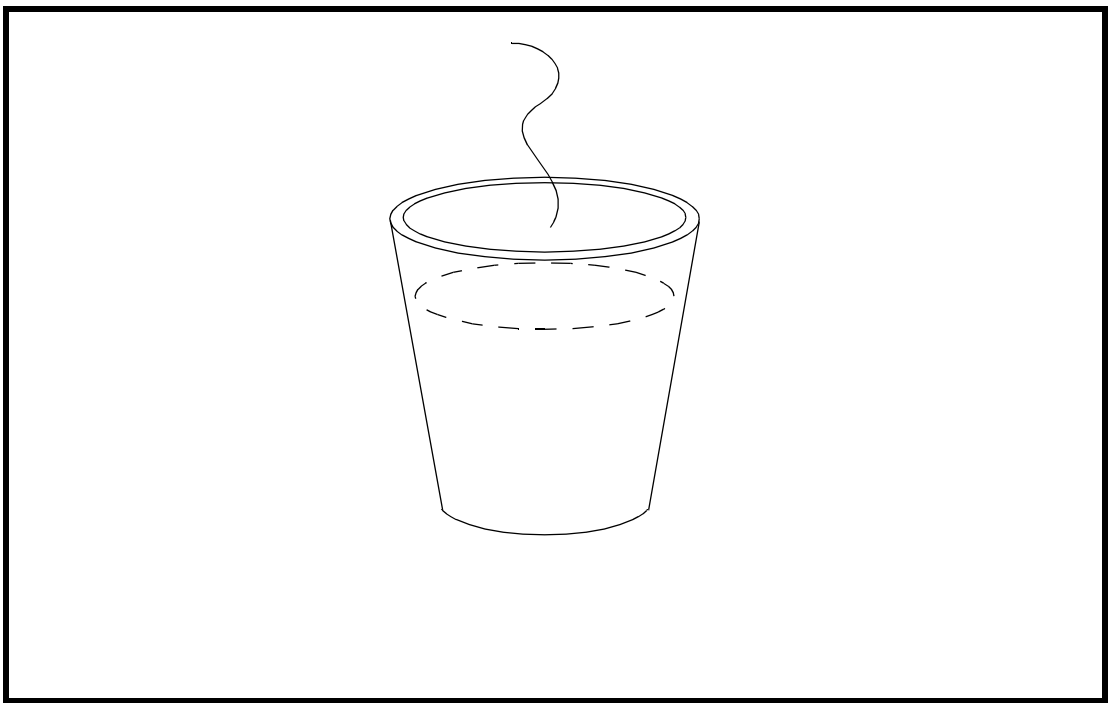
APPENDIX E

Static Analysis of A Coffee Cup



Objectives:

- Manually create the geometry of the coffee cup using the given dimensions.
- Input the hydrostatic loading conditions by creating function.
- Submit the job for analysis.
- Review the results from the analysis.

Model Description:

The coffee cup is a “real-life” problem which requires using a function to define the fluid pressure load.

