Example 5/5

Courtesy of Shouxu Qiao

An example of systematic study of effects of 1) element type; 2) element number and 3) geometry model on the resulting stress.

Also, a good example of comparing analytical solution with simulation results in plots.

2.2 Mesh

Meshing is very important for finite element simulation. If the mesh is too coarse, the solution calculation may not be accurate. If the mesh is too fine, it will consume too much computer time which is not economic. So the mesh quality is relative. In general, a good mesh means a relatively accurate simulation can be obtains and the computing time is efficient. To achieve this, following methods can be considered. (1) To use symmetric prosperity of the geometry; (2) apply fine mesh in the region with large stress gradient while coarse mesh in the other regions. For the current model, both methodologies are applied in the generating mesh. In other words, both quad-cell and tri-cell meshes are tested. Furthermore, the mesh near the center hole is denser than near the edge. But how dense the mesh should be is still undetermined. Therefore, four meshes with increasing mesh number are simulated and compared in order to find the best mesh which gives accurate results and high computing efficiency. In addition, two types of meshes, i.e. Quad and Tri are tested.

<u>2.2.1 Sensitively study of mesh types</u>

Figure 3 (a) and (b) show the meshes of using Quad-cell and Tri-cell, respectively.

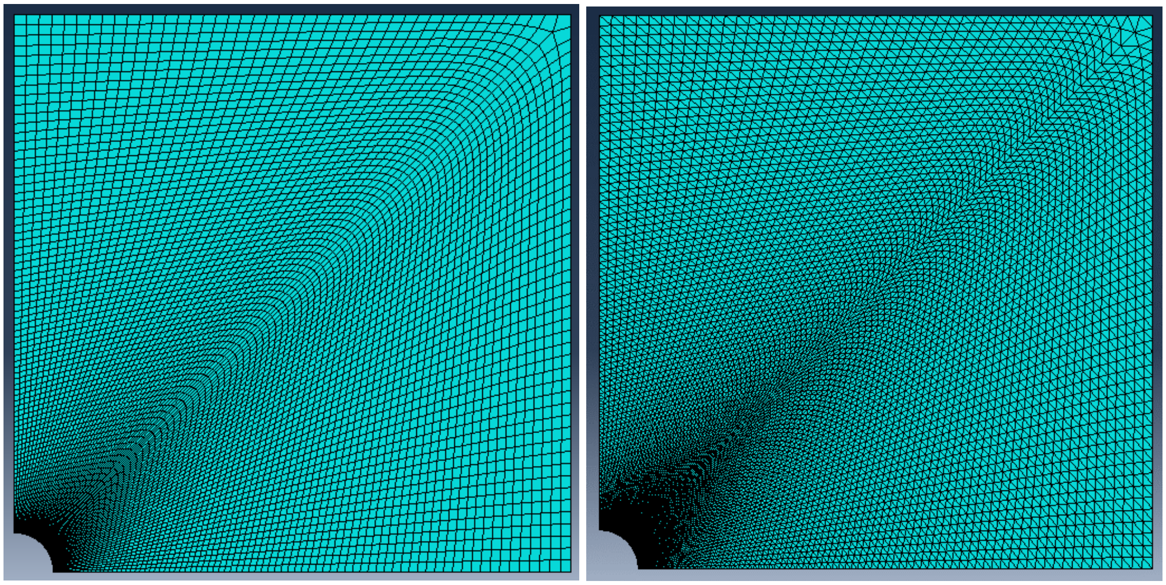
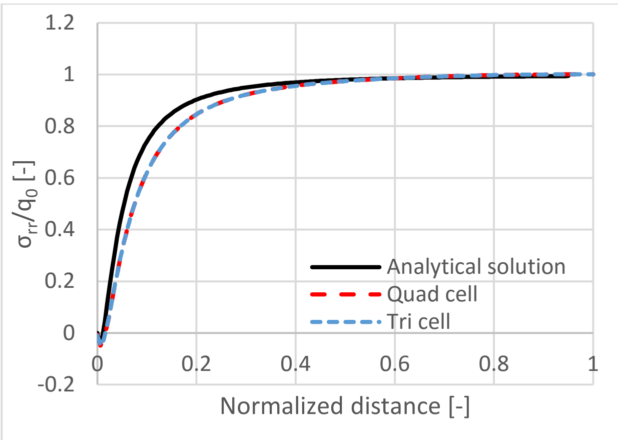
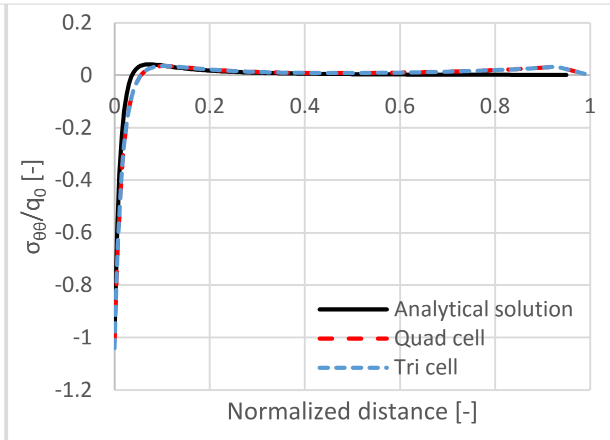


