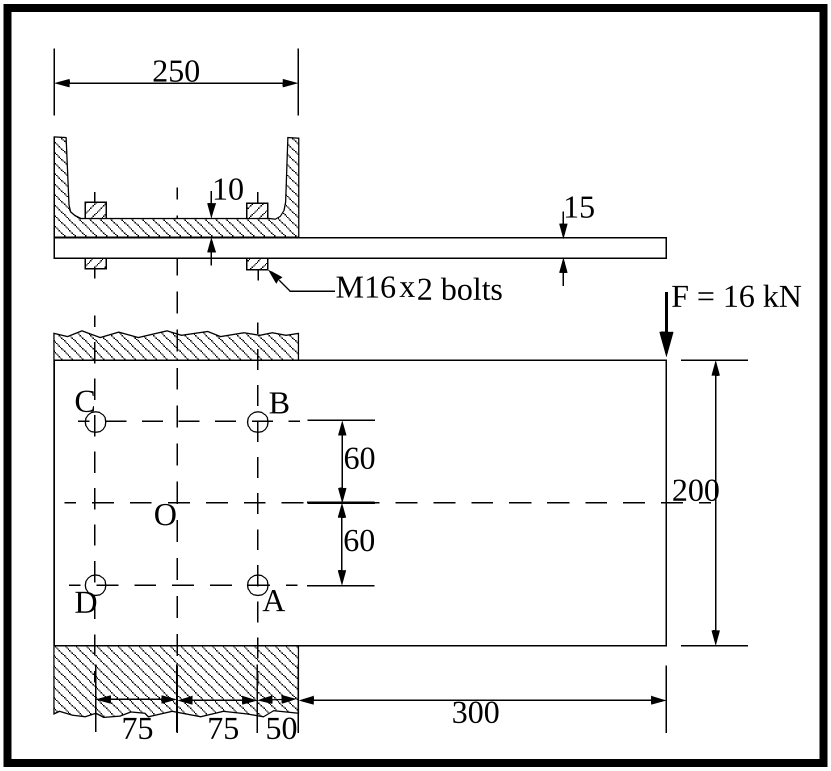
WORKSHOP 10a

Shear and Moment Reactions - Linear Static Analysis with RBE3



Objectives:

- Create a geometric representation of the bolts.
- Use the geometry model to define an analysis model comprised of bar elements.
- Idealize a rigid end using RBE3 elements.
- Run an MSC.Nastran linear static analysis.
- Visualize analysis results.

Model Description:

The goal of the example is to analyze the shear and moment reactions at the four bolts by using RBE3 elements, instead of drawing **Figure 10a10a.1**.

Force F and moments that exist on **Figure 10a.1** will be applied at point O.

Below in **Figure 10a.1** is a diagram of a rectangular steel bar cantilevered to a steel channel using four bolts. There is an external 16 kN load appled, what is the resultant load on each bolt.

Figure 10a.1 - Diagram and Dimension of Bolts and Fixture

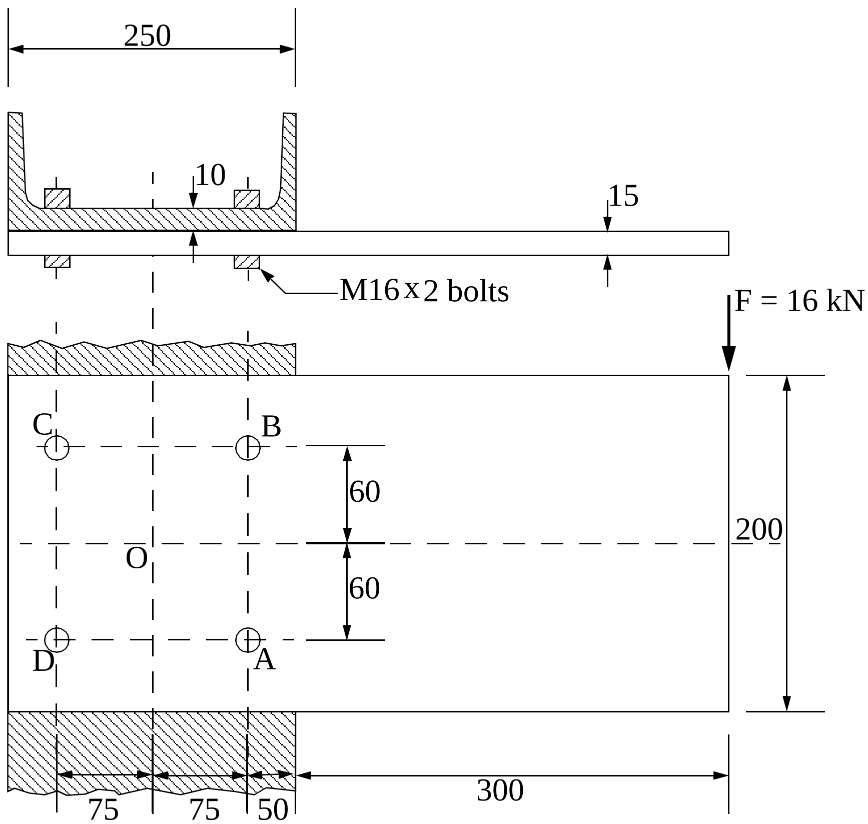
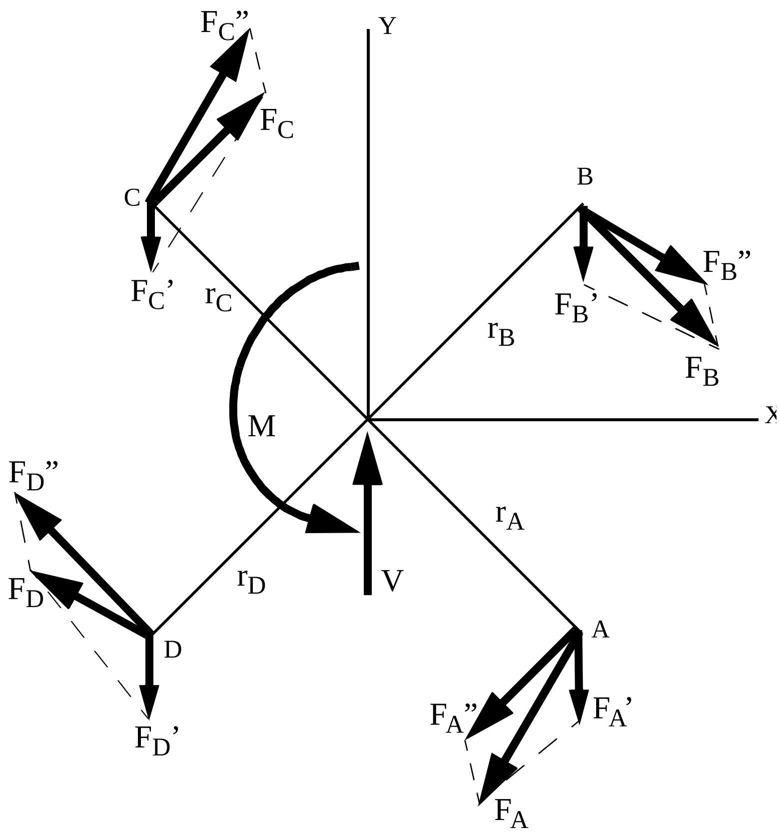


