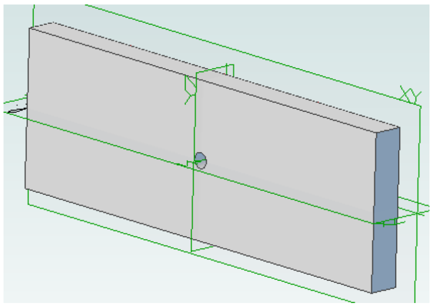
FEMdesigner AD Accuracy Verification Examples

Elastic Analysis

1. Stress concentration in plate with hole



From Shigley, Mechanical Engineering Design, McGraw-Hill, 1st Ed, 1986, Table A-23, page 673

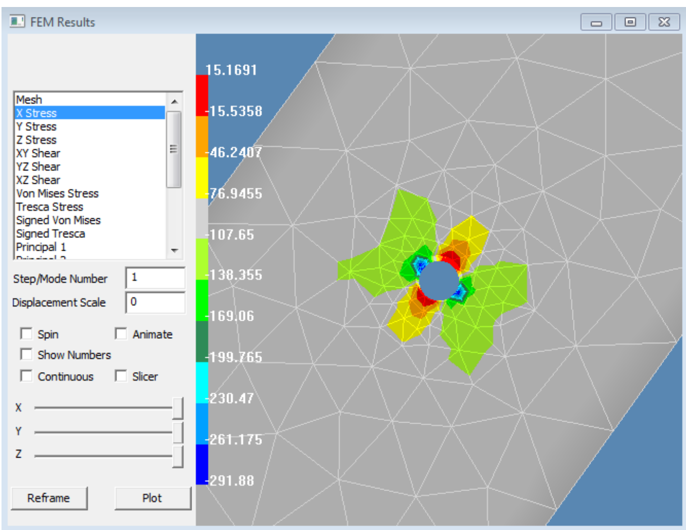
Length =15m, Width = 5m, Thickness=1m, hole radius = 0.5m

Young's modulus= 1000Pa, Poisson's ratio = 0

Left face fixed, right face loaded with -100 Pa

Theoretical result: Maximum Normal X Stress = -312.5

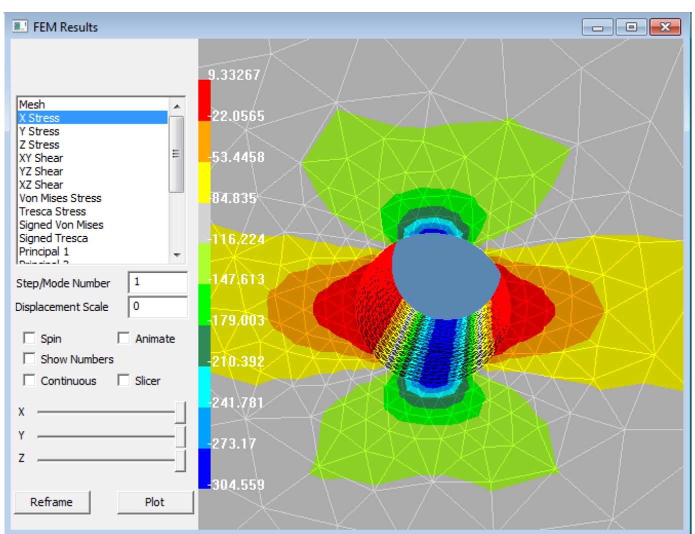
Results:



Default mesh

Max X Stress = -291.7

Error = 6.6%



Default mesh with 50mm elements specified in hole face

Max X Stress = -304.6

Error = 2.5%

2. Thick cylinder under internal pressure, with radial symmetry constraint

Inner radius, b=0.5, outer radius, a=1, pressure, q=10,

5 degree slice was simulated, with a gap-to-ground symmetry constraint on the angled face and a traditional symmetry restraint on the bottom face.

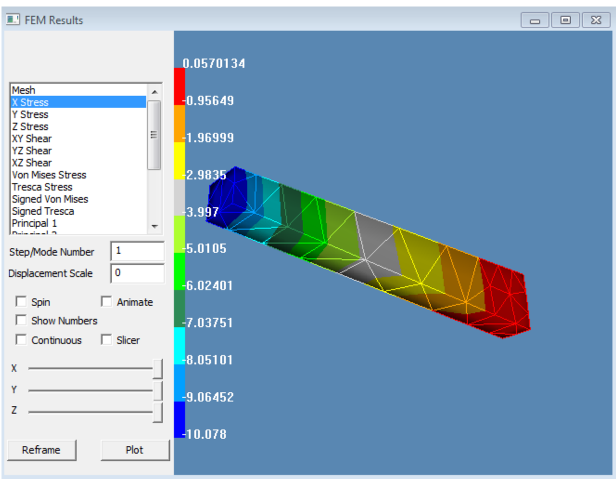
Young's modulus= 200e3, Poisson's ratio = 0.3

