

Chapter 3

2D Simulations

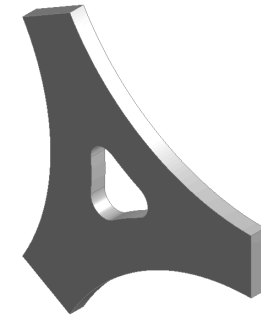
- 3.1 Triangular Plate
- 3.2 Threaded Bolt-and-Nut
- 3.3 More Details
- 3.4 Spur Gears
- 3.5 Structural Error, FE Convergence, and Stress Singularity
- 3.6 Review

Section 3.1

Triangular Plate

Problem Description

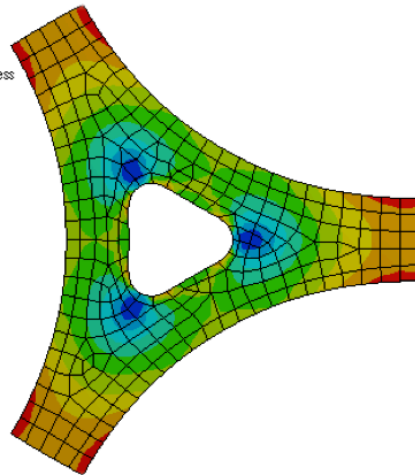
- The plate is made of steel, designed to withstand a tensile force of 20,000 N on each side face.
- We are concerned about the deformations and the stresses.



Techniques/Concepts

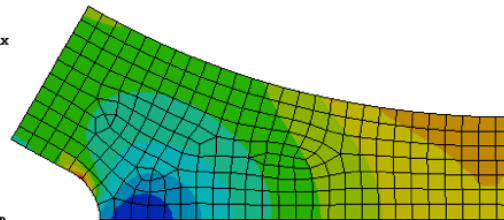
C: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1