Figure E.1 - Coffee Cup

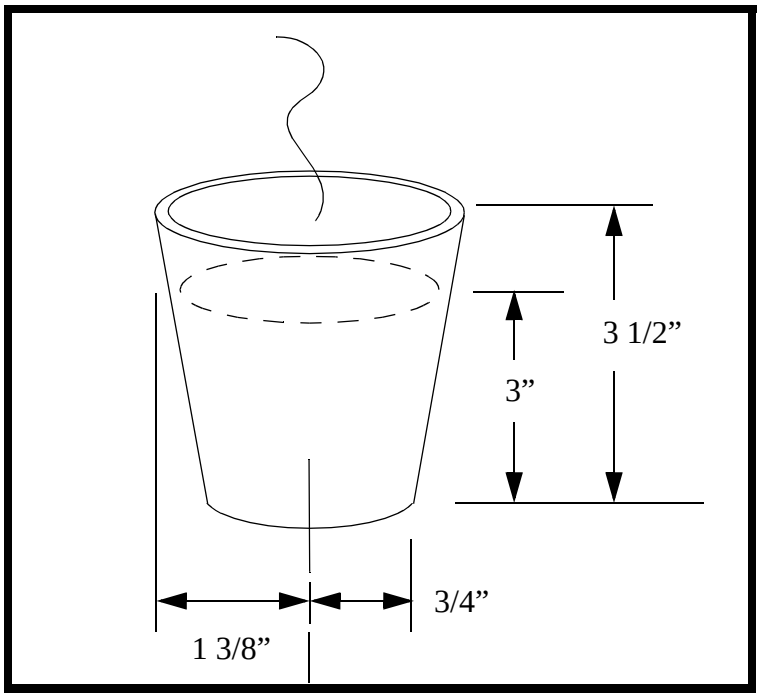


Table E.1 - Material Properties

Thickness (t):	**1/8 inches**
Young’s Modulus (E)	**470,000 psi**
Poisson’s Ratio (*v*)	**0.333**
Density (*p*)	**0.0362 lb_f/in^3**

To find the Hoop Stress of the cup, the following equation is used:

$$HoopStress \cong \frac{P \cdot r}{t}$$

and in the case of this coffee cup, it will yield a **Hoop Stress of 0.6 psi**.

Exercise Procedure:

1. Start up MSC/NASTRAN for Windows 3.0 and begin to create a new model.

Double click on the icon labeled **MSC/NASTRAN for Windows V3.0**.

On the *Open Model File* form, select **New Model.**

Open Model File:	**New Model**

2. Create a material called **mat_1**.

From the pulldown menu, select **Model/Material.**

Model/Material...

Title:	**mat_1**
Youngs Modulus:	**4.7e5**
Poisson's Ratio:	**0.333**

OK

Cancel

3. Create a property called **prop_1** to apply to the members of the cup itself.

From the pulldown menu, select **Model/Property**.

Model/Property...

Title:	**prop_1**
Material:	**1..mat_1**
Thickness:	**0.125**

OK

Cancel

4. Create the cup's geometry.

Tools/Advanced Geometry...

Geometry Engine: ● **Standard**

OK

First, create a cylindrical coordinate system.

Model/Coord Sys...

ID: **99**

Title: **Coord 99**

Method: ● **XY Axis**

Type: ● **Cylindrical**

OK

Define Coordinate System Origin.

X:	*Y:*	*Z:*	
0	**0**	**0**	**OK**

Define Vector along CSys X-Axis.

	X:	*Y:*	*Z:*	
Base:	**0**	**0**	**0**	
Tip:	**1**	**0**	**0**	**OK**

Define Vector in CSys XY-Plane.

	X:	*Y:*	*Z:*	
Base:	**0**	**0**	**0**	
Tip:	**1**	**0**	**-1**	**OK**

Cancel

Geometry/Curve-Line/Coordinates...

Enter First Location for Line.

CSys: **99..Coord 99**

R:	*T:*	*Z:*	
0	**0**	**0**	**OK**

Enter Second Location for Line.

R:	*T:*	*Z:*	
-0.75	**0**	**0**	**OK**
			Cancel

Geometry/Curve-Line/Coordinates...

Enter First Location for Line.

CSys: **99..Coord 99**

R:	*T:*	*Z:*	
-0.75	**0**	**0**	**OK**

Enter Second Location for Line.

R:	*T:*	*Z:*	
-1.375	**0**	**3.5**	**OK**
			Cancel

Geometry/Curve-Line/Coordinates...

Enter First Location for Line.

CSys: **99..Coord 99**

R:	*T:*	*Z:*	
-3	**0**	**3**	**OK**

Enter Second Location for Line.

R:	*T:*	*Z:*	
3	**0**	**3**	**OK**

Cancel

Break the vertical curve with the newly constructed line.

Modify/Break...

Select Curve(s) to Break: *Select Curve 2*

OK

Methods^

Intersect - Curves

Curve ID 1: **3**

Curve ID 2: **2**

OK

Cancel

Delete the line used for the break.

Delete/Geometry/Curve...

Select Curve 3

OK

When asked if it is OK to Delete 1 Selected Curve(s), Click Yes.

Delete the points remaining from the deleted line.

Delete/Geometry/Point...

Select Points 5 and 6

OK

When asked if it is OK to Delete 2 Selected Point(s), Click Yes.

