CAD import for MONK and MCBEND by converting to Tetrahedral Mesh format

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INTRODUCTION

Reactor components (e.g. fuel assemblies) and other equipment (e.g. transport flasks) are designed using Computer Aided Design (CAD) packages. It is useful to be able to directly use these geometries in Monte Carlo calculations; Monte Carlo tracking using these geometries requires processing of complex surfaces which may slow the calculation. Here we describe a simplified approach of converting the CAD file into an Ansys ASCII-format tetrahedral mesh, and importing this into the ANSWERS codes MONK[1] and MCBEND[2].

OVERVIEW OF METHOD

The approach chosen is to convert the CAD model into a format that is easier to track in a Monte Carlo code. The format chosen is a tetrahedral mesh representation. There is a considerable amount of software available on the market for converting CAD models into meshes of tetrahedra. Serco has used the ICEM-CFD workbench to produce meshes. ICEM-CFD is part of the CFX modelling package, which has powerful meshing capabilities including functions for cleaning 'dirty' or 'bad' CAD

For particle tracking, a process called Woodcock tracking is employed. This means it is only required to know the material present at a point **p** rather than the distance along the current track to the next material boundary. Finding the tetrahedron that contains point **p** is relatively straightforward. For each of its four faces, the dot product of **p** and the normal to the face must have the same sign as the dot product of the normal and one of the edges that does not bound the face.

Despite being a simple calculation, searching millions of tetrahedra every time a point is sampled is prohibitively slow. To optimise the calculation the volume containing the mesh is divided into voxels, which are equal-sized cubes aligned with the model axis. First the voxel containing point **p** is determined then the tetrahedra that overlap that voxel are tested to determine which tetrahedron and hence which material is at point **p**. This greatly reduces the number of tetrahedra to search but requires a setup stage to construct the list of the tetrahedra that overlap each voxel.

RESULTS

An initial test calculation took 11 minutes to set up and 5 minutes to run, whereas the equivalent MONK/MCBEND geometry (FG) case took 2 seconds in total. After some algorithm re-design and further optimization a typical mesh case containing 2 million tetrahedra is now only 25% slower than the FG equivalent.

The test model was a Co60 transport flask. The calculation tallied energy deposition at 40 positions through the shield and dose rates around the flask. Figure 1 shows four images of the Co60 rods inside the flask and compares geometry detail of three meshes, comprising 120 thousand, 1 million and 2 million tetrahedral, with the FG model. The images are ray-traced pictures of the models produced by Visual Workshop[3] using the tracking routines of MONK & MCBEND.

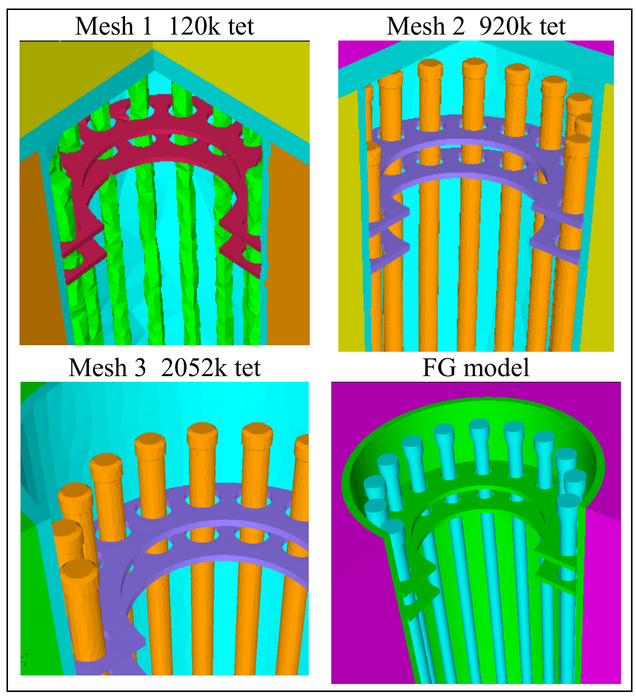

Figure 1 Representations of the geometry

The variance on the energy deposition results was between 1% and 5% and for the dose results between

0.5% and 2%. The mesh cases produced an approximately 5% underestimate compared to the FG results. There was little difference between the results of the 1 million and 2 million tetrahedra mesh models.

It was found that the run time of the calculation is not dependent on the mesh size. Instead it was dependent on a value we called the Voxel Ratio, this is a value that defines how many average volume tetrahedra will fit into the volume of 1 voxel. It defines the size of the voxel grid. Reducing the voxel ratio speeds up the calculation but increases the memory requirements. Altering the voxel ratio such that 1.6Gb of RAM was required for the 1 million tetrahedral mesh produced a calculation that ran only 2% slower than the FG equivalent.

CONCLUSION

A route for importing CAD files, via a meshing program, into the Monte Carlo codes MONK and MCBEND is described. The route gives accurate results, is simple to use and requires little additional processing power.

The next stage of work is to gain experience on the sensitivity of calculations to the approximation of representing the model as a tetrahedral mesh. The tetrahedral mesh import facility is currently available in BETA versions of MONK and MCBEND.

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