53.029 Max
49.253
45.476
41.699
37.922
34.145
30.368
26.592
22.815
19.038 Min



D: 2D Symmetric Model
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1

56.422 Max
52.269
48.116
43.963
39.81
35.657
31.504
27.351
23.198
19.046 Min

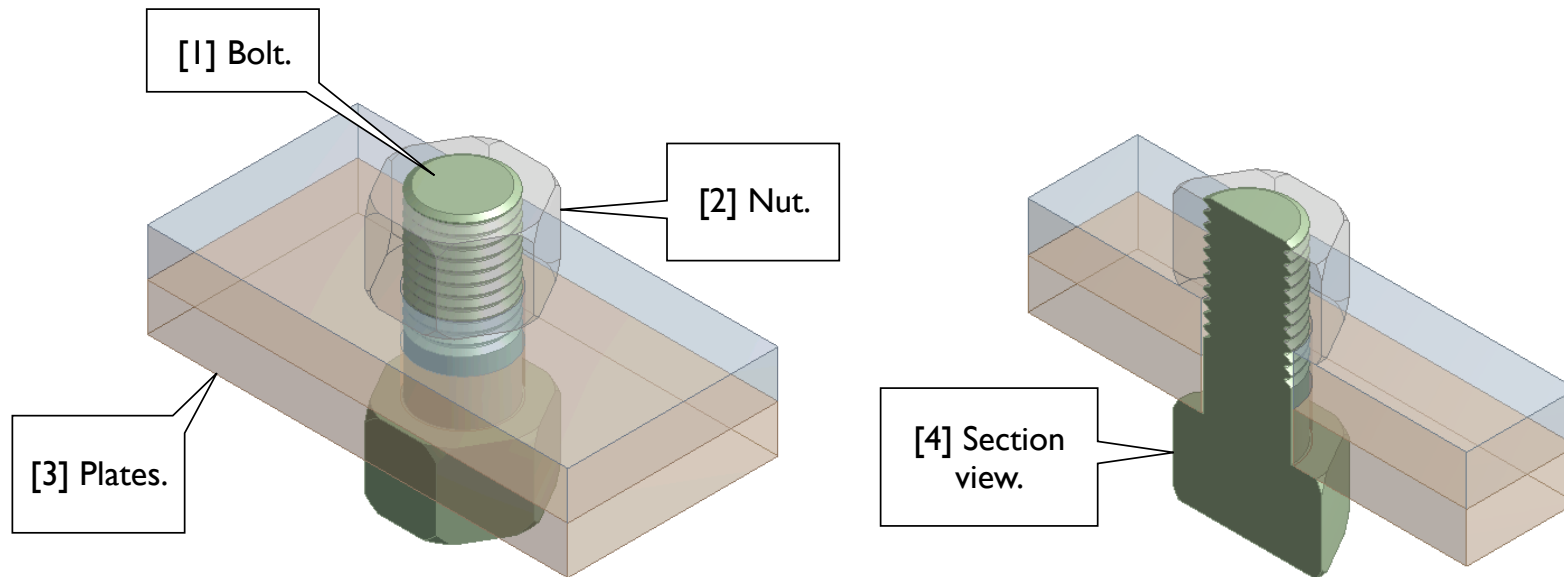


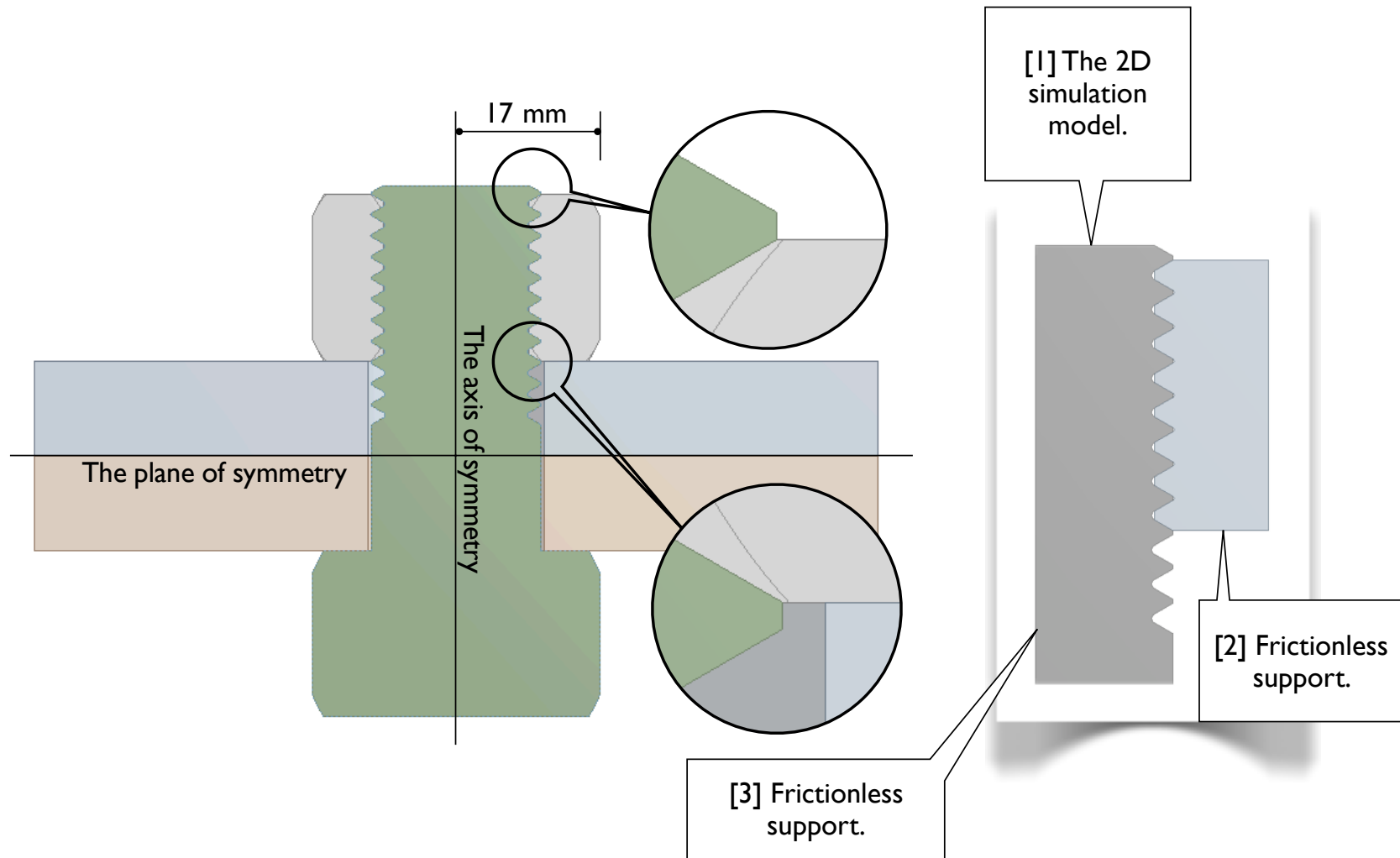
- Project Schematic
- Concepts>Surface From Sketches
- Analysis Type (2D)
- Plane Stress Problems
- Generate 2D Mesh
- 2D Solid Elements
- Relevance Center and Relevance
- Loads>Pressure
- Weak Springs
- Solution>Total Deformation
- Solution>Equivalent Stress
- Tools>Symmetry
- Coordinate System

Section 3.2

Threaded Bolt-and-Nut

Problem Description

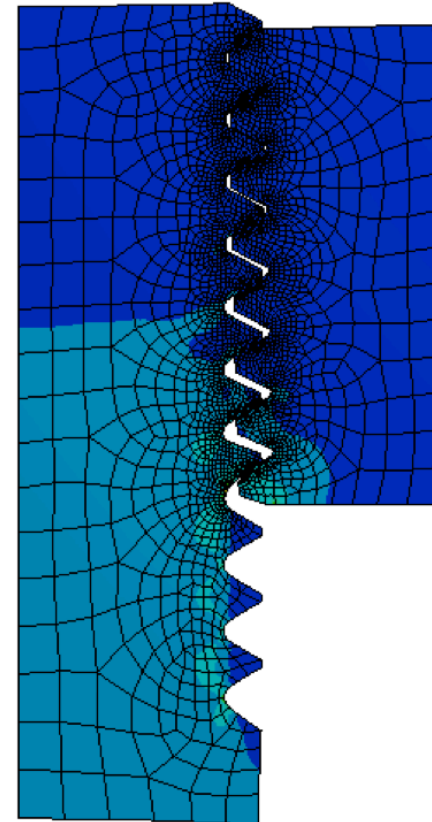
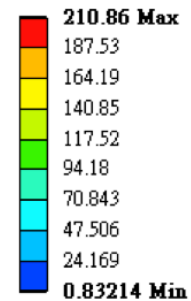




Techniques/Concepts

- Hide/Show Sketches
- Display Model/Plane
- Add Material/Frozen
- Axisymmetric Problems
- Contact/Target
- Frictional Contacts
- Edge Sizing
- Loads>Force
- Supports>Frictionless Support
- Solution>Normal Stress
- Radial/Axial/Hoop Stresses
- Nonlinear Simulations

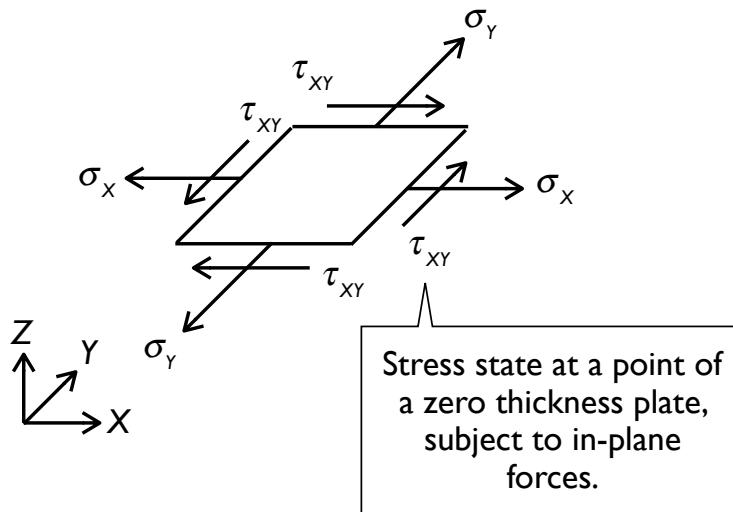
C: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1



Section 3.3

More Details

Plane-Stress Problems



- Plane stress condition:

$$\sigma_z = 0, \quad \tau_{zy} = 0, \quad \tau_{zx} = 0$$

- The Hook's law becomes

$$\varepsilon_x = \frac{\sigma_x}{E} - \nu \frac{\sigma_y}{E}$$

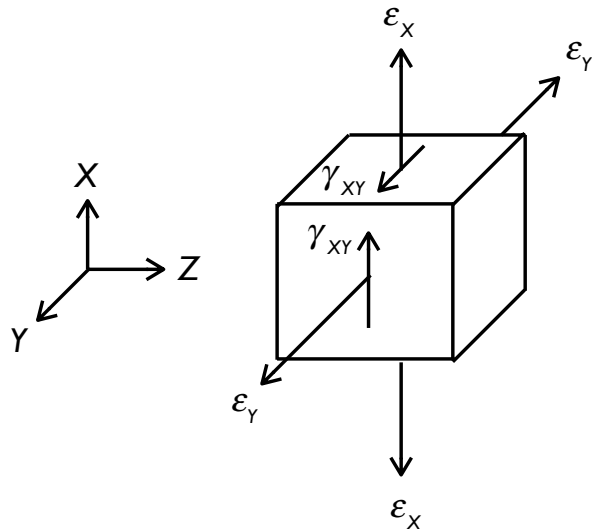
$$\varepsilon_y = \frac{\sigma_y}{E} - \nu \frac{\sigma_x}{E}$$

$$\varepsilon_z = -\nu \frac{\sigma_x}{E} - \nu \frac{\sigma_y}{E}$$

$$\gamma_{xy} = \frac{\tau_{xy}}{G}, \quad \gamma_{yz} = 0, \quad \gamma_{zx} = 0$$

- A problem may assume the plane-stress condition if its thickness direction is not restrained and thus free to expand or contract.