5. Create the surface of the cup.

Note: Only a section of the cup will be modeled. The solution will use symmetry for the overall analysis.

Geometry/Surface/Revolve...

Select Curve(s) to Revolve.

Select All
OK

Select Axis of Rotation.

	R:	*T:*	*Z:*	
Base:	**0**	**0**	**0**	
Tip:	**0**	**0**	**1**	**OK**

Rotation Angle: **45**

OK
Cancel

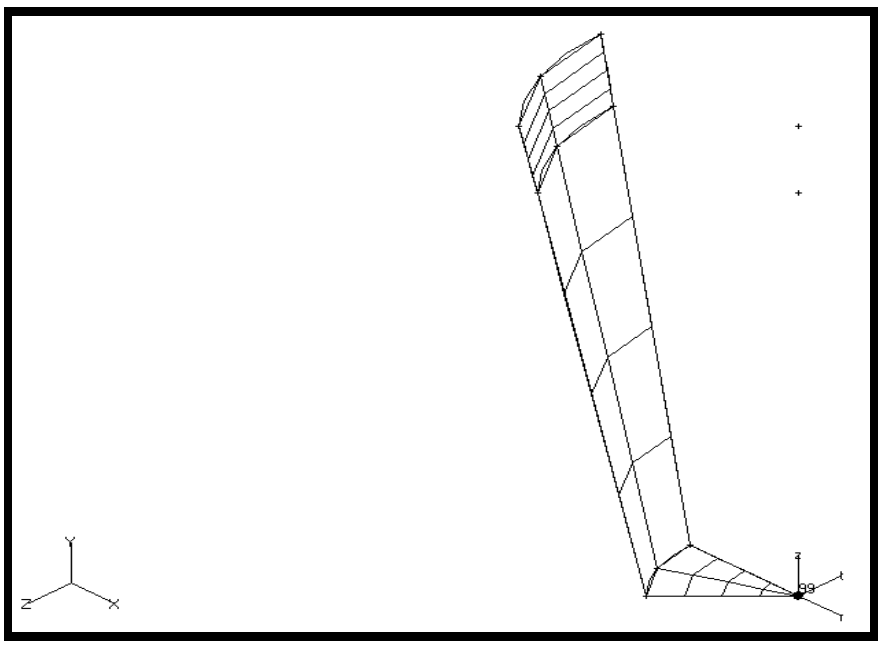
6. Use **Autoscale** and **Rotate** to better view model.

View/Autoscale

View/Rotate... **Isometric**

OK

The viewport should appear as follows:



7. Now define the mesh size on the cup section.

Mesh/Mesh Control/Size on Surface...

Select All

OK

Element Size: **0.075**

OK

Cancel

Mesh/Mesh Control/Mapped Divisions on Surface...

Select Surface 2

	s	**t**	
Number of Elements:	**14**	**41**	
Bias:	**1**	**1**	**OK**

Cancel

8. Finally, create the finite element entities.

Mesh/Geometry/Surface...

Select All

OK

When asked if it is OK to create a Boundary Mesh, click NO.

Property: **1..prop_1**

OK

The *Messages and Lists* window should confirm with “Merging”, which signals auto-merging of the coincident nodes. Below that, there is a line that reads “Ready - Nodes: 901, Elements: 812”.

9. Create the constraints.

Model/Constraint/Set...

ID: **1**

Title: **bottom_center**

OK

Now define the relevant constraint for the center of the cup.

Model/Constraint/Nodal...

ID: **151**

OK

Coord Sys: **99..Coord 99**

Fixed

OK

Cancel

Define the relevant constraint for the bottom of the cup.

Model/Constraint/Set...

ID: **2**

Title: **bottom**

OK

Model/Constraint/Nodal...

Methods^

On Surface

Select Surface 1

OK

Coord Sys: **99..Coord 99**

DOF (click to select): ☐ **TX** ☐ **TY** ☒ **TZ**

☐ **RX** ☐ **RY** ☐ **RZ**

OK

When asked to Update the Output CSys of the Constrained Nodes, Click Yes.

Cancel

Define the relevant constraint for the sides of the cup.

