Tri-tree Based FEM Analysis of Wave Interactions with 3D Cylindrical Structures

Z.Z. Hu, G.X. Wu* and P.X. Hu
Dept. of Mechanical Engineering, UCL, Torrington Place, London WC1E 7JE, U.K.
* Tel.00-44-(0)20-76793870, Fax 00-44-(0)20-73880180 email gx_wu@meng.ucl.ac.uk

Recently, the finite element method (FEM) has been extensively used to analyse wave interactions with a floating structure [1,4,5,7]. It has been found that the method is less CPU intensive than the more commonly used boundary element method. Its drawback is the complexity of its mesh generation. Because of that the applications of FEM in 3D are mainly limited to relatively simple domains where a mesh can be obtained rather easily. For an arbitrary 3D structure, a sophisticated mesh generator would be required. Although it is in principle possible, the CPU requirement could still be prohibitive. In the present work, we focus on cylindrical structures which are commonly used in the offshore industry. A 2D mesh is first generated for a cross section on a horizontal plane. The 3D mesh is then obtained by drawing vertical lines across the nodes of the 2D grid.

The 2D grid is obtained using the tri-tree mesh generation technique. The detailed procedure is given in refs.2&3. Here we give a brief summary.

1) Define an initial equilateral triangle, within which the desired fluid domain will lie and define a set of seeding points about which the mesh will be generated. (Fig.1)
2) If the triangle contains a seeding point, divide the triangle otherwise move to next one, and repeat until the maximum division level has been reached. (Fig.2)
3) Subdivide all grid elements to minimum level. (Fig.3)
4) Apply face regulation to restrict the ratio of triangle sides sharing a common edge to 2:1 and eliminate hanging nodes. (Fig.4)
5) Apply special boundary treatment around interior boundaries and corner regulation. (Fig.5)

After above procedures, the completed tri-tree mesh is shown in Fig.6 with the details near the cylinder given in Fig.7. Fig.8 gives an example for four cylinders.

Once the 2D mesh is generated, the 3D mesh is obtained through the following steps:

1) Extend the 2D tri-tree plane in the third direction forming the 3D mesh with prismatic elements
2) Split each individual prismatic element into three tetrahedral elements.

A completed tetrahedral mesh for four bottom mounted circular cylinders is shown in Figs.9& 10.

The tetrahedral mesh for four truncated circular cylinders is obtained through two additional steps:

1) Apply a special treatment around the cylinder boundary for the inner tri-tree elements in 2D (Fig.11).
2) Eliminate the tetrahedral elements within truncated cylinders in 3D (Fig.12) after the tetrahedral mesh generation process.

Figure 13 shows the part of meshes around boundaries for four truncated circular cylinders.

The generated mesh is then used to simulate the case in ref.6 where extensive experimental study was undertaken. The simulation was also made in ref.1. But the structured mesh based on a simple procedure was used, which did not allow the connectivity of the elements to change with time. Here such restriction has been removed and the mesh structure is more rational. Fig.14 gives a calculated example while detailed results will be given in the workshop.

ACKNOWLEGEMENT
Z.Z.Hu is supported through an EU research programme (G3RD-CT2000-00308) while P.X.Hu is supported by an EPSRC grant (GR/N08766), to which all the authors are most grateful.