Figure 3. Meshes with different cell types. (a) Quad-cell, (b) Tri-cell

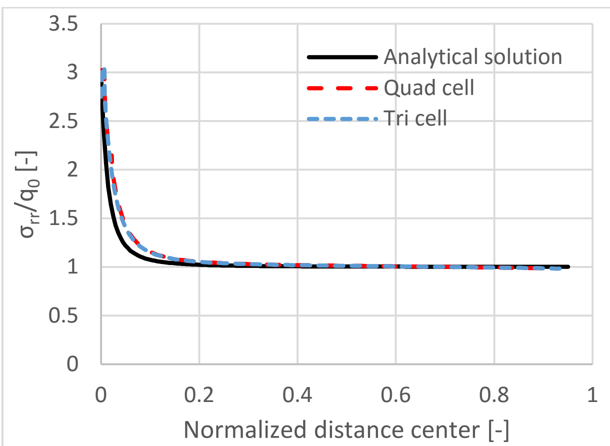
To test which cell type is better in the current simulation, the simulated results are compared with each other and also with the analytical solution along 0 degree and 90 degree. Figure 4 (a) - (d) show the comparison of σ_{rr} and $\sigma_{\theta\theta}$ values along 0° and 90° for each simulation using different cell number and the analytical solution. It is observed that, both mesh give similar simulation results. Furthermore, both results are similar as the analytical solution. From Figure 4(c), it is observed that, the maximum circumferential stress equals approximately $3q_0$ which is consistent with the analytical solution. It can be concluded that both can be used to perform the finite element simulation. However, the Tri-cell has more element nodes which requires longer computing time. Therefore, the Quod-cell mesh is selected to perform mesh number sensitivity study.



