Introduction

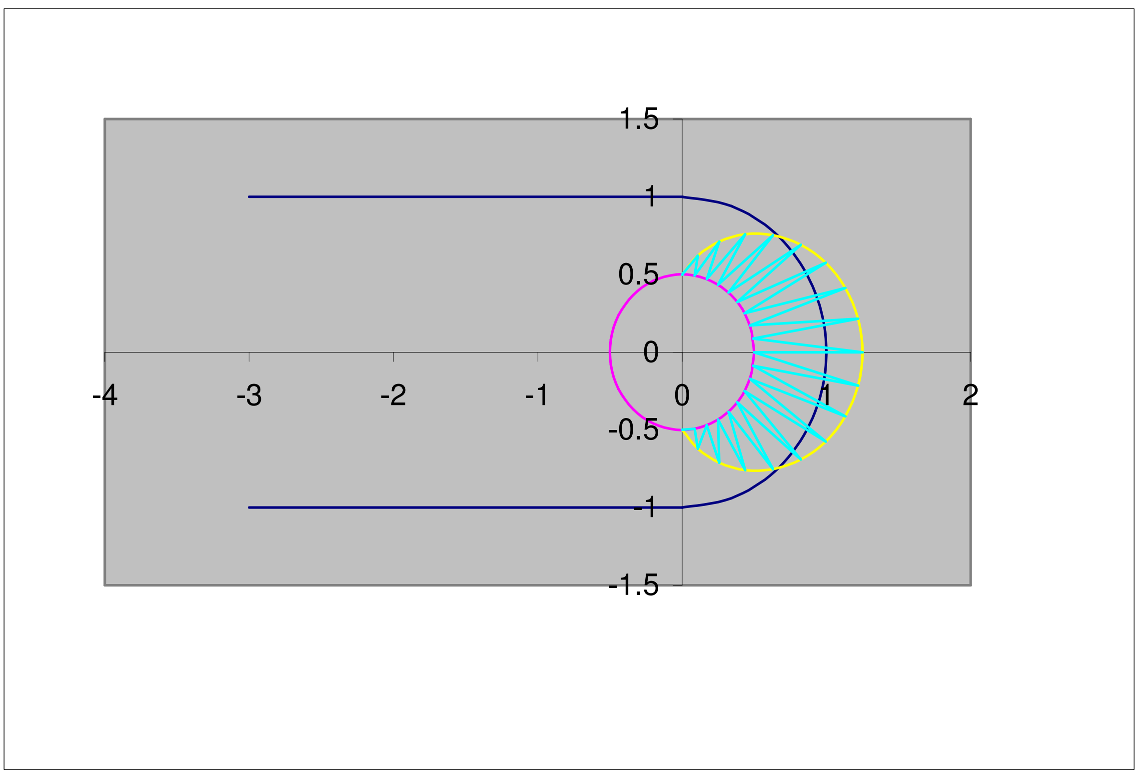
Application of a bearing load (or 'pin load') is a frequently encountered situation. There are many ways to simulate this boundary condition through multipoint constraints, regular constraints, or even non-linear GAP elements.

Many FEM pre-processors include the bearing load option as a standard feature, however PATRAN has not seen this functionality as a necessary component.

PATRAN does have the ability to model complex loadings through the use of fields and PCL formulas. This capability will be exploited to simulate a bearing load.

The following is untested on releases prior to 2008R1; there was a time in the past where certain functions could not be used with fields (when they had implicit 'ifs' such as the *mth_max()* used herein).

