<div align="center">**Concept Map Manual**</div>

Purpose:
This manual contains the instructions for using the Concept Map software. We will show the features by solving three problems: (i) rosette and maximum, shear strain calculation, (ii) rosette and maximum, shear stress calculation, and (iii) stress-strain calculation for a thin-walled, cylindrical pressure vessel.

Start-Up
Two concept maps are included in this package: (i) thin-walled, cylindrical pressure vessels, and (ii) stress-strain calculations. We can choose which concept to use as follows:

- ✓ Choose open from the "File" menu
- ✓ Click radio-button to select map.
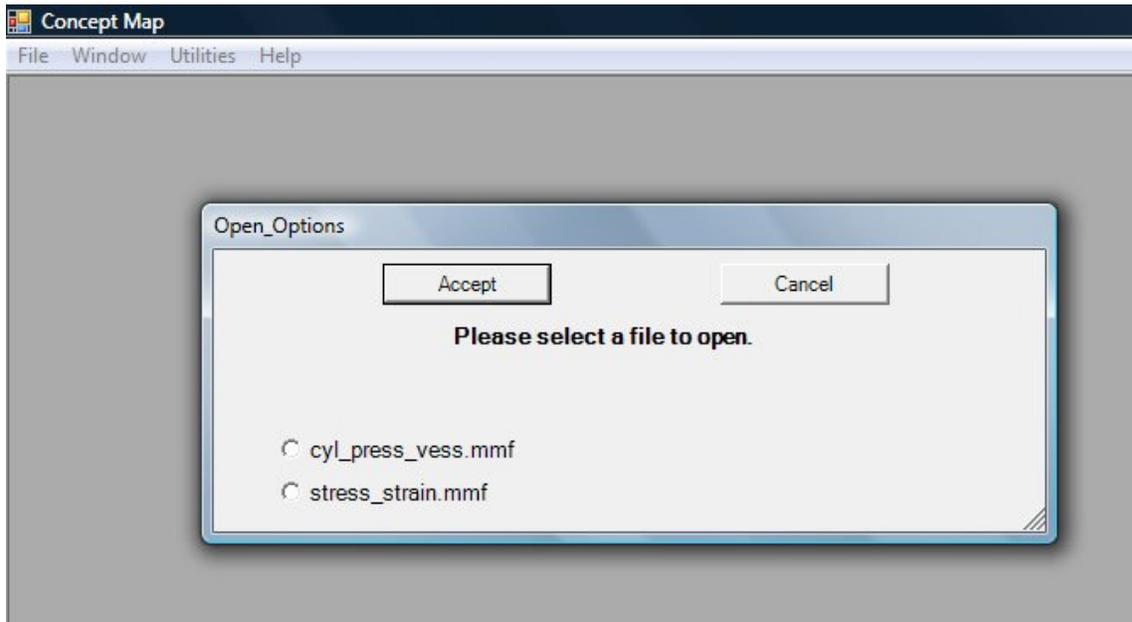
Features of Start-up Window:
1. From the "File" drop down menu you can open concept maps and close the program.
2. In the 'Utilities' drop down menu, you will find a calculator
3. In the 'Mode' drop down menu, you will find and 'Angle' selector which allows you to choose either degrees or radians as your unit of angle measurement.

Three example problems are used to demonstrate the use of the Concept Map tool.
1. Maximum shear strain
2. Maximum shear stress
3. Cylindrical Pressure Vessel

Calculate Maximum Shear Strain:
A strain rosette, composed of three electrical resistance strain gages making angles of 0, 60, and 120 degrees with the x-axis was mounted on the free surface of a material for which Poisson's ratio is 1/3. Under load, the following strains were measured:

$\varepsilon_a = +1000\mu$ $\qquad \varepsilon_b = +750\mu$ $\qquad \varepsilon_c = -650\mu$

Determine the principal strains and maximum shear strain.

Main Screen
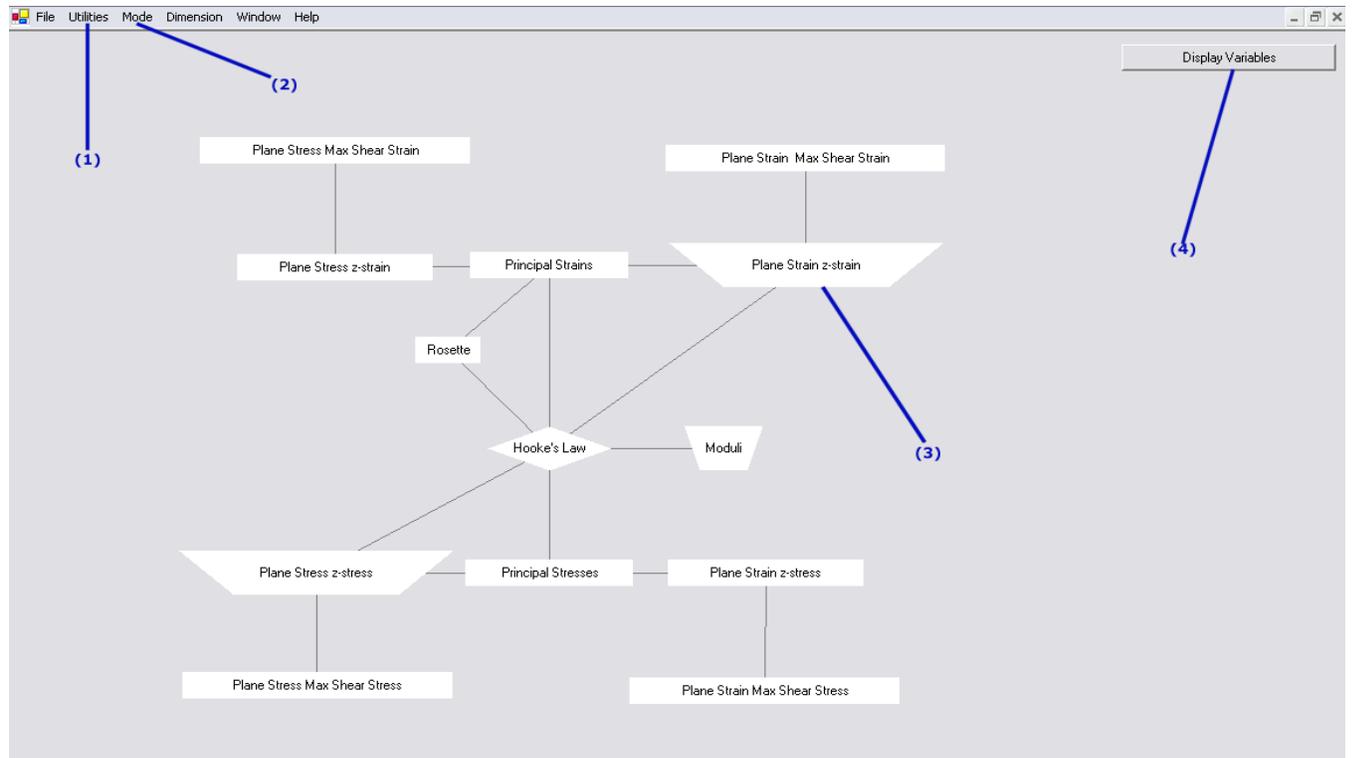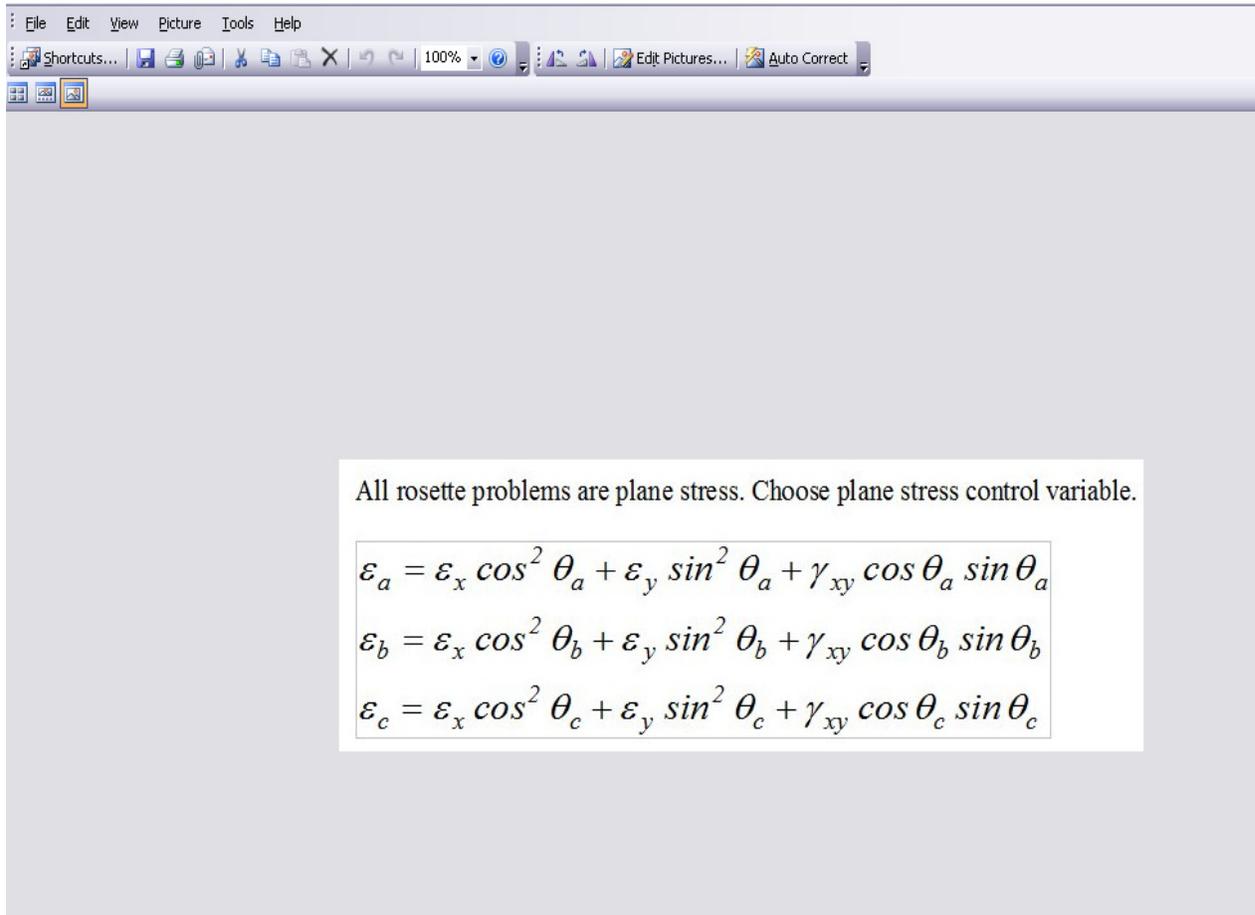The main screen of the stress-strain concept map is shown in Figure-1.