Plane-Strain Problems



[2] Strain state at a point of a plane-strain structure.

- Plane strain condition:

$$\varepsilon_z = 0, \quad \gamma_{zx} = 0, \quad \gamma_{zy} = 0$$

- The Hook's law becomes

$$\sigma_x = \frac{E}{(1+\nu)(1-2\nu)} [(1-\nu)\varepsilon_x + \nu\varepsilon_y]$$

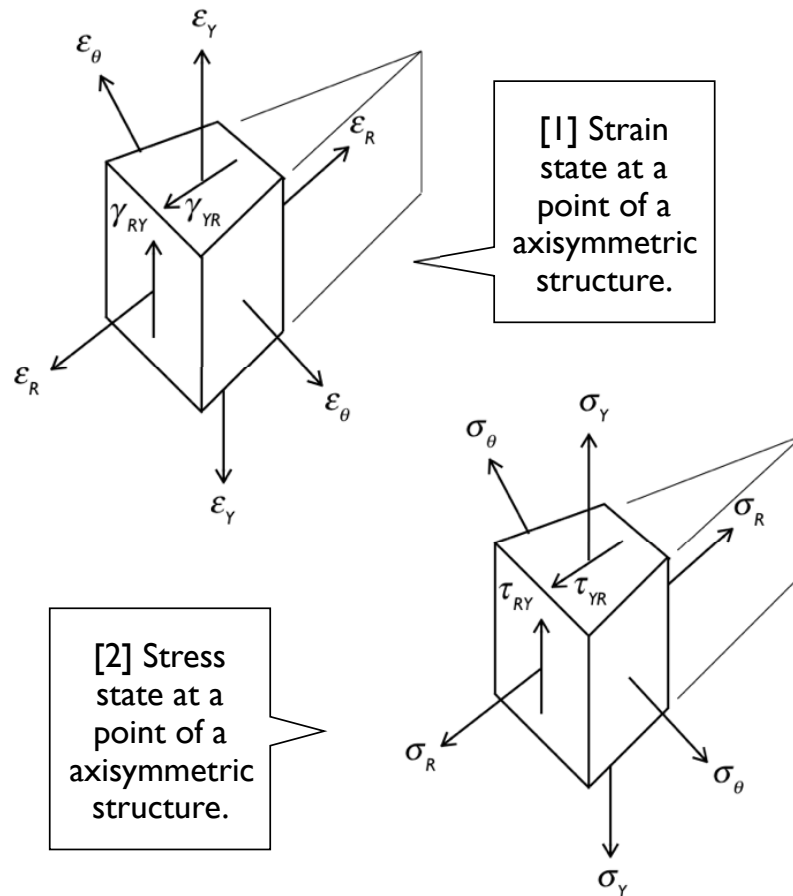
$$\sigma_y = \frac{E}{(1+\nu)(1-2\nu)} [(1-\nu)\varepsilon_y + \nu\varepsilon_x]$$

$$\sigma_z = \frac{E}{(1+\nu)(1-2\nu)} [\nu\varepsilon_x + \nu\varepsilon_y]$$

$$\tau_{xy} = G\gamma_{xy}, \quad \tau_{yz} = 0, \quad \tau_{zx} = 0$$

- A problem may assume the plane-strain condition if its Z-direction is restrained from expansion or contraction, all cross-sections perpendicular to the Z-direction have the same geometry, and all environment conditions are in the XY plane.

Axisymmetric Problems



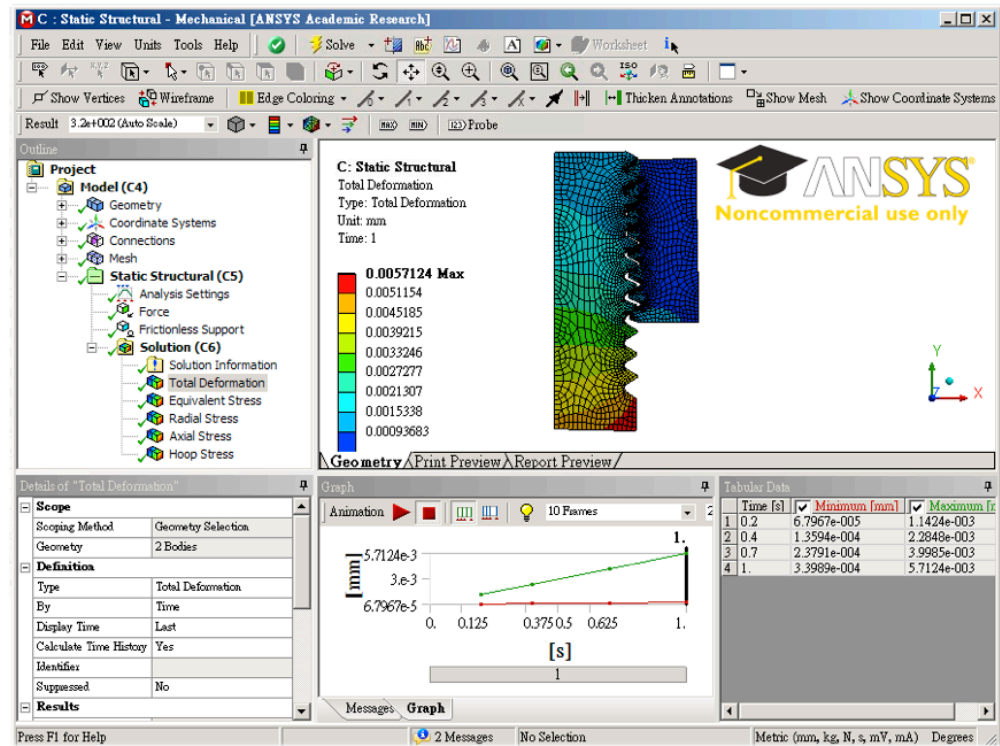
- If the geometry, supports, and loading of a structure are axisymmetric about the Y -axis, then all response quantities are independent of θ coordinate.
- In such a case,

$$\gamma_{\theta R} = 0, \quad \gamma_{\theta Y} = 0$$

$$\tau_{\theta R} = 0, \quad \tau_{\theta Y} = 0$$
- both σ_θ and ϵ_θ are generally not zero. They are termed *hoop stress* and *hoop strain* respectively.