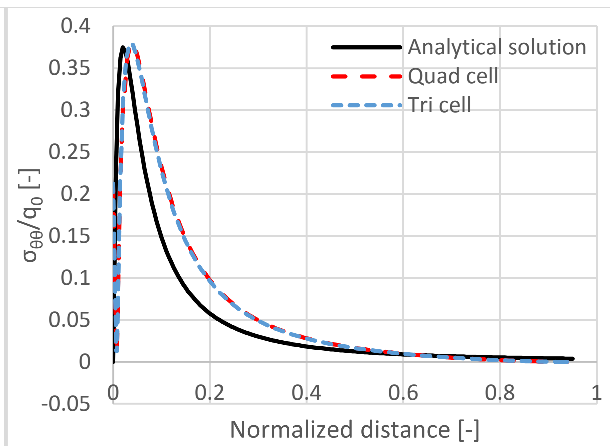
(a) 0°, σ_{rr}/q_0,



(b) 0°, $\sigma_{\theta\theta}/q_0$



(c) 90°, σ_{rr}/q_0,

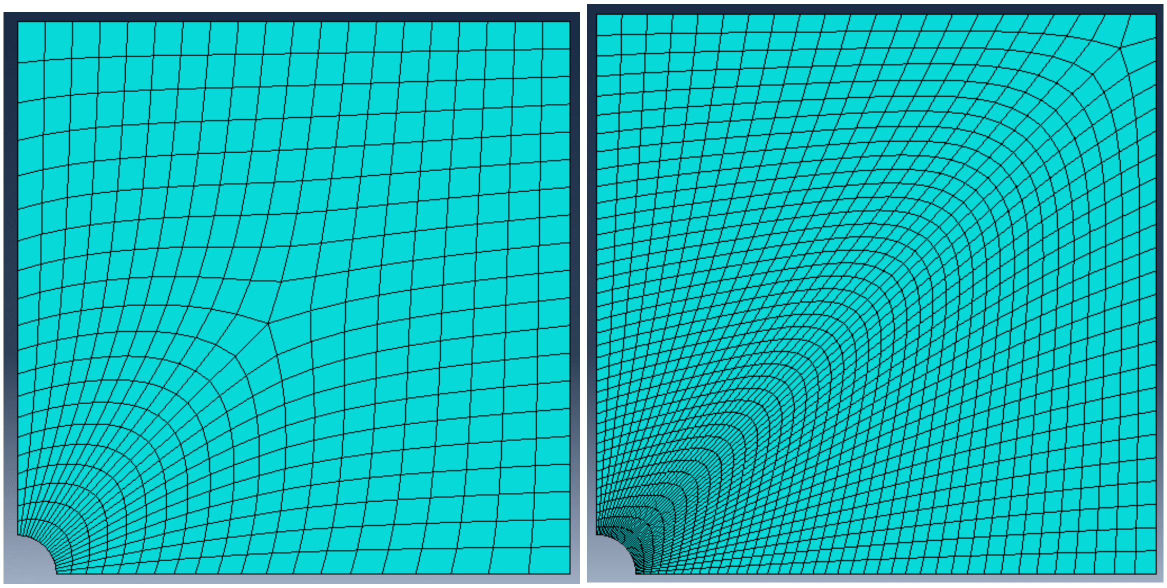


(d) 90°, $\sigma_{\theta\theta}/q_0$

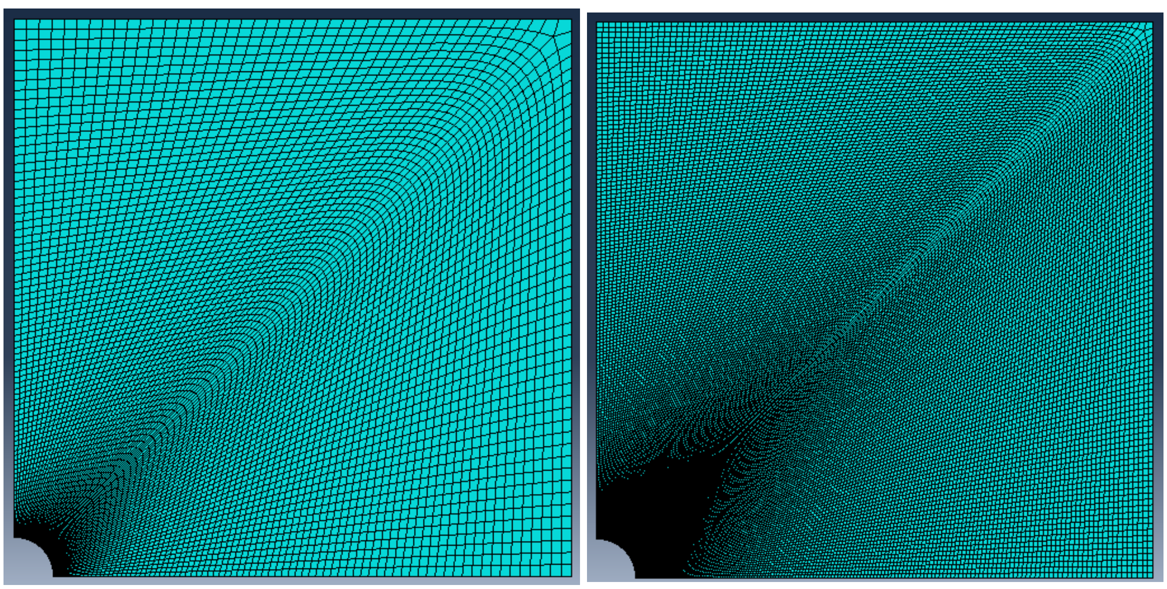
Figure 4. Comparison of the simulation results using meshes with different cell type