Table 10a.1 - Vaules for Bolt Model

Outer Radius	**2 mm**
Inner Radius	**1.9 mm**
Elastic Modulus	**7.1E10 N/mm^2**
Poisson's Ratio	**0.3**

Figure 10a.2 - Diagram of Force Componets



Solution

Point *O*, the centroid of the bolt group in **Figure 10a.2**, is found by symmetry. If a free-body diagram of the beam were constructed, the shear reaction *V* would pass through *O* and the moment reaction *M* would be about *O*. These reactions are:

$$V = 16kN \qquad M = 16(425) = 6800Nm$$

In **Figure 10a.2**, the bolt group has been drawn to a larger scale and the reactions are shown. The distance from the centroid to the center of each bolt is:

$$r = \sqrt{(60)^2 + (75)^2} = 96.0mm$$

The primary shear load per bolt is:

$$F' = \frac{V}{n} = \frac{16}{4} = 4kN$$

Since the secondary shear froces are equal, the calculatons comes to:

$$F'' = \frac{Mr}{4r^2} = \frac{M}{4r} = \frac{6800}{4(96.0)} = 17.7kN$$

Suggested Exercise Steps:

- Generate a geometry model of the four bolts and create finite element for each bolt.
- Create node 999 to represent point O.
- Define material (MAT1) and element (PORP1) properties.
- Apply the fixed boundary constraints on each bolt. Create shear, and moment reactions at node 999.
- Idealize a rigid end connecting node 999 and one end of each bolt with rigid elements (RBE2).
- Prepare the model for linear static analysis (SOL 101).
- Generate an input file and submit it to the MSC.Nastran solver for normal modes analysis.
- Review the results.

Exercise Procedure:

1. Users who are not utilizing MSC.Patran for generating an input file should go to Step 16 otherwise, proceed to Step 2.

2. Create a new database called **bolt_load.db**

File/New Database

New Database Name	**bolt_load**

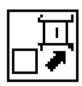
OK

In the ***New Model Preference*** form set the following. :

Tolerance	◆ **Default**
Analysis code:	**MSC/NASTRAN**

OK

3. Activate the entity labels by selecting the **Show Labels** icon on the toolbar.

 **Show Labels**

4. Create curves to represent the bolts.

◆ **Geometry**

Action:	**Create**
Object:	**Curve**
Method:	**XYZ**
Vector Coordinate List:	**<0 0 10>**

❑ *Auto Execute*

Origin Coordinates List:	**[75 -60 0]**

Apply

Repeat Step 3, changing *Origin Coordinates List* to **[75 60 0]**, **[-75 60 0]**, and **[-75 -60 0]**.