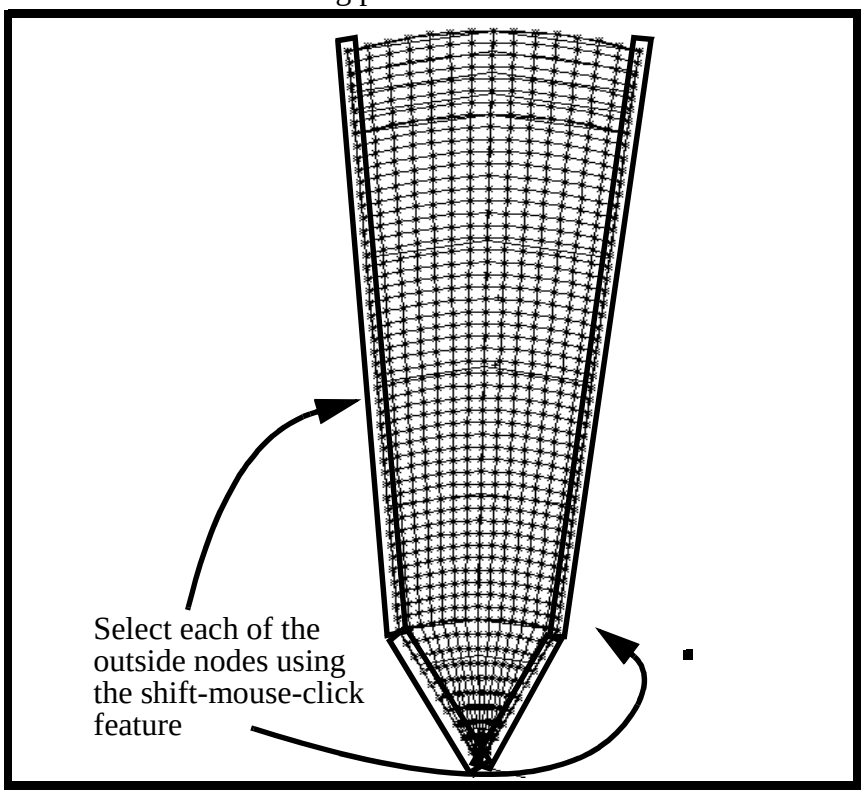
Model/Constraint/Set...

ID: **3**

Title: **sides**

OK

Refer to the following pictures for the node locations.



Model/Constraint/Nodal...

Click on **Method^** and then **on Curve** to select the nodes on the curves shown on the previous page.

OK

Coord Sys: **99..Coord 99**

Y Symmetry

OK

Cancel

Combine all of the constraints.

Model/Constraint/Combine...

From Set: **1..bottom_center**

More

From Set: **2..bottom**

More

From Set: **3..sides**

Last One

10. Verify the normal vectors to each of the loading surfaces.

View/Options...

Options: **Element - Directions**

Normal Style: **1..Normal Vectors**

Show Direction ☒

Apply

OK

Reverse the direction of the normal vectors. They should be pointing outwards. Check for coincident nodes.

Tools/Check/Coincident Nodes...

Select All

OK

When asked if it is OK to Specify Additional Range of Nodes to Merge, click NO.

☒ **Merge Coincident Entities**

OK

The status window should reveal 30 Node(s) Merged.

Modify/Update Elements/Reverse...

