The Launch of MCBEND 10

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MCBEND 10 is the latest release of the general radiation transport Monte Carlo code from the ANSWERS Software Service of Serco Assurance. MCBEND is developed within a Nuclear Code Development partnership (NCD) between Serco Assurance and BNFL. The ANSWERS vision is 'to provide easy-to-use software that meets the current and emerging needs of the user community'. In the case of MCBEND this vision focuses on the key areas of accuracy, understanding of uncertainties, efficiency and user-friendliness. MCBEND 10 is a major launch of the code with many new and enhanced features.

New developments in MCBEND 10 include: automatic splitting mesh generation, point energy adjoint for neutrons, calculation of uncertainty in the results due to material cross-section uncertainties and a unified source facility. Enhanced features include: improved temperature treatment, extended scoring of sensitivity to geometry perturbations, geometry improvements, extensions to formulae and improved user guide image.

The user friendliness of the MCBEND code has been further enhanced by recent developments to the visualisation tools VISAGE and VISTA-RAY. Developments have been made to the 3-dimensional visualisation tool VISTA-RAY to simplify the detailed checking of a model, with the option to use a mouse-pointer to select regions of interest for further detail, and to visually highlight incorrectly defined areas. A further development to VISTA-RAY is the inclusion of the capability to overlay a representation of a user-designated set of results from a MCBEND analysis on the model.

Improvements have also been made to the Graphical User Interface LaunchPad for submitting and controlling calculation submission, with a common user-image across all systems. Recent enhancements to LaunchPad include a job-scheduler to simplify processing multiple tasks.

A selection of the new developments in MCBEND 10, VISTA-RAY and LAUNCHPAD will be described in the paper.

INTRODUCTION

MCBEND is a generalised 3D Monte Carlo code for radiation shielding and dosimetry applications. Neutron, gamma ray, electron and coupled neutron-gamma calculations can be performed. MCBEND 10 is the latest release and is a major launch of the code with many new and enhanced features which focus on the key areas of improving accuracy, understanding of uncertainties, efficiency and user-friendliness.

This paper gives a brief overview of MCBEND 10, concentrating on its main attributes. The following sections describe specific developments in MCBEND 10 and its supporting visualisation and verification tools.

MAIN ATTRIBUTES OF MCBEND 10

Powerful Geometry Modelling Package

The MCBEND geometry modelling and tracking package [1] comprises, a) a simple body component, known as Fractal Geometry (FG) using conventional ray tracing and, b) the additional power of hole geometries employing Woodcock tracking.

Fractal Geometry is a system of solid geometry modelling where the problem geometry is subdivided into zones of uniform material. These zones are defined as the intersections and differences of simple mathematical bodies such as cuboids, cylinders and spheres. The bodies are assembled into structures called parts. Parts are self contained to simplify the model construction and to take advantage of any replication which may be present. Parts may be included within other parts to any depth of nesting and a given part may be included more than once within the geometry. The ability to break down complex models into parts, each separately described in its own local co-ordinate system, simplifies the preparation and checking of the input data.

In MCBEND 10 a number of new operators allow even more flexibility to easily model complicated structures. The OR operator allows a zone to be defined as the *union* of two or more bodies. The zone complement operator, NOT, allows entire zones to be excluded from the definition of other zones. A new option allows a body to be rotated about a point other than its origin.

Hole geometries are used in conjunction with simple body geometries by placing a hole geometry inside a zone (taking the place of a physical material or a subsidiary part). Hole geometries can be used to model common replicating arrangements and simple intersecting configurations in a short-cut form, e.g. when modelling fine detail such as large arrays of fuel pins. In MCBEND 10 a new coil hole is available. This hole defines a set of concentric spiral pipes.

Advanced Acceleration Options

MCBEND has efficient and robust built-in acceleration (variance reduction) techniques which enable even novice users to perform efficient calculations. The principal method of variance reduction in MCBEND is the use of splitting and Russian roulette (S/R) under the control of a space/energy importance map. As an integral part of the code, an adjoint multigroup diffusion theory calculation [2] may be performed to estimate importances in an orthogonal (XYZ or RθZ) mesh, known as a splitting mesh, that overlays the problem space. As the splitting mesh is completely separate from the geometry model, the problem geometry does not have to be complicated by dividing material regions into cells for acceleration purposes. This method has been available for over 15 years, and it has proved very effective in a wide range of applications.

