides users with a powerful tool for checking the accuracy of their models. KENO3D can read the KMART output file and plot the results overlaid on the KENO geometry model.

Javapeño plots sensitivity, reaction rate, or flux data by geometry region as a function of energy group, normalized per unit lethargy for each group, thus eliminating the relative group width from the analysis. Because of the cross-platform capabilities of Java, Javapeño can execute on any computer for which the Java Runtime Environment is available.

An advanced HTML-formatted output interface for KENO has been developed as part of the integrated visualization package. The use of HTML as an alternative output interface for SCALE codes provides the user with a convenient and familiar means of navigating and visualizing data. HTML presents a wide variety of formatting options for differing fonts, colors, and data tables. More advanced technologies such as Java applets and JavaScript are readily incorporated into the output for advanced navigation and data visualization. In addition to easily navigated and color-coded tables of data, interactive plotting capabilities are available.

SUMMARY

Continuous-energy treatment capability has been successfully implemented in the KENO codes. Many user-friendly visualization programs have been developed and integrated, making it possible for a user to set up, execute, plot, and view results from KENO in a friendly, colorful, and interactive computing environment without ever using a text editor or a command prompt.

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TABLE I. Comparison of k_{eff} Values Calculated via SCALE and Benchmark Values.[a]

Benchmark Used[b]	Benchmark k_{eff}	SCALE 5.1 (MG) ENDF/B-VI.7	% diff	SCALE 6 (CE) ENDF/B-VI.7	% diff	SCALE 6 (CE) ENDF/B-VII.0	% diff
HST-001.1	1.0004	0.9986	-0.18	0.9969	-0.35	0.9968	-0.36
HST-001.2	1.0021	0.9963	-0.58	0.9940	-0.81	0.9937	-0.83
HST-001.3	1.0003	1.0012	0.09	1.0004	0.01	1.0001	-0.02
HST-001.4	1.0008	0.9991	-0.17	0.9955	-0.53	0.9956	-0.52
HST-001.5	1.0001	1.0000	-0.01	0.9982	-0.19	0.9989	-0.12
HST-001.6	1.0002	1.0035	0.33	1.0022	0.20	1.0022	0.20
HST-001.7	1.0008	0.9984	-0.24	0.9966	-0.42	0.9959	-0.49
HST-001.8	0.9998	0.9996	-0.02	0.9967	-0.31	0.9963	-0.36
HST-001.9	1.0008	0.9952	-0.56	0.9919	-0.89	0.9916	-0.92
HST-001.10	0.9993	0.9942	-0.52	0.9924	-0.69	0.9919	-0.75
HST-009.1	0.9990	1.0004	0.14	0.9978	-0.12	0.9983	-0.07
HST-009.2	1.0000	1.0009	0.09	0.9986	-0.14	0.9995	-0.05
HST-009.3	1.0000	1.0004	0.04	0.9987	-0.13	0.9990	-0.10
HST-009.4	0.9986	0.9958	-0.28	0.9932	-0.54	0.9937	-0.49
HST-010.1	1.0000	1.0012	0.12	0.9997	-0.03	0.9992	-0.08
HST-011.1	1.0000	1.0055	0.55	1.0041	0.41	1.0037	0.37
HST-011.2	1.0000	1.0017	0.17	1.0001	0.01	1.0001	0.01
HST-012	0.9999	1.0015	0.16	1.0007	0.08	1.0003	0.04
HST-013.1	1.0012	0.9991	-0.21	0.9982	-0.30	0.9981	-0.31
HST-032	1.0015	0.9965	-0.50	0.9999	-0.16	0.9969	-0.46
HST-042.1	0.9957	0.9969	0.12	0.9961	0.04	0.9963	0.06
HST-042.2	0.9965	0.9969	0.04	0.9961	-0.04	0.9963	-0.02
HST-042.3	0.9994	0.9969	-0.25	0.9961	-0.33	0.9963	-0.31
HST-042.4	1.0000	1.0020	0.20	1.0007	0.07	1.0003	0.03
HST-042.5	1.0000	0.9990	-0.10	0.9985	-0.15	0.9986	-0.14
HST-042.6	1.0000	0.9998	-0.02	0.9987	-0.13	0.9988	-0.12
HST-042.7	1.0000	1.0005	0.05	1.0001	0.01	0.9994	-0.06
HST-042.8	1.0000	1.0011	0.11	1.0002	0.02	1.0000	0.00
HST-043.1	0.9986	0.9963	-0.23	0.9941	-0.46	0.9936	-0.50
HST-043.2	0.9995	1.0068	0.73	1.0051	0.56	1.0053	0.58
HST-043.3	0.9990	1.0019	0.29	1.0010	0.20	1.0005	0.15

[a]MG = multigroup; CE = continuous energy.

[b]From *International Handbook of Evaluated Criticality Safety Benchmark Experiments*.[3]