Select All

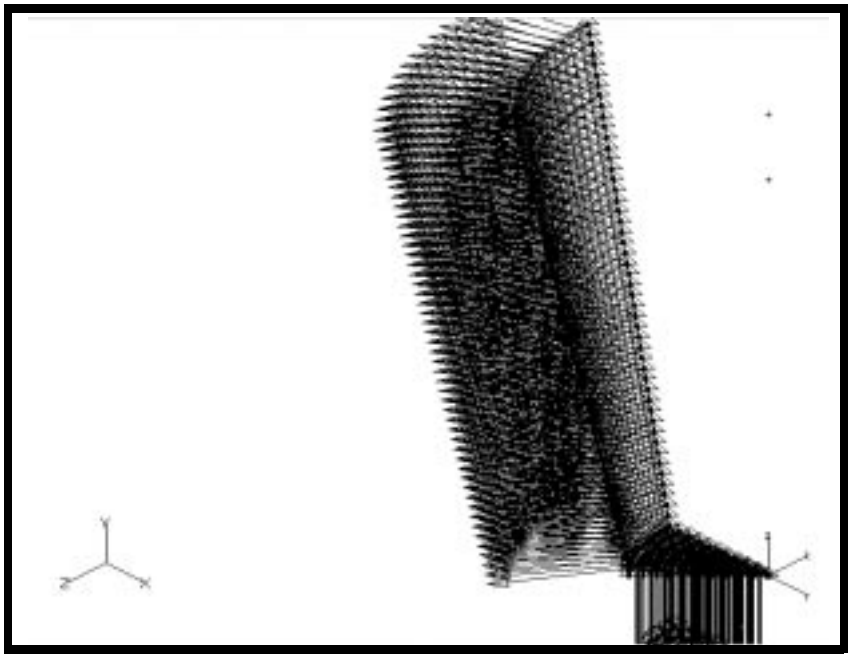
OK

☒ **All Normals Outward**

OK

View/Autoscale

The viewport should appear as follows.



View/Options...

Options: **Element - Directions**

Normal Style: **1..Normal Vectors**

Show Direction ☐

Apply

OK

11. Create the loading condition.

Model/Load/Set...

Title: **pressure**

OK

Now define the pressure on the relevant surfaces. The pressure that will be created will be applied to the center of each element. Later in the exercise, you will create a pressure applied over the entire element.

Model/Load/On Surface...

Select surfaces 1 and 2

OK

Create Loads on Surfaces: **Pressure**

Coord Sys: **99..Coord 99**

Method: **Variable**

Advanced...

Multiply By: ● **Equation**

Equation: **0.0362*(3-!z)**

OK

Pressure: **-1**

OK

Cancel

Model/Load/Expand...

OK

View/Options...

Options: **Load Vectors**

Vector Length: **1..Scale by Magnitude**

OK

Modify/Update Other/Output CSys...

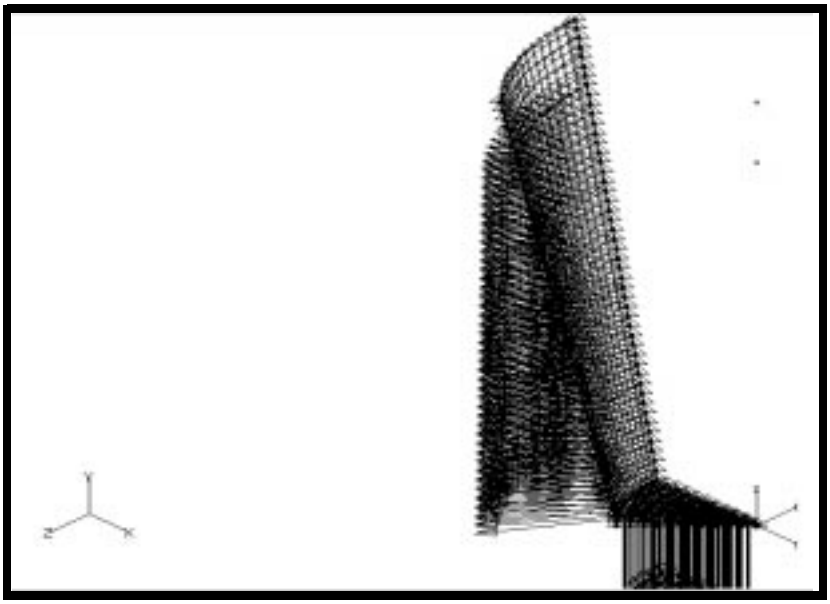
Select All

OK

Entity ID: **99..Coord 99**

OK

The viewport should appear as follows:



12. Create the input file for analysis.

File/Export/Analysis Model...

Type: **1..Static**

OK

Change the directory to **C:\temp**.

File name: **coffee_cup**

Write

☒ **Run Analysis**

OK

13. When asked if you wish to save the model, respond **Yes**.

Yes

File name: **coffee_cup**

Save

When the MSC/NASTRAN manager is through running, MSC/NASTRAN will be restored on your screen, and the *Message Review* form will appear. To read the messages, you could select **Show Details**. Since the analysis ran smoothly, we will not bother with the details this time.