Figure 1: Stress-Strain Concept Map

The 'spine' of the map includes three nodes: Principal Strains, Hooke's Law, and Principal Stresses. These three nodes represent the three fundamental concepts in the area of stress-strain calculation. The 'right limbs' deal with the plane strain situations, and the "left limbs" deal with the plane stress situations. In addition, there are two more limbs that deal rosettes and elastic properties. This tool will aid you in identifying the most efficient path to take in order to calculate your desired quantities. The tool also identifies ill-posed problems with insufficient information.
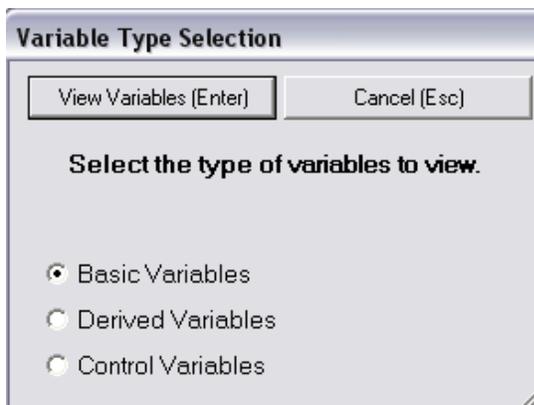
More Info:

The information contained in each node can be viewed by right-clicking on a node, and clicking "More Info". If we did this for the "Rosette" node, the information contained in the "Rosette" node will be displayed as follows.

All rosette problems are plane stress. Choose plane stress control variable.

$$\varepsilon_a = \varepsilon_x \cos^2 \theta_a + \varepsilon_y \sin^2 \theta_a + \gamma_{xy} \cos \theta_a \sin \theta_a$$

$$\varepsilon_b = \varepsilon_x \cos^2 \theta_b + \varepsilon_y \sin^2 \theta_b + \gamma_{xy} \cos \theta_b \sin \theta_b$$

$$\varepsilon_c = \varepsilon_x \cos^2 \theta_c + \varepsilon_y \sin^2 \theta_c + \gamma_{xy} \cos \theta_c \sin \theta_c$$

Problem Setup:

✓ Click the 'Display Variables' button to get the following window:

Variable Type Selection

| View Variables (Enter) | Cancel (Esc) |

Select the type of variables to view.

⦿ Basic Variables

○ Derived Variables

○ Control Variables

✓ Click the 'View Variables' button

The 'Basic Variables' option is set as the default as seen from the label "Basic" in the drop-down menu at top right.

✓ Check the boxes for the known variables on the left side of the window under the heading 'KNOWN Variables' heading.

The rosette is mounted on the free surface of a material; therefore, the present problem is a plane-stress problem.

✓ Select the 'Control' option in pull-down menu at top right.
✓ Click the 'Add Other Variables' button.

✓ Select 'Plain Strain Control-C_stress'.

Finally we must select the desired variable.

- ✓ Select 'Derived' from the drop down menu in the upper right
- ✓ Click the 'Add Other Variables' button once.

Displaying all variables in map

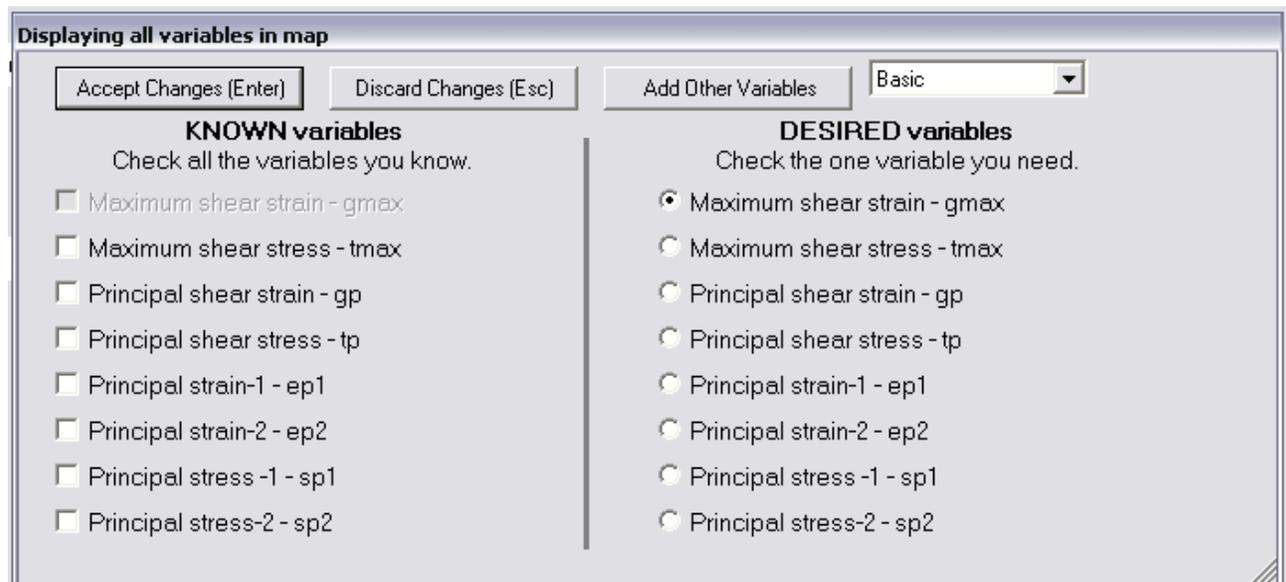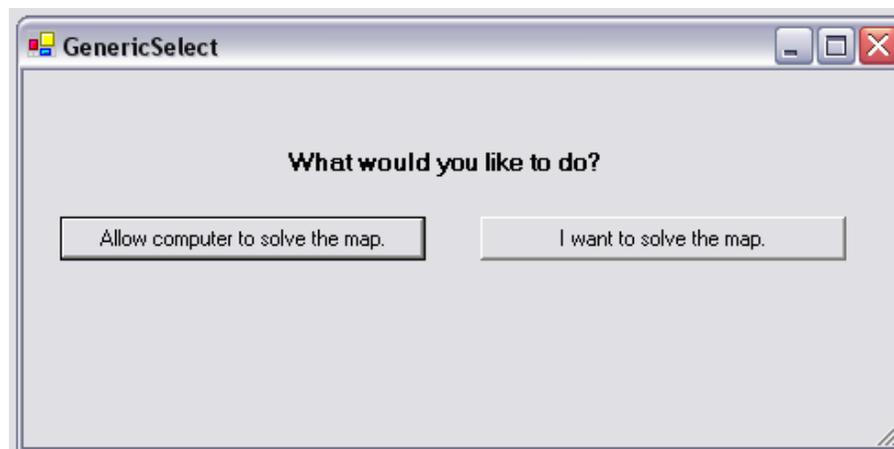| Accept Changes (Enter) | Discard Changes (Esc) | Add Other Variables | Basic ▾ |