Origin Coordinates List:	**[75 60 0]**

Apply

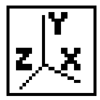
Origin Coordinates List: **[-75 60 0]**

Apply

Origin Coordinates List: **[-75 -60 0]**

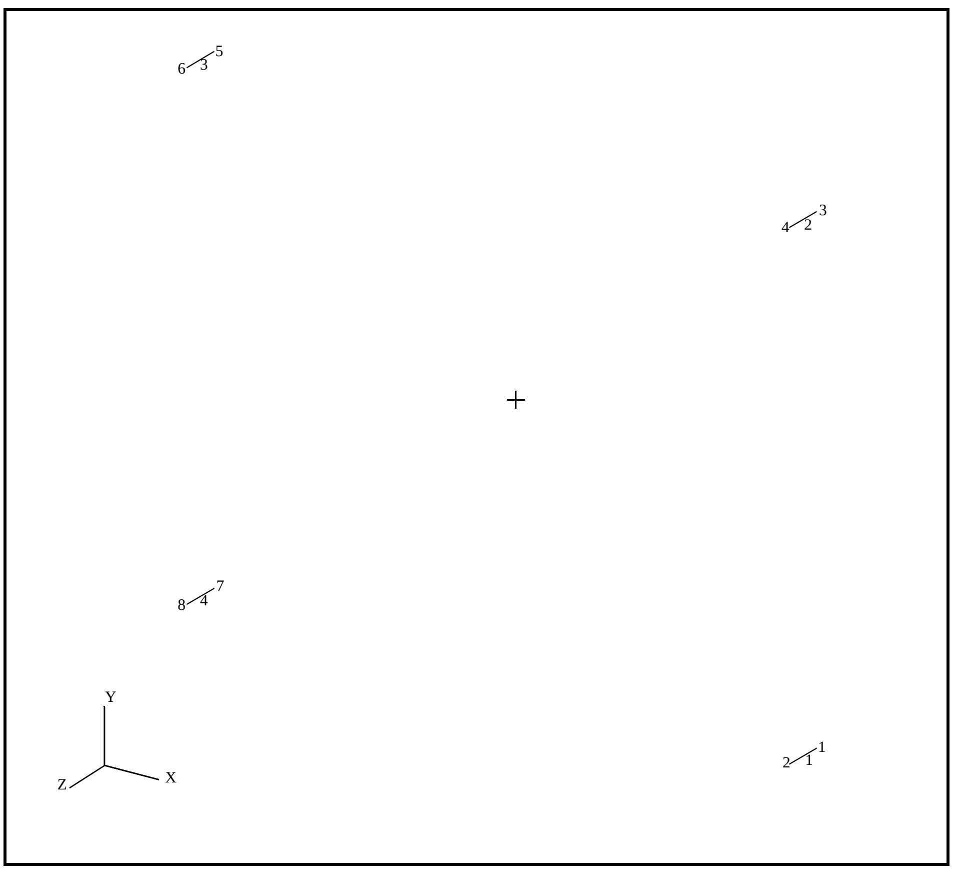
Apply

To see the curves that was just created, change the view to **Iso 1 View** by selecting on this icon:



Iso 1 View

Figure 10a.3 - Geometry Model Of the Bolts



5. Create the finite element model and mesh the curves.

◆ **Finite Elements**

Action:	**Create**
Object:	**Mesh**
Type:	**Curve**
Glogal Edge Length:	**10**
Curve List:	**Curve 1:4**

Apply

6. Node create node 999 and add to model.

◆ **Finite Elements**

Action:	**Create**
Object:	**Node**
Type:	**Edit**
Node ID List:	**999**

❑ *Associate with Geometry*

❑ *Auto Execute*

Node Loocation List:	**[0 0 0]**

Apply

To see the node, node 999, use **Node Size** by clicking on this icon:

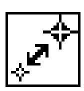
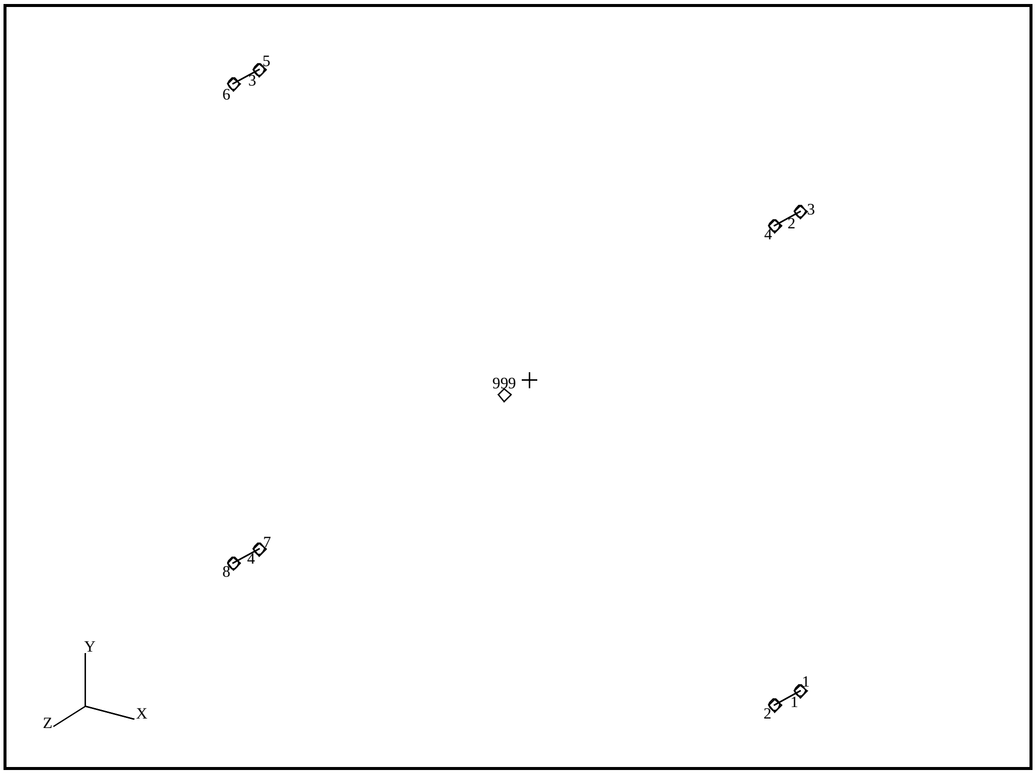
 **Node Size**

Figure 10a.4 - Geometry, Finite Elements, and Node 999



7. Now you will create the material properties for the plate.

◆ **Materials**

Action:	**Create**
Object:	**Isotropic**
Method:	**Manual Input**
Material Name	**mat_1**
Input Properties ...	
Elastic Modulus	**7.1E10**
Poisson Ratio	**0.3**
Apply	
Cancel	

8. Give the curves a 3D shape by using Properties.

◆ **Properties**

Action: **Create**

Dimension: **1D**

Type: **Beam**

Property Set Name **Prop_1**

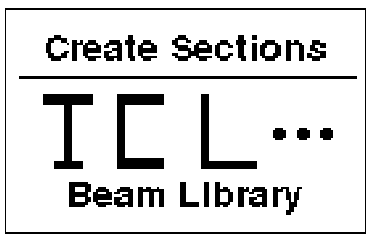
Input Properties ...