Continue

View/Options...

Category: ● **Post Processing**

Options: **Deformed Style**

Scale %: **1**

Scale Act: **1**

OK

View/Select...

Deformed Style: ● **Deform**

Contour Style: ● **Contour**

Deformed and Contour Data...

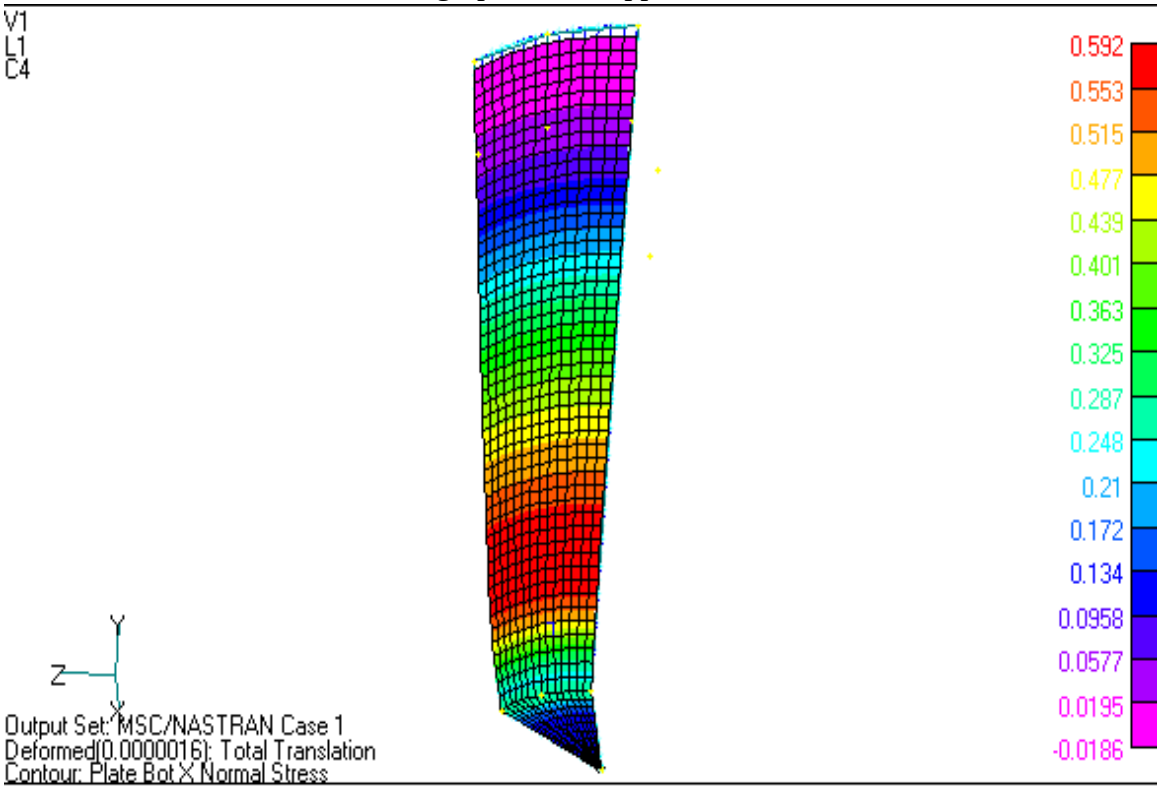
Deformation: **1..Total Translation**

Contour: **7420..Plate Bot X Normal Stress**

OK

OK

The final results graph should appear as follows:



14. Open a text editor and view the .DAT file. Examine the pressure load that you created.

The file should appear similar to the exerpts shown on the next page.

```
$ MSC/NASTRAN for Windows Load Set 1 : pressure
PLOAD4          1      673  0.1086
PLOAD4          1      674  0.1086
PLOAD4          1      675  0.1086
PLOAD4          1      676  0.1086
PLOAD4          1      677  0.1086
PLOAD4          1      678  0.1086
PLOAD4          1      679  0.1086
PLOAD4          1      680  0.1086
                        .
                        .
PLOAD4          1      809  0.1086
PLOAD4          1      810  0.1086
PLOAD4          1      811  0.1086
PLOAD4          1      812  0.1086
PLOAD4          1       991.324E-3
PLOAD4          1     1001.324E-3
PLOAD4          1     1011.324E-3
PLOAD4          1     1021.324E-3
PLOAD4          1     1031.324E-3
$ MSC/NASTRAN for Windows Constraint Set 1 : bottom_center
SPC             1      901  123456      0.
$ MSC/NASTRAN for Windows Constraint Set 2 : bottom
SPC             2      736       3      0.
SPC             2      737       3      0.
SPC             2      739       3      0.
SPC             2      741       3      0.
                        .
                        .
$ MSC/NASTRAN for Windows Constraint Set 3 : sides
SPC             3        1     246      0.
SPC             3       15     246      0.
SPC             3       16     246      0.
SPC             3       30     246      0.
SPC             3       31     246      0.
                        .
                        .
$ MSC/NASTRAN for Windows Constraint Set 4 : Combined Set
SPC             4        1     246      0.
SPC             4       15     246      0.
SPC             4       16     246      0.
SPC             4       30     246      0.
SPC             4       31     246      0.
SPC             4       45     246      0.
$ MSC/NASTRAN for Windows Property 1 : prop_1
PSHELL          1        1   0.125       1               1               0.
$ MSC/NASTRAN for Windows Material 1 : mat_1
MAT1            1 470000.           0.333      0.      0.      0.
GRID            1       99   1.375    180.     3.5      99
GRID            2       99   1.375-176.786     3.5      99
GRID            3       99   1.375-173.571     3.5      99
GRID            4       99   1.375-170.357     3.5      99
GRID            5       99   1.375-167.143     3.5      99
GRID            6       99   1.375-163.929     3.5      99
```

15. Return to NASTRAN for Windows and change the type of surface pressure.

File/Save As...

File Name: **coffee_cup2**

Save

Modify/Edit/Load...

☒ *Select All*

Defined On: ● **Surface**

Elemental Loads: ● **Pressures**

OK

☒ *At Corners*

OK

Cancel

16. Re-Analyze the model.

File/Export/Analysis Model...

Type: **1..Static**

OK

Change the directory to **C:\temp**.

File name: **coffee_cup2**

Write

☒ **Run Analysis**

OK

17. When asked if it is OK to save the model, respond **Yes**.

Yes

When the MSC/NASTRAN manager is through running, MSC/NASTRAN will be restored on your screen, and the *Message Review* form will appear. To read the messages, you could select **Show Details**. Since the analysis ran smoothly, we will not bother with the details this time.

Continue

View/Select...

Deformed Style: ● **Deform**

Contour Style: ● **Contour**

Deformed and Contour Data...

