Introduction

Application of a moment to a solid surface, for example to represent a bending moment or torsion is a frequently encountered requirement. Use of a multipoint constraint (RBE3) is a common technique to accomplish this, and has its advantages and disadvantages. The main drawback is that the RBE3 cannot be created until the model is meshed, and is associated to a specific mesh and not the geometric surface.

Many FEM pre-processors include a “Total Load at a Point” option. It allows the specification of a load point and one or more surfaces to which the load will be distributed. PATRAN does include a “Total Load” option however moments are not supported. Application of a moment using the “Force, Nodal” option is a common error made by new users. This is basically invalid, as it applies the specified moment to each node. Not only does this not deliver the desired total moment; solid elements have no rotational degrees of freedom, so the load is transmitted directly to ground (provided the AUTOSPC parameter is active).

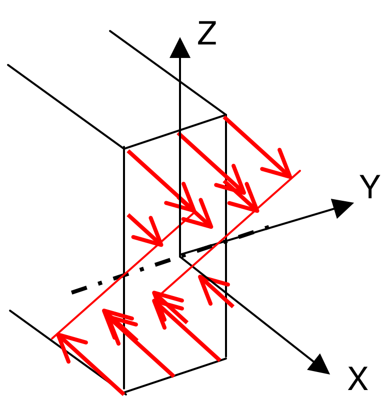
PATRAN does have the ability to model complex loadings through the use of fields and PCL formulas. This capability will be exploited to distribute moments over surfaces, and provide the “Total Load at a Point” functionality.

The following is untested on releases prior to 2008R1.

Linearly Distributed Load Approach

Beam and torsion theories assume a linear stress distribution originating from the neutral axis / centroid. It is fairly reasonable then to assume a linearly distributed surface traction to represent an applied moment. A rigorous mathematical proof of the technique presented herein is not provided. Rather, the core thought processes are discussed, and the method validated by examples.

Consider first, a simple rectangular beam with a linearly distributed applied load:



$$f_x(z) = k \cdot z$$

$$M_y = \oint_S f_x(z) \cdot z dS = k \oint_S z^2 dS$$

Recognizing that,

$\oint_S z^2 dS = I_y$ is a key to the method. Thus,

$$k = \frac{M_y}{I_y}$$

Further, the applied distributed load results in zero net force and zero moments in the other directions.

The exercise can be repeated to produce M_z. For this case, a negative sign is introduced to account for the coordinate system sign convention:

$$f_x(y) = l \cdot y$$

$$M_z = -\oint_S f_x(y) \cdot y dS = -l \oint_S y^2 dS$$

$$M_z = -l \cdot I_z$$

$$l = -\frac{M_z}{I_z}$$

Since neither of these two load distributions affects the moment in the other directions, they may be superposed. A load distribution can be expressed to produce target M_y and M_z:

$$f_x(y,z) = -\frac{M_z}{I_z} \cdot y + \frac{M_y}{I_y} \cdot z$$

Beam cross-sections normal to the remaining y- and z- axes can be treated in the same manner to determine $f_y(x,z)$ and $f_z(x,y)$:

$$f_y(x,z) = \frac{M_z}{I_z} \cdot x - \frac{M_x}{I_x} \cdot z$$

$$f_z(x,y) = -\frac{M_y}{I_y} \cdot x + \frac{M_x}{I_x} \cdot y$$

Believing that the above force distribution is applicable to a generalized 3D case requires some intuition on how loads and moments of inertia can be decomposed / projected onto the coordinate planes. The validity shall be demonstrated by several examples.

First however, the capability to include force components is incorporated by adding a uniform load of form *F/A*. Additionally, the above equations are based on a coordinate system at the surface centroid. To allow an arbitrary coordinate system, offsets are incorporated:

$$f_x(y,z) = -\frac{M_z}{I_z} \cdot (y - \bar{y}) + \frac{M_y}{I_y} \cdot (z - \bar{z}) + \frac{F_x}{A}$$

$$f_y(x,z) = \frac{M_z}{I_z} \cdot (x - \bar{x}) - \frac{M_x}{I_x} \cdot (z - \bar{z}) + \frac{F_y}{A}$$

$$f_z(x,y) = -\frac{M_y}{I_y} \cdot (x - \bar{x}) + \frac{M_x}{I_x} \cdot (y - \bar{y}) + \frac{F_z}{A}$$

Note that the formulation still represents loads at the centroid, however allows the use of an arbitrary coordinate system to define the equations. For true “Total Load at a Point” functionality the moment terms must be modified to include extra moments caused by forces applied offset from the centroid. The additional moment terms could be include in the equations, however it is probably more convenient to calculate the adjusted moments first then use the results:

$$M'_x = M_x + F_z \cdot (y_p - \bar{y}) - F_y \cdot (z_p - \bar{z})$$
$$M'_y = M_y - F_z \cdot (x_p - \bar{x}) + F_x \cdot (z_p - \bar{z})$$
$$M'_z = M_z + F_y \cdot (x_p - \bar{x}) - F_x \cdot (y_p - \bar{y})$$

$$f_x(y,z) = -\frac{M'_z}{I_z} \cdot (y - \bar{y}) + \frac{M'_y}{I_y} \cdot (z - \bar{z}) + \frac{F_x}{A} \qquad (1)$$
$$f_y(x,z) = \frac{M'_z}{I_z} \cdot (x - \bar{x}) - \frac{M'_x}{I_x} \cdot (z - \bar{z}) + \frac{F_y}{A}$$
$$f_z(x,y) = -\frac{M'_y}{I_y} \cdot (x - \bar{x}) + \frac{M'_x}{I_x} \cdot (y - \bar{y}) + \frac{F_z}{A}$$

where (x_p, y_p, z_p) is the load application point and $(\bar{x}, \bar{y}, \bar{z})$ is the centroid of the reaction surface(s).

Limitations and Generalized Extension

Through testing and experimentation, it was discovered that the above only holds true when working in a coordinate system orthogonal to the principal inertia directions (i.e. the non-diagonal inertia matrix terms equal zero). When this is not the case, the assertion that the field for example to create the x-moment results in zero y- or z- moments is invalid due to cross-talk from the non-diagonal terms.

For the majority of practical cases, the non-diagonal terms will be zero, however if not, one option to overcome this issue is to transform the applied loads into the principal inertia coordinate system. This is not that difficult, however requires the creation of and use of (for the field and load definition) a new Coord in the model.

Alternatively, an expanded set of equations has been determined that incorporate the non-diagonal terms to provide the correct result in an arbitrary Coord.

The formulation was determined by inspection; a rule that produced the correct equations for the orthogonal oriented case was determined, and then investigated to see if it worked in the general case.

First, it is evident that $\frac{M}{I}$ terms are prevalent. In general tensor scope, this suggests that the inverse of the inertia matrix is required.

Next it was observed that:

$$\begin{bmatrix} 0 & z & -y \\ -z & 0 & x \\ y & -x & 0 \end{bmatrix} \begin{pmatrix} \frac{M_x}{I_x} \\ \frac{M_y}{I_y} \\ \frac{M_z}{I_z} \end{pmatrix} = \begin{pmatrix} f_x \\ f_y \\ f_z \end{pmatrix}$$

Is equivalent to Eqn. (1) (ignoring the pure forces and centroid offset).

It was thus hypothesized that:

$$\begin{pmatrix} f_x \\ f_y \\ f_z \end{pmatrix} = \begin{bmatrix} 0 & z & -y \\ -z & 0 & x \\ y & -x & 0 \end{bmatrix} \begin{bmatrix} I_{11}^{-1} & I_{12}^{-1} & I_{13}^{-1} \\ & I_{22}^{-1} & I_{23}^{-1} \\ sym. & & I_{33}^{-1} \end{bmatrix} \begin{pmatrix} M_x \\ M_y \\ M_z \end{pmatrix} \qquad where\ I_{nm}^{-1}\ are\ terms\ from\ [I]^{-1}$$

Expanding and collecting terms, and including the pure forces and centroid offsets, Eqn. (2) was tested and validated.

$$\begin{aligned} M'_x &= M_x + F_z \cdot (y_p - \bar{y}) - F_y \cdot (z_p - \bar{z}) \\ M'_y &= M_y - F_z \cdot (x_p - \bar{x}) + F_x \cdot (z_p - \bar{z}) \\ M'_z &= M_z + F_y \cdot (x_p - \bar{x}) - F_x \cdot (y_p - \bar{y}) \end{aligned} \qquad \text{———} \quad (2)$$

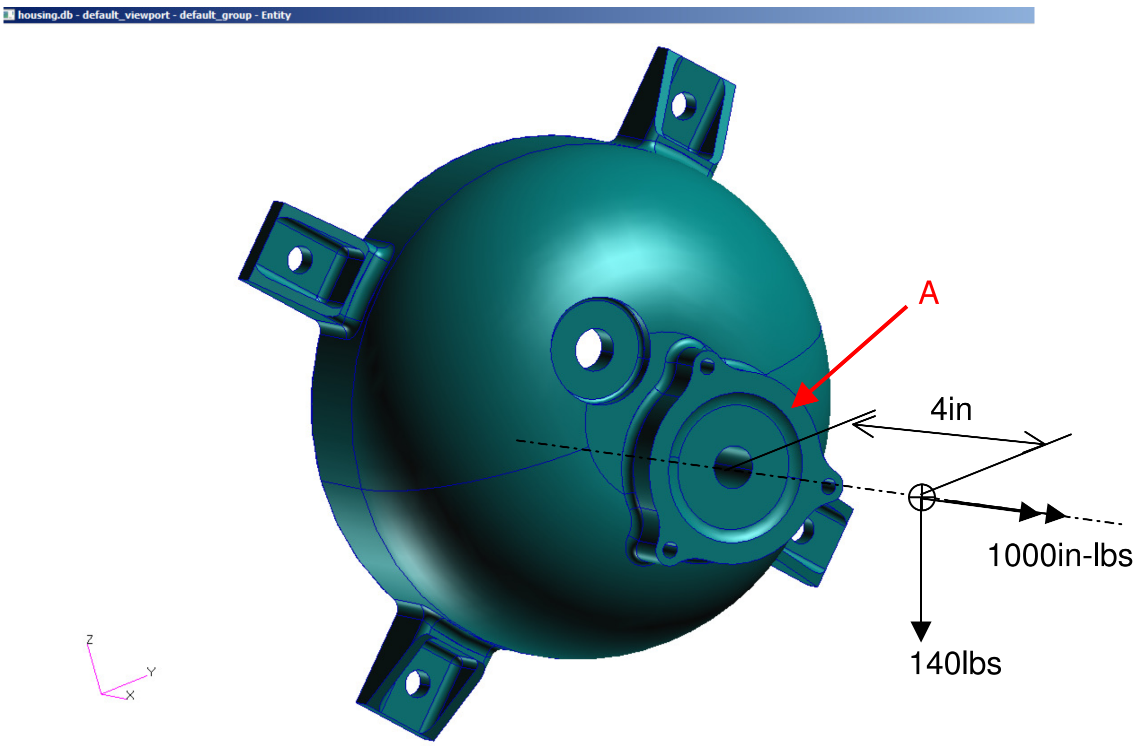
$$\begin{aligned} f_x(y,z) &= -(M'_x \cdot I_{13}^{-1} + M'_y \cdot I_{23}^{-1} + M'_z \cdot I_{33}^{-1}) \cdot (y - \bar{y}) + (M'_x \cdot I_{12}^{-1} + M'_y \cdot I_{22}^{-1} + M'_z \cdot I_{23}^{-1}) \cdot (z - \bar{z}) + \frac{F_x}{A} \\ f_y(x,z) &= (M'_x \cdot I_{13}^{-1} + M'_y \cdot I_{23}^{-1} + M'_z \cdot I_{33}^{-1}) \cdot (x - \bar{x}) - (M'_x \cdot I_{11}^{-1} + M'_y \cdot I_{12}^{-1} + M'_z \cdot I_{13}^{-1}) \cdot (z - \bar{z}) + \frac{F_y}{A} \\ f_z(x,y) &= -(M'_x \cdot I_{12}^{-1} + M'_y \cdot I_{22}^{-1} + M'_z \cdot I_{23}^{-1}) \cdot (x - \bar{x}) + (M'_x \cdot I_{11}^{-1} + M'_y \cdot I_{12}^{-1} + M'_z \cdot I_{13}^{-1}) \cdot (y - \bar{y}) + \frac{F_z}{A} \end{aligned}$$

An MS/Excel spreadsheet has been created to facilitate the calculations and field creation. It is illustrated in Example 2.