2.2.2 Sensitivity study of mesh number

The mesh sensitivity was also tested by increasing the cell number. Figure 5(a)-(d) show the mesh with increasing element number using Quad type cell. Starting from mesh (a), mesh (b), (c) and (d) each has nodes member doubled on each edge compared with mesh (a), (b), and (c). Mesh (c) is the same mesh as mesh (a) in Figure 4 which is used for cell type sensitivity study.



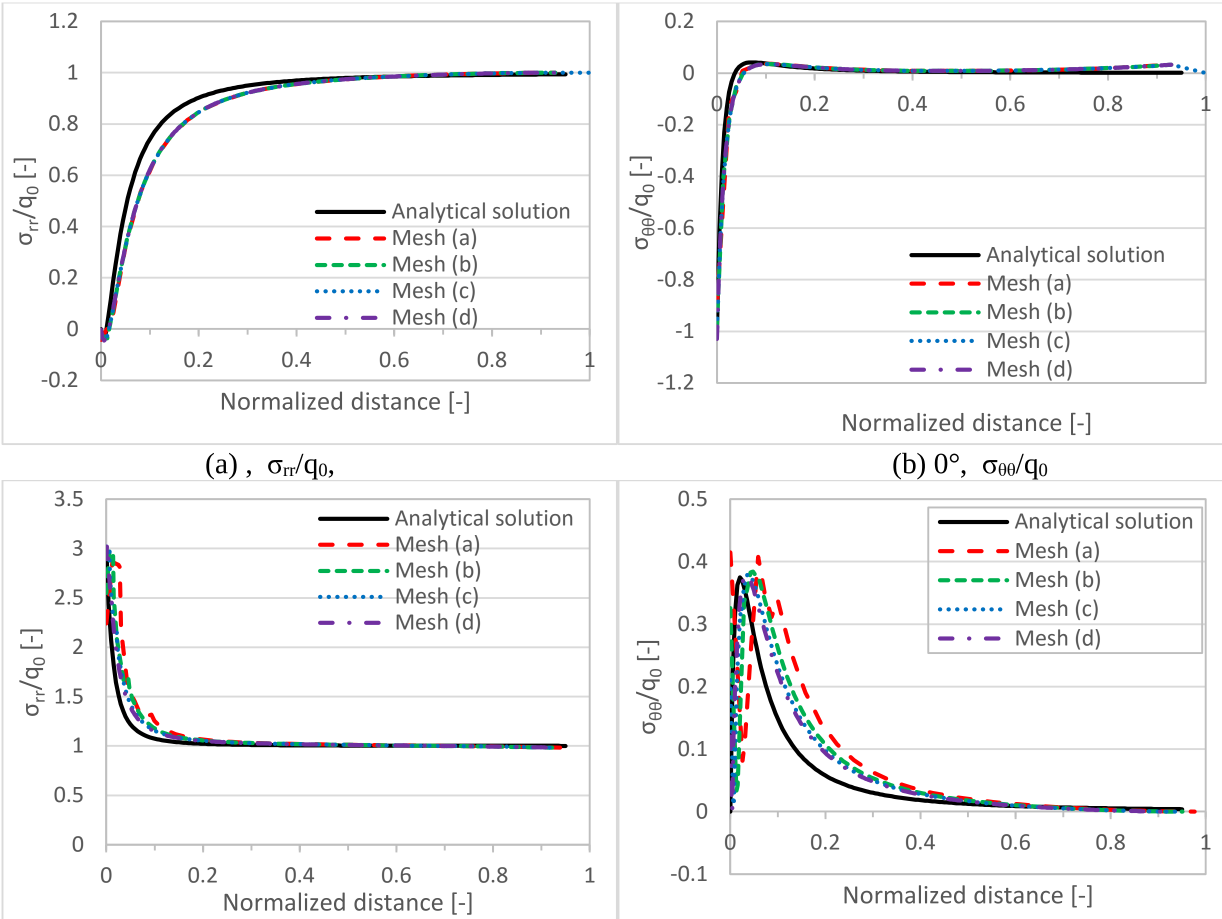
(a) Base mesh (b) Double nodes number as compared with (a)