Output Set: **2..MSC/NASTRAN Case 1**

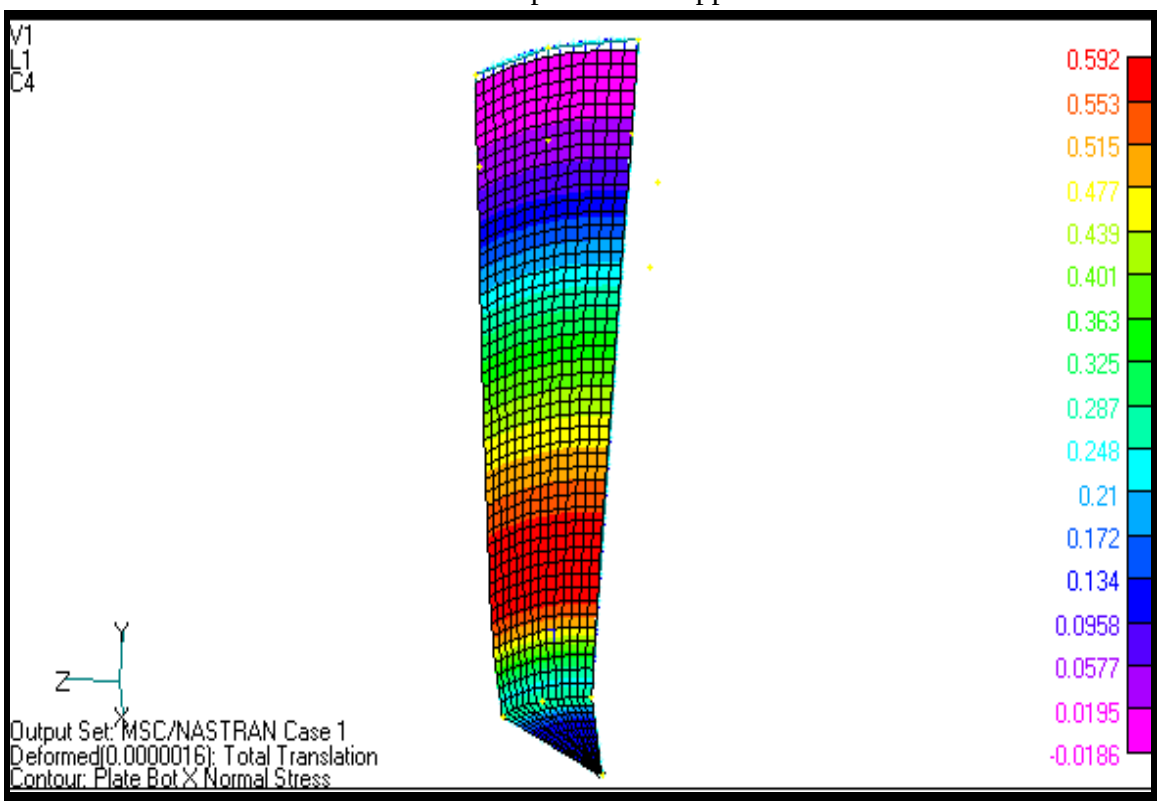
Deformation: **1..Total Translation**

Contour: **7420..Plate Bot X Normal Stress**

OK

OK

Notice that the new contour plot and the results are exactly the same as in the first case. The plot should appear as follows:



18. Open a text editor and view the .DAT file. Examine the pressure load that you created.

Notice the differences in the PLOAD4 cards. This time, NASTRAN for Windows created a variable pressure accross each element.

The file should appear similar to the exerpts shown on the next page.

```
$ MSC/NASTRAN for Windows Load Set 1 : pressure
PLOAD4          1     673  0.1086  0.1086  0.1086  0.1086
PLOAD4          1     674  0.1086  0.1086  0.1086  0.1086
PLOAD4          1     675  0.1086  0.1086  0.1086  0.1086
PLOAD4          1     676  0.1086  0.1086  0.1086  0.1086
PLOAD4          1     677  0.1086  0.1086  0.1086  0.1086
                      .
                      .
PLOAD4          1    1132.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1142.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1152.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1162.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1172.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1182.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1192.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1202.649E-35.298E-35.298E-32.649E-3
PLOAD4          1    1212.649E-35.298E-35.298E-32.649E-3
                      .
                      .
$ MSC/NASTRAN for Windows Constraint Set 1 : bottom_center
SPC             1     901  123456      0.
$ MSC/NASTRAN for Windows Constraint Set 2 : bottom
SPC             2     736       3      0.
SPC             2     737       3      0.
SPC             2     739       3      0.
SPC             2     741       3      0.
                      .
                      .
$ MSC/NASTRAN for Windows Constraint Set 3 : sides
SPC             3       1     246      0.
SPC             3      15     246      0.
SPC             3      16     246      0.
SPC             3      30     246      0.
SPC             3      31     246      0.
SPC             3      45     246      0.
SPC             3      46     246      0.
                      .
                      .
$ MSC/NASTRAN for Windows Constraint Set 4 : Combined Set
SPC             4       1     246      0.
SPC             4      15     246      0.
SPC             4      16     246      0.
SPC             4      30     246      0.
SPC             4      31     246      0.
SPC             4      45     246      0.
$ MSC/NASTRAN for Windows Property 1 : prop_1
PSHELL          1       1   0.125       1               1              0.
$ MSC/NASTRAN for Windows Material 1 : mat_1
MAT1            1 470000.           0.333      0.      0.      0.
GRID            1      99   1.375    180.     3.5      99
GRID            2      99   1.375-176.786     3.5      99
GRID            3      99   1.375-173.571     3.5      99
GRID            4      99   1.375-170.357     3.5      99
GRID            5      99   1.375-167.143     3.5      99
```