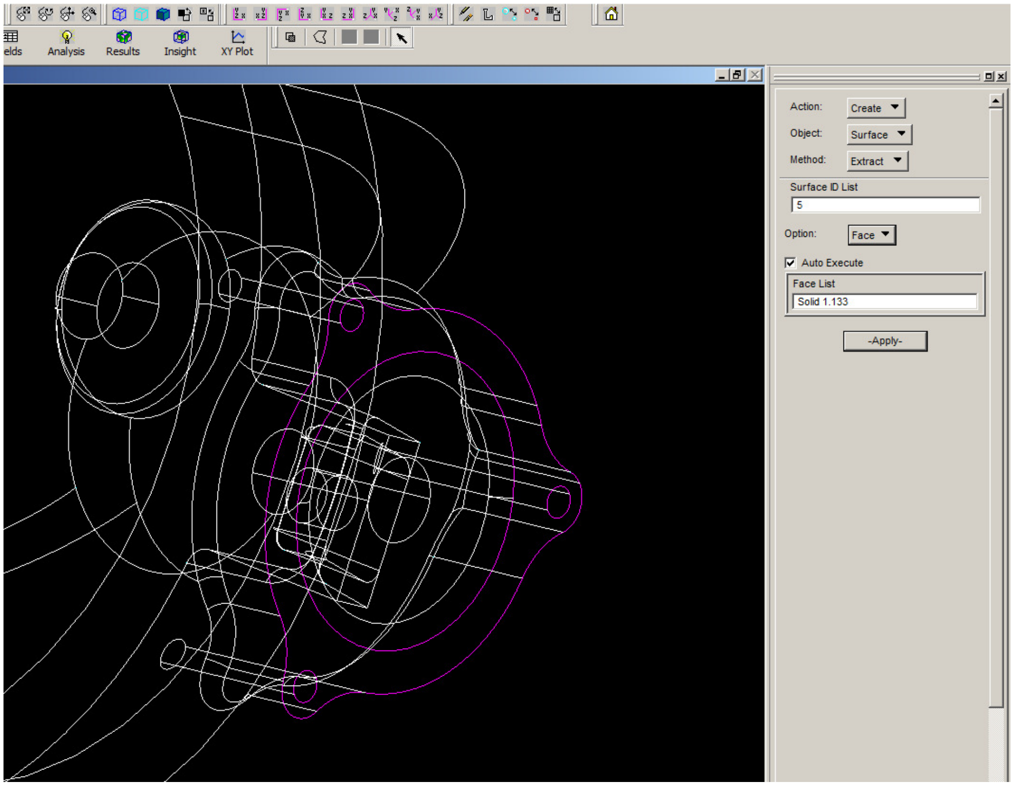
Example Implementation in PATRAN

The gearbox housing pictured below supports a motor fastened to surface 'A'. No other part of the gear train reacts torque to the housing except for the bolt feet. Grounding the feet will represent the connection to the adjacent structure.

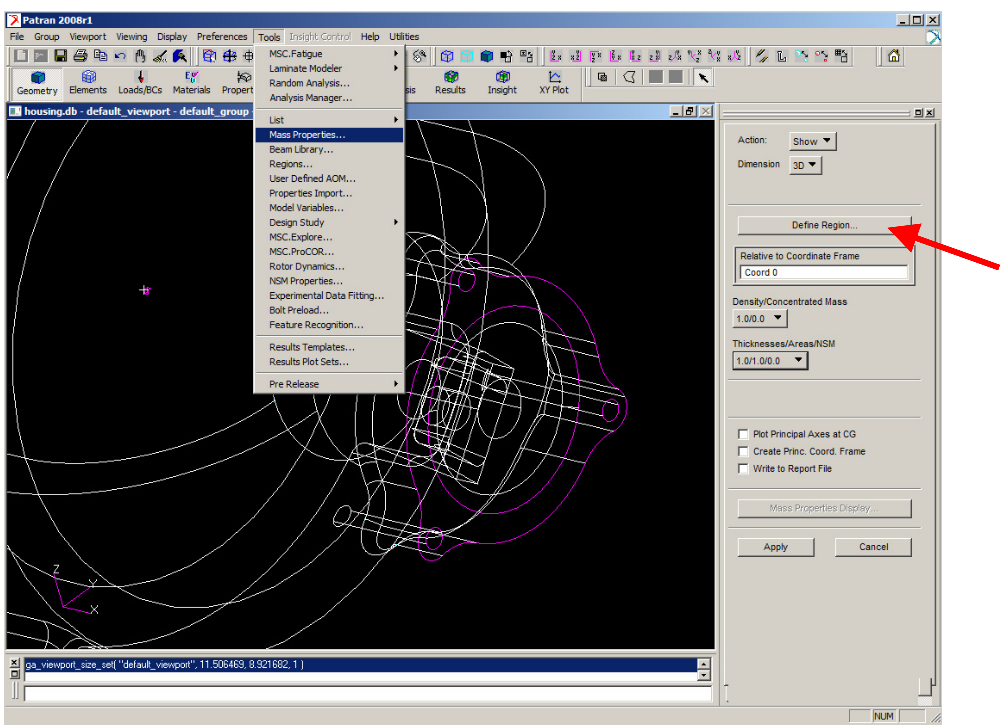
The motor weighs 20lbs and may be subject to 7G vertical acceleration (generating –140lbs negative Z load). The centre of gravity of the motor is 4in from the mounting surface. Simultaneously, the motor produces 1000in-lbs of torque about the positive X-axis.



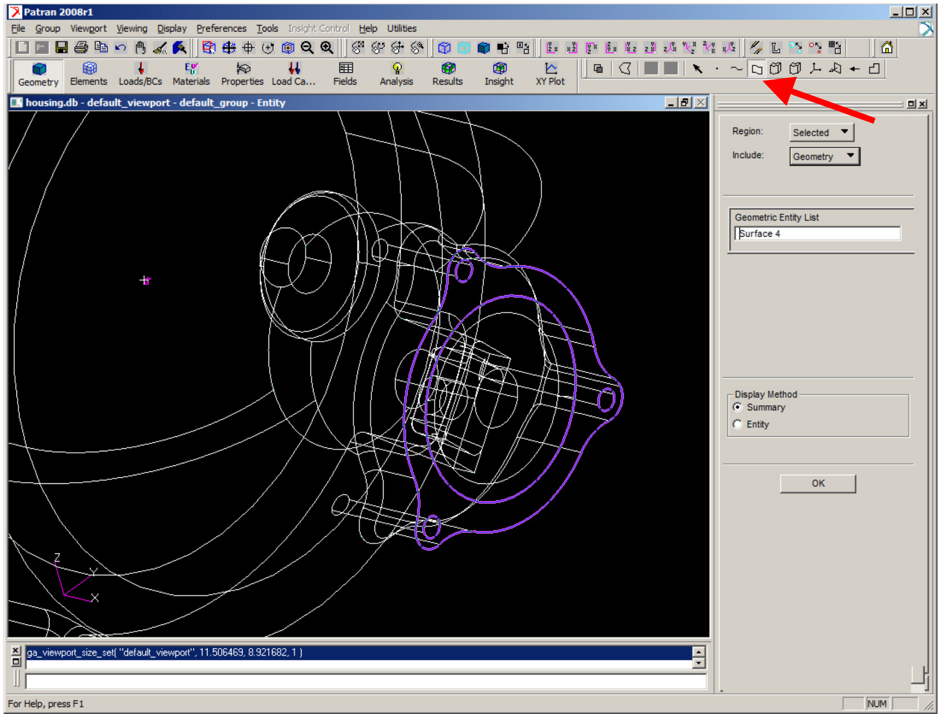
First the inertial properties of the reaction surface must be extracted. PATRAN includes a mass property tool, however it requires surfaces (rather than solid faces) as input. The surface is easily created using the *"Create, Surface, Extract, Face"* option:



Next the *"Tools, Mass Properties, Show, 3D"* menu is used. Setting *Density* and *Thickness* to *1.0* will allow the calculation of surface properties:

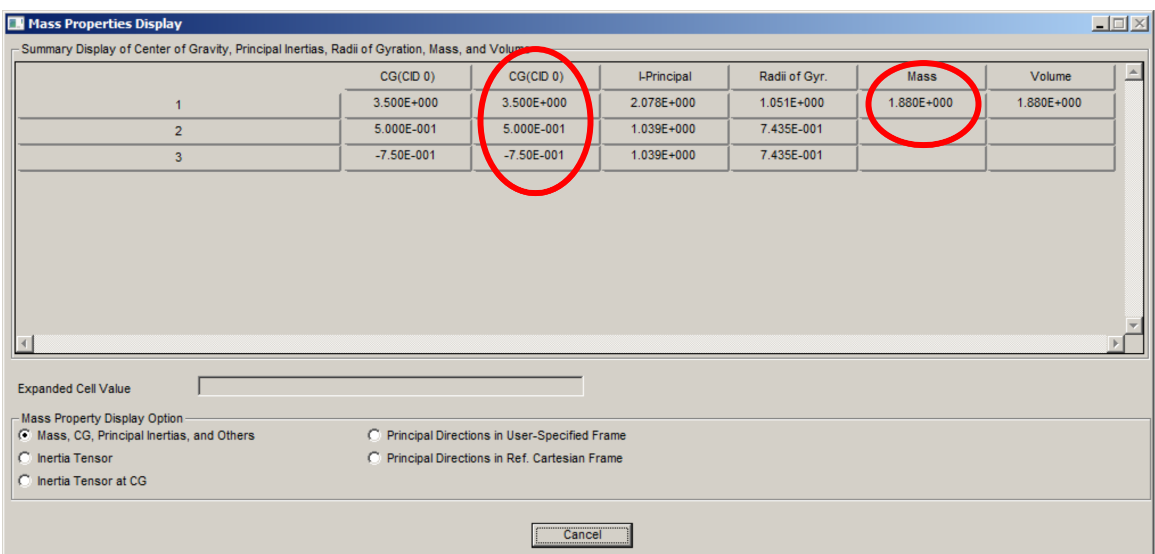


Choosing the "*Define Region*" button, then *"Selected, Geometry"* allows selection of the surface (filtering surfaces from the entity type menu may facilitate the selection of the desired surface):



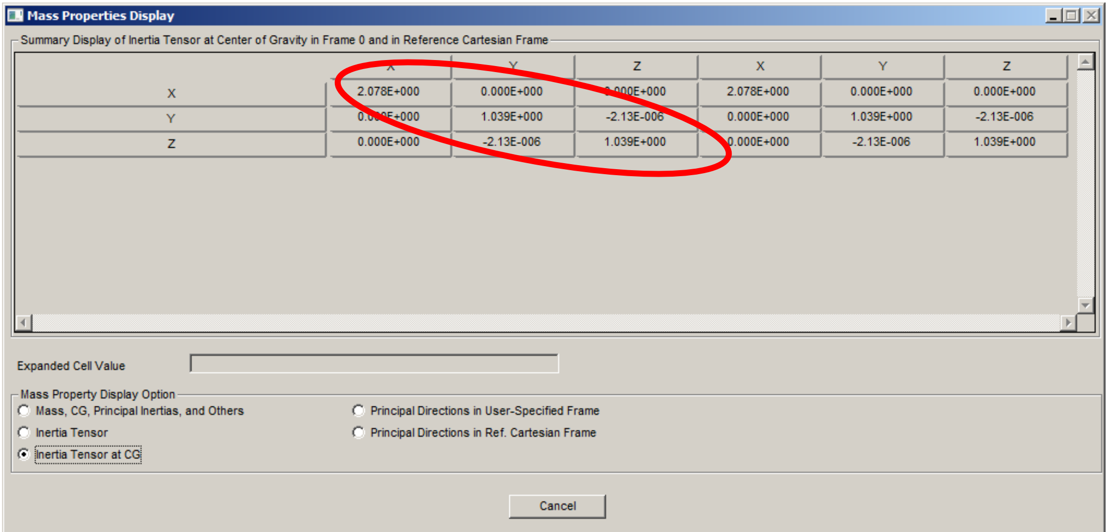
For this example, we shall use the global coordinate system. If an alternate system is desired, be sure to enter it in the *"Relative to Coordinate Frame"* box.