In MCBEND 10 a facility for automatically generating the splitting meshes has been implemented for neutron calculations. The user has to specify basic information such as the number of meshes in each direction, the target response, a reference (target) point and the principal attenuation direction(s). MCBEND uses this information to set a splitting mesh for each energy group. Generally the splitting mesh at low energies needs to be fine near a thermal detector but can be coarser further away from the detector. At high energies a coarser mesh is appropriate. Thus different mesh locations are set at different energies, however a common number of meshes is used for each energy group. This keeps the importance map as a regular array with dimensions NX x NY x NZ in all groups. The sets of boundaries form a composite mesh, allowing an accurate solution of the adjoint diffusion equations and providing a suitable importance map at all energies. Tracking then uses the composite mesh to determine when splitting/Russian roulette in space and energy are required.

Some difficult radiation transport problems require additional help with variance reduction. MCBEND provides options for automatically improving the importance map as the calculation proceeds [3] and for deriving an importance map based on Monte Carlo sampling, rather than deterministic methods. MCBEND also has a forced flight method of variance reduction, particularly applicable to situations where particles pass through narrow openings.

Source Representation

Prior to MCBEND 10, there were two separate options for modelling the source. One option (simple source) primarily defines the source using an orthogonal (XYZ or RθZ) mesh. Point, surface and volume sources can be modelled. Some geometric flexibility is provided by restricting sources to certain FG zones or materials. Source weighting can be provided by the importance map. The simple source option has a number of in-built neutron spectra, or the source can be defined as a histogram or discrete lines. The other option (complex source) defines the source using freely oriented bodies or surfaces. This gives much greater geometric flexibility. The complex source option contains fission and activation product spectra. However only manual source weighting is available for the complex source.

In MCBEND 10 a unified source option is available, which implements most of the features of the simple and complex source options or equivalent capabilities. One main advantage to the user is that the input is all contained in a single unit and the user image is more modern and coherent than the old source definition units. The original source modules are retained for back-compatibility.

In the unified source option the spatial distribution of the source is defined using a set of freely oriented bodies similar to those used in the definition of the problem geometry. Alternatively the source can be defined as an FG body or an FG zone defined in the material geometry, or the source can be restricted to within specified materials. Point, line, surface and volume sources can be modelled and source bodies can be subdivided, as required. The unified source option contains a number of built-in spectra: single spectra (U235 or Pu239 fission, AmBe, 1/E) or mixed fission spectra. The source can be a histogram in a defined group scheme, discrete lines, a combination of generation fluxes and emission matrices or a general variation over energy group and angular bin. Specification of different source spectra is straightforward. Automatic source weighting

can be provided by the importance map. Automatic weighting can be used even if the source energy groups do not match the importance energy groups. This is a significant improvement over the automatic weighting that is available with the simple source option.

Nuclear Data

The most accurate MCBEND calculations are performed with energy as a continuous variable and the nuclear data is tabulated at a large number of energy points. Libraries of such data for most common nuclides are available from different sources for neutron calculations using 13193 energy groups. The 13193 group library is used in conjunction with a detailed treatment of thermal neutron scattering. An equivalent point-energy library is available for gamma-ray calculations. The data in these libraries are derived from the UK Nuclear Data Library (UKNDL), the Joint Evaluated File (JEF), ENDF/B-VI and JENDL.

A method of achieving greater efficiency for some problems is to perform the whole Monte Carlo calculation in adjoint mode. Multigroup data has long been available in MCBEND for performing adjoint calculations. However for increased accuracy, it is important that the accurate nuclear data representation should be preserved even for adjoint calculations. A new development in MCBEND 10 has therefore been to provide the option of performing adjoint Monte Carlo calculations for neutrons using point energy data. A full description of the point energy adjoint facility has been given previously [3].