KNOWN variables
Check all the variables you know.

- ☐ Maximum shear strain - gmax
- ☐ Maximum shear stress - tmax
- ☐ Principal shear strain - gp
- ☐ Principal shear stress - tp
- ☐ Principal strain-1 - ep1
- ☐ Principal strain-2 - ep2
- ☐ Principal stress -1 - sp1
- ☐ Principal stress-2 - sp2

DESIRED variables
Check the one variable you need.

- ⊙ Maximum shear strain - gmax
- ○ Maximum shear stress - tmax
- ○ Principal shear strain - gp
- ○ Principal shear stress - tp
- ○ Principal strain-1 - ep1
- ○ Principal strain-2 - ep2
- ○ Principal stress -1 - sp1
- ○ Principal stress-2 - sp2

- ✓ Select "Maximum shear strain – gmax" as the desired variable.
- ✓ Click the 'Accept Changes (Enter)' button.

GenericSelect

What would you like to do?

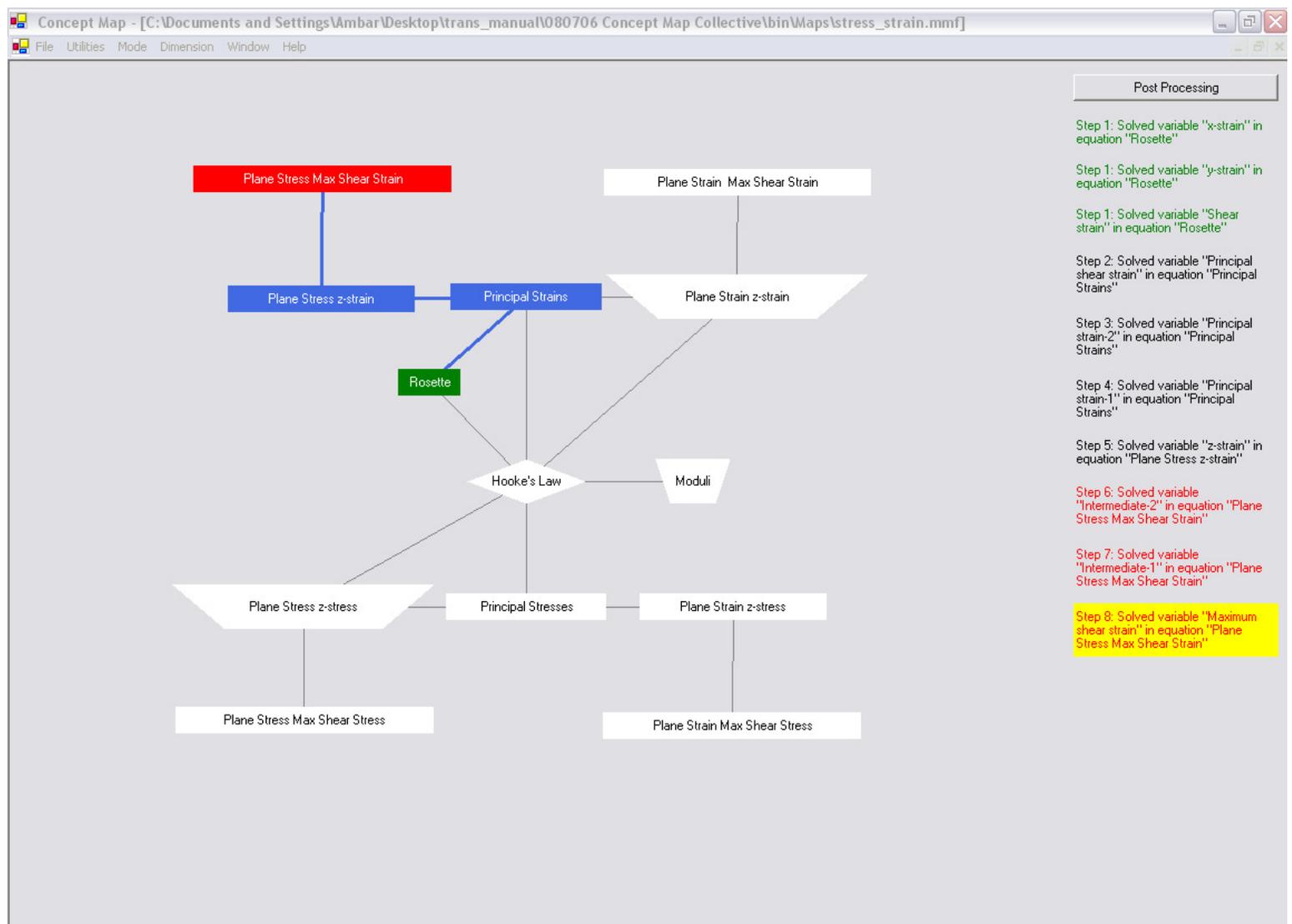| Allow computer to solve the map. | I want to solve the map. |

At this point, we will allow the computer to solve the problem for us.

- ✓ Click 'Allow computer to solve the map' button.

After the application processes the possible solutions, we will be presented with the following window:
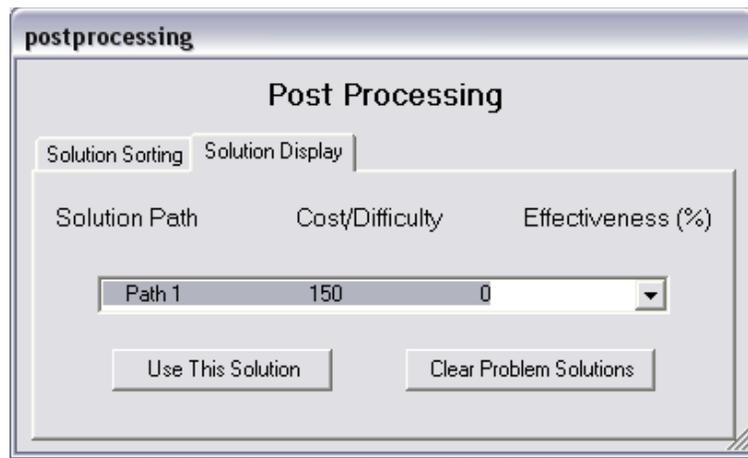
✓ Click the 'Use This Solution' button.

The highlighted nodes represent the concepts required for solving the problem.

✓ You can see the information contained in the nodes in the solution path by right-clicking on any node and by selecting "More Info".

On the right hand side of the screen, we see the steps involved in reaching the solution. **We will notice that "Step 1" appears three times. When a solution step appears more than once, it means that the step requires solution of simultaneous equations.**

✓ Double-click anywhere on the text-block "Step-1: …"

The boxes with the yellow shading represent known variables where the software expects numeric values for the corresponding variables. We cannot enter exponents in these boxes, so 1000μ has to be entered as 0.001.

✓ Enter numeric values for ea, eb, ec, theta_a, theta_b, theta_c.
✓ Check ex (Solved variable x-strain)
✓ Check ey (Solved variable y-strain)
✓ Check gxy (Solved variable shear strain)
✓ Click "Solve"

When the solution is complete, the scroll bar on the right will shrink. We can now scroll down to see the calculated values.