Upon entering apply the following information is displayed:



Since Coord 0 has been selected as the relative frame, columns 1 and 2 are identical providing the coordinates of the centroid. Had an alternate frame been selected, the second column provides the results in that system. The Mass (or Volume) result provides the area of the surface (recall that density and thickness were set to 1.0).

Next *"Inertia Tensor at CG"* provides the remaining required information:



Again, two sets of data are provided. The first matrix corresponds to the selected relative frame, the diagonal provides I_x, I_y and I_z.

The last piece of information required is the coordinates of the load application point. For this problem, we know it is 4in from the centroid thus (x_p,y_p,z_p)=(7.5,0.5,-0.75). The example is fully defined:

$$F_x = 0 \qquad F_y = 0 \qquad F_z = -140$$
$$M_x = 1000 \qquad M_y = 0 \qquad M_z = 0$$

$$A = 1.88$$
$$x_p = 7.5 \qquad y_p = 0.5 \qquad z_p = -0.75$$
$$\bar{x} = 3.5 \qquad \bar{y} = 0.5 \qquad \bar{z} = -0.75$$
$$I_x = 2.078 \qquad I_y = 1.039 \qquad I_z = 1.039$$

Eqn. (1) is used since the inertia non-diagonal terms are zero

$$M'_x = M_x + F_z \cdot (y_p - \bar{y}) - F_y \cdot (z_p - \bar{z}) = 1000 - 140(0.5 - 0.5) - 0(-0.75 + 0.75) = 1000$$
$$M'_y = M_y - F_z \cdot (x_p - \bar{x}) + F_x \cdot (z_p - \bar{z}) = 0 + 140(7.5 - 3.5) + 0(-0.75 + 0.75) = 560$$
$$M'_z = M_z + F_y \cdot (x_p - \bar{x}) - F_x \cdot (y_p - \bar{y}) = 0 + 0(7.5 - 3.5) - 0(0.5 - 0.5) = 0$$

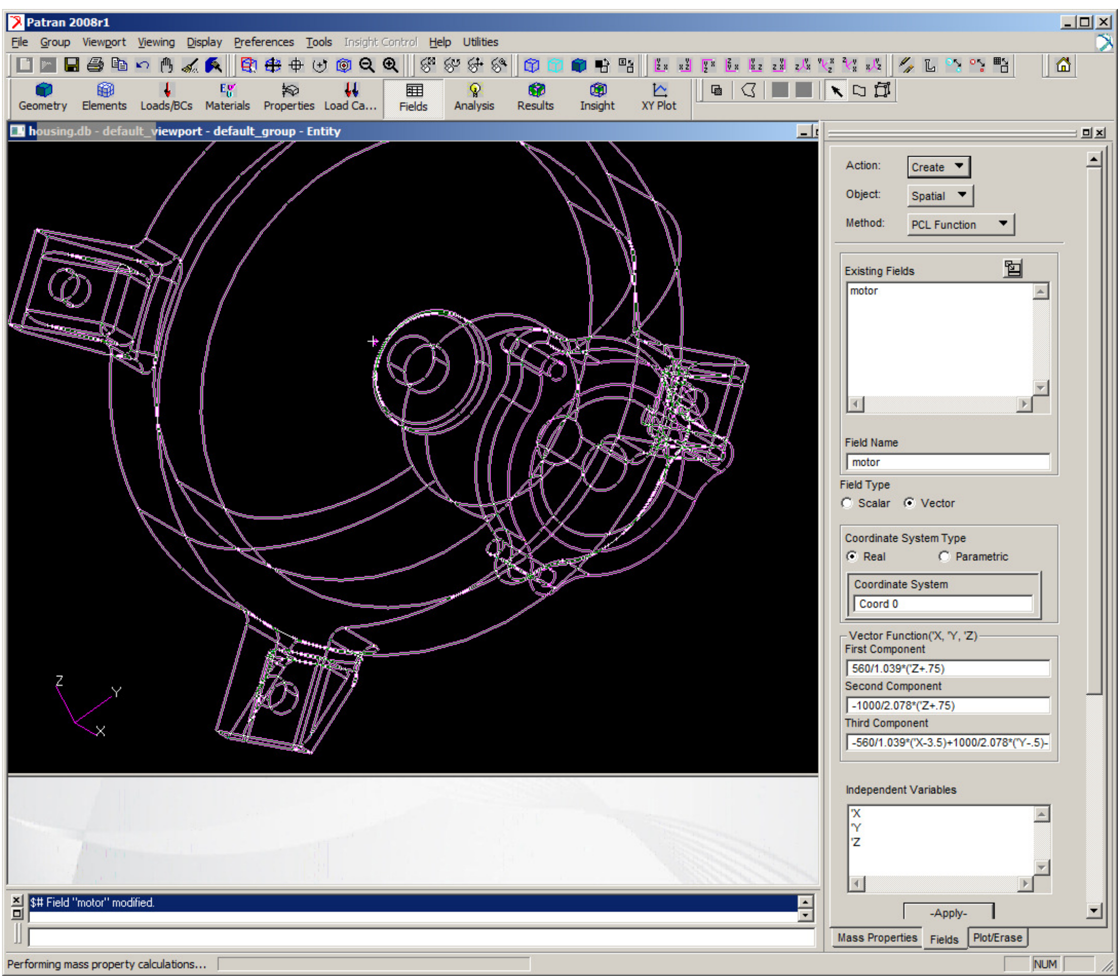
$$f_x(y,z) = -\frac{M'_z}{I_z} \cdot (y - \bar{y}) + \frac{M'_y}{I_y} \cdot (z - \bar{z}) + \frac{F_x}{A} = \frac{560}{1.039} \cdot (z + 0.75)$$
$$f_y(x,z) = \frac{M'_z}{I_z} \cdot (x - \bar{x}) - \frac{M'_x}{I_x} \cdot (z - \bar{z}) + \frac{F_y}{A} = -\frac{1000}{2.078} \cdot (z + 0.75)$$
$$f_z(x,y) = -\frac{M'_y}{I_y} \cdot (x - \bar{x}) + \frac{M'_x}{I_x} \cdot (y - \bar{y}) + \frac{F_z}{A} = -\frac{560}{1.039} \cdot (x - 3.5) + \frac{1000}{2.078} \cdot (y - 0.5) - \frac{140}{1.88}$$

It should be pointed out that these load distributions are in pressure units. PATRAN allows the definition of pressure based on a field, however that would only allow loads normal to the surface. The Distributed Load option also functions in units of pressure, but is not applicable to 3D elements. The load option we want is *"CID Distributed Load"*.

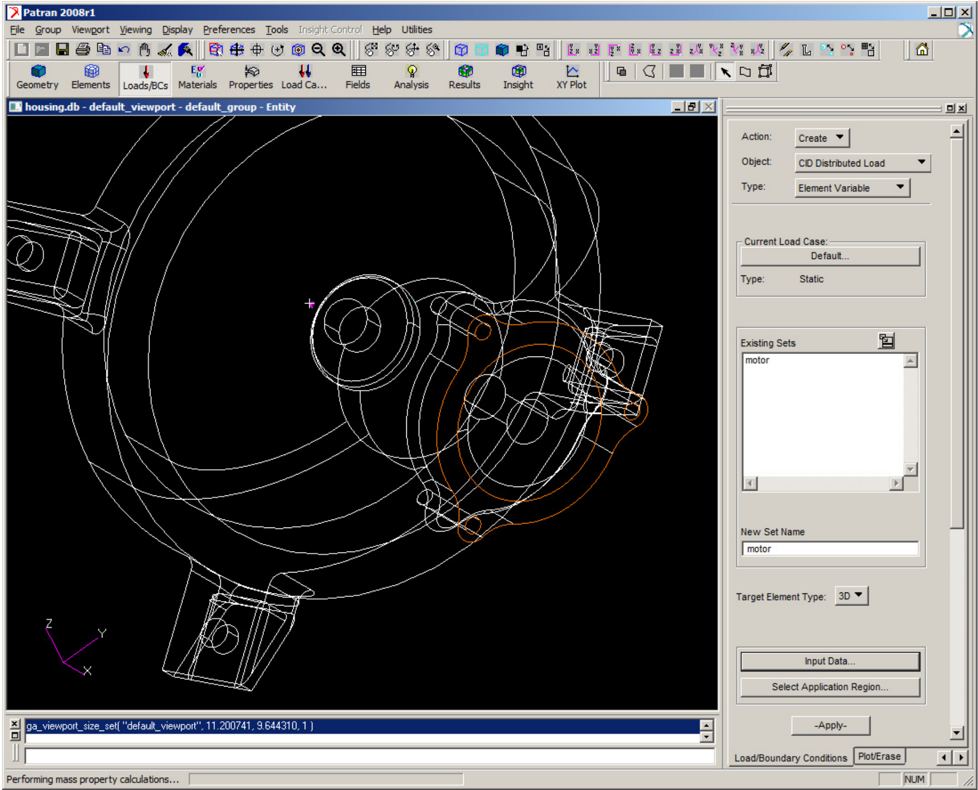
First however, a field must be created to reproduce the above equations.

"Fields, Create, Spatial, PCL Function, Vector, Real" are the required options, plus specification of a name for the field. The desired relative coordinate system must be specified the same both on this field entry, and later on the CID Distributed Load entry. (Default Coord 0 for this example).

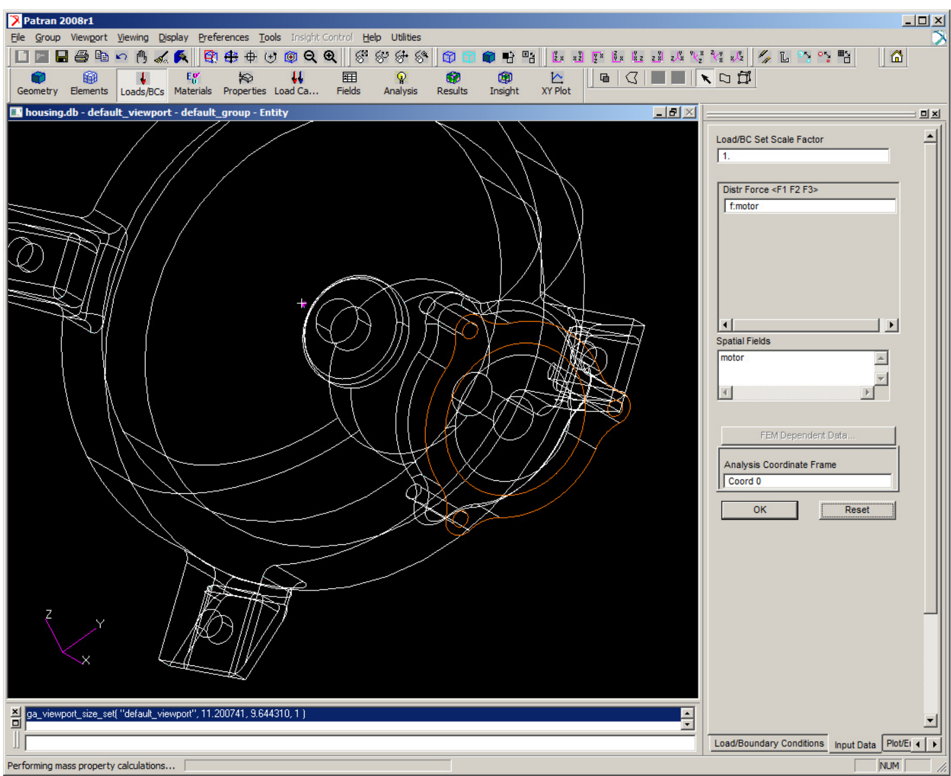
The Vector Function definition, first, second, third direction corresponds to our f_x, f_y, f_z force distributions. x, y, and z are permitted as variables within the functions and are denoted with the (‘) symbol. The input looks as follows (the third component is not fully visible as the input scrolls):