Scoring

The primary results from a MCBEND calculation are the average particle fluxes in user-defined scoring volumes as a function of space, energy and, optionally, time since birth. Scoring can be defined in the material geometry or in the overlaying splitting mesh. This allows a significant amount of flexibility to allow results to be scored in fine scoring regions.

The code will also score responses for which there are libraries of response functions including dose, activation and damage; alternatively, the user can specify the response function in an energy scheme which can be independent of the flux scoring group scheme. In gamma-ray calculations the energy deposition or pulse height distribution may be scored. When tracking electrons, the energy deposited by these particles may be evaluated. These quantities may be scored accurately in MCBEND, even in conjunction with variance reduction techniques [4].

All results are presented with an estimate of the variance associated with the stochastic nature of the calculation. A dump and restart capability allows calculations to be extended to greater numbers of samples until satisfactory variances are obtained.

In point-energy neutron or gamma-ray calculations, the sensitivity of responses and particle fluxes to small changes in basic nuclear data may be calculated using perturbations of selected cross-sections [5]. A new option in MCBEND 10 provides estimates of the uncertainties in the calculated fluxes and/or responses due to uncertainties in the cross-section data for the materials present in the system being modelled. The cross-section uncertainties are expressed in the form of covariances, which are stored in a library. The uncertainties in the calculated results are obtained by combining the covariances with sensitivities calculated in the same run.

SUPPORTING TOOLS

As well as a powerful and versatile geometry modelling package, it is essential that a Monte Carlo code has a visual means of checking and verifying the specified geometry model. MCBEND is supported by VISAGE and the VISTA codes for this purpose. These packages provide interactive high-resolution facilities and enable two- and three-dimensional images of the geometry model to be displayed and manipulated. To assist the user in submitting calculations, the supporting tool LaunchPad is used.

VISAGE

VISAGE displays two-dimensional slices though the geometry model at any user specified location. The mouse/menu can be used to check co-ordinates, dimensions of components and identify materials, zones or regions. The image is generated using identical tracking routines to those used in MCBEND, hence undefined or multiply defined regions can be located and identified using VISAGE. An example of a VISAGE image showing a multiply defined region is shown in Figure 1. VISAGE can also be used to display the splitting mesh and the source bodies, overlaid on the geometry model, to verify that they are correctly positioned. A number of

enhancements have been made to VISAGE for the launch of MCBEND 10, including the facility to overlay user-defined grid lines on the image.

VISTA-RAY

VISTA-RAY displays the geometry model in three-dimensions. User-defined cutaway planes and boxes can be used to view inside the model. The most recent developments for the launch of MCBEND 10 have focussed on improved three-dimensional images via enhanced shading algorithms, new transparent filter options and the ability to overlay a display of source regions. An example of a VISTA-RAY image of a flask with the outer bodies displayed as 'transparent', hence revealing the location of the inner body, is shown in Figure 2. A further development is the inclusion of the capability to overlay a graphical representation of scored results from a MCBEND analysis on the model, in the form of shading. For this option an additional results file must be loaded. An example of a VISTA-RAY image with a graphical representation of scored results displayed as shading is shown in Figure 3.

LaunchPad

LaunchPad provides a common graphical user interface on all computer platforms and is primarily used to launch and monitor the progress of MCBEND calculations. LaunchPad can also be used as a convenient tool to check, visualise and edit an input file, as it provides links to the visualisation tools VISAGE and VISTA-RAY. LaunchPad simplifies the selection of nuclear data libraries and also provides a tool to run the standard verification tests shipped with the ANSWERS codes. Enhancements to LaunchPad for MCBEND 10 include a job-scheduler to enable multiple jobs to be submitted together and queued for execution.

CONCLUSIONS

MCBEND 10 is a major launch of the general radiation transport Monte Carlo code with many new and enhanced features, which have been described here. Recent developments to the visualisation tools VISAGE and VISTA-RAY and the graphical user interface LaunchPad for controlling calculation submission, have also been described.