Simultaneous Equations

☑ ex - x-strain	=	0
☐ theta_a - Angle-a	=	0
☑ ey - y-strain	=	0
☑ gxy - Shear strain	=	0
☐ ea - Strain-a	=	.001

Node Rosette

☑ ex - x-strain	=	0
☐ theta_b - Angle-b	=	60
☑ ey - y-strain	=	0
☑ gxy - Shear strain	=	0
☐ eb - Strain-b	=	.00075

Node Rosette

☑ ex - x-strain	=	0
☐ theta_c - Angle-c	=	120
☑ ey - y-strain	=	0
☑ gxy - Shear strain	=	0
☐ ec - Strain-c	=	-.00065

Solve   Resolve   Clear Solution   Finished

Solution:

ex = 0.00099999999999

ey = -0.0002666666666

gxy = 0.00161658075373

After we obtain the solutions to this step, we have several options: (i) we can click 'Resolve' to determine another solution (some problems, such as quadratic equations have multiple solutions). (ii) We can clear the solution, enter new values for the known variables and "Solve" again. (iii) Click 'Finished' tab and move to the next step.

✓ Click the 'Finished' button.

When a step has been completed, its corresponding text on the right side of the screen will turn blue.

✓ Double-click anywhere on the text-box for Step-2

- ✓ Uncheck "Solve Equation-1" (we are not solving for ep1)
- ✓ Uncheck "Solve Equation-2" (we are not solving for ep2)
- ✓ Check "Solve Equation-3" (we are solving for Principal shear strain)
- ✓ Check gp (Solved variable Principal shear strain)
- ✓ Click "Solve"

- ✓ Click "Finished"
- ✓ Double-click anywhere on the text-box for Step-3

- ✓ Uncheck "Solve Equation-2" (we are not solving for ep1)
- ✓ Check "Solve Equation-1" (we are solving for ep2)
- ✓ Uncheck "Solve Equation-3" (we are not solving for gp)
- ✓ Check "ep2" (Solved variable principal strain-2)
- ✓ Click "Solve"

Solve Equation

☐ Solve equation 1?

☐ ex - x-strain   =   0.0009999

☐ ey - y-strain   =   -0.0002666

☐ gxy - Shear strain   =   0.0016165

☐ ep1 - Principal strain-1   =   0

Equation 2

☑ Solve equation 2?

☐ ex - x-strain   =   0.0009999

☐ ey - y-strain   =   -0.0002666

☐ gxy - Shear strain   =   0.0016165

☑ ep2 - Principal strain-2   =   0

Equation 3

☐ Solve equation 3?

☐ ex - x-strain   =   0.0009999

☐ ey - y-strain   =   -0.0002666

☐ gxy - Shear strain   =   0.0016165

☐ gp - Principal shear strain   =   0.0020537

| Solve | Resolve | Clear Solution | Finished |

Solution:

ep2 =   -0.0006601949105

- ✓ Click "Finished"
- ✓ Double-click anywhere on the text-box for Step-4

- ✓ Check "Solve Equation-1" (we are solving for ep1)
- ✓ Uncheck "Solve Equation-2" (we are not solving for ep2)
- ✓ Uncheck "Solve Equation-3" (we are not solving for gp)
- ✓ Check "ep1" (Solved variable principal strain-1)
- ✓ Click "Solve"
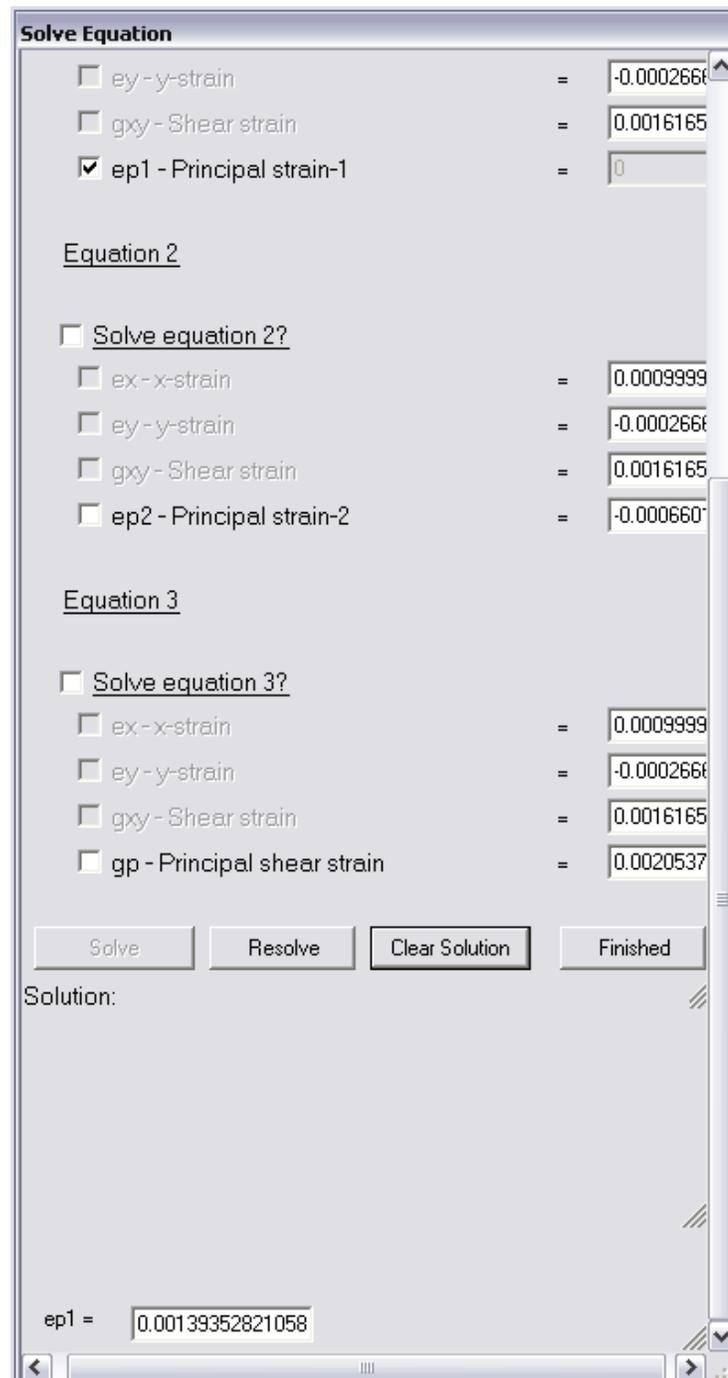
- ✓ Click the "Finished" button
- ✓ Double Click anywhere on the "Step 5" text

- ✓ Enter Poisson's ratio
- ✓ Check "z-strain"
- ✓ Click "Solve"

Solve Equation

Plane Stress z-strain

pl_stress_ez.jpg

Select one variable per group to solve for:

Give values to known variables

Equation 1

☑ Solve equation 1?

☐ nu - Poisson's Ratio	=	0.3333
☐ ex - x-strain	=	0.0009999
☐ ey - y-strain	=	-0.0002666
☐ C_stress - Plane Stress Control	=	Turned On
☑ ez - z-strain	=	0

| Solve | Resolve | Clear Solution | Finished |

Solution:

ez = -0.0003666116527

- ✓ Click "Finished"
- ✓ Double Click on the "Step 6" text

- ✓ Uncheck Solve Equations1 and Solve Equation 3
- ✓ Check Solve equation 2
- ✓ Check "Intermediate 2"
- ✓ Click "Solve"
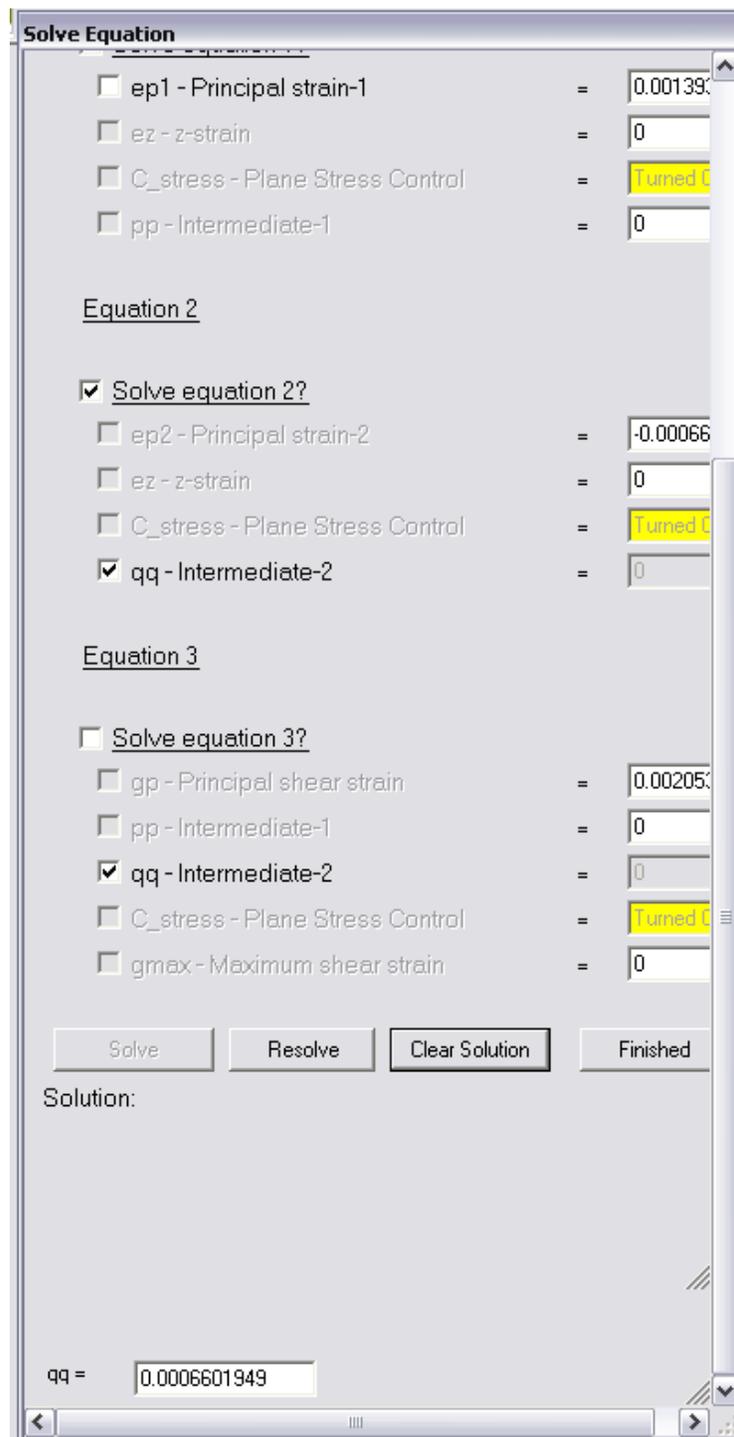
- ✓ Hit "Finished"
- ✓ Double click on "Step 7" text

- ✓ Uncheck Solve Equation 2 and Solve Equation 3
- ✓ Check Solve equation 1
- ✓ Check "Intermediate 1"
- ✓ Hit "Solve"

Solve Equation

Select one variable per group to solve for:

Give values to known variables

Equation 1

☑ Solve equation 1?
- ☐ ep1 - Principal strain-1   =   0.0013935
- ☐ ez - z-strain   =   0
- ☐ C_stress - Plane Stress Control   =   Turned On
- ☑ pp - Intermediate-1   =   0

Equation 2

☐ Solve equation 2?
- ☐ ep2 - Principal strain-2   =   -0.0006601
- ☐ ez - z-strain   =   0
- ☐ C_stress - Plane Stress Control   =   Turned On
- ☐ qq - Intermediate-2   =   0.0006601

Equation 3

☐ Solve equation 3?
- ☐ gp - Principal shear strain   =   0.0020537
- ☑ pp - Intermediate-1   =   0
- ☐ qq - Intermediate-2   =   0.0006601
- ☐ C_stress - Plane Stress Control   =   Turned On
- ☐ gmax - Maximum shear strain   =   0

| Solve | Resolve | Clear Solution | Finished |

Solution:

- ✓ Hit "Finished"
- ✓ Double click the "Step 8" text

- ✓ Uncheck Solve Equation 1 and Solve Equation 2
- ✓ Check Solve Equation 3
- ✓ Check "Maximum Shear Strain"
- ✓ Hit "Solve"

Solve Equation

Solve equation 1?
- ep1 - Principal strain-1   =   0.00139
- ez - z-strain   =   0
- C_stress - Plane Stress Control   =   Turned O
- pp - Intermediate-1   =   0.00139

Equation 2

Solve equation 2?
- ep2 - Principal strain-2   =   -0.00066
- ez - z-strain   =   0
- C_stress - Plane Stress Control   =   Turned O
- qq - Intermediate-2   =   0.000660

Equation 3

☑ Solve equation 3?
- gp - Principal shear strain   =   0.002053
- pp - Intermediate-1   =   0.00139
- qq - Intermediate-2   =   0.000660
- C_stress - Plane Stress Control   =   Turned O
- ☑ gmax - Maximum shear strain   =   0

| Solve | Resolve | Clear Solution | Finished |

Solution:

Maximum Shear Stress Concept Map:

A strain rosette makes angles of 0, 45 and 90 with the x-axis. At a point on the free surface of steel (E = 30,000 ksi and v = 0.30) machine part, the strain rosette used to obtain the following normal strain data:

$\varepsilon_a = 650\mu$ $\qquad\qquad$ $\varepsilon_b = 475\mu$ $\qquad\qquad$ $\varepsilon_c = -250\mu$

Determine the principal stresses and the maximum shearing stress at the point.

Problem Setup:

✓ Click the 'Display Variables' button to get the following window:
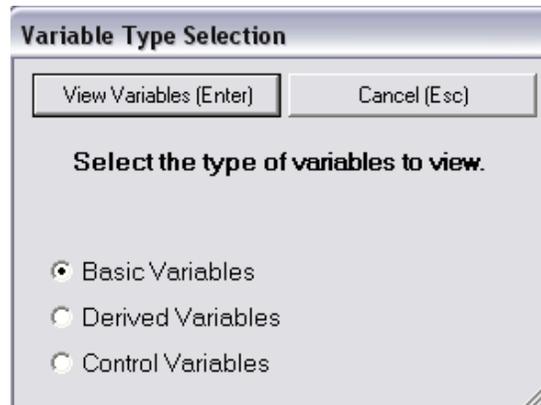
✓ Click the 'View Variables' button

- ✓ Select the given variables: theta_a, theta_b, theta-c, Poisson's ratio, strain-a, strain-b, strain-c and Young's Modulus
- ✓ Select "Control" from the drop down menu
- ✓ Hit the "Add Other Variables" button

- ✓ Select "Plain Strain Control-C_stress"
- ✓ Select "Derived" from the drop down menu
- ✓ Hit the "Add Other Variables" button

Accept Changes (Enter)	Discard Changes (Esc)	Add Other Variables	Basic ▼

KNOWN variables
Check all the variables you know.

☐ Maximum shear strain - gmax
☐ Maximum shear stress - tmax
☐ Principal shear strain - gp
☐ Principal shear stress - tp
☐ Principal strain-1 - ep1
☐ Principal strain-2 - ep2
☐ Principal stress -1 - sp1
☐ Principal stress-2 - sp2

DESIRED variables
Check the one variable you need.

