Expert Group on 3D Radiation Transport Benchmarks

A Proposal for a

Benchmark to Assess the Accuracy of the Various Different Methods Used

by Transport Codes to Model Material Interfaces.

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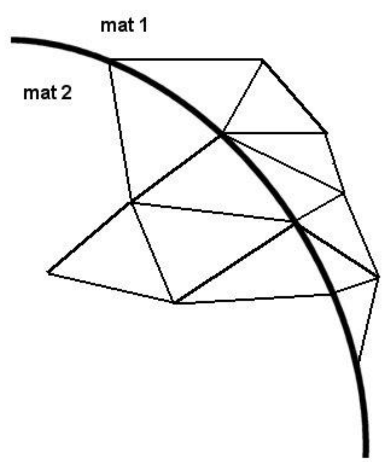
7 May 2009

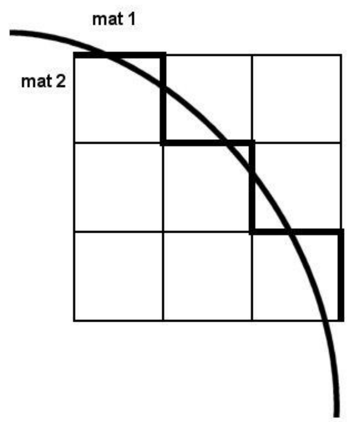
Transport codes use many different spatial meshing or grid generation techniques: e.g. ATTILA uses a conformal or body fitted mesh, whereas TORT is restricted to a regular Cartesian grid. When faced with a configuration with curved interfaces between distinct materials, these codes will model these interfaces using different approximations.

The conformal mesh code will align the cell edges along the material interface thus resulting in a situation where every cell contains a single material (such cells are sometimes called “clean” cells).



Conformal mesh

A regular Cartesian grid code will necessarily need to have a different meshing strategy. A “staircase” or “step” could be used which maintains clean cells; an alternative approach is to allow cells to contain more than one material (such cells are sometimes called “multimaterial” or “mixed” cells). Mixed cells require homogenisation. Depending on the material properties of the configuration these different modelling approximations of the interfaces can have a significant effect on calculated quantities such as k_{eff} and flux distributions.

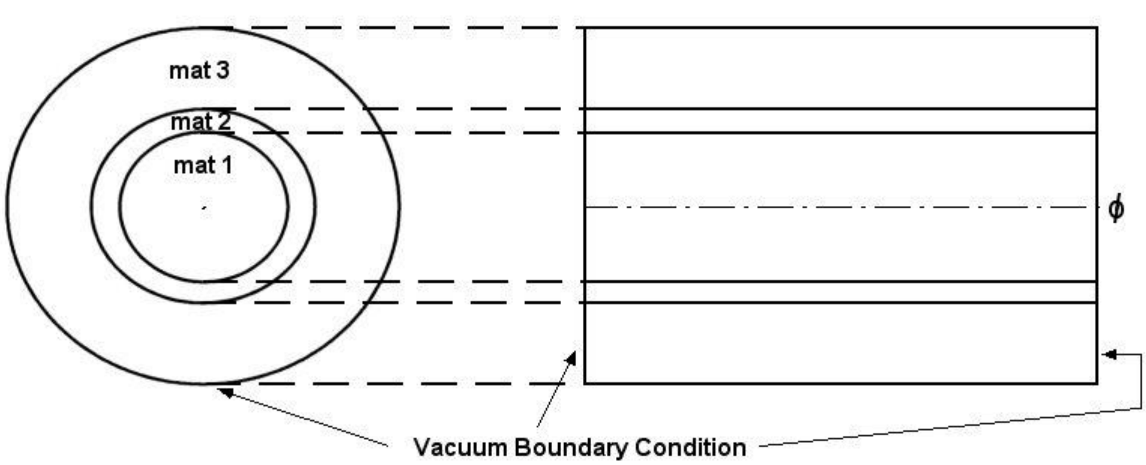


Cartesian mesh staircase

The idea behind this benchmark proposal is to provide a simple test problem that quantifies and qualifies these effects.

Proposal

Concentric cylinders consisting of different materials.



Concentric cylinders

The different materials will have defined macroscopic cross-sections. If at least one of these materials is fissile, then the problem can be treated as a k_{eff} problem.