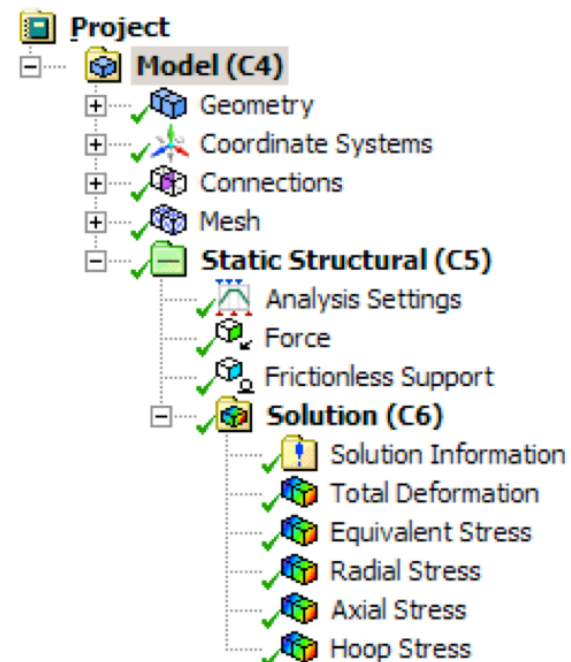
Mechanical GUI

- Pull-down Menus and Toolbars
- Outline of Project Tree
- Details View
- Geometry
- Graph
- Tabular Data
- Status Bar
- Separators



Project Tree

- A project tree may contain one or more simulation models.
- A simulation model may contain one or more **Environment** branches, along with other objects. Default **Environment** branch name is the analysis system name.
- An **Environment** branch contains **Analysis Settings**, environment conditions, and a **Solution** branch.
- A **Solution** branch contains **Solution Information** and results objects.



Unit Systems

- Consistent versus Inconsistent Unit Systems.
- Built-in versus User-Defined Unit Systems.
- Project Unit System.
- Internal Consistent Unit System.

The screenshot shows a dialog box for selecting a unit system. It has four columns: A (Unit System), B (radio button), C (checkbox), and D (checkbox). The rows list various unit systems, including SI, Metric, U.S. Customary, U.S. Engineering, and several Consistent systems (CGS, NMM, μMKS, BIN, BFT). Callouts provide context for the interface elements.

	A	B	C	D
1	Unit System	☒	☐	☒
2	SI (kg,m,s,K,A,N,V)	☐	☐	☐
3	Metric (kg,m,s, °C,A,N,V)	☒	☒	☐
4	Metric (tonne,mm,s, °C,mA,N,mV)	☐	☐	☐
5	U.S.Customary (lbm,in,s, °F,A,lbF,V)	☐	☐	☐
6	U.S.Engineering (lb,in,s,R,A,lbF,V)	☐	☐	☐
7	Metric (g,cm,s, °C,A,dyne,V)	☐	☐	☒
8	Metric (kg,mm,s, °C,mA,N,mV)	☐	☐	☒
9	Metric (kg,μm,s, °C,mA,μN,V)	☐	☐	☒
10	Metric (decatonne,mm,s, °C,mA,N,mV)	☐	☐	☒
11	U.S.Customary (lbm,ft,s, °F,A,lbF,V)	☐	☐	☒
12	Consistent CGS	☐	☐	☒
13	Consistent NMM	☐	☐	☒
14	Consistent μMKS	☐	☐	☒
15	Consistent BIN	☐	☐	☒
16	Consistent BFT	☐	☐	☒

[1] Built-in unit systems.

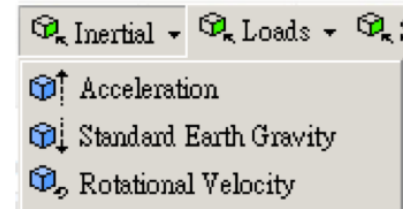
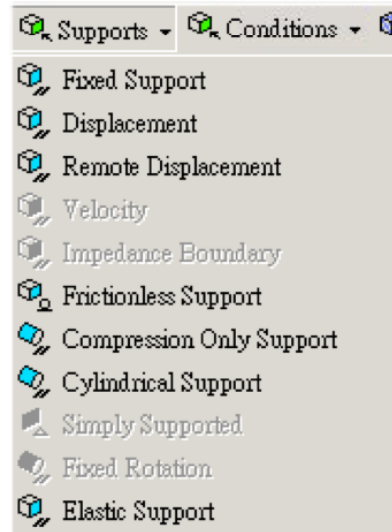
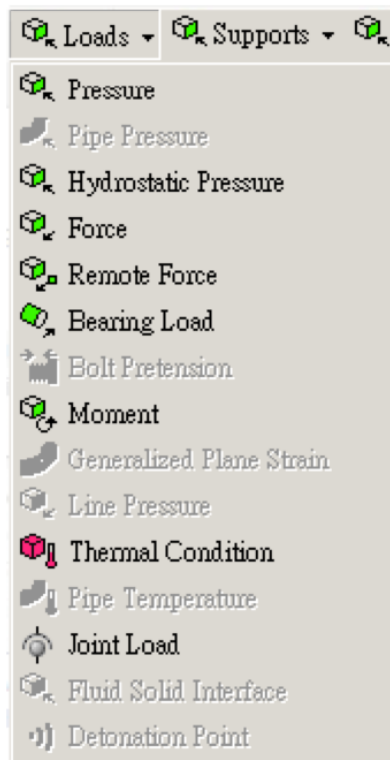
[2] Unit system for current project.

[3] Default project unit system.

[4] Checked unit systems won't be available in the pull-down menu.

[5] These, along with the SI, are consistent unit systems.