○ Maximum shear strain - gmax
◉ Maximum shear stress - tmax
○ Principal shear strain - gp
○ Principal shear stress - tp
○ Principal strain-1 - ep1
○ Principal strain-2 - ep2
○ Principal stress -1 - sp1
○ Principal stress-2 - sp2

- ✓ Select 'Maximum shear stress-tmax'
- ✓ Double click on the text for "Step 1"
- ✓ Enter the values for Poisson's Ratio and Young's Modulus
- ✓ Hit "Solve" button

Solve Equation

Moduli

moduli.jpg

Select one variable per group to solve for:

Give values to known variables

Equation 1

☑ Solve equation 1?
  ☑ G - Shear Modulus   =   11538461.
  ☐ nu - Poisson's Ratio   =   0.3
  ☐ E - Young's Modulus   =   30000000

Solve	Resolve	Clear Solution	Finished

Solution:

G =   11538461.5384616

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step2

- ✓ Check the "z-stress" box
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 3

- ✓ Enter the "Angle" and "Strain" values
- ✓ Check the box for "x-strain"
- ✓ Check the box for "y-strain'
- ✓ Check the box for "shear strain"
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 4

- ✓ Uncheck Equations 1, 2 and 3
- ✓ Check the box for "Shear stress" in Equation 4
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 5

- ✓ Check the boxes for x-stress and y-stress
- ✓ Hit "Solve" button

Simultaneous Equations Solution

Node Hooke's Law

☑ sx – x-stress	=	0
☐ nu – Poisson's Ratio	=	0.3
☑ sy – y-stress	=	0
☐ sz – z-stress	=	0
☐ E – Young's Modulus	=	30000000
☐ ex – x-strain	=	0.0006499

Node Hooke's Law

☑ sy – y-stress	=	0
☐ nu – Poisson's Ratio	=	0.3
☑ sx – x-stress	=	0
☐ sz – z-stress	=	0
☐ E – Young's Modulus	=	30000000
☐ ey – y-strain	=	-0.0002499

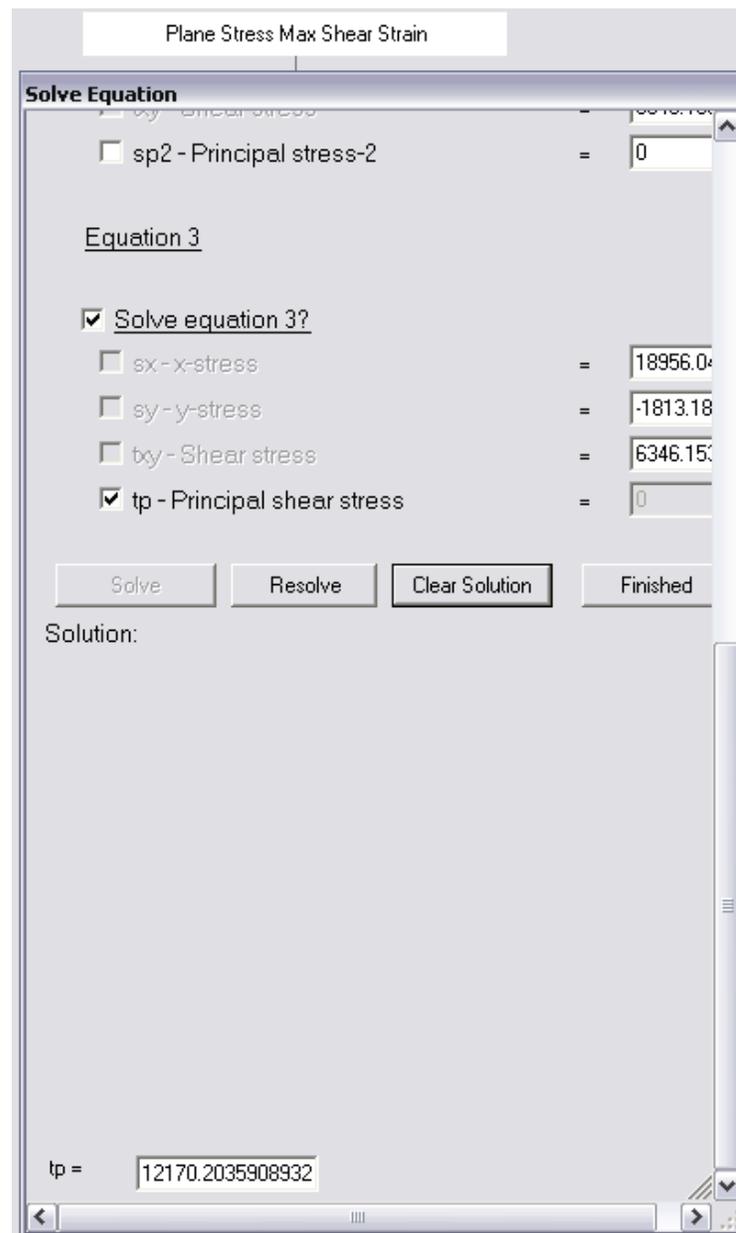[Solve] [Resolve] [Clear Solution] [Finished]

Solution:

sx = | 18956.0439560439 |
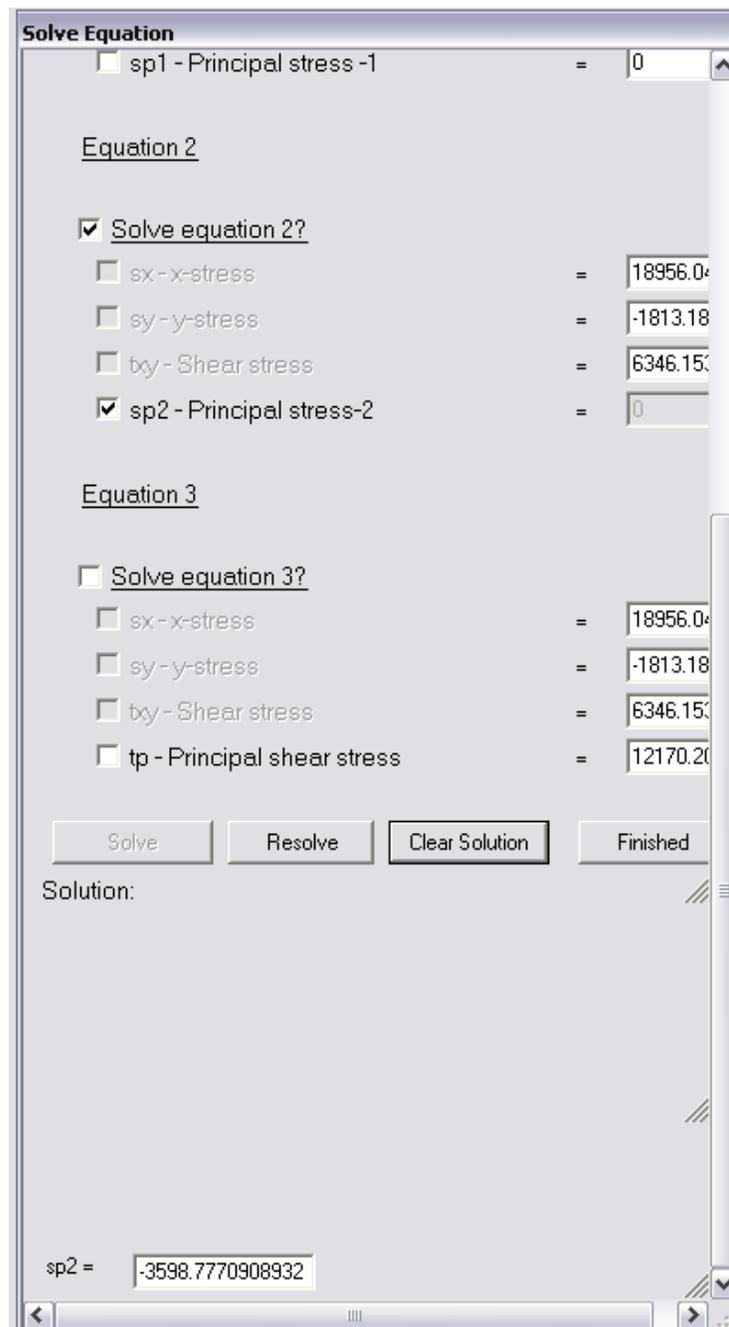
sy = | -1813.1868131868 |

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 6

- ✓ Uncheck Equations 1 and 2, leaving Equation 3 checked
- ✓ Select "Principal shear stress"
- ✓ Hit "Solve"

Plane Stress Max Shear Strain

Solve Equation

☐ sp2 - Principal stress-2   =   0

Equation 3

☑ Solve equation 3?
    ☐ sx - x-stress   =   18956.04
    ☐ sy - y-stress   =   -1813.18
    ☐ txy - Shear stress   =   6346.153
    ☑ tp - Principal shear stress   =   0

| Solve | Resolve | Clear Solution | Finished |

Solution:

tp =   12170.2035908932

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 7

- ✓ Uncheck Equations 1 and 3
- ✓ Select "Principal stress-2"
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 8