(c) Double nodes number as compared with (b) (d) Double nodes number as compared with (c)

Figure 5. Meshes with increasing element number using Quad-cell.

Figure 6 (a) - (d) show the comparison of σ_{rr} and $\sigma_{\theta\theta}$ values along 0° and 90° for each simulation using different cell number and the analytical solution. It is observed that, the stress values along the 0° line given by all four meshes are very similar. However, the stresses values along the 90° line given by all four meshes show some differences. From Figure 6 (c) and (d), it is observed that with increasing element number, the simulated stresses are more close to the analytical solution. The stress values given by mesh (c) and mesh (d) are very close. But mesh (d) has much more cell numbers than mesh (c) and requires more computing time. Therefore, mesh (c) was selected to perform the following study.



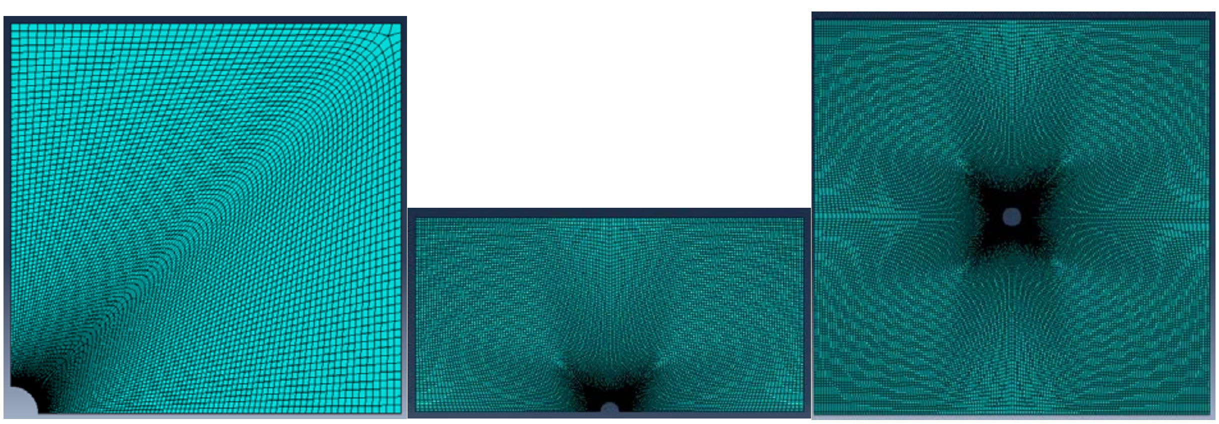
(a) , σ_{rr}/q_0, (b) 0°, $\sigma_{\theta\theta}/q_0$

(c) 90°, σ_{rr}/q_0, (d) 90°, $\sigma_{\theta\theta}/q_0$

Figure 6. Comparison of the simulation results using meshes with different cell number.