Material Name **m:mat_1**
*(Select from **Material Property Sets** box)*

Bar Orientation: **Node 999**
note: both lines are for Bar Orientation **Node Id**

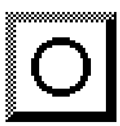
■ **Asscoiate Beam Selection**

Click the beam library icon:



New Section Name: **Prop_1**

Choose **Tube Section**:


Tube Section

R1 **2.0**

R2 **1.9**

OK

OK

Select Members **Curve 1:4**

Add

Apply

9. Next, apply the boundary conditions to the model.

◆ **Loads/BCs**

Action:	**Create**
Object:	**Displacement**
Type:	**Nodal**
New Set Name	**Fixed_ends**

Input Data...

Translations <T1 T2 T3>	**<0, 0, 0>**
Rotations <R1 R2 R3>	**<0, 0, 0>**

OK

Select Application Region...

Geometry Filter	◆ **Geometry**
Curve List *(See Figure D.3)*	**Point 1:7:2**

Add

OK

Apply

10. Now create the force on node 999.

◆ **Loads/BCs**

Action:	**Create**
Object:	**Froce**
Type:	**Nodal**
New Set Name	**Shear_Reaction**

Input Data...

Forces <F1 F2 F3>	**<0, -16, 0>**

OK

Select Application Region...

Geometry Filter ◆ **FEM**

Curve List **Node 999**
(See Figure D.4)

Add

OK

Apply

11. Apply the moment to the model.

◆ **Loads/BCs**

Action:	**Create**
Object:	**Froce**
Type:	**Nodal**
New Set Name	**Moment_Reaction**

Input Data...

Forces <F1 F2 F3>	**<0, 0, 0>**
Moment <M1 M2 M3>	**<0, 0, 6800>**

OK

Select Application Region...

Geometry Filter ◆ **FEM**

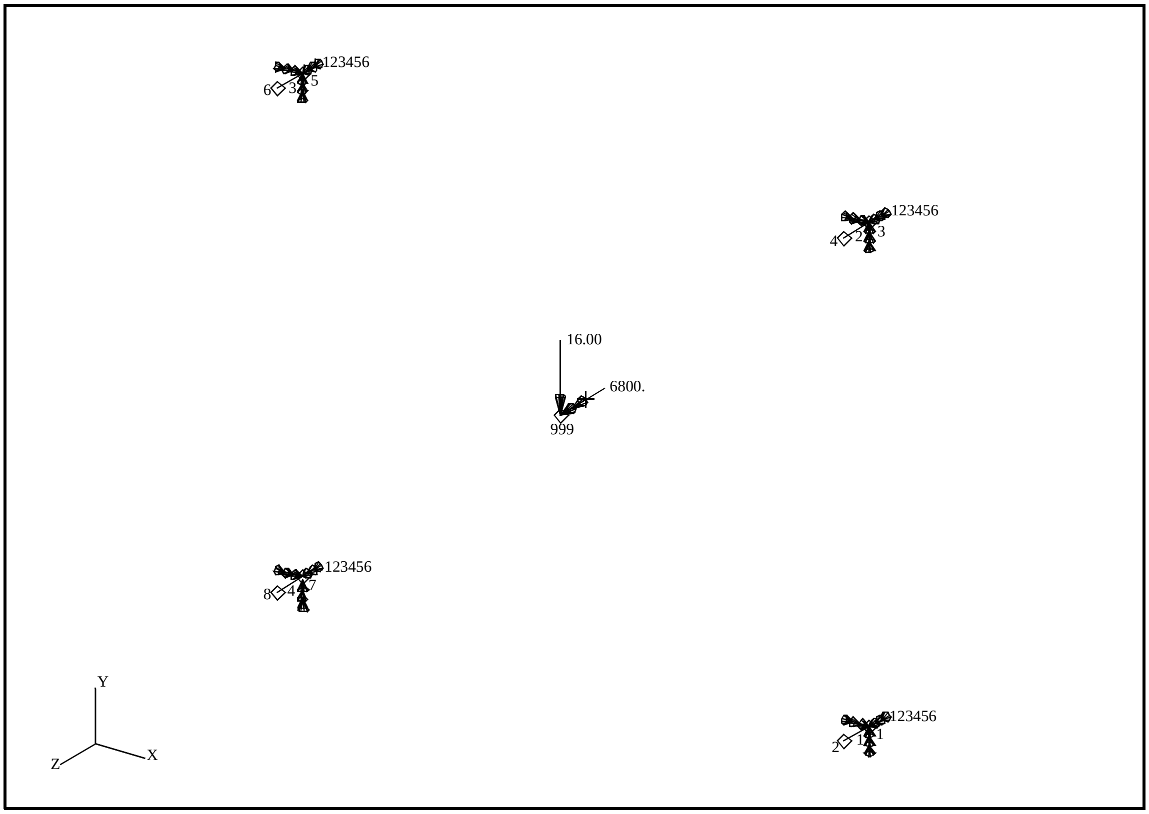
Curve List **Node 999**
(See Figure D.4)

Add

OK

Apply

Figure 10a.5 - Froces and Boundry Conditions



12. Create the rigid element.

◆ **Finite Elements**

Action:	**Create**
Object:	**MPC**
Type:	**RBE3**

Define Terms...