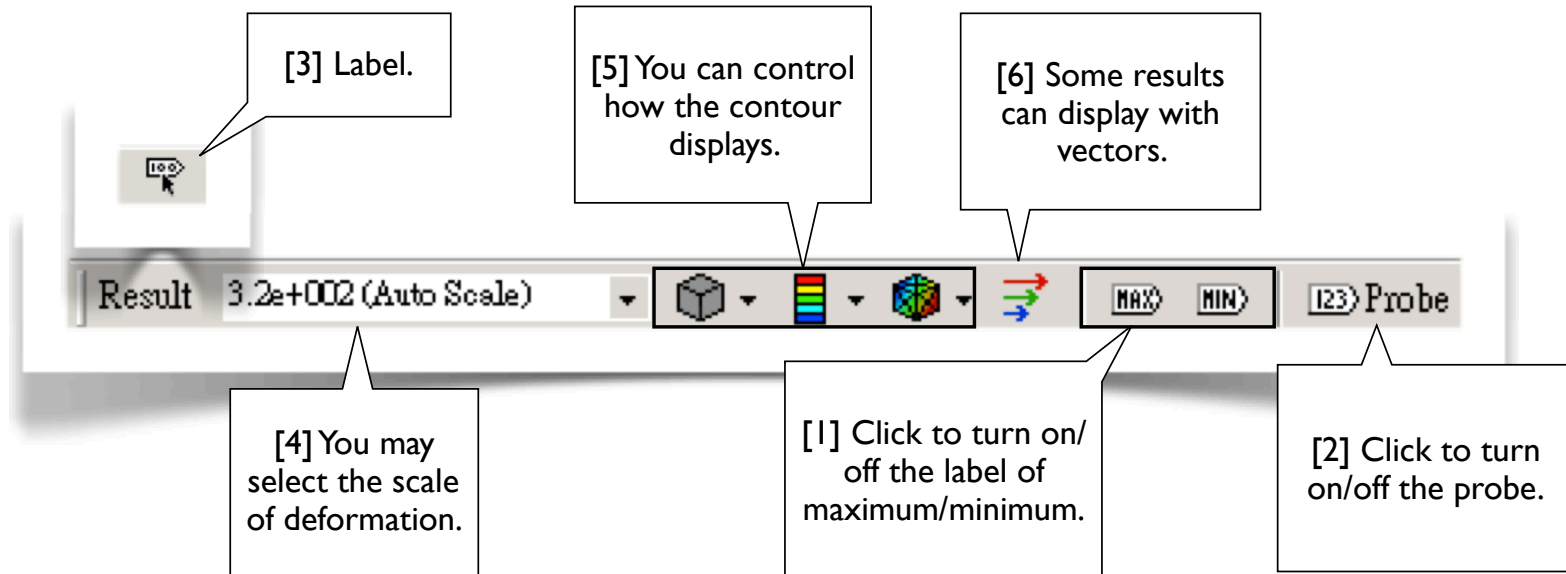
Environment Conditions



Results Objects



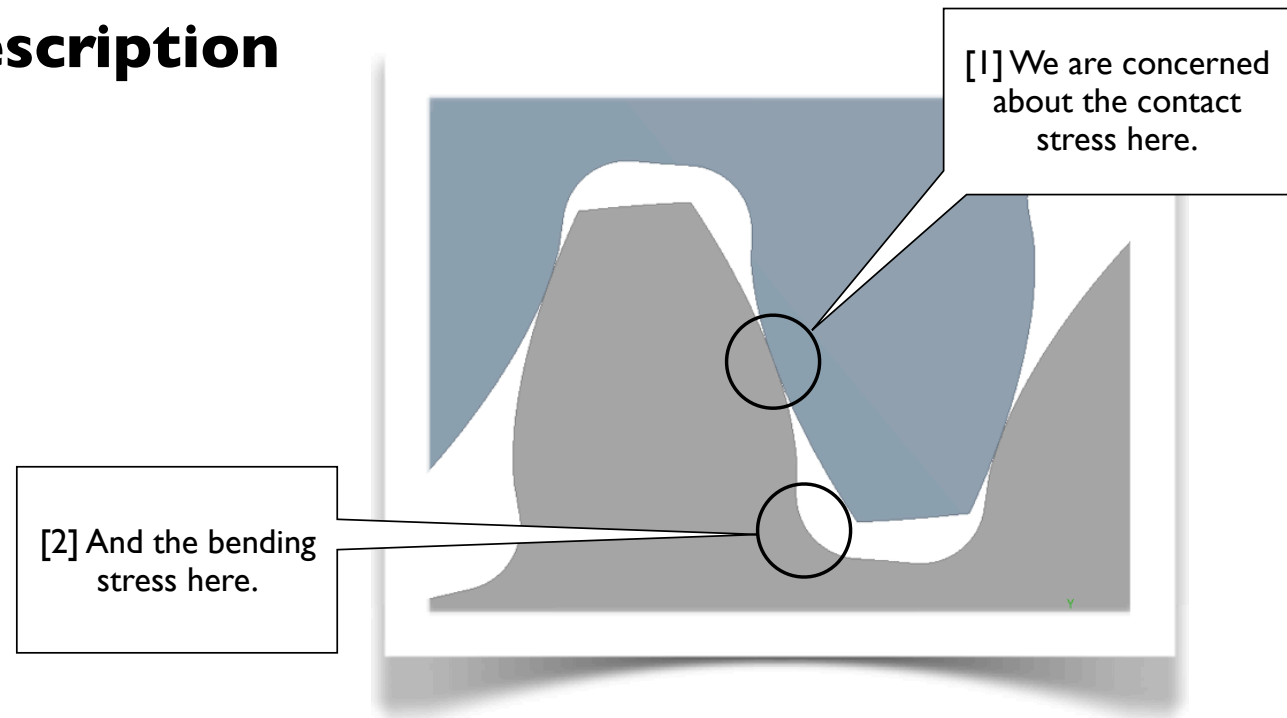
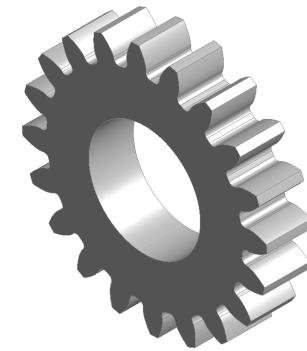
View Results



Section 3.4

Spur Gears

Problem Description



Techniques/Concepts

- Copy bodies (Translate)
- Contacts
 - Frictionless
 - Symmetric (Contact/Target)
 - Adjust to Touch
- Loads>Moment
- True Scale