2.2.3 Sensitivity study of geometry model

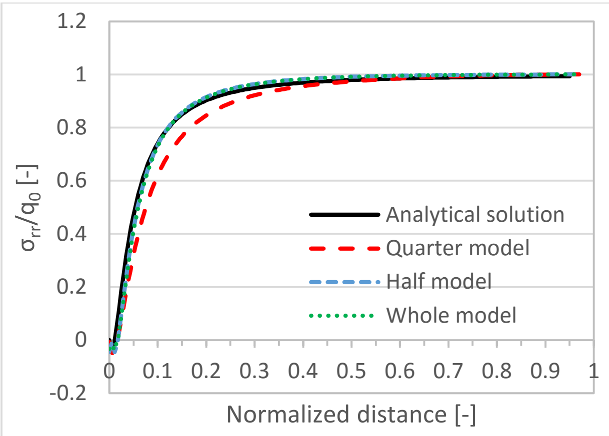
As discussed in Section 2.1, in addition to the quarter model, simulation was also performed with the whole model and half model. Figure 7 shows meshes for different geometries.

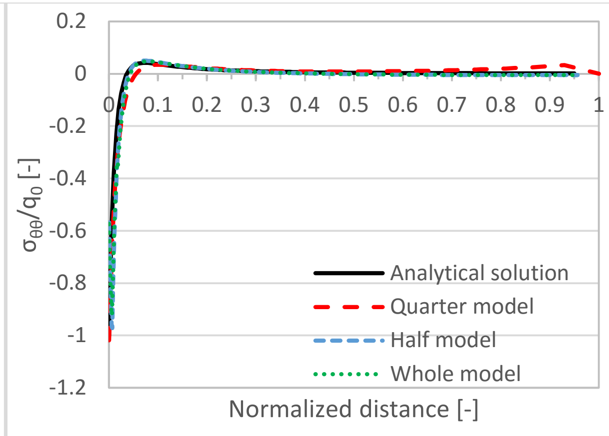


(c) Quarter geometry mesh (b) half geometry mesh (d) whole geometry mesh

Figure 7. Meshes with increasing element number using Quad-cell.

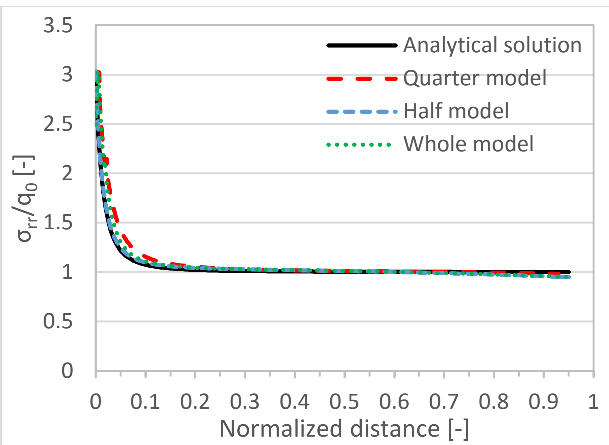
Figure 8 (a) - (d) show the comparison of σ_{rr} and $\sigma_{\theta\theta}$ values along 0° and 90° for each simulation using different geometries and the analytical solution. Surprisingly, the half model and whole model give very close results as the analytical solution. Since whole model requires more mesh number and more computing time, it is recommended to use the half model to perform finite element simulation for the current project.

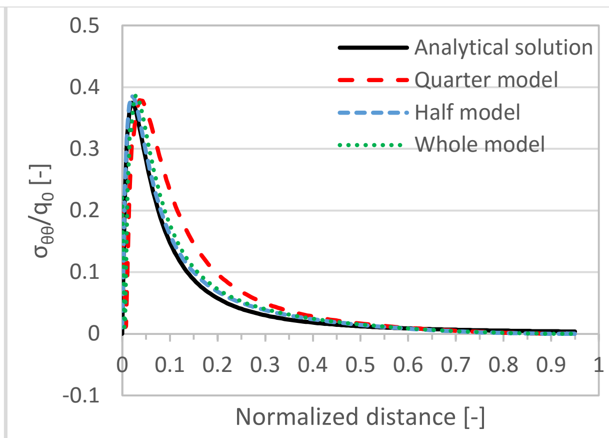




(a) , σ_{rr}/q_0,

(b) 0°, $\sigma_{\theta\theta}/q_0$





(c) 90°, σ_{rr}/q_0,

(d) 90°, $\sigma_{\theta\theta}/q_0$

Figure 8. Comparison of the simulation results using meshes for different geometries.