REFERENCES
1. **Hu P.X., Wu G.X. and Ma QW (2002),** "Numerical simulation of nonlinear wave radiation by a moving vertical cylinder" Ocean Eng. (accepted)
2. **Hu Z.Z. (2000),** "Numerical simulation of laminar separated flows on adaptive tri-tree grids with the finite volume method", *Ph.D. thesis, Department of Mechanical Engineering University College London*.
3. **Hu Z.Z. Greaves D.M. and Wu G.X. (2002),** "Numerical simulation of fluid flow using an unstructured finite volume method with adaptive tri-tree grids", *Int. J. for Num. Methods in Fluids*, (accepted)
4. **Ma QW, Wu GX and Eatock Taylor R. (2001a),** "Finite element simulation of fully non-linear interaction between vertical cylinders and steep waves. Part 1: Methodology and numerical procedure", *Int. J. for Num. Methods in Fluids,* Vol. 36, pp. 265-285.
5. **Ma QW, Wu GX and Eatock Taylor R. (2001b),** "Finite element simulation of fully non-linear interaction between vertical cylinders and steep waves. Part 2: Numerical results and validation", *Int. J. for Num. Methods in Fluids,* Vol. 36, pp. 287-308.
6. **C.H. Retzler, J.R. Chaplin and R.C.T. Rainey (2000),** "Transient motion of a vertical cylinder: measurements and computations of the free surface", *Proceedings of 15th International Workshop on Water Waves and Floating Bodies, Israel.*
7. **Wu GX, Ma QW and Eatock Taylor R. (1998),** "Numerical simulation of sloshing waves in a 3D tank based on a finite element method", *Applied Ocean Research,* Vol. 20, pp. 337-355.