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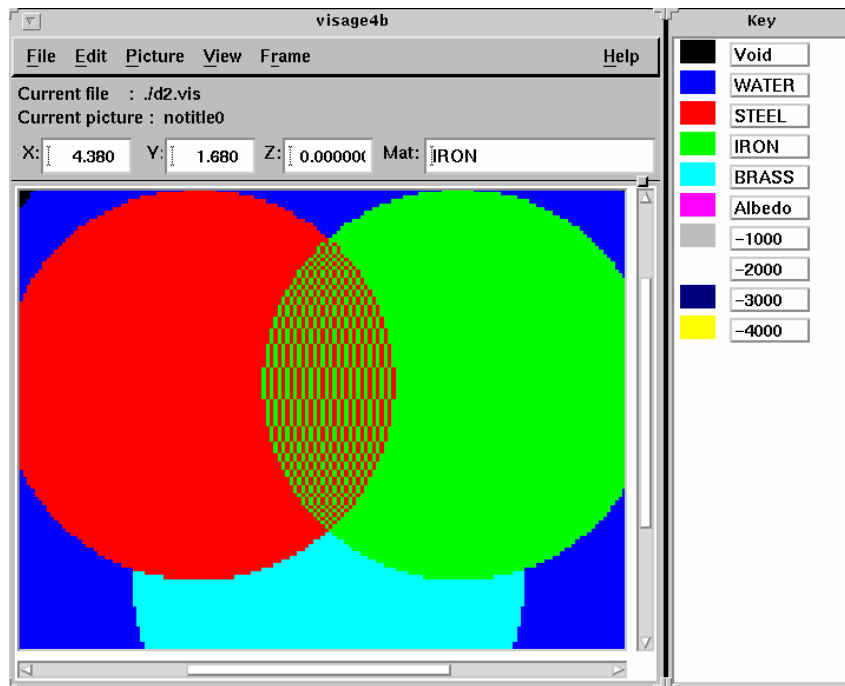
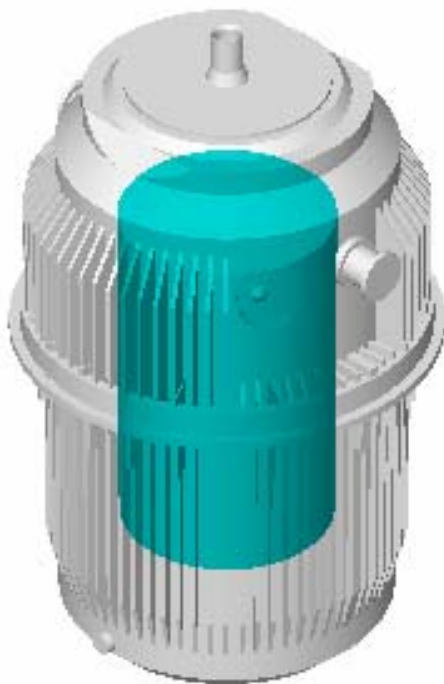Figure 1 VISAGE image showing a multiply defined region
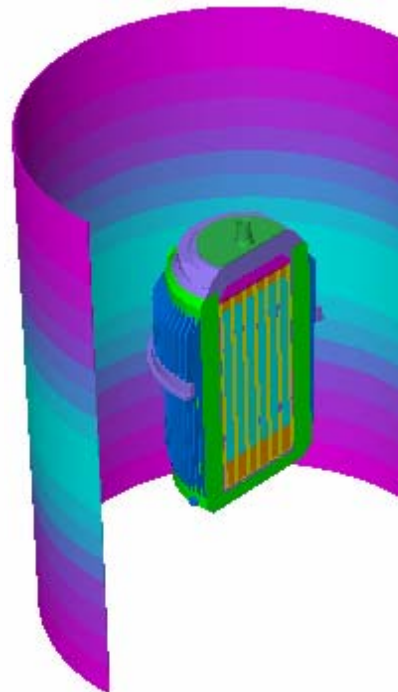

Figure 2
VISTA-RAY image showing transparent shading

Figure 3
VISTA-RAY image with results displayed as shading