◆ **Create Dependent**

❑ *Auto Execute*

Node List	**Node 999**

Select DOFs by holding the Shift key down while clicking with the left mouse button. .

DOFs	**UX** **UY** **UZ** **RX** **RY** **RZ**

Apply

◆ **Create Independent**

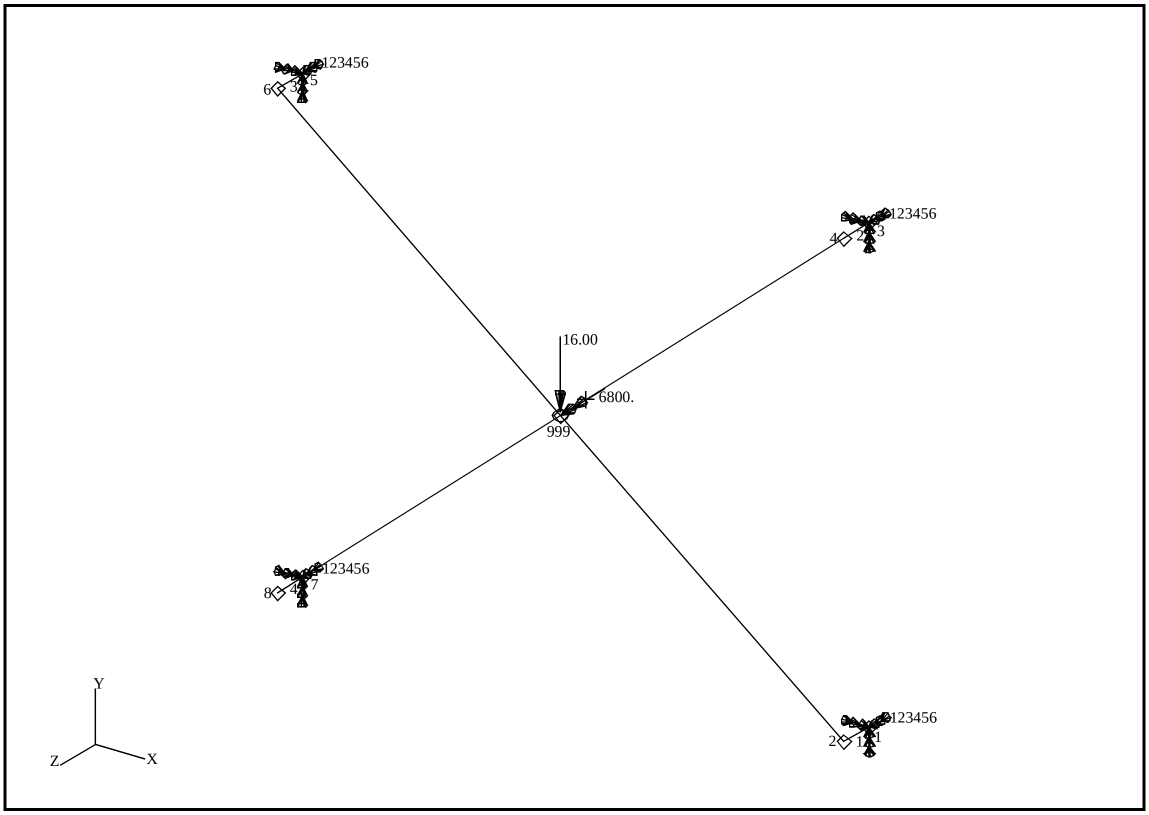
Node List *(See Figure D.4)*	**Node 2:8:2**
DOFs	**UX** **UY** **UZ**

Apply

Cancel

Apply

Figure 10a.6 - RBE3 Elements, Loads, and Boundary Conditions



13. Choose the desired analysis for Case1.

◆ **Load Cases**

Action:	**Create**
Load Case Name:	**Case_1**

Asign/Prioritize Loads/BCs

Select Loads/BCs to Add to Spreadsheet:	**Displ_Fixed_ends** **Force_Shear_Reaction**

OK

Apply

14. Choose the desired analysis for Case2. .

◆ **Load Cases**

Action:	**Create**

Load Case Name:	**Case_2**
Asign/Prioritize Loads/BCs	
Select Loads/BCs to Add to Spreadsheet:	**Force_Moment_Reaction**
Load/BC Name:	**Shear_Reaction**
Remove Selected Row	
OK	
Apply	

15. Now you are ready to run the analysis.

◆ **Analysis**	
Action:	**Analyze**
Object:	**Entire Model**
Method:	**Analysis Deck**
Jobname	**bolt_load**
Solution Type...	
Solution Type	◆ **Linear Static**
OK	
Subcase Create...	
Available Subcases:	**Case_1**
Output Requests...	
Select Result Type	**Multi-Point Constraint Forces** **Element Forces** **Applied Load** **Grid Point Froce Balance** (Click on each item onece to select.)
OK	
Apply	
Available Subcases:	**Case_2**
Output Requests...	

Select Result Type	**Multi-Point Constraint Forces** **Element Forces** **Applied Load** **Grid Point Froce Balance**

OK

Apply

Cancel

Subcase Select...

Subcases For Solution Sequence: 101	**Case_1** **Case_2** (Click on these to select.)
Subcases Selected:	**Default** (Click on this to deselect.)