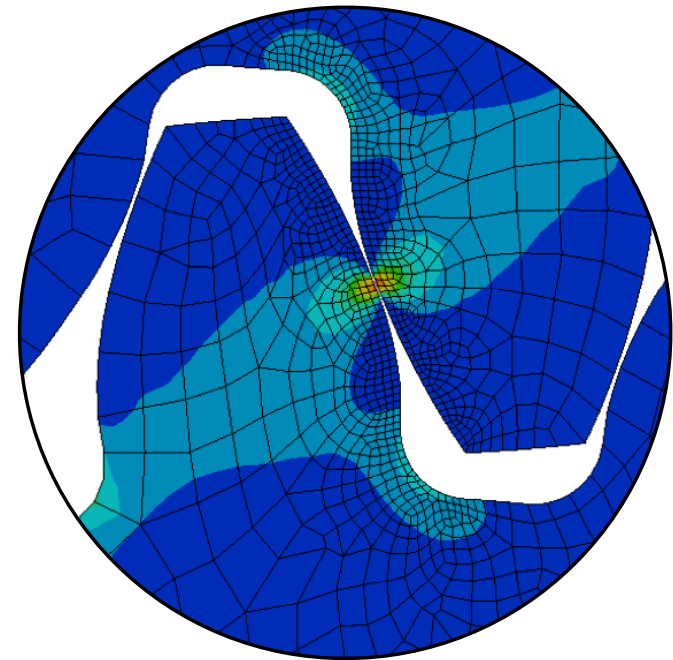
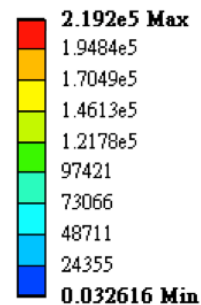
C: 2D Gear Set Simulation

Equivalent Stress

Type: Equivalent (von-Mises) Stress

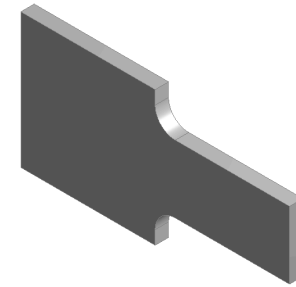
Unit: psi

Time: 1

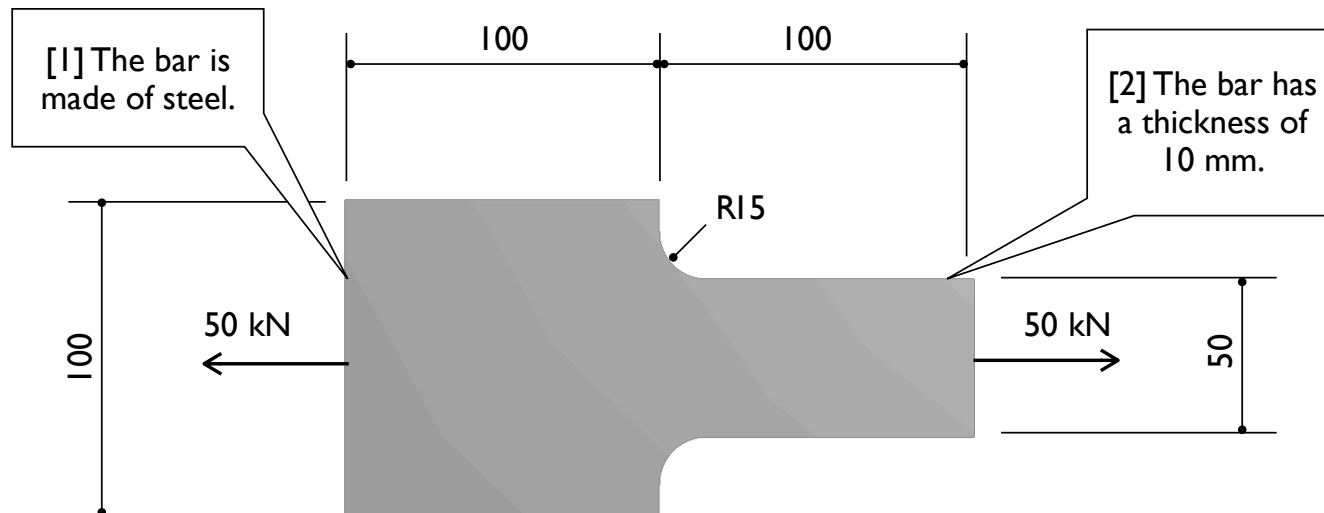


Section 3.5

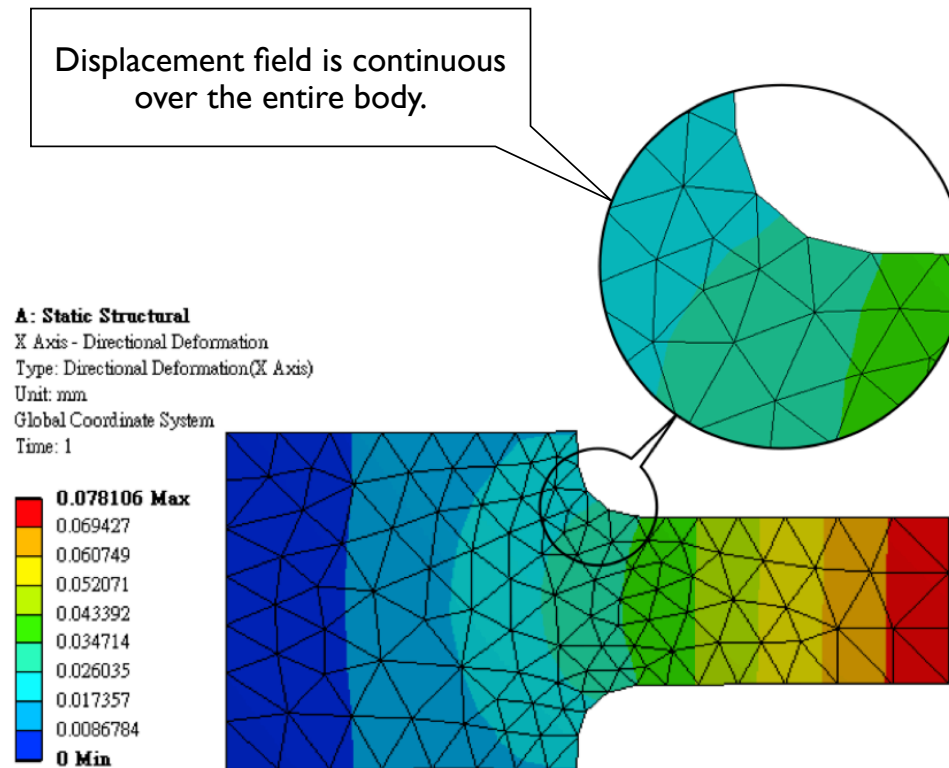
Structural Error, FE Convergence, and Stress Singularity



Problem Description



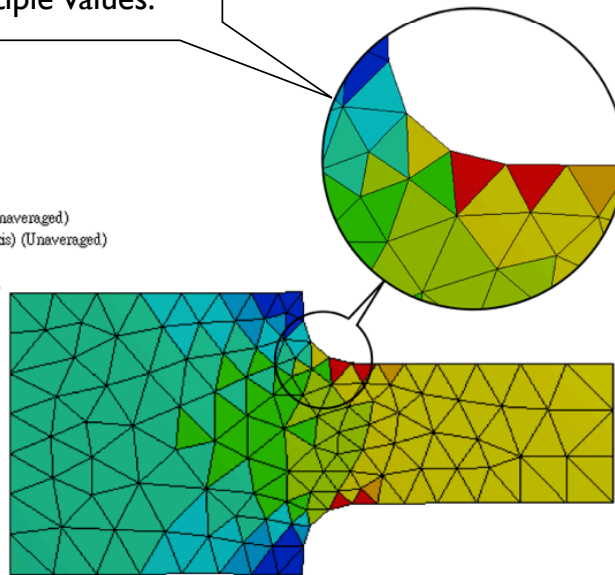
Part A. Stress Discontinuity



[1] Original calculated stresses (unaveraged) are not continuous across element boundaries, i.e., stress at boundary has multiple values.