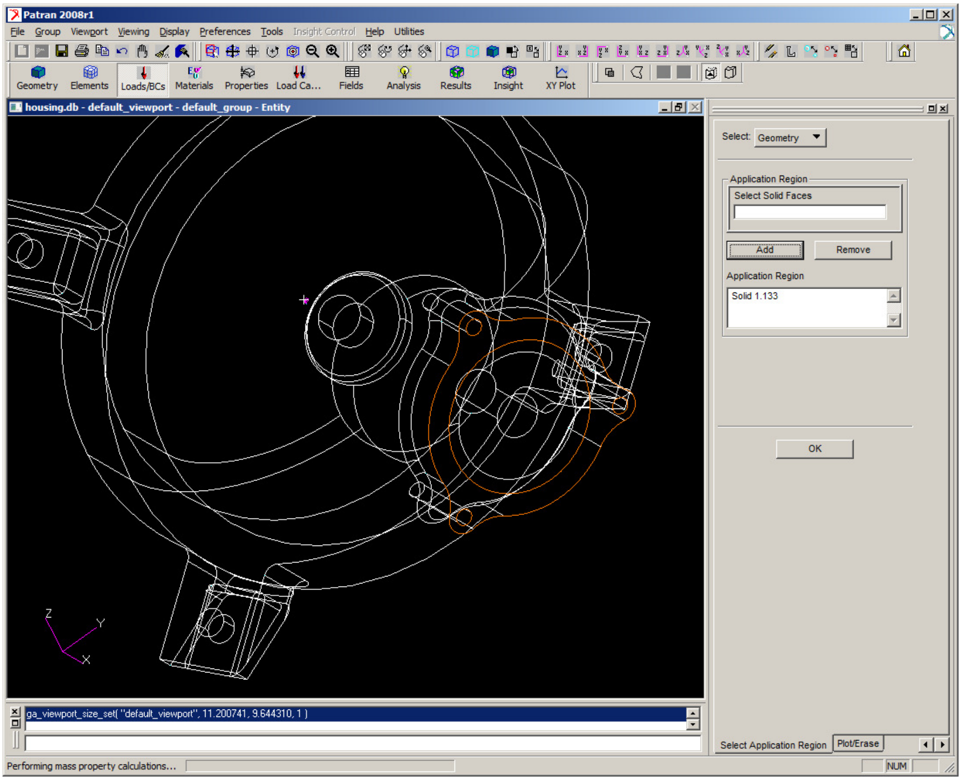
Finally, the load can be created. *"Load/BCs, Create, CID Distributed Load, Element Variable, (Target Element Type) 3D"*. A name must be specified as well.



The *"Input Data"* menu allows selection of the field to define the force. Recall, the *"Analysis Coordinate Frame"* must be the same as the relative frame for mass property calculation and the field definition.

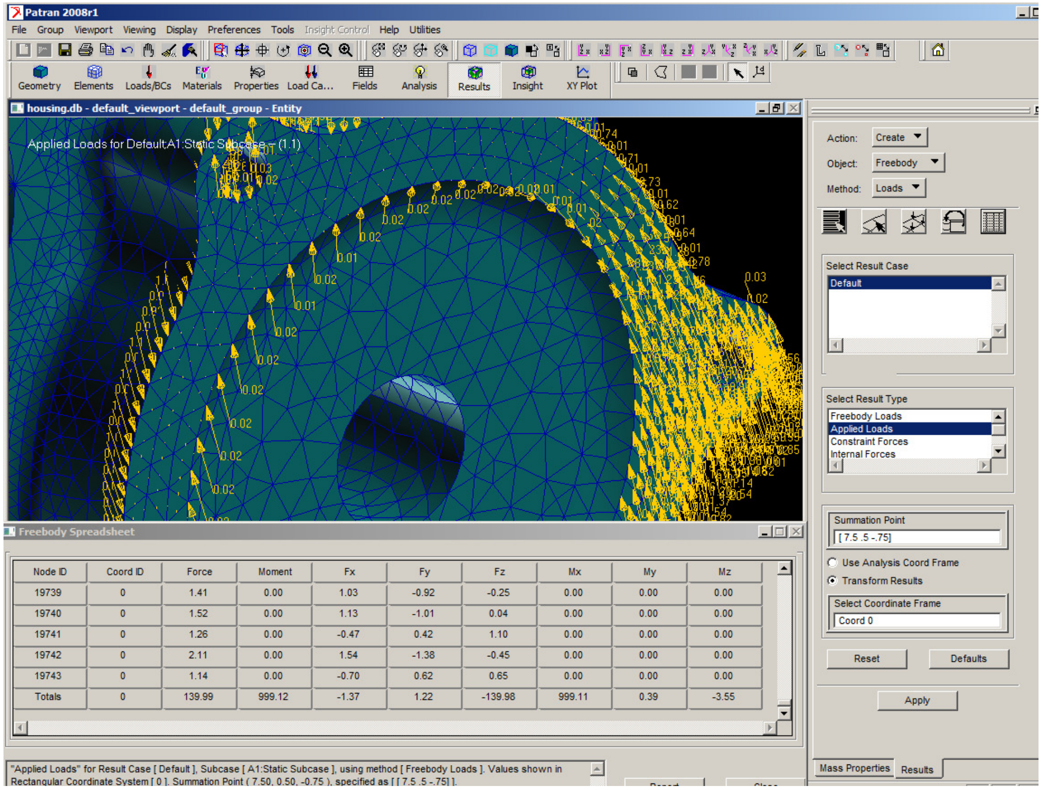


Last, *"Select Application Region, (Select) Geometry"* is used to select the solid face on which to apply the load. (Note that now the actual solid is referenced; the surface created for the mass property calculation is no longer need and may be deleted if desired).



The bolt hole surfaces of the feet are grounded in all directions for simplicity. The resulting graphical display is not always very useful, however after the model is executed, *Freebody* results are used to better visualize the loading, and validate the applied values. (Be sure to enable *Grid Point Force Balance* from the *"Analysis, Subcases, Global Data, Output Requests"* in order to display Freebody Results).

The use of *"Results, Freebody, Loads, Applied Loads"* allows review of the resulting reaction. Specifying the load application point coordinates as the *"Summation Point"* should closely reproduce the intended load. (The values will not be exact due to discretization of the field onto the mesh). If the Global Coordinate system is not used, then the *"Transform Results"* option should specify the relative coordinate system. Further note, even when *"Transform Results"* is selected, the *"Summation Point"* is specified in Coord 0. It is often convenient to create a geometrical point at the load position and select it.



Target Load:

$F_x = 0 \quad F_y = 0 \quad F_z = -140$

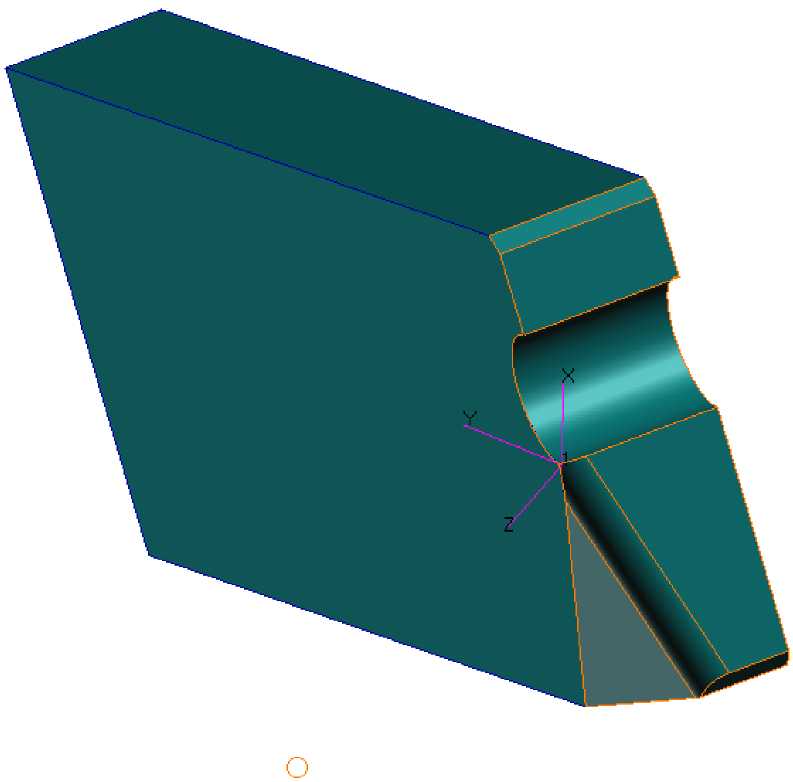
$M_x = 1000 \quad M_y = 0 \quad M_z = 0$

Applied Load:

$F_x = -1.37 \quad F_y = 1.22 \quad F_z = -139.98$

$M_x = 999.11 \quad M_y = 0.39 \quad M_z = -3.55$

Example 2: Random Surfaces and Load (Spreadsheet Usage)

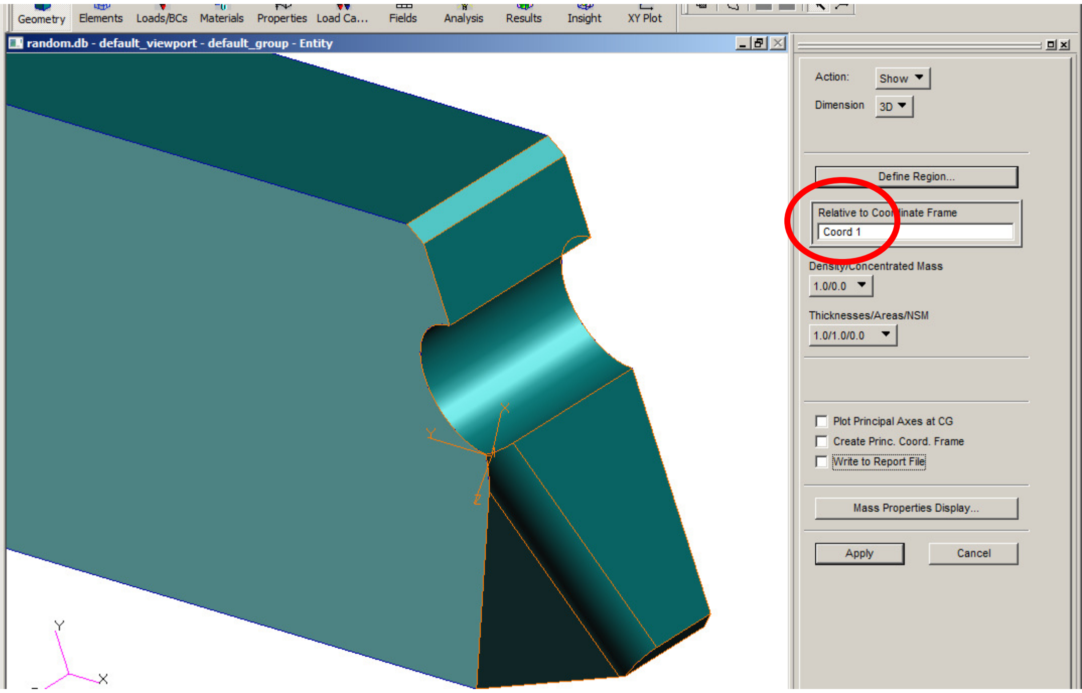


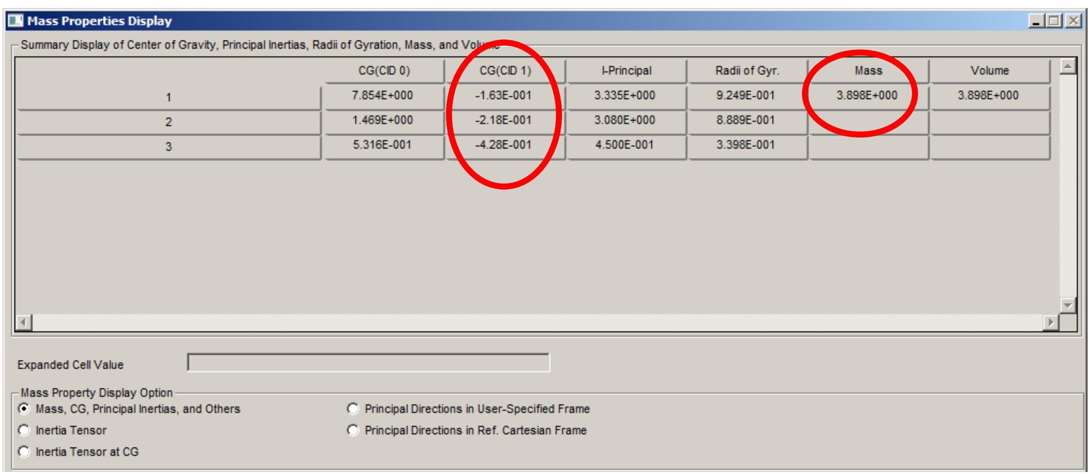
Relative Coord 1 is used and load applied at point 3in along z-axis. Load distributed over all end surfaces (multiple surfaces may be selected for mass property calculations and the CID Distributed Load application).