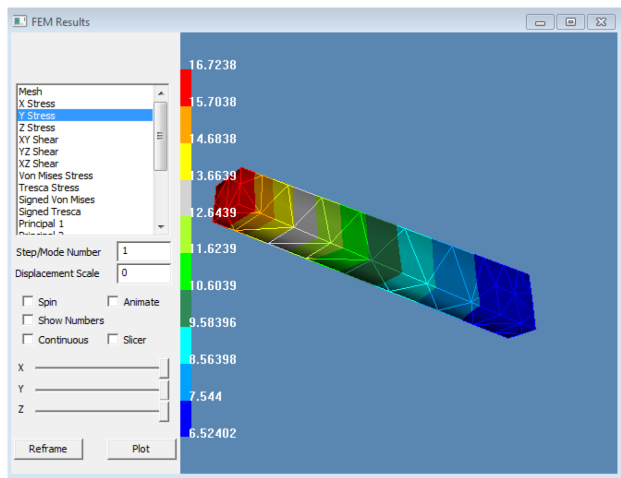
From Roark's formulas for Stress and Strain, 6th Ed., Table 32, case 1a:

At b, Hoop stress = $q(a^2+b^2)/[(a^2-b^2)] = 16.67$, Radial stress=-q = -10

At a, Hoop stress = $2.q.b^2/(a^2-b^2) = 6.67$, Radial Stress = 0

Results (default mesh):





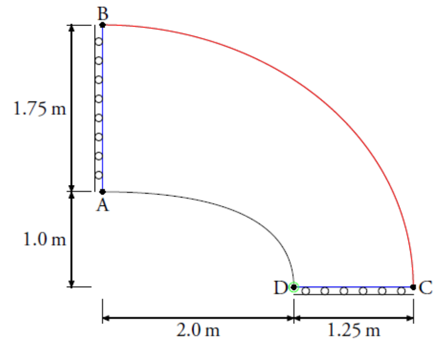
Radial Stress at b = -10.08, error = 0.8%

Radial stress at a = -0.06, target is zero

Hoop Stress at b = 16.72, error= 0.3%

Hoop Stress at a = 6.52, error=2.2%

<u>3. Elliptical Section Bending, NAFEMS benchmark LE10</u>



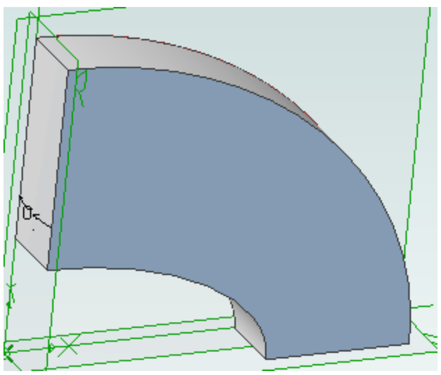
Plot on xy plane, z thickness = 0.6m

Young's modulus = 210 GPa
Poisson's ratio = 0.3

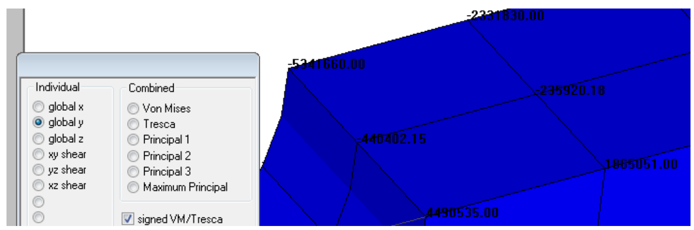
Symmetry restraints and x,y held on outer edge, z restraint is at midline. Load is 1MPa in z direction.

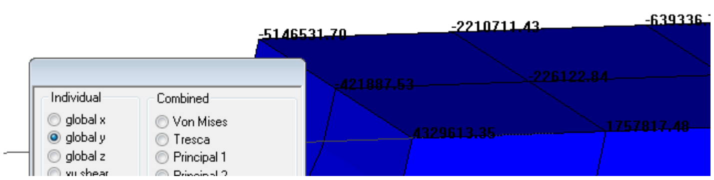
Desired result of Y Stress at bore on long radius and loaded corner = 5.38MPa

Because the midline z restraint cannot be applied to an unstructured tetrahedral mesh, we will compare the FEMdesigner AD tetrahedral model to the corresponding FEMdesigner standalone hex mesh model, where such a restraint is possible.