OK

Apply

An MSC.Nastran input file called **bolt_load.bdf** will be generated. This process of translating your model into an input file is called the Forward Translation. The Forward Translation is complete when the Heartbeat turns green. MSC.Patran Users should proceed to Step 16.

Generating an input file for MSC.Nastran Users:

MSC.Nastran users can generate an input file using the data from table 10a.1 and figure 10a.1. The result should be similar to the output below.

16. MSC.Nastran input file: **bolt_load.bdf**

```
ID SEMINAR, APPENDIX D
SOL 101
TIME 600
CEND
TITLE = Shear and Moment Reactions - Linear Static Analysis with RBE3
SUBCASE 1
   SPC = 2
   LOAD = 2
   DISPLACEMENT(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   OLOAD(SORT1,REAL)=ALL
   MPCFORCES(SORT1,REAL)=ALL
   GPFORCE=ALL
   STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
   FORCE(SORT1,REAL,BILIN)=ALL
SUBCASE 2
   SPC = 2
   LOAD = 4
   DISPLACEMENT(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   OLOAD(SORT1,REAL)=ALL
   MPCFORCES(SORT1,REAL)=ALL
   GPFORCE=ALL
   STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
   FORCE(SORT1,REAL,BILIN)=ALL
BEGIN BULK
PARAM    POST    -1
PARAM    PATVER  3.
PARAM    AUTOSPC YES
PARAM    INREL   0
PARAM    ALTRED  NO
PARAM   COUPMASS -1
PARAM    K6ROT   0.
PARAM    WTMASS  1.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PBARL    1       1               TUBE                                    +      A
+      A 2.      1.9
CBAR     1       1       1       2       999
CBAR     2       1       3       4       999
CBAR     3       1       5       6       999
CBAR     4       1       7       8       999
MAT1*    1               7.1+10                          .3              *       B
*      B
RBE3     5               999     123456  1.      123     2       4       +       C
+      C 6       8
GRID     1               75.    -60.     0.
GRID     2               75.    -60.     10.
GRID     3               75.     60.     0.
GRID     4               75.     60.     10.
```

```
GRID     5               -75.     60.      0.
GRID     6               -75.     60.      10.
GRID     7               -75.    -60.      0.
GRID     8               -75.    -60.      10.
GRID     999              0.      0.       10.
SPCADD   2       3
LOAD     2       1.      1.       1
LOAD     4       1.      1.       3        1.      5
SPC1     3       123456  1        3        5       7
FORCE    1       999     0        16.      0.     -1.      0.
FORCE    3       999     0        0.       .57735  .57735  .57735
MOMENT   5       999     0        6800.    0.      0.      1.
ENDDATA
```

Submit the input file for analysis:

17. Submit the input file to MSC.Nastran for analysis.

    17a. To submit the MSC.Patran **.bdf** file for analysis, find an available UNIX shell window. At the command prompt enter: **nastran bolt_load.bdf scr=yes**. Monitor the run using the UNIX **ps** command.

    17b. To submit the MSC.Nastran **.dat** file for analysis, find an available UNIX shell window. At the command prompt enter: **nastran bolt_load scr=yes**. Monitor the run using the UNIX **ps** command.

18. When the run is completed, edit the **bolt_load.f06** file and search for the word **FATAL**. If no matches exist, search for the word **WARNING**. Determine whether existing WARNING messages indicate modeling errors.

19. While still editing **bolt_load.f06**, search for the word:

M U L T (spaces are necessary)

Comparison of Results:

20. Compare the results obtained in the .f06 file with the results onthe following page:

SUBCASE 1

F O R C E S   O F   M U L T I P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
2	G	0.0	-4.000000E+00	0.0	0.0	0.0	0.0
4	G	0.0	-4.000000E+00	0.0	0.0	0.0	0.0
6	G	0.0	-4.000000E+00	0.0	0.0	0.0	0.0
8	G	0.0	-4.000000E+00	0.0	0.0	0.0	0.0
999	G	0.0	1.600000E+01	0.0	0.0	0.0	0.0

CASE_2

0 SUBCAS

F O R C E S   O F   M U L T I P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
2	G	1.105691E+01	1.382114E+01	0.0	0.0	0.0	0.0
4	G	-1.105691E+01	1.382114E+01	0.0	0.0	0.0	0.0
6	G	-1.105691E+01	-1.382114E+01	0.0	0.0	0.0	0.0
8	G	1.105691E+01	-1.382114E+01	0.0	0.0	0.0	0.0
999	G	0.0	0.0	0.0	0.0	0.0	-6.800000E+03

21. Result Verification

Subcase 1 (Point 2)

T_2 = -4kN (F' = 4 kN, Pg.5)

Subcase 2 (Point 2)

T_1 = 11.057kN T_2 = 13.82kN

$$F'' = \sqrt{(T_1)^2 + (T_2)^2} = \sqrt{(11.057)^2 + (13.82)^2}$$

F" = 17.70kN (F" = 17.7kN, Pg. 5)

22. MSC.Nastran Users have finished this exercise. MSC.Patran Users should proceed to the next step.

23. Proceed with the Reverse Translation process, that is importing the **bolt_load.op2** results file into MSC.Patran. To do this, return to the ***Analysis*** form and proceed as follows:

◆ **Analysis**

Action:	**Read Output2**
Object:	**Result Entities**
Method	**Translate**
Select Results File...	
Select Results File	**bolt_load.op2**
OK	
Apply	

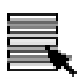
24. When the translation is complete bring up the **Results** form.

Select **Fringe** to view different results with color spectrum analysis.