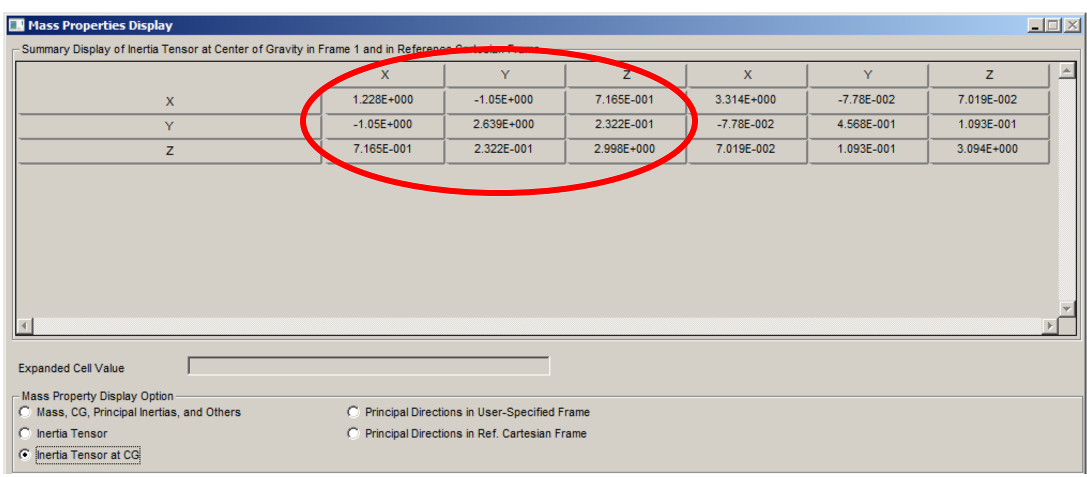
$F_x = 1200$ $F_y = -700$ $F_z = 2000$

$M_x = -5000$ $M_y = 2000$ $M_z = 3000$

The MS/Excel spreadsheet *fields_calc.xls* was created to facilitate the generalized 3D field calculation. First, we must extract the mass properties for the loaded surfaces:



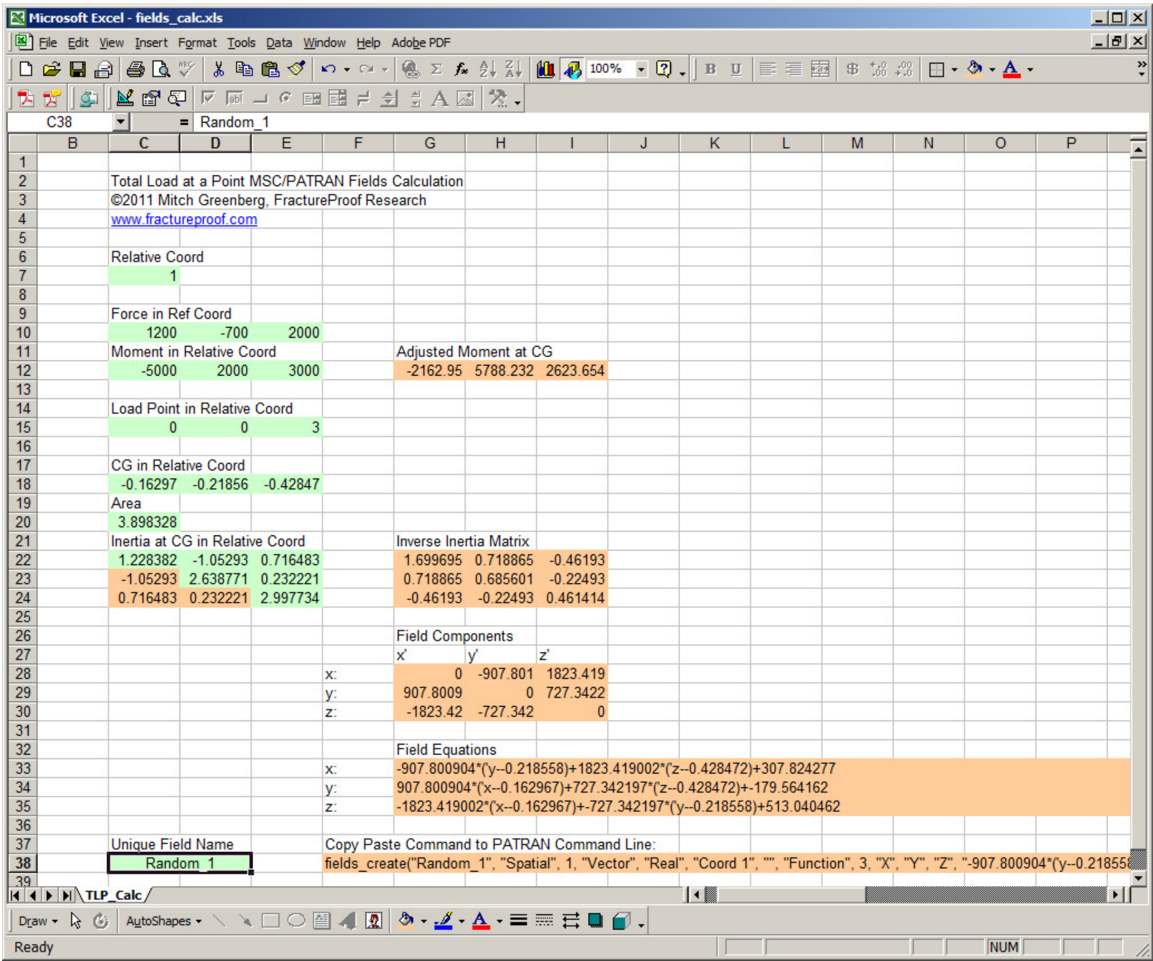




Higher precision is possible if *"Write to Report File"* is chosen:

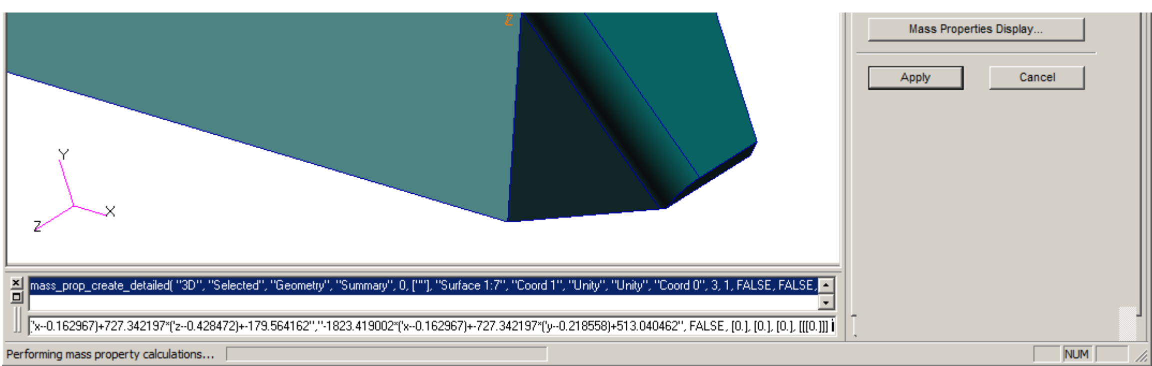
```
*******************************************************************************************
*                                                      MASS PROPERTIES REPORT
*
*******************************************************************************************
*
File: C:\msc_work\pcl_dev\TotalLoadatPoint\random.db
Date: 26-Sep-11
Time: 14:39:58

Scalar Properties:
         Volume            Mass
       3.898328        3.898328
Center of Gravity in Coordinate Frame:
   Comp.    Ref. Cartes.         Frame 1
       X        7.854010       -0.162967
       Y        1.469017       -0.218558
       Z        0.531551       -0.428472
Principal Inertia Quantities:
   Pr. Inertias   Rad. of Gyr.
       3.334837       0.924907
       3.080040       0.888872
       0.450010       0.339760
Inertia Tensor in Coordinate Frame:
   Comp.    Ref. Cartes.         Frame 1
      XX       12.827685        2.130284
      YY      242.028442        3.457993
      ZZ      251.977295        3.287481
      XY      -45.055447       -1.191775
      YZ       -2.934718       -0.132842
      ZX      -16.204571        0.444275
Inertia Tensor at CG in Coordinate Frame:
   Comp.    Ref. Cartes.         Frame 1
      XX        3.313596        1.228382
      YY        0.456805        2.638771
      ZZ        3.094486        2.997734
      XY       -0.077818       -1.052925
      YZ        0.109318        0.232221
      ZX        0.070188        0.716483
Principal Directions in Reference Cartesian Frame:
       Vector 1       Vector 2       Vector 3
       0.961679      -0.272727      -0.028170
      -0.015605       0.048134      -0.998719
       0.273734       0.960887       0.042033
Principal Directions in Frame 1:
       Vector 1       Vector 2       Vector 3
       0.495845      -0.162095      -0.853149
      -0.517363       0.733910      -0.440127
       0.697477       0.659622       0.280044
Space-Fixed and Body-Fixed Rotation Angles in Reference Cartesian Frame
    Space 3-2-1     Body 3-1-3
      15.833065      -1.615691
      -1.614262      87.590973
      87.590012      15.900995
Space-Fixed and Body-Fixed Rotation Angles in Coordinate Frame 1:
    Space 3-2-1     Body 3-1-3
      18.102892     -62.711433
     -58.555843      73.737190
      57.532280      46.597782

Mass Properties Entity List:
Surface 1:7
The number of included entities is 7.

The Mass Properties entity rejection list is empty.
```

The identified values are simply entered into the green fields:

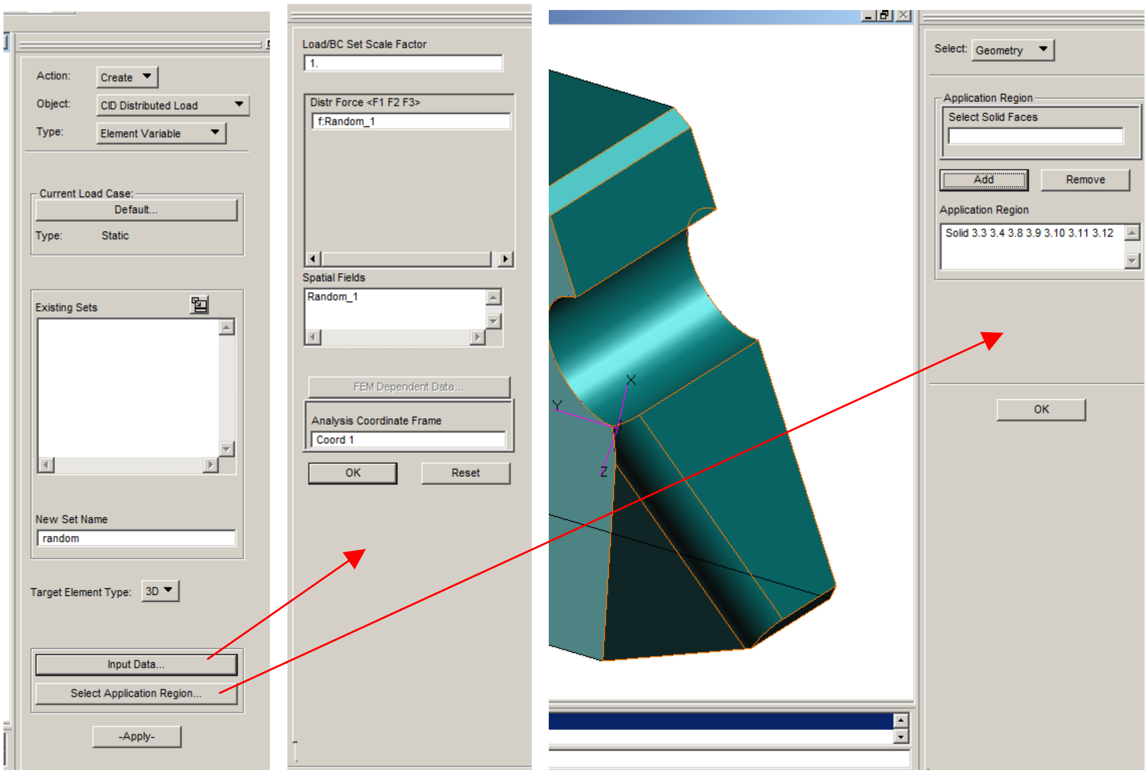


The field may be created manually by using the *"Field Equations".* However, it is even simpler to copy and paste the command. Make sure a unique field name is chosen, then use CTLR-C to copy the contents of cell F38.

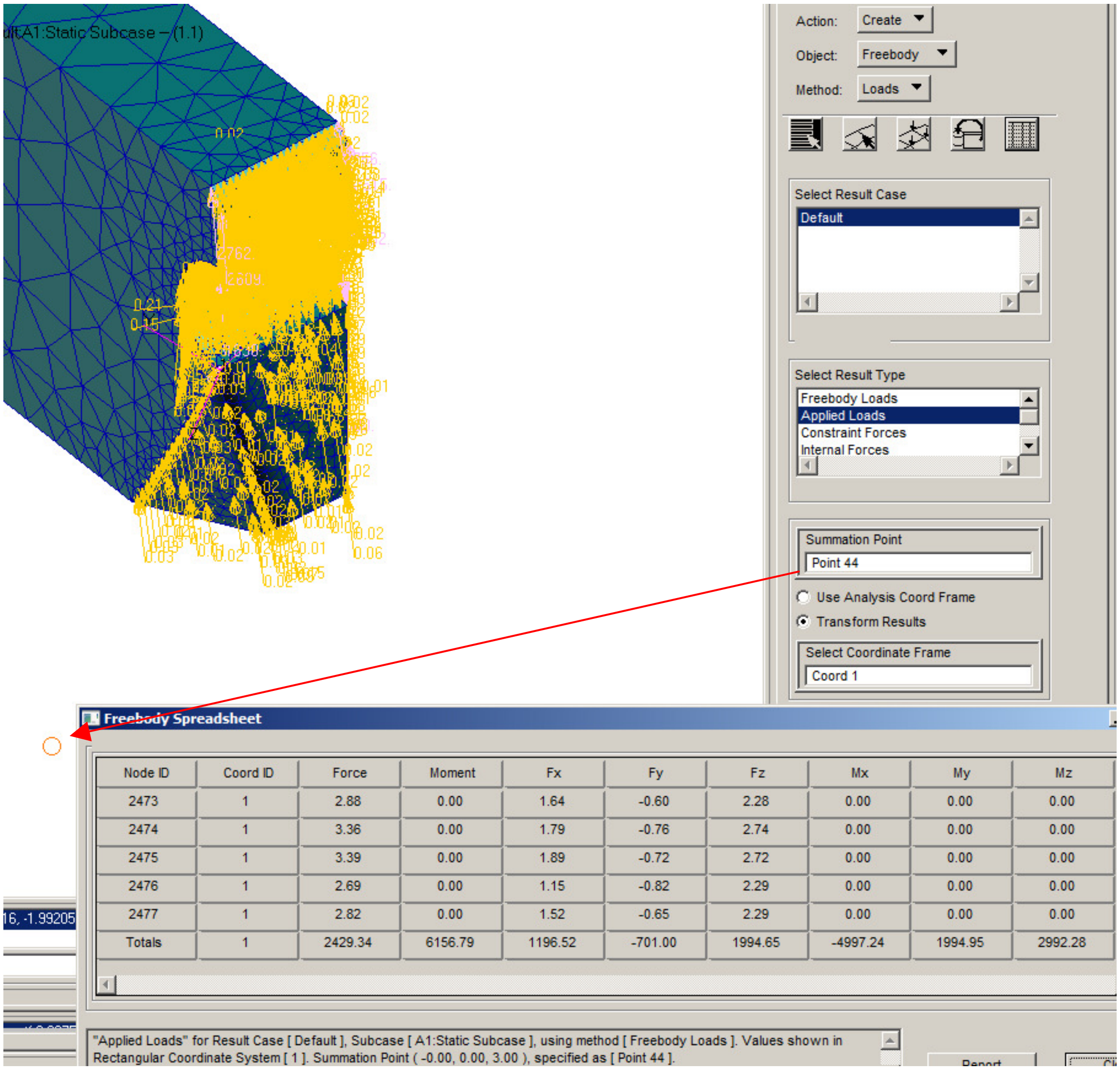
Use CTLR-V to paste into PATRAN's command line and hit enter to create the field:



Finally, create the *CID Distributed Load*:



The opposite end of the beam is grounded, material and properties defined, then the model is solved.

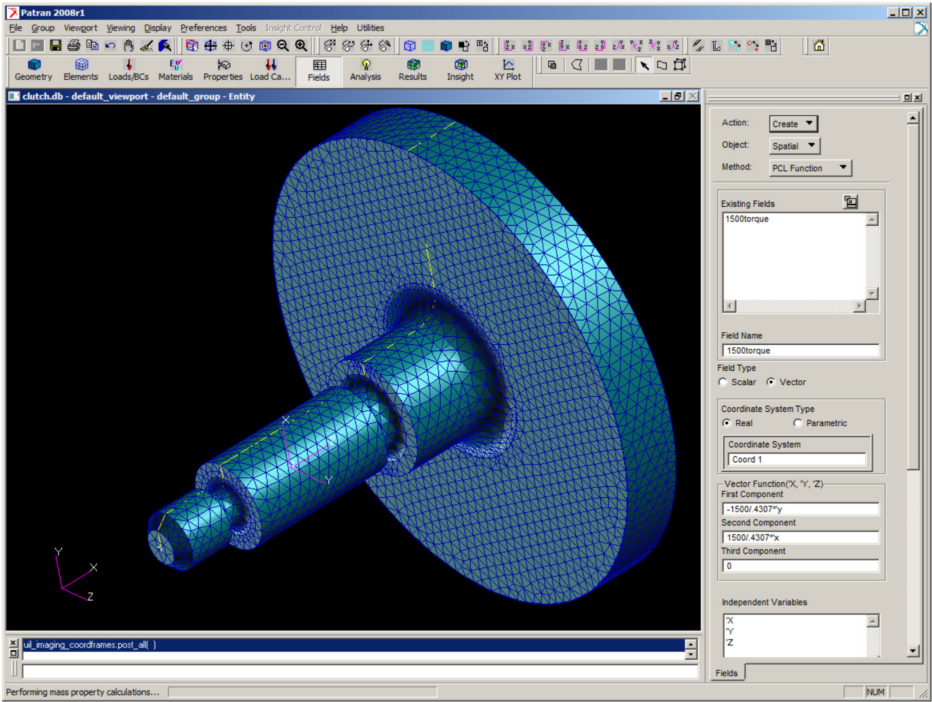


Node ID	Coord ID	Force	Moment	Fx	Fy	Fz	Mx	My	Mz
2473	1	2.88	0.00	1.64	-0.60	2.28	0.00	0.00	0.00
2474	1	3.36	0.00	1.79	-0.76	2.74	0.00	0.00	0.00
2475	1	3.39	0.00	1.89	-0.72	2.72	0.00	0.00	0.00
2476	1	2.69	0.00	1.15	-0.82	2.29	0.00	0.00	0.00
2477	1	2.82	0.00	1.52	-0.65	2.29	0.00	0.00	0.00
Totals	1	2429.34	6156.79	1196.52	-701.00	1994.65	-4997.24	1994.95	2992.28

(Remember *Summation Point* is referenced to Coord 0, so use of a point is convenient).

Target Load:			Applied Load:		
$F_x = 1200$	$F_y = -700$	$F_z = 2000$	$F_x = 1197$	$F_y = -701$	$F_z = 1995$
$M_x = -5000$	$M_y = 2000$	$M_z = 3000$	$M_x = -4997$	$M_y = 1995$	$M_z = 2992$

Validation Example 1: Torsion on a Cylinder



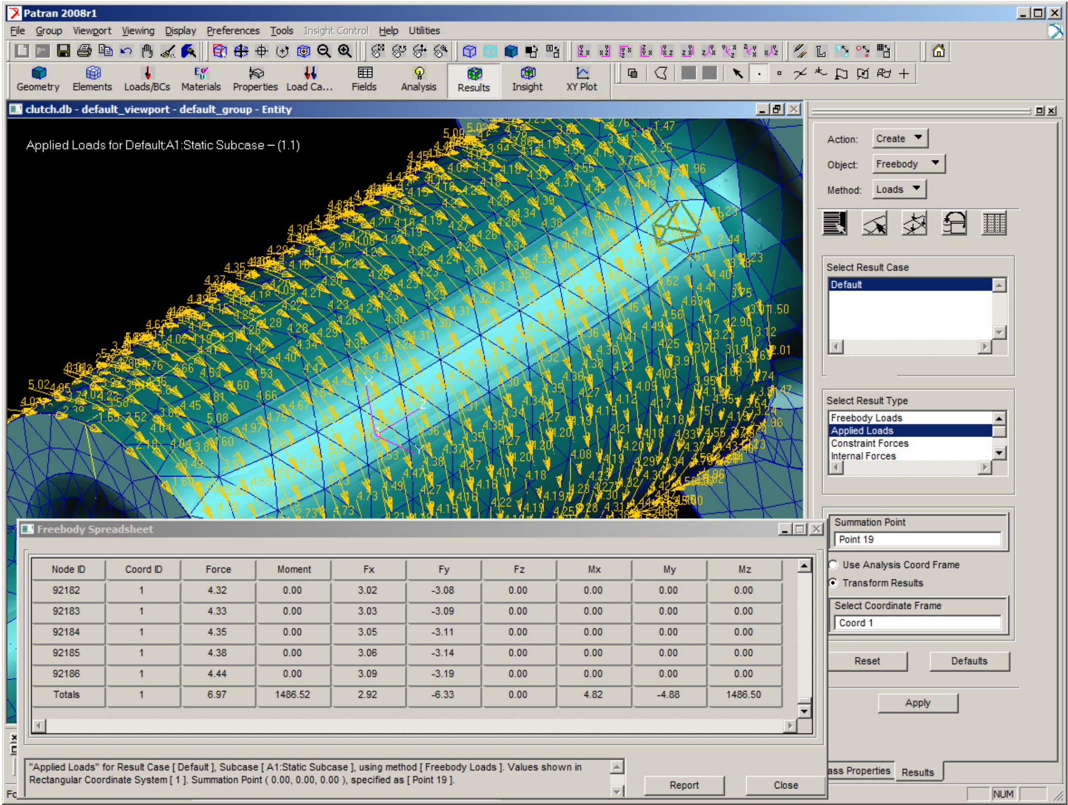
Loading: 1500in-lbs about +z-axis of Coord 1 (located at the centroid of the cylindrical surface of the shaft segment). Eqn. (1) used since Coord 1 is orthogonal to inertia principal coordinate system.