- ✓ Uncheck Equations 2 and 3
- ✓ Select "Principal shear stress-1"
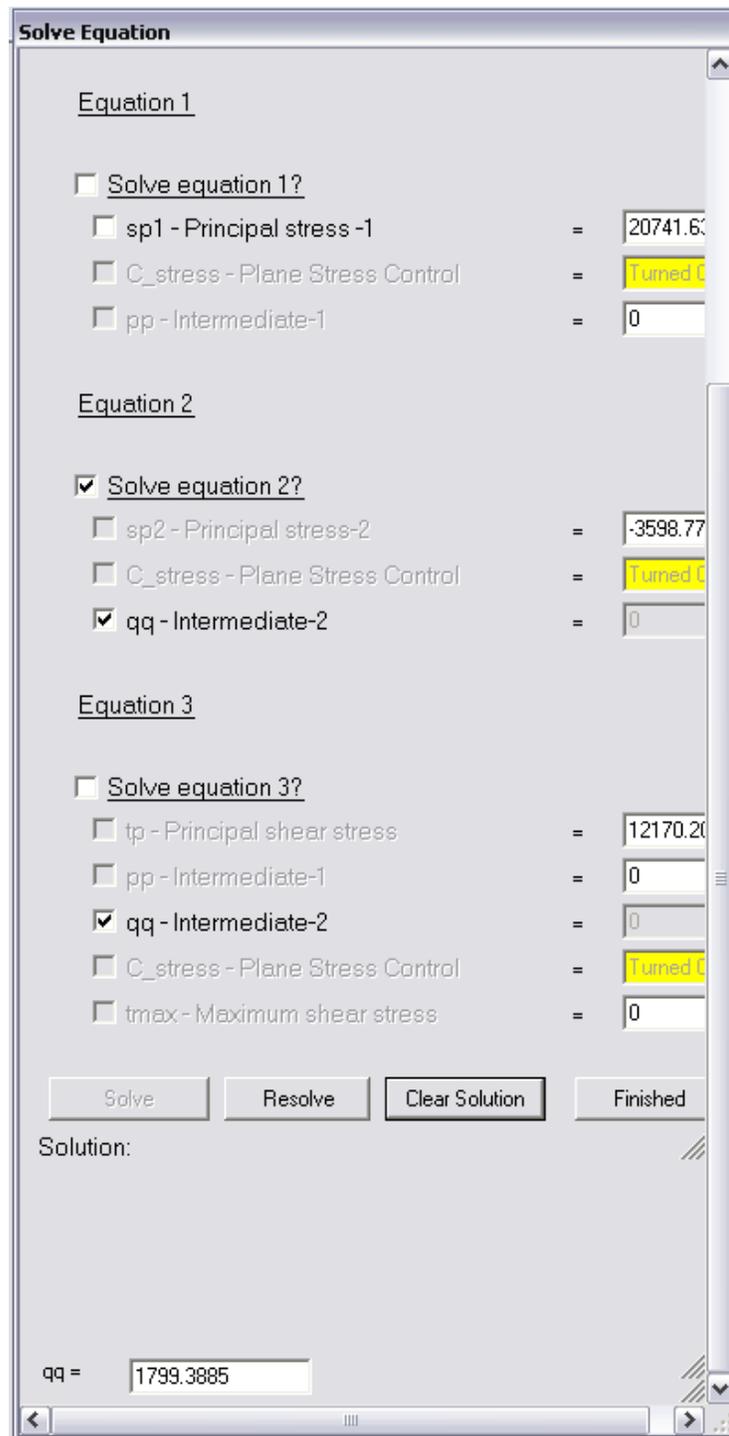- ✓ Hit "Solve" button
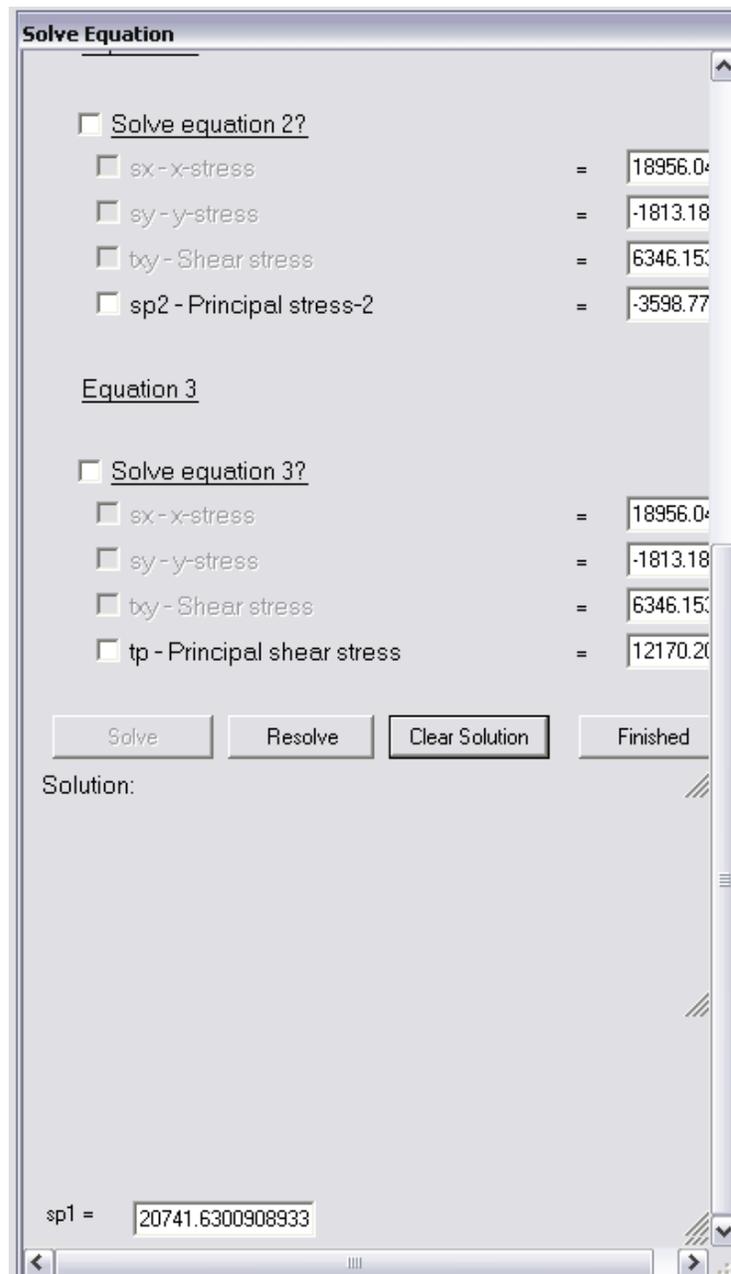
- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 9