A: Static Structural
 X Axis - Normal Stress (Unaveraged)
 Type: Normal Stress(X Axis) (Unaveraged)
 Unit: MPa
 Global Coordinate System
 Time: 1

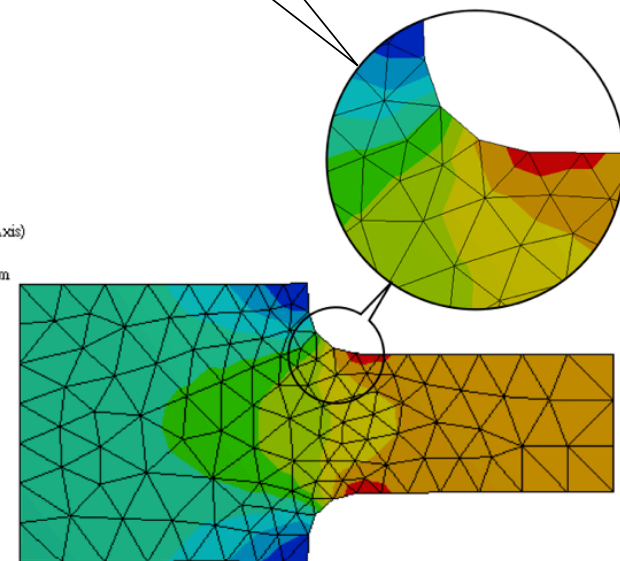
138.5 Max
 123
 107.49
 91.989
 76.485
 60.982
 45.478
 29.974
 14.471
-1.0331 Min



[2] By default, stresses are averaged on the nodes, and the stress field is recalculated. That way, the stress field is continuous over the body.

A: Static Structural
 X Axis - Normal Stress
 Type: Normal Stress(X Axis)
 Unit: MPa
 Global Coordinate System
 Time: 1

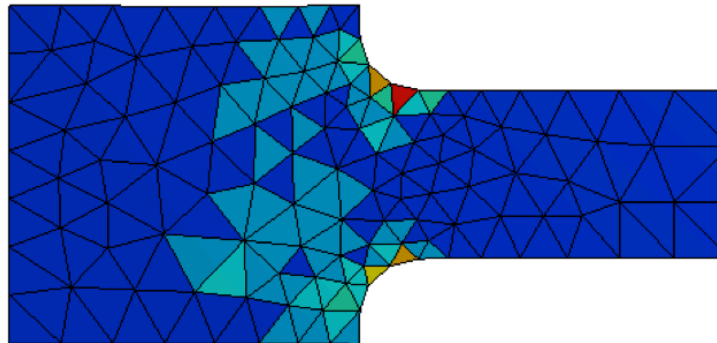
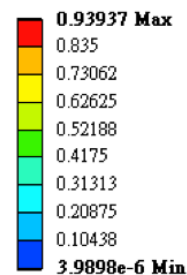
122.9 Max
 109.44
 95.982
 82.522
 69.062
 55.602
 42.142
 28.682
 15.222
1.7623 Min



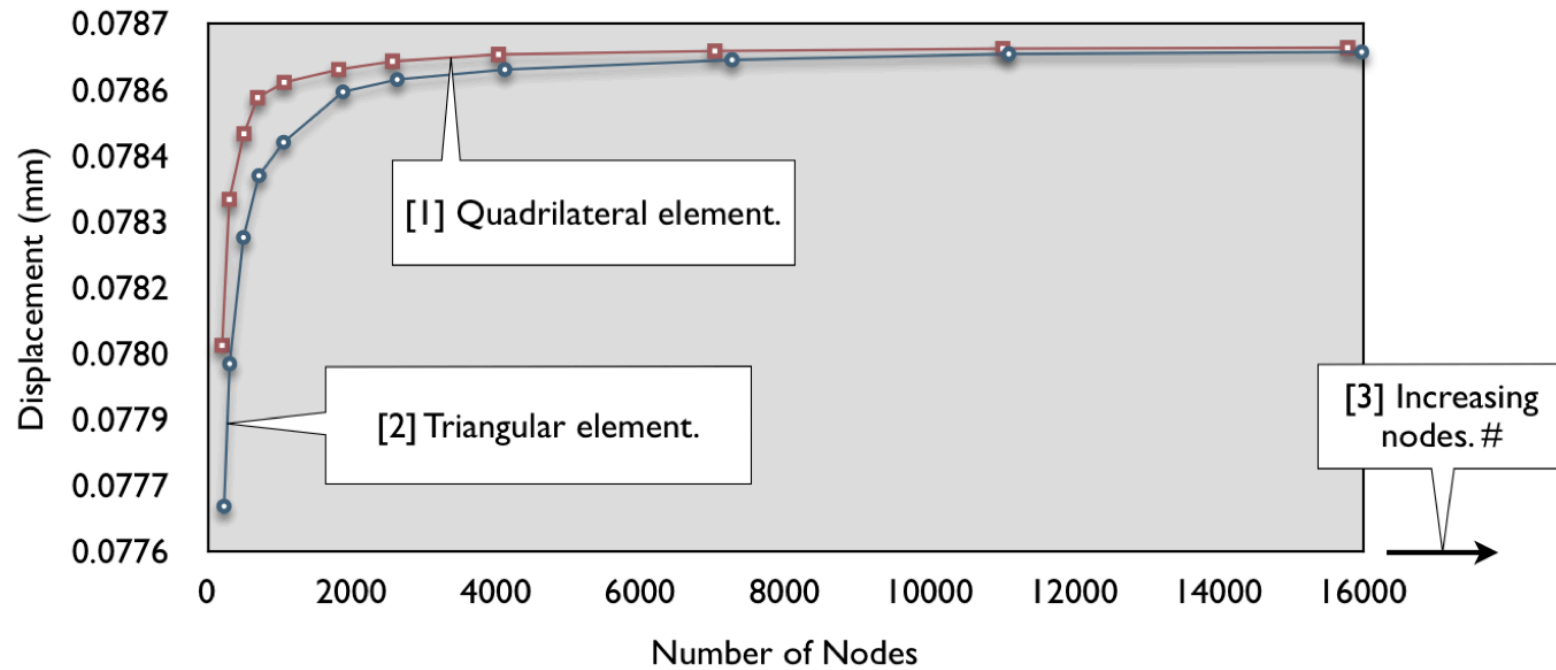
Part B. Structural Error

- For an element, strain energies calculated using averaged stresses and unaveraged stresses respectively are different. The difference between these two energy values is called **Structural Error** of the element.
- The finer the mesh, the smaller the structural error. Thus, the structural error can be used as an indicator of mesh adequacy.