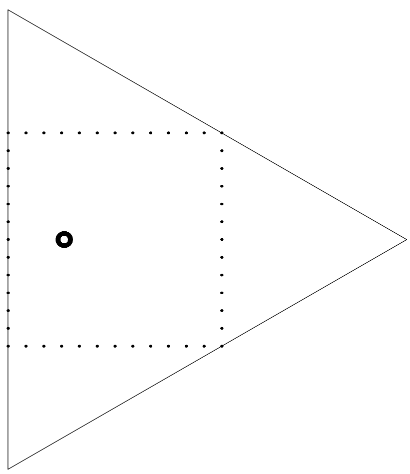

Figure 1 Seeding points

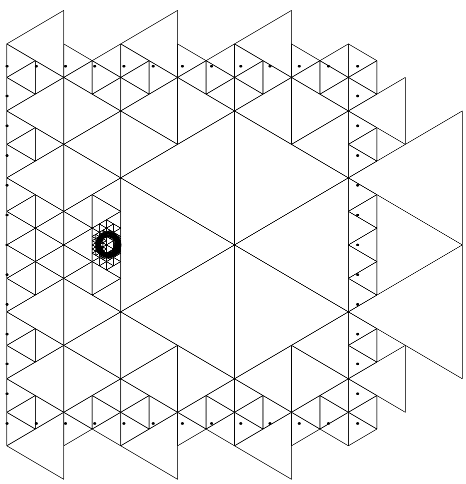

Figure 2 Ninth division

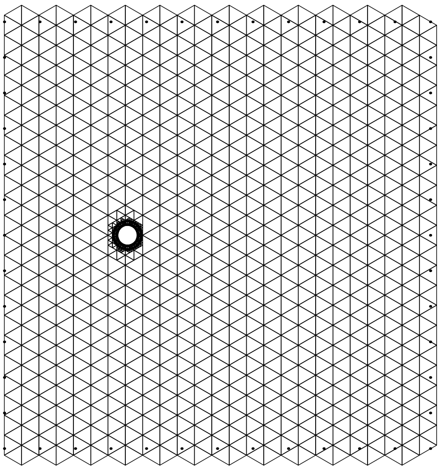

Figure 3 Application of minimum level 5

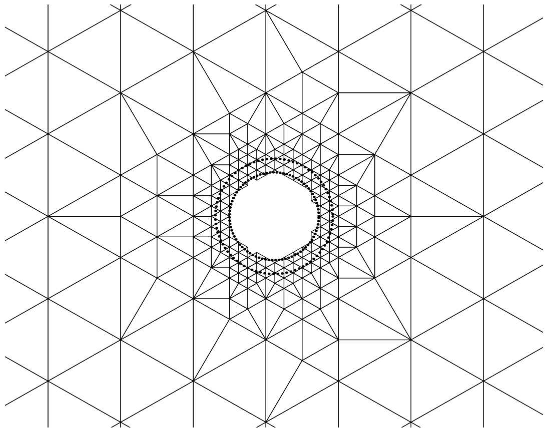

Figure 4 Grid after face regulation and elimination of hanging nodes

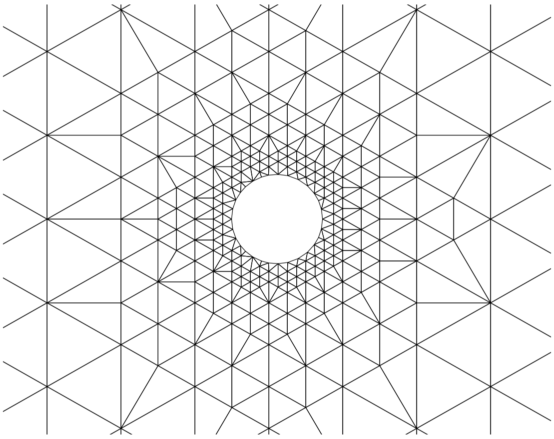

Figure 5 Grid after boundary treatment and corner regulation

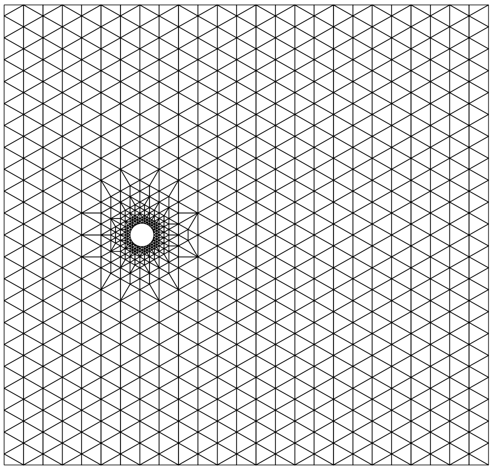

Figure 6 Entire grid, level 9

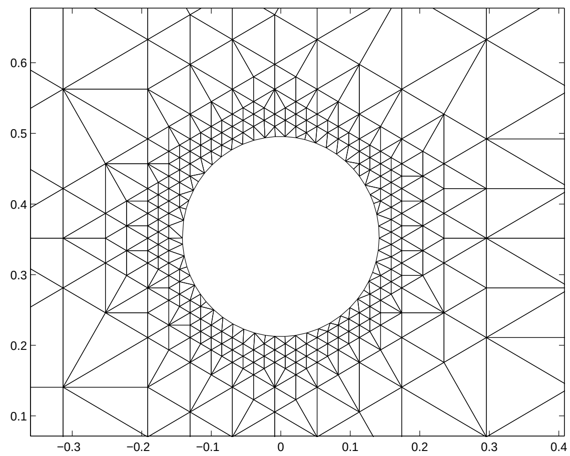

Figure 7 Detail of one cylinder