- ✓ Uncheck Equations 1, 2 and 4
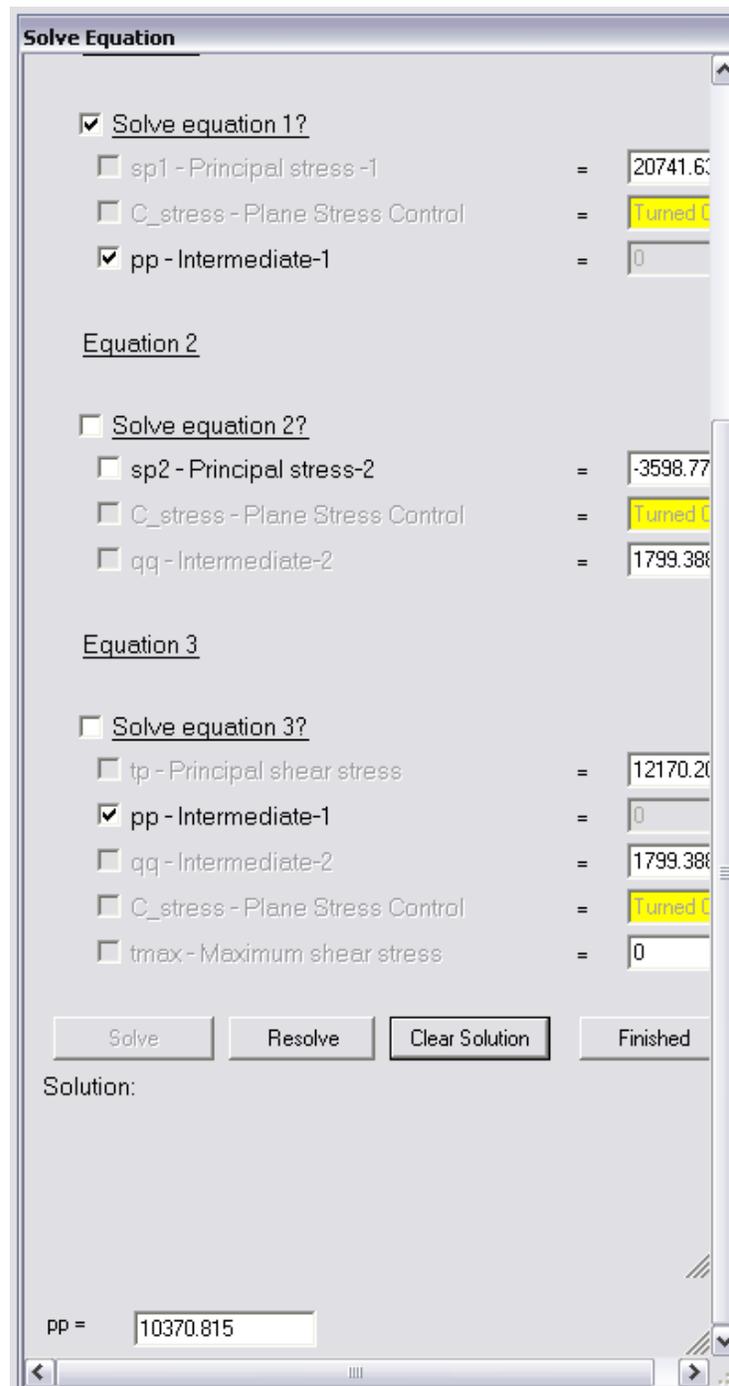- ✓ Select "z-strain" in Equation 3
- ✓ Hit "Solve"

Solve Equation

☑ ez - z-strain = 0

Equation 4

☐ Solve equation 4?

☐ txy - Shear stress = 6346.153

☐ G - Shear Modulus = 1153846

☐ gxy - Shear strain = 0.000549

| Solve | Resolve | Clear Solution | Finished |

Solution:

ez = -0.00017142853

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 10

- ✓ Uncheck Equations 1 and 3
- ✓ Select "Intermediate-2" in Equation 2
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 11

- ✓ Uncheck Equations 2 and 3
- ✓ Select "Intermediate-1" in Equation 2
- ✓ Hit "Solve"

Solve Equation

☑ Solve equation 1?

☐ sp1 - Principal stress -1   =   20741.6:

☐ C_stress - Plane Stress Control   =   Turned C

☑ pp - Intermediate-1   =   0

Equation 2

☐ Solve equation 2?

☐ sp2 - Principal stress-2   =   -3598.77

☐ C_stress - Plane Stress Control   =   Turned C

☐ qq - Intermediate-2   =   1799.388

Equation 3

☐ Solve equation 3?

☐ tp - Principal shear stress   =   12170.20

☑ pp - Intermediate-1   =   0

☐ qq - Intermediate-2   =   1799.388

☐ C_stress - Plane Stress Control   =   Turned C

☐ tmax - Maximum shear stress   =   0

| Solve | Resolve | Clear Solution | Finished |

Solution:

pp =   10370.815

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 12

- ✓ Uncheck Equations 1 and 2
- ✓ Select "Maximum shear stress"
- ✓ Hit "Solve"
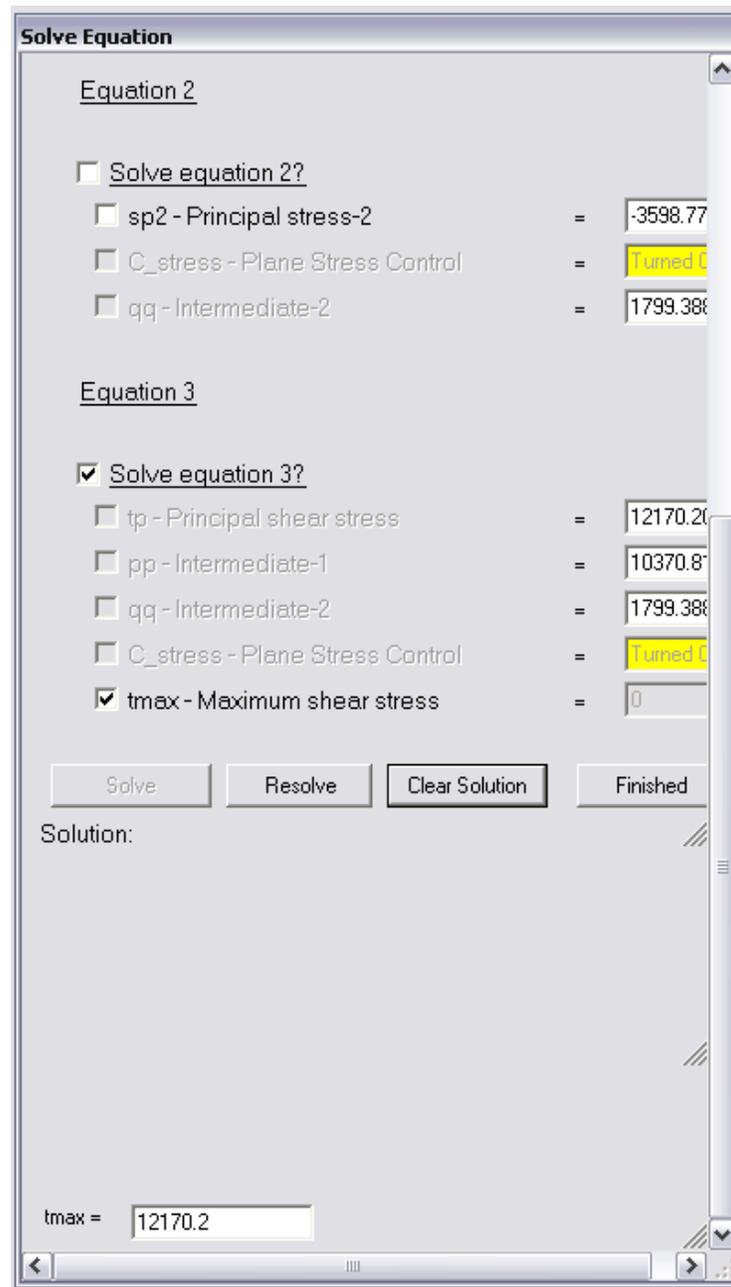
Cylindrical Pressure Vessel:

A cylindrical pressure vessel with an inside diameter of 1.50 m is constructed by wrapping a 15-mm thick steel plate into a spiral and butt-welding the mating edges of the plate. The butt-welded seams form an angle of 30 degrees with a transverse plane through the cylinder. Determine the normal stress perpendicular to the weld and the shearing stress parallel to the weld when the internal pressure in the vessel is 1500 kPa.

Problem Setup:

✓ Click the 'Display Variables' button to get the following window:

✓ Select the given variables: pressure, radius, thickness, Young's modulus, and theta
✓ Select "Derived" from the pull down menu
✓ Hit the "Accept Other Variables" button
✓ Select "Inclined plain stress –sn"
✓ Hit the "Accept Changes [Enter]" button
✓ Allow the computer to find a solution
✓ Hit the "Use this Solution" button
✓ Double click "Step 1" text

- ✓ Enter the given values for pressure, radius, and skin thickness
- ✓ Select "axial stress"
- ✓ Hit "Solve"

Solve Equation

Axial Stress

axial_stress.jpg

Select one variable per group to solve for:

Give values to known variables

Equation 1

☑ Solve equation 1?

☐ p - Pressure = 1500

☐ R - Radius = .75

☐ t - Skin thickness = .015

☑ sa - Axial stress = 0

[Solve] [Resolve] [Clear Solution] [Finished]

Solution:

sa = 37500

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 2

- ✓ Enter "theta" in the yellow box
- ✓ Uncheck Equation 1
- ✓ Check Inclined plane shear
- ✓ Hit "Solve"

- ✓ Hit the "Finished" button
- ✓ Double click on the text for Step 3

- ✓ Uncheck Equation 2
- ✓ Select "Inclined plane stress"
- ✓ Hit "Solve"

Our problem is solved.