◆ **Results**

Action:	**Create**
Object:	**Fringe**

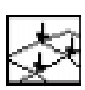
To select results, click on the **Select Results** icon.



Select Result

Select Result Case(s):	**Case_1, Static Subcase**
Select Fringe Result:	**Grid Point Forces, Total**

To change the display attributes of the plot, click on the **Display Attributes** icon.



Display Attributes

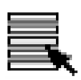
Style:	**Continus**
Element Shrink Factor	**0.05**
Display:	**Element Edges**
Style:	▬▬▬▬
Label Style...	
Label Format	**Exponential**
Significant figures	**5**
OK	
Apply	

Select **Deformation** to view physical changes of the model.

◆ **Results**

Action:	**Create**
Object:	**Deformation**

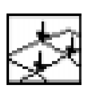
To select results, click on the **Select Results** icon.



Select Result

Select Result Case(s):	**Case_1, Static Subcase**
Select Deformation Result:	**Grid Point Forces, Total**

To change the display attributes of the plot, click on the **Display Attributes** icon.



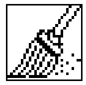
Display Attributes

❑ **Show Undeformed**

❑ **Show Max/Min Label**

Apply

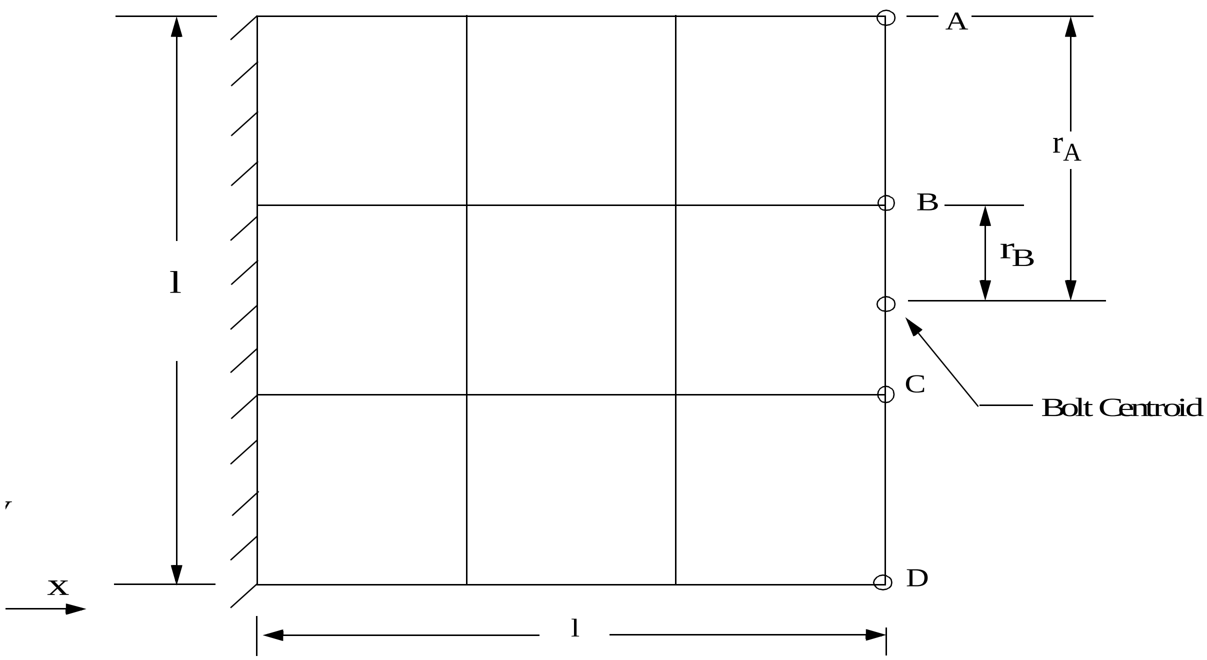
25. If you wish to reset your display graphics to the state it was in before you began post-processing your model, remember to select the **Reset Graphics** icon.



Reset Graphics

To view different results, after **Reset Graphics** repeat step 23 and change *Result Case(s), Fringe Result,* and *Deformation Result*.

Quit MSC.Patran when you are finished with this exercise.



$$M = F_A''r_A + F_B''r_B + F_C''r_C + F_D''r_D$$

Since $$\frac{F_A''}{r_A} = \frac{F_B''}{r_B} = \frac{F_C''}{r_C} = \frac{F_D''}{r_D}$$

$$F_n'' = \frac{Mr_n}{r_A^2 + r_B^2 + r_C^2 + r_D^2}$$

Reference: Shigley & Mischke, Mechanical Engineering Design, Fifth Edition
McGraw-Hill Book Company

Sample Calculation:

$$F_A" = (1000 \cdot 0.5)/(0.5^2 + 0.1667^2 + 0.1667^2 + 0.5^2)$$
$$= (1000 \cdot 0.5)/(0.555)$$
$$= 900$$