$$F_x = 0 \qquad F_y = 0 \qquad F_z = 0$$
$$M_x = 0 \qquad M_y = 0 \qquad M_z = 1500$$

$$A = 3.063$$
$$x_p = 0 \qquad y_p = 0 \qquad z_p = 0$$
$$\bar{x} = 0 \qquad \bar{y} = 0 \qquad \bar{z} = 0$$
$$I_x = 0.6468 \qquad I_y = 0.6468 \qquad I_z = 0.4307$$

$$M'_x = M_x + F_z \cdot (y_p - \bar{y}) - F_y \cdot (z_p - \bar{z}) = 0$$
$$M'_y = M_y - F_z \cdot (x_p - \bar{x}) + F_x \cdot (z_p - \bar{z}) = 0$$
$$M'_z = M_z + F_y \cdot (x_p - \bar{x}) - F_x \cdot (y_p - \bar{y}) = 1500$$

$$f_x(y,z) = -\frac{M'_z}{I_z} \cdot (y - \bar{y}) + \frac{M'_y}{I_y} \cdot (z - \bar{z}) + \frac{F_x}{A} = -\frac{1500}{0.4307} \cdot y$$
$$f_y(x,z) = \frac{M'_z}{I_z} \cdot (x - \bar{x}) - \frac{M'_x}{I_x} \cdot (z - \bar{z}) + \frac{F_y}{A} = \frac{1500}{0.4307} \cdot x$$
$$f_z(x,y) = -\frac{M'_y}{I_y} \cdot (x - \bar{x}) + \frac{M'_x}{I_x} \cdot (y - \bar{y}) + \frac{F_z}{A} = 0$$



Target Load:

$F_x = 0$ $\quad F_y = 0$ $\quad F_z = 0$

$M_x = 0$ $\quad M_y = 0$ $\quad M_z = 1500$

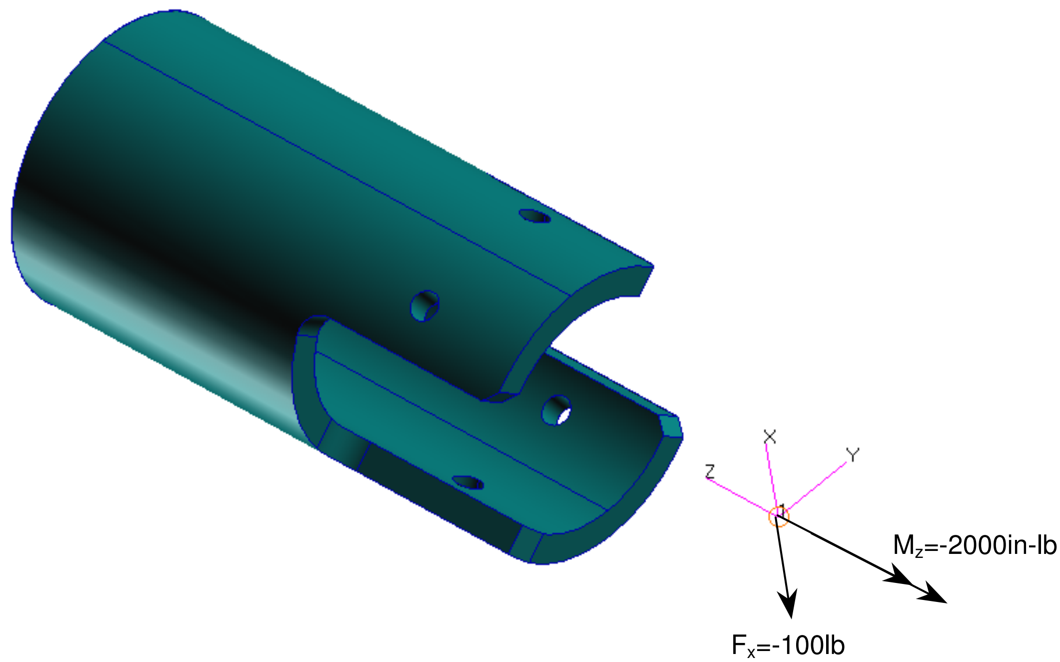
Applied Load:

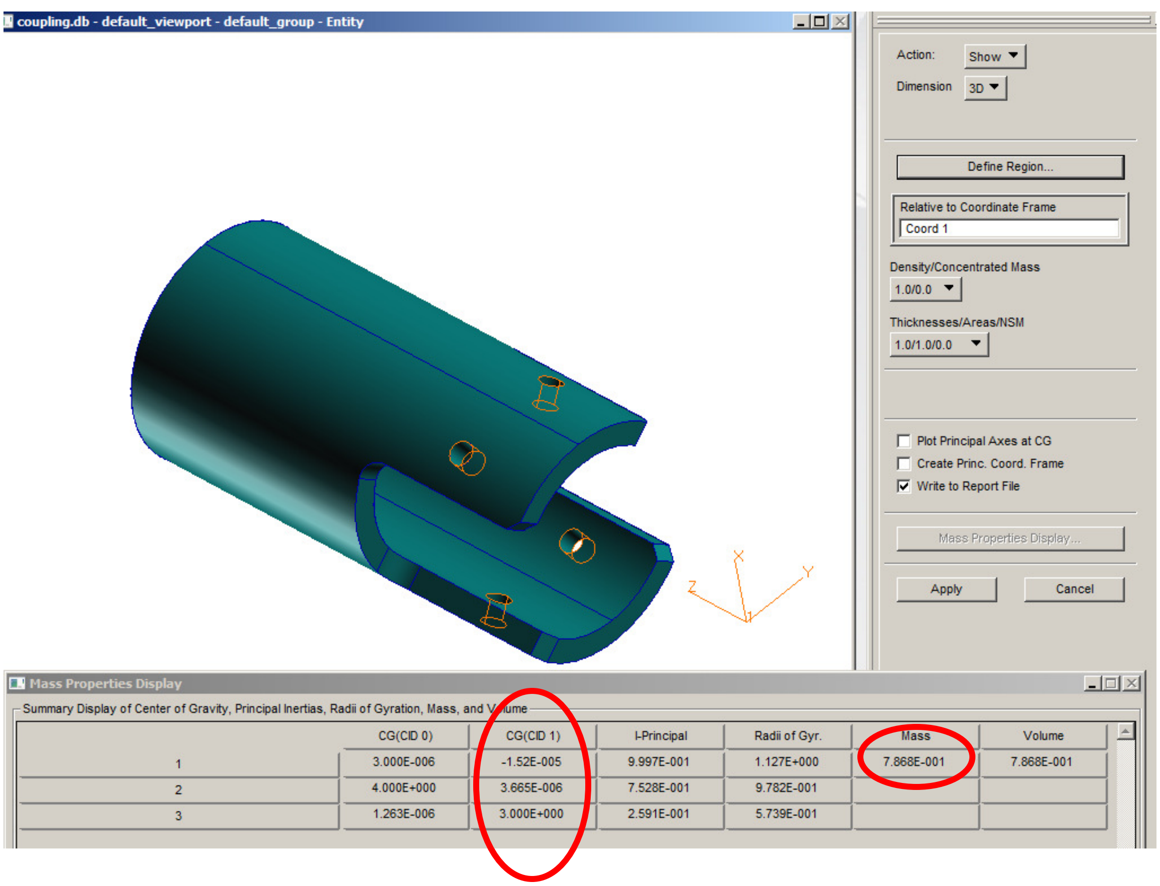
$F_x = 2.92$ $\quad F_y = -6.33$ $\quad F_z = 0.0$

$M_x = 4.82$ $\quad M_y = -4.88$ $\quad M_z = 1486.50$

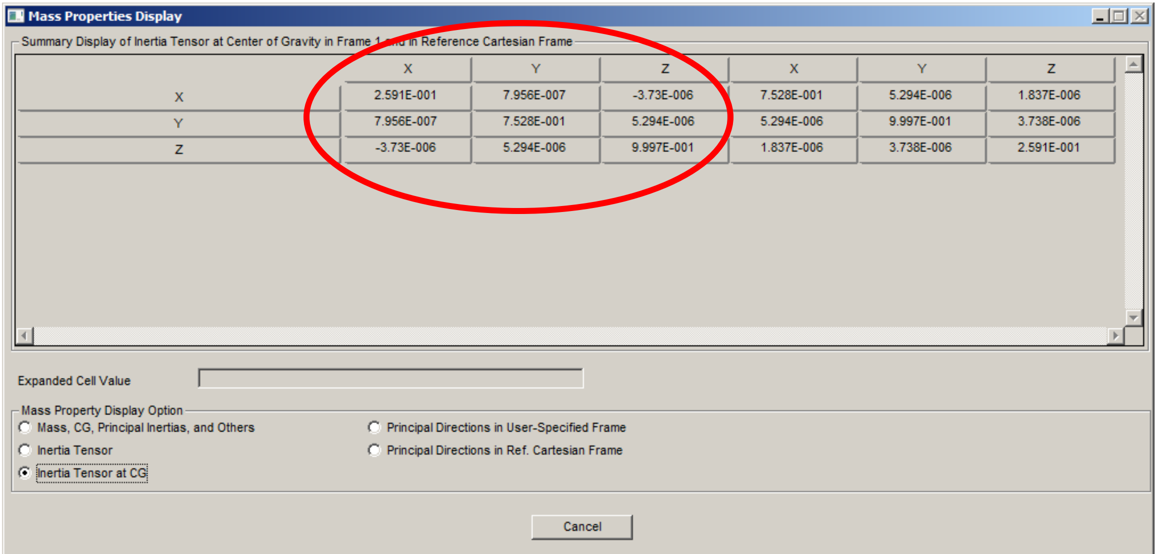
(Note: Point 19 was created at the centroid of the cylindrical surface / origin of Coord 1)

Validation Example 2: Bolt Pattern



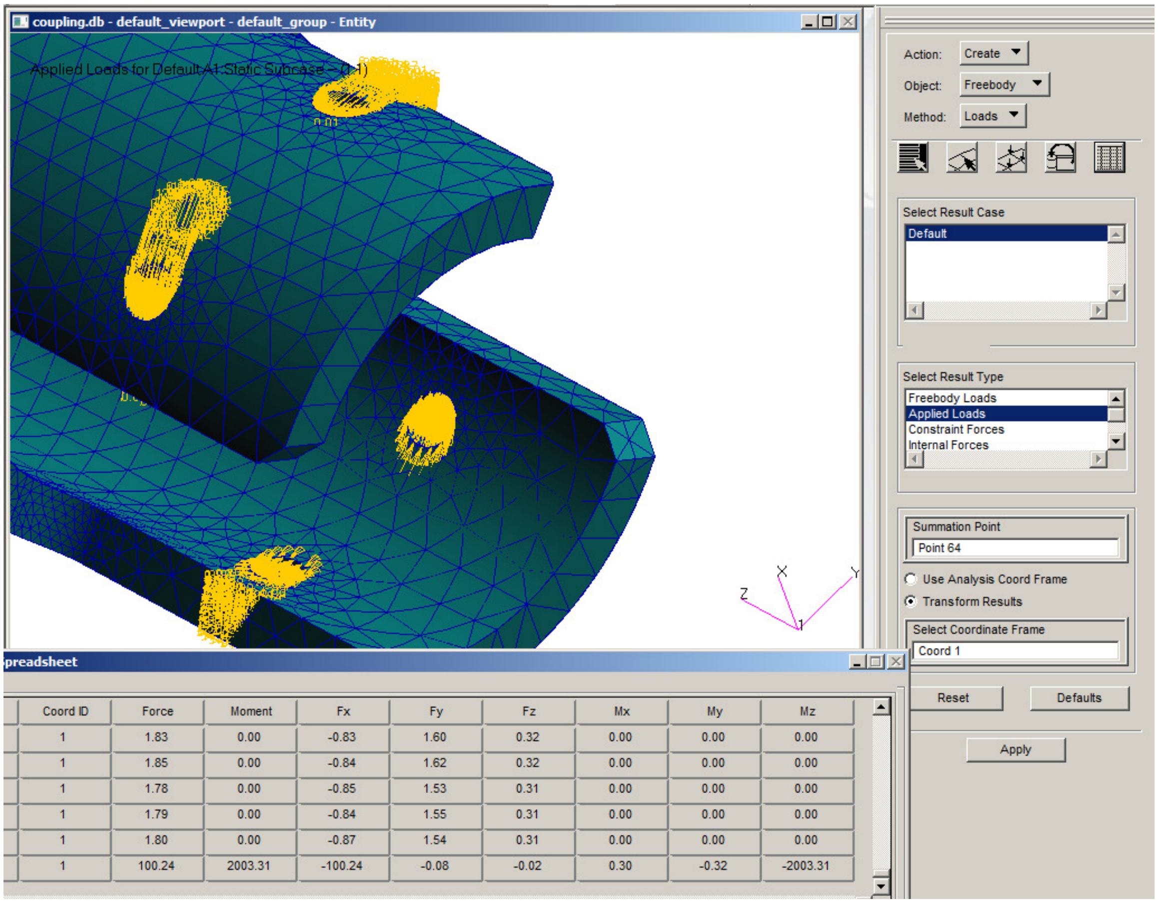


	CG(CID 0)	CG(CID 1)	I-Principal	Radii of Gyr.	Mass	Volume
1	3.000E-006	-1.52E-005	9.997E-001	1.127E+000	7.868E-001	7.868E-001
2	4.000E+000	3.665E-006	7.528E-001	9.782E-001		
3	1.263E-006	3.000E+000	2.591E-001	5.739E-001		



Although the inertia diagonal terms are zero, the spreadsheet may be used for convenience nonetheless.