Cosine Distribution Approach



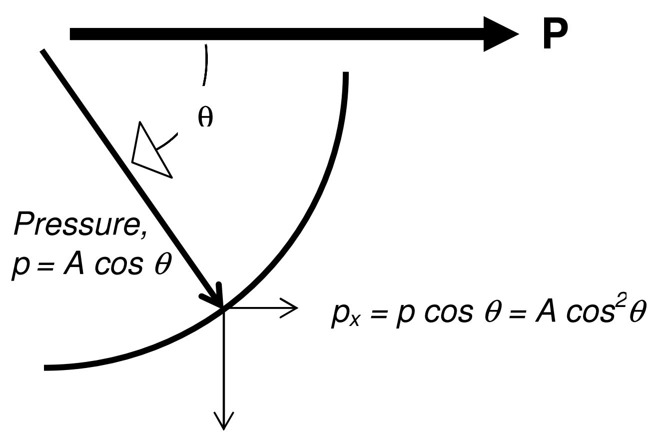
A common simple approach is to assume that the surface pressure on the 180 degrees portion of the hole in compression follows the equation:

$$p = A\,Cos(\theta),\ \ -\pi/2 \le \theta \le \pi/2, \quad else\ p=0$$

The maximum pressure, *A*, can be determined by trial and error, however it can easily be calculated (for basic holes with uniform thickness) given a desired target pin load, *P*:

By symmetry the vertical load is zero; the pin load is oriented in the horizontal direction (horizontal and vertical are chosen later by a user created coordinate system, so the load can be oriented as desired).

Since the pressure is normal to the surface, not all is projected as a horizontally oriented force.



Thus,

$$P = A \cdot t \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos^2 \theta \cdot R d\theta$$

$$P = A \cdot t \cdot R \left[\frac{\theta}{2} + \frac{\sin 2\theta}{4} \right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$P = \frac{A \cdot t \cdot R \cdot \pi}{2}$$

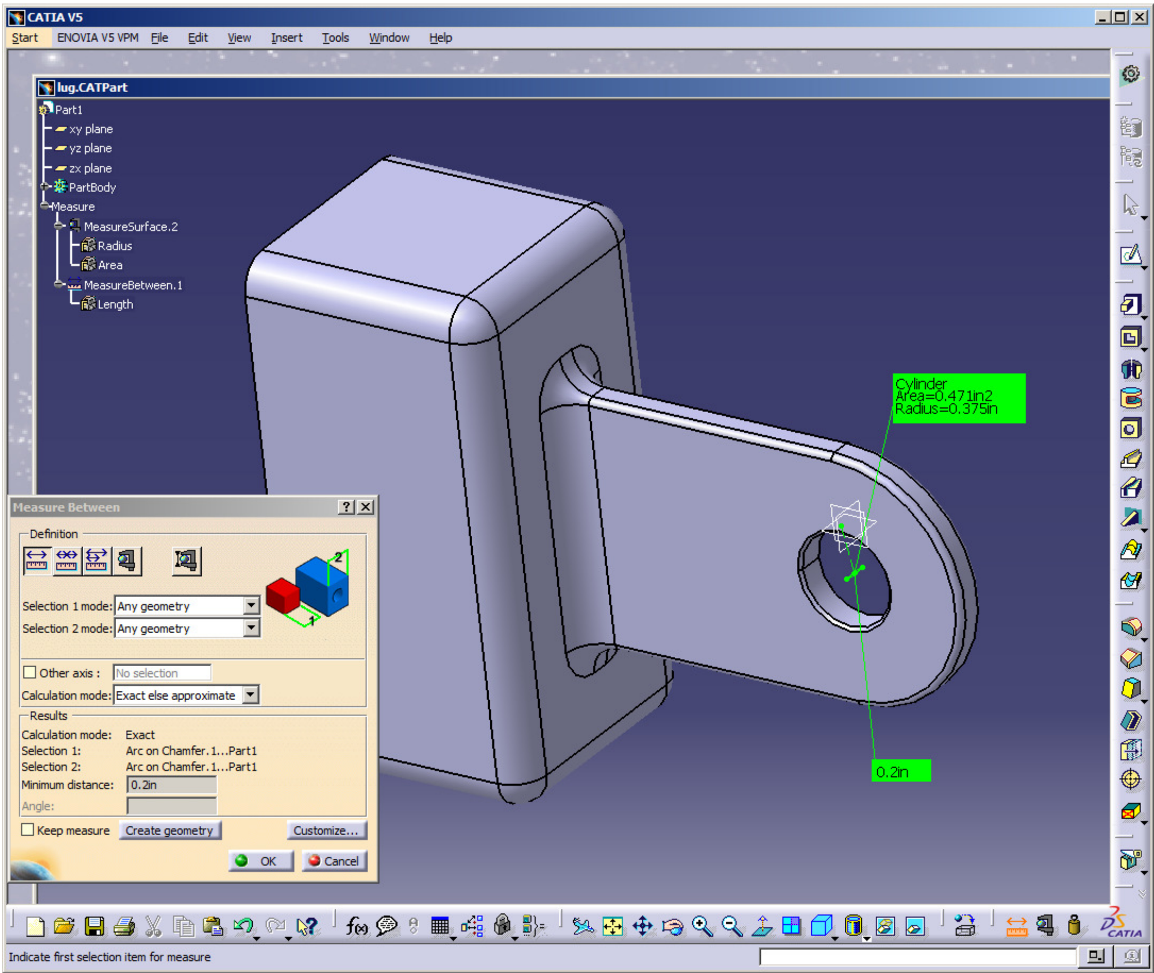
$$\Rightarrow \quad A = \frac{2P}{\pi \cdot R \cdot t}$$