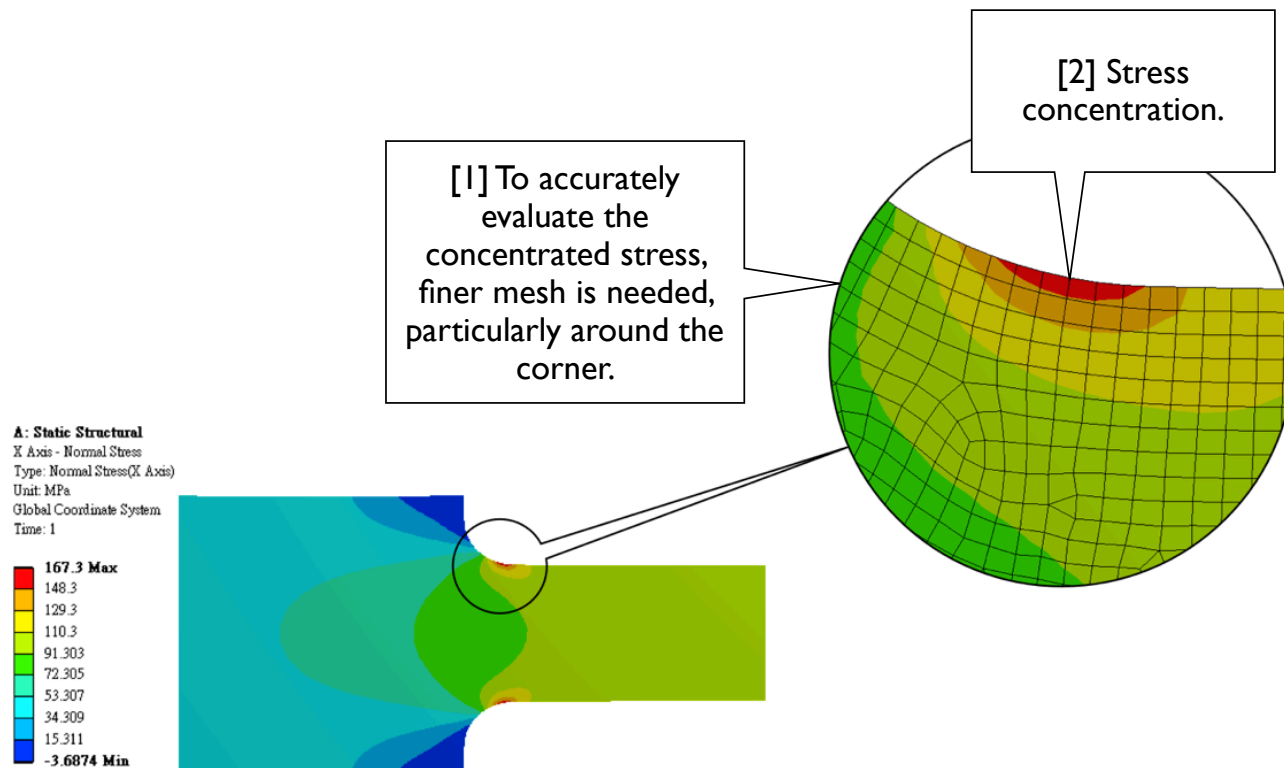
A: Static Structural
Structural Error
Type: Structural Error
Unit: mJ
Time: 1



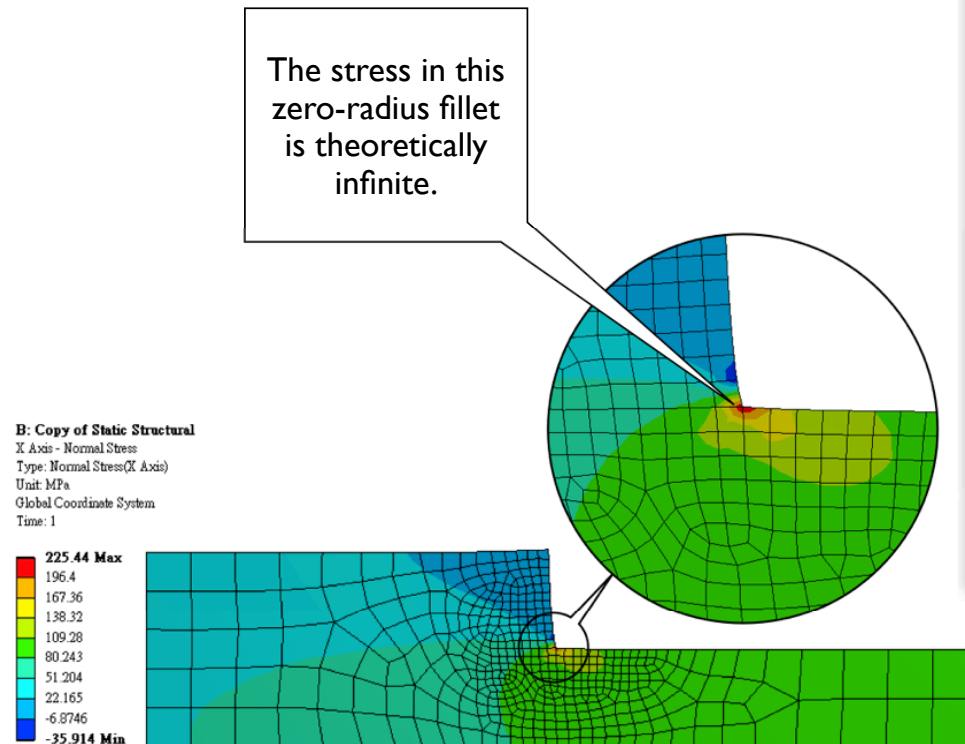
Part C. Finite Element Convergence



Part D. Stress Concentration



Part E. Stress Singularity



- Stress singularity is not limited to sharp corners.
- Any locations that have stress of infinity are called singular points.
- Besides a concave fillet of zero radius, a point of concentrated forces is also a singular point.