$$F_B" = \frac{(1000 \cdot 0.1667)}{(0.5^2 + 0.1667^2 + 0.1667^2 + 0.5^2)}$$

$$= 300$$

```
SOL 101
CEND
ECHO = NONE
SUBCASE 1
           SPC                 1
     LOAD                      1
     MPCFORCE=all
SUBCASE 2
     SPC = 1
     LOAD = 2
     MPCFORCE=all
SUBCASE 3
     SPC = 1
     LOAD = 3
     MPCFORCE=all
SUBCASE 4
     SPC = 1
     LOAD = 4
     MPCFORCE=all
SUBCASE 5
     SPC                1
     LOAD                      5
     MPCFORCE=all
SUBCASE 6
     SPC                1
     LOAD                      6
     MPCFORCE=all
BEGIN BULK

PARAMPOST   -
PSHELL      1      1      .1     1                1

CQUAD4      1      1      1      2        6       5
CQUAD4      2      1      2      3        7       6
CQUAD4      3      1      3      4        8       7
CQUAD4      4      1      5      6        10      9
CQUAD4      5      1      6      7        11      10
CQUAD4      6      1      7      8        12      11
CQUAD4      7      1      9      10       14      13
CQUAD4      8      1      10     11       15      14
CQUAD4      9      1      11     12       16      15

MAT1        1      1.+7          .3
RBE3               10     999    123456  1.       12354     8
     +      A
+           A 12   16
GRID        1             0.       0.       0.
GRID        2          .333333     0.       0.
GRID        3          .666667     0.       0.
GRID        4             1 .      0.       0.
GRID        5             0.     .333333   0.
GRID        6          .333333   .333333    0.
GRID        7          .666667   .333333    0.
GRID        8             1.     .333333    0.
GRID        9             0.     .666667    0.
GRID        10         .333333   .666667    0.
```

```
GRID        11      .666667      .666667   0.
GRID        12        1.        .666667  0.
GRID        3         0.         1.       0.
GRID        4       .333333      1.        0.
GRID        5       .666667      1.        0.
GRID        16      1.           1.       0.
GRID        999     1.           .5       0.

spCi        1    123456  1       5        9      13

FORCE       1      999    0      1000.     1.     0.       0.
FORCE       2      999    0      1000.     0.     1.       0.
FORCE       3      999    0      1000.     0.     0.       1.
MOMENT      4      999    0      1000.     1.     0.       0.
MOMENT      5      999    0      1000.     0.     1.       0.
MOMENT      6      999    0      1000.     0.     0.       1.

ENDDATA
```

Question: What happen if RBE3 is modified to reflect the following independent DOFs?

0 SUBCASE 1

F 0 R C E S 0 F M U L T I P O I N T C 0 N S T R A I N T

POINT ID.	TYPE	Tl	T2	T3	Rl	R2	R3
4	G	2.500000E+02	0.0	0.0	0.0	0.0	0.0
8	G	2.500000E+02	0.0	0.0	0.0	0.0	0.0
12	G	2.500000E+02	0.0	0.0	0.0	0.0	0.0
16	G	2.500000E+02	0.0	0.0	0.0	0.0	0.0
999	G	-1.00000E+03	0.0	0.0	0.0	0.0	0.0

0 SUBCASE 2

F 0 R C E S 0 F M U L T I P O I N T C 0 N S T R A I N T

POINT ID.	TYPE	Tl	T2	T3	Rl	R2	R3
4	G	0.0	2.500000E+02	0.0	0.0	0.0	0.0
8	G	0.0	2.500000E+02	0.0	0.0	0.0	0.0
12	G	0.0	2.500000E+02	0.0	0.0	0.0	0.0
16	G	0.0	2.500000E+02	0.0	0.0	0.0	0.0
999	G	0.0	-1.00000E+03	0.0	0.0	0.0	0.0

0 SUBCASE 3

F 0 R C E S 0 F M U L T I P O I N T C 0 N S T R A I N T

POINT ID.	TYPE	Tl	T2	T3	Rl	R2	R3
4	G	0.0	0.0	2.500000E+02	0.0	0.0	0.0
8	G	0.0	0.0	2.500000E+02	0.0	0.0	0.0
12	G	0.0	0.0	2.500000E+02	0.0	0.0	0.0
16	G	0.0	0.0	2.500000E+02	0.0	0.0	0.0
999	G	0.0	0.0	-1.00000E+03	0.0	0.0	0.0

0 SUBCASE 4

F 0 R C E S 0 F M U L T I P O I N TC 0 N S T R A I N T

POINT ID.	TYPE	Tl	T2	T3	Rl	R2	R3
4	G	0.0	0.0	-8.999996E+02	0.0	0.0	0.0
8	G	0.0	0.0	-3.000005E+02	0.0	0.0	0.0
12	G	0.0	0.0	3.000005E+02	0.0	0.0	0.0
16	G	0.0	0.0	8.999996E+02	0.0	0.0	0.0
999	G	0.0	0.0	0.0	-1.000000E+03	0.0	0.0

0 SUBCASE 5

F 0 R C E S 0 F M U L T I P O I N TC 0 N S T R A I N T

POINT ID.	TYPE	Tl	T2	T3	Rl	R2	R3
4	G	0.0	0.0	0.0	0.0	2.500000E+02	0.0
8	G	0.0	0.0	0.0	0.0	2.500000E+02	0.0
12	G	0.0	0.0	0.0	0.0	2.500000E+02	0.0
16	G	0.0	0.0	0.0	0.0	2.500000E+02	0.0
999	G	0.0	0.0	0.0	0.0	-1.000000E+03	0.0

0 SUBCASE 6

F 0 R C E S 0 F M U L T I P O I N TC 0 N S T R A I N T

POINT ID.	TYPE	TI	T2	T3	Rl	R2	R3
4	G	8.999996E+02	0.0	0.0	0.0	0.0	0.0
8	G	3.000005E+02	0.0	0.0	0.0	0.0	0.0
12	G	-3.000005E+02	0.0	0.0	0.0	0.0	0.0
16	G	-8.999996E+02	0.0	0.0	0.0	0.0	0.0
999	G	0.0	0.0	0.0	0.0	0.0	-1.00000000E+03