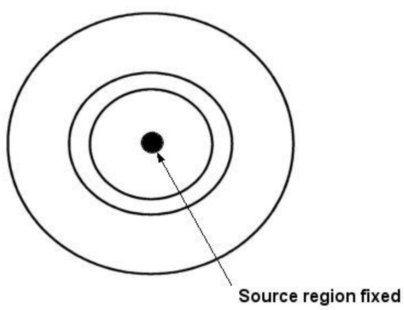
e.g. MAT3: reflector

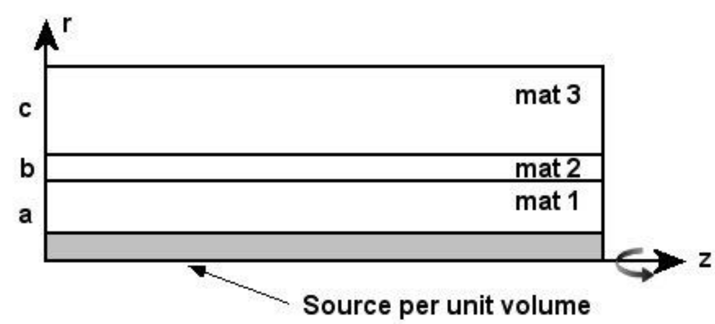
MAT2: fissile 2

MAT1: fissile 1

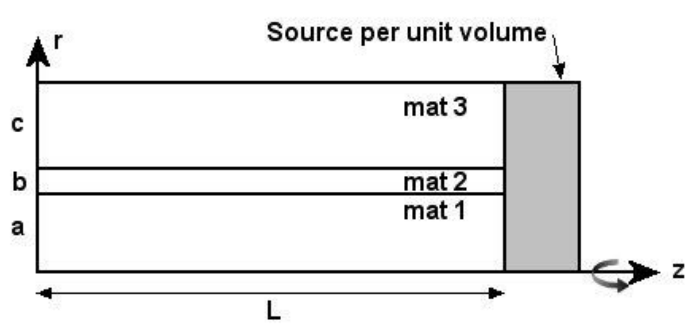
Cross-sections for each of the materials will have to be chosen so that ray effect is an insignificant factor for an S_N code. It is also important that the choice of cross-sections ensures that the material interfaces between MAT3 and MAT2 and MAT1 are significantly important features. The dimensions a, b, c, L will also have to be chosen with care.

Alternatively, or perhaps as a variant, a source region could be introduced so that the problem would be run as a fixed source problem. This fixed source could be along the centre of the cylinder





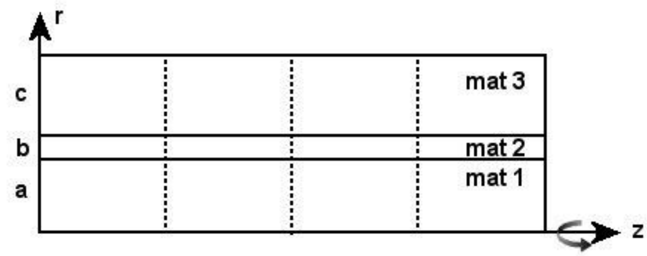
or perhaps as an end cap to the cylinder:



NOTE: the modelling of material interfaces will also affect the interface between the source and other materials.

Output/metrics

Divide the cylinder along its axis into a number of regions.



Output for the test problem could include:

i. k_{eff}
ii. region integrated flux
iii. Leakage between regions and out of external boundaries.

Note that the leakage across the curved faces of the cylinder (i.e. radial leakage) is not a straight forward quantity to determine and each code will have to state how it is calculated.

Reference solution

A Monte Carlo code should be able to easily produce a definitive answer.

Comments

i. A body fitted mesh code should produce highly accurate solutions. A mesh convergence study should provide the basis for comparison with other types of code
ii. A mesh convergence study for "staircase" and "homogenisation" codes will demonstrate how seriously their material interface modelling degrades the solution when compared to a body fitted code as well as the Monte Carlo reference.
iii. For codes with a 2D cylindrical co-ordinate (r,z) option the problem can be run in 2D. Meshing strategies could be devised so that within code comparisons could be made between calculations with mixed cells and with clean cells only[1].
iv. It is important that participants provide results that cover the region of convergence. How a code, together with its associated method of modelling an interface approaches a converged solutions is just as important as the converged answer itself.

[1] It is the author's experience that when using an "homogenisation" code for a mesh convergence study on a problem that goes through a sequence of having all clean cells, to mixed cells at interfaces, to clean cells, to mixed cells, and so on, interesting convergence behaviour can arise.