where, *t = thickness, and R = hole radius*.

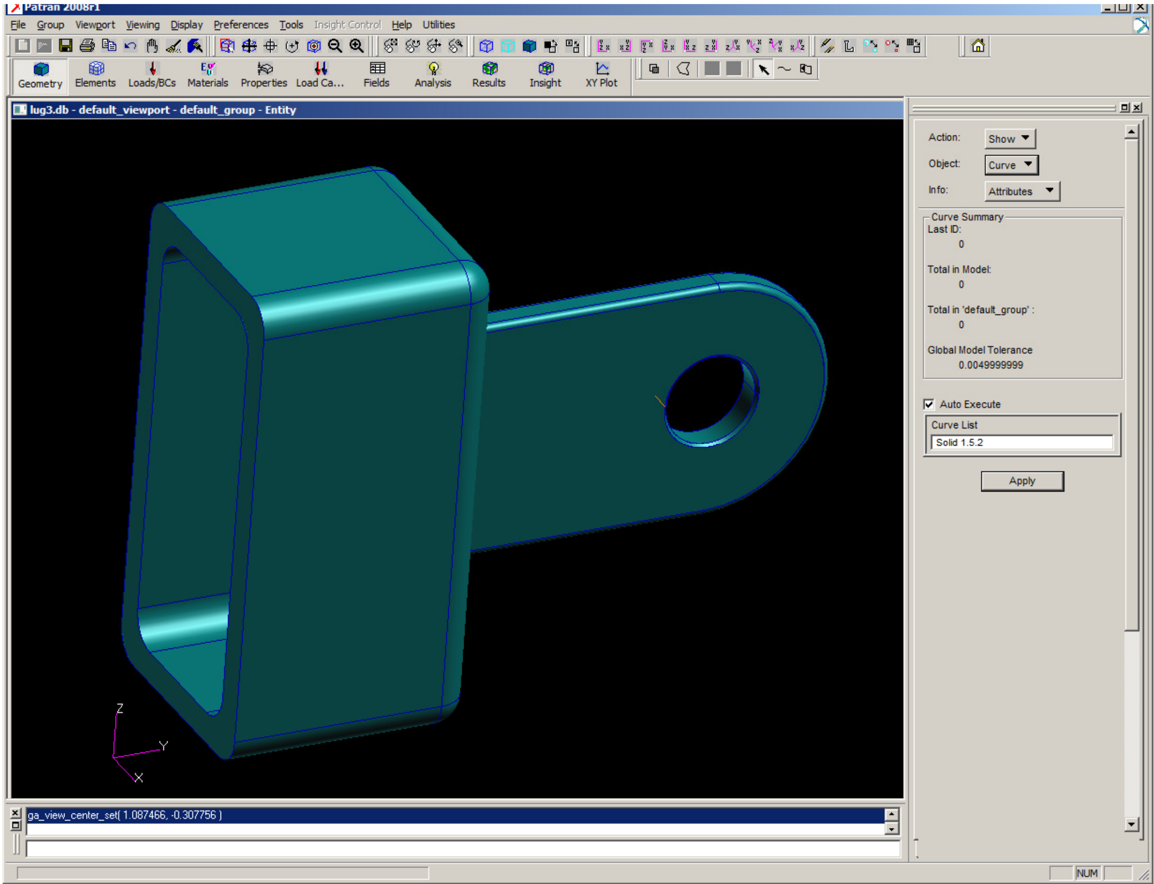
(Note: This formula is also applicable for 2D shells, however since edge pressure is applied as lb/in instead of psi, the thickness term, t, is omitted from the denominator)