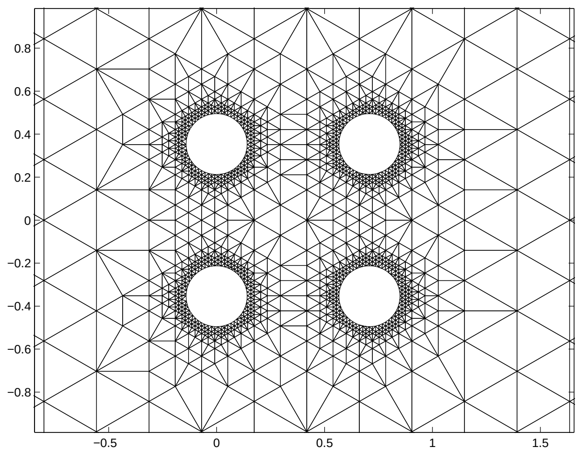

Figure 8 Detail of four cylinders

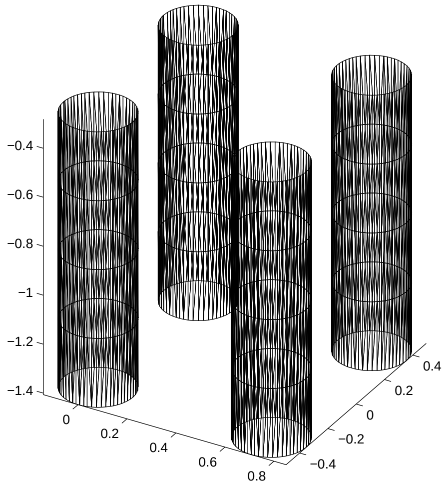

Figure 9 3D mesh on cylinder surface

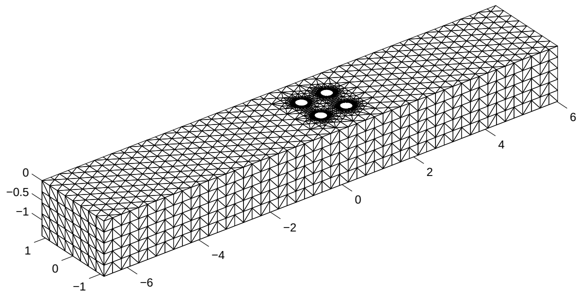

Figure 10 3D mesh on the boundary

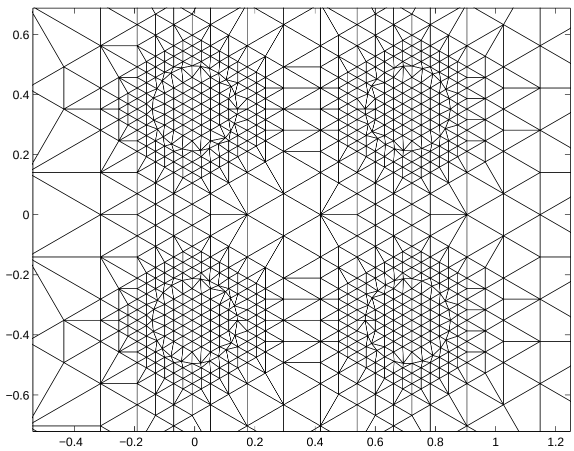

Figure 11 2D mesh (cell =2574, node =1348)

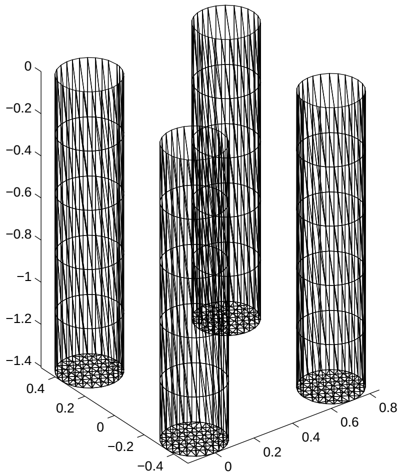

Figure 12 Surface mesh for 4 truncated cylinders

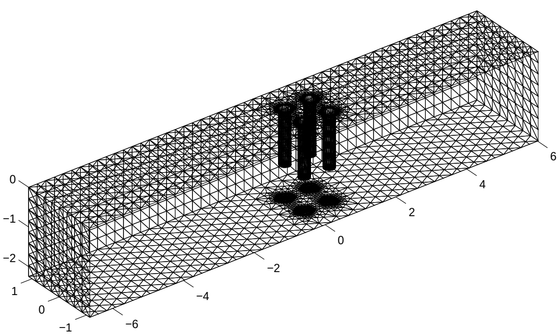

Figure 13 Part of meshes around boundaries

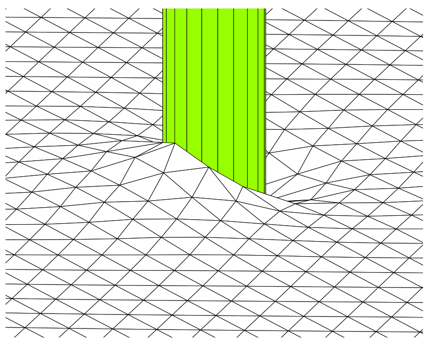

Figure 14 Wave profiles around the cylinder at t=2.5s