Total Load at a Point MSC/PATRAN Fields Calculation						
©2011 Mitch Greenberg, FractureProof Research						
www.fractureproof.com						
Relative Coord						
1						
Force in Ref Coord						
-100	0	0				
Moment in Relative Coord				Adjusted Moment at CG		
0	0	-2000		0	300	-2000
Load Point in Relative Coord						
0	0	0				
CG in Relative Coord						
0	0	3				
Area						
0.786765						
Inertia at CG in Relative Coord				Inverse Inertia Matrix		
0.259142	0	0		3.858888	0	0
0	0.752809	0		0	1.328358	0
0	0	0.999682		0	0	1.000318
				Field Components		
				x'	y'	z'
			x:	0	2000.636	398.5075
			y:	-2000.64	0	0
			z:	-398.507	0	0
				Field Equations		
			x:	2000.636202*(y-0.000000)+398.507457*(z-3.000000)+-127.102756		
			y:	-2000.636202*(x-0.000000)		
			z:	-398.507457*(x-0.000000)		
Unique Field Name			Copy Paste Command to PATRAN Command Line:			
coupling			fields_create("coupling", "Spatial", 1, "Vector", "Real", "Coord 1", "", "Function", 3, "X",			



Coord ID	Force	Moment	Fx	Fy	Fz	Mx	My	Mz
1	1.83	0.00	-0.83	1.60	0.32	0.00	0.00	0.00
1	1.85	0.00	-0.84	1.62	0.32	0.00	0.00	0.00
1	1.78	0.00	-0.85	1.53	0.31	0.00	0.00	0.00
1	1.79	0.00	-0.84	1.55	0.31	0.00	0.00	0.00
1	1.80	0.00	-0.87	1.54	0.31	0.00	0.00	0.00
1	100.24	2003.31	-100.24	-0.08	-0.02	0.30	-0.32	-2003.31

Target Load:

$F_x = -100 \quad F_y = 0 \quad F_z = 0$

$M_x = 0 \quad M_y = 0 \quad M_z = -2000$

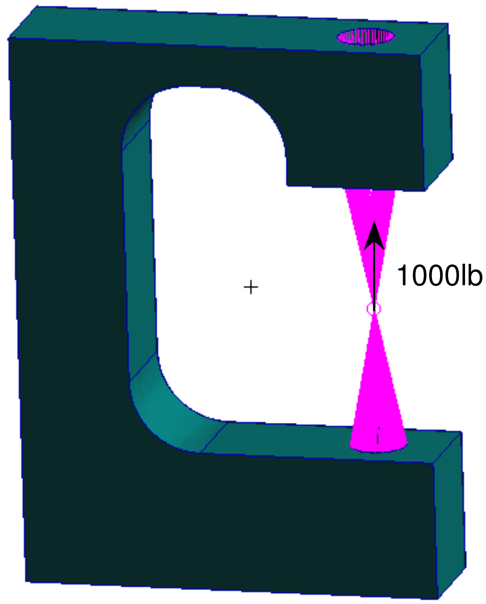
Applied Load:

$F_x = -100.2 \quad F_y = -0.08 \quad F_z = -0.02$

$M_x = 0.30 \quad M_y = -0.32 \quad M_z = -2003.3$

CAUTION

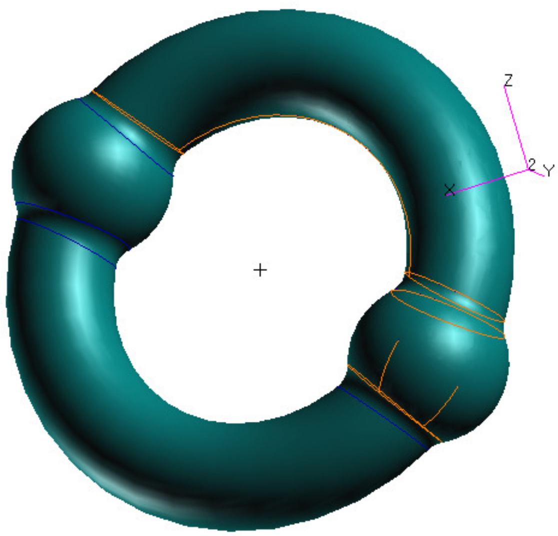
The preceding methodology will determine fastener loads similar to typical bolt pattern techniques (i.e. Swift, T., in-house tools). None of these methods account for the underlying stiffness of the structure. The RBE3 method suffers from the same limitation. Consider:



The two hole surfaces were connected to the load application point with RBE3`s, once analyzed 500lbs is reacted at each hole. In reality due to the lower stiffness of the upper hole, less load should have been taken there. The same is true with the subject method of this document; forces are applied simply by *F/A*. Since the hole surfaces have equal area, they will receive equal load.

Situations where relative stiffness come into play, require more extensive modeling of the mating structures.

Validation Example 3: Random



Mass Properties Display

Summary Display of Center of Gravity, Principal Inertias, Radii of Gyration, Mass, and Volume

	CG(CID 0)	CG(CID 2)	I-Principal	Radii of Gyr.	Mass	Volume
1	4.716E-001	1.306E+000	5.555E+001	1.659E+000	2.018E+001	2.018E+001
2	1.216E+000	-1.12E+000	4.949E+001	1.566E+000		
3	-3.38E-005	2.174E-001	1.218E+001	7.770E-001		

Mass Properties Display

Summary Display of Inertia Tensor at Center of Gravity in Frame 2 and in Reference Cartesian Frame

	X	Y	Z	X	Y	Z
X	4.783E+001	7.836E+000	-6.28E+000	1.621E+001	1.157E+001	1.088E-003
Y	7.836E+000	3.964E+001	1.920E+001	1.157E+001	4.547E+001	-7.62E-004
Z	-6.28E+000	1.920E+001	2.975E+001	1.088E-003	-7.62E-004	5.555E+001

Total Load at a Point MSC/PATRAN Fields Calculation
©2011 Mitch Greenberg, FractureProof Research
www.fractureproof.com

Relative Coord

2		

Force in Ref Coord

300	200	100

Moment in Relative Coord				Adjusted Moment at CG		
3000	2000	-1000		2928.581	2470.081	-1725.9

Load Point in Relative Coord

1.63418	1.518468	1.893729

CG in Relative Coord

1.306	-1.12	0.2174

Area

20.18

Inertia at CG in Relative Coord				Inverse Inertia Matrix		
47.83	7.836	-6.28		0.024203	-0.01056	0.011924
7.836	39.64	19.2		-0.01056	0.041306	-0.02889
-6.28	19.2	29.75		0.011924	-0.02889	0.054774

Field Components

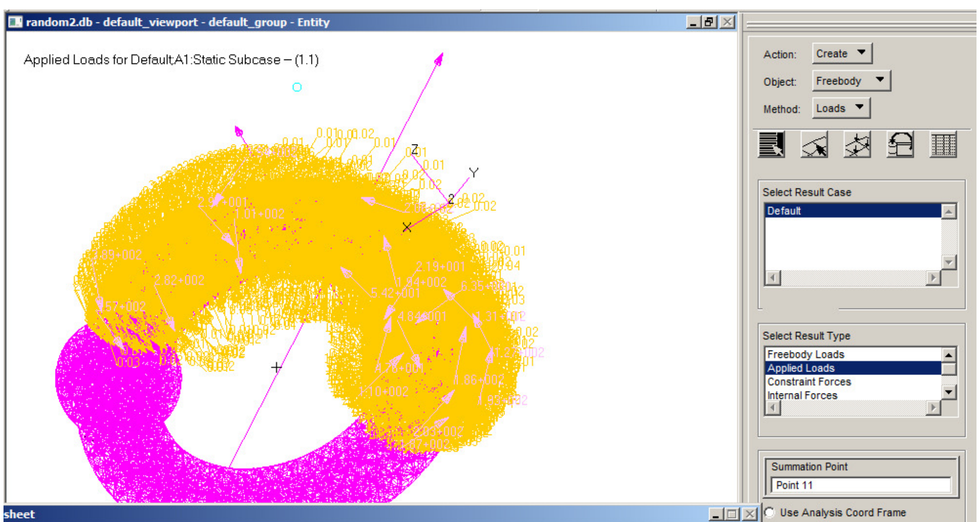
	x'	y'	z'
x:	0	130.9674	120.9611
y:	-130.967	0	-24.2161
z:	-120.961	24.21607	0

Field Equations

x: 130.967416*(y--1.120000)+120.961099*(z-0.217400)+14.866204
y: -130.967416*(x-1.306000)+-24.216066*(z-0.217400)+9.910803
z: -120.961099*(x-1.306000)+24.216066*(y--1.120000)+4.955401

Unique Field Name: random2b

Copy Paste Command to PATRAN Command Line:
fields_create("random2b", "Spatial", 1, "Vector", "Real", "Coord 2", "", "Function", 3, "X



Coord ID	Force	Moment	Fx	Fy	Fz	Mx	My	Mz
2	0.19	0.00	-0.17	0.09	0.03	0.00	0.00	0.00
2	0.12	0.00	0.12	-0.02	-0.02	0.00	0.00	0.00
2	0.02	0.00	-0.01	0.01	0.01	0.00	0.00	0.00
2	0.13	0.00	0.12	0.06	0.01	0.00	0.00	0.00
2	0.01	0.00	0.01	-0.00	0.01	0.00	0.00	0.00
2	355.72	3770.01	279.72	199.30	92.58	3011.38	2011.16	-1048.75

Target Load:

$F_x = 300 \quad F_y = 200 \quad F_z = 100$

$M_x = 3000 \quad M_y = 2000 \quad M_z = -1000$

Applied Load:

$F_x = 279.7 \quad F_y = 199.3 \quad F_z = 92.6$

$M_x = 3011.4 \quad M_y = 2011.2 \quad M_z = -1048.8$

Conclusion

Surface moments and "Total Load at a Point" functionality has been demonstrated by determination of appropriate PCL functions and application of field based CID Distributed Load. The method provides an alternative to mesh dependent multipoint constraint techniques. Reasonable accuracy has been demonstrated; it should be noted that accuracy of the total load should improve with mesh refinement.

Creation of a PCL User Form add-in that takes as input the force and moment vectors, load application point, and surface list could automate the creation of the field, and load. This activity is suggested for consideration as a future project for FractureProof Research.