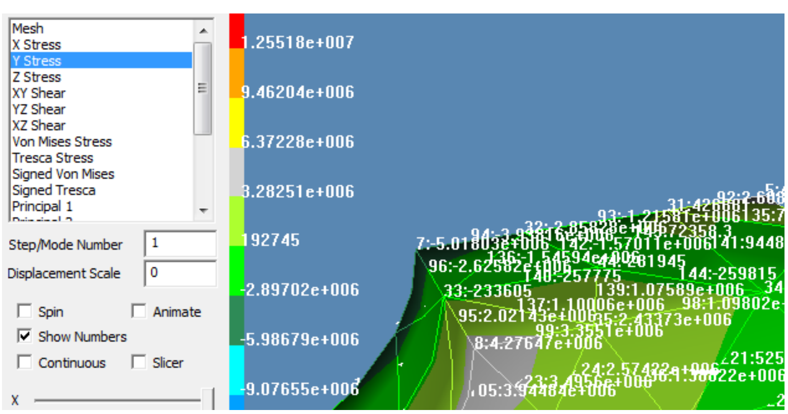


Hex model, fixed midline, Sy=5.34, <u>error=0.4%</u>





Hex model, fully fixed edge, Sy=5.15

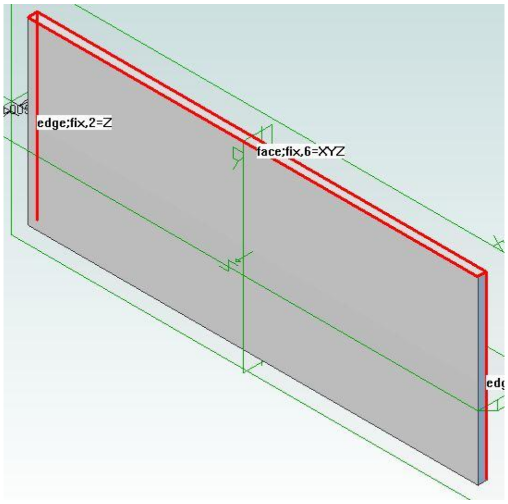


Tet Model, unstructured mesh, fully fixed edge, Sy = 5.01

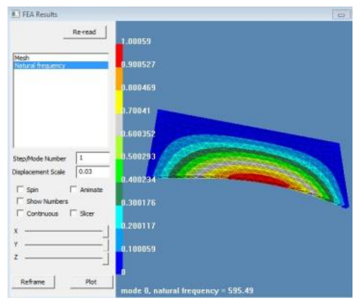
<u>Error = 6.8%</u> from the theoretical structured mesh result

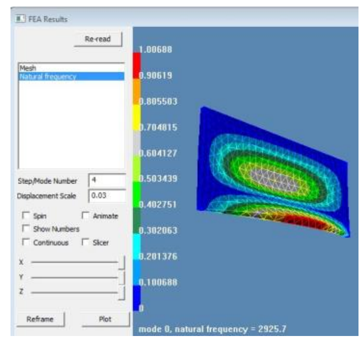
4. Natural frequencies of a rectangular plate

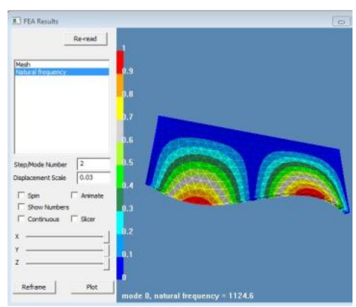
Reference: Blevins, Formula for Natural Frequency and Mode Shape, Van Nostrand Rheinhold Company, Inc., 1979 Table 11-4, Case 11, Page 256.

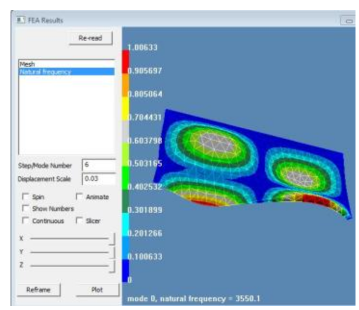


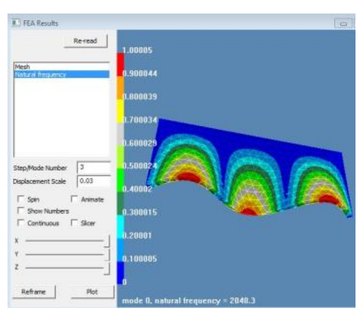
Length = 0.25 m, Width = 0.1m, Thickness = 0.005m
Density = 7850 kg/m^3
Youngs Modulus = 2e11 Pa
Poissons Ratio = 0.3
Local Element Size on face set at 0.01m
One Long End Fully Fixed, Two Short Ends Simply Supported

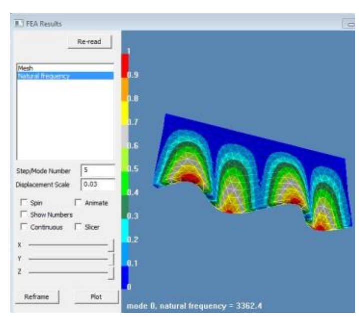












Natural Frequency Results (Hz)

Mode	Target	Result	Error
1	595.7	595.5	0.03%
2	1129.55	1124.6	0.44%
3	2051.79	2048.3	0.17%
4	2906.73	2925.7	0.65%
5	3366.48	3362.4	0.12%