Example Implementation in PATRAN

Consider a 0.75in diameter hole in a 0.25in thick lug with a 2.0in OD. A 2,500lb load is applied obliquely 25 degrees from vertical:

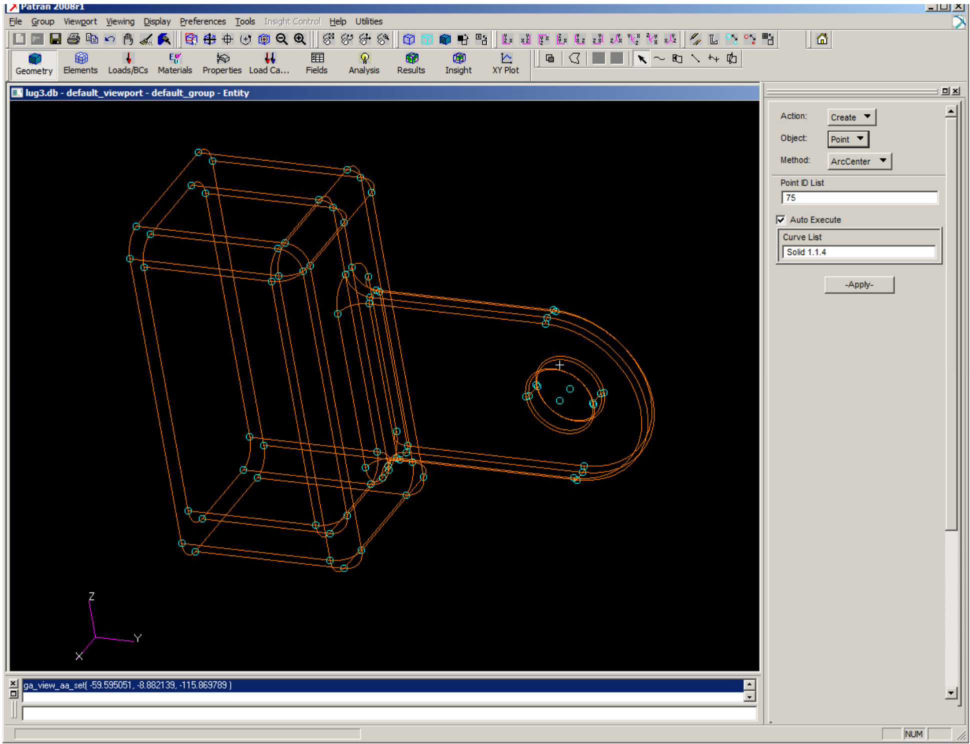


Although the lug is 0.25in thick, chamfers reduces the bearing surface to 0.2in. The above geometry was created in CATIA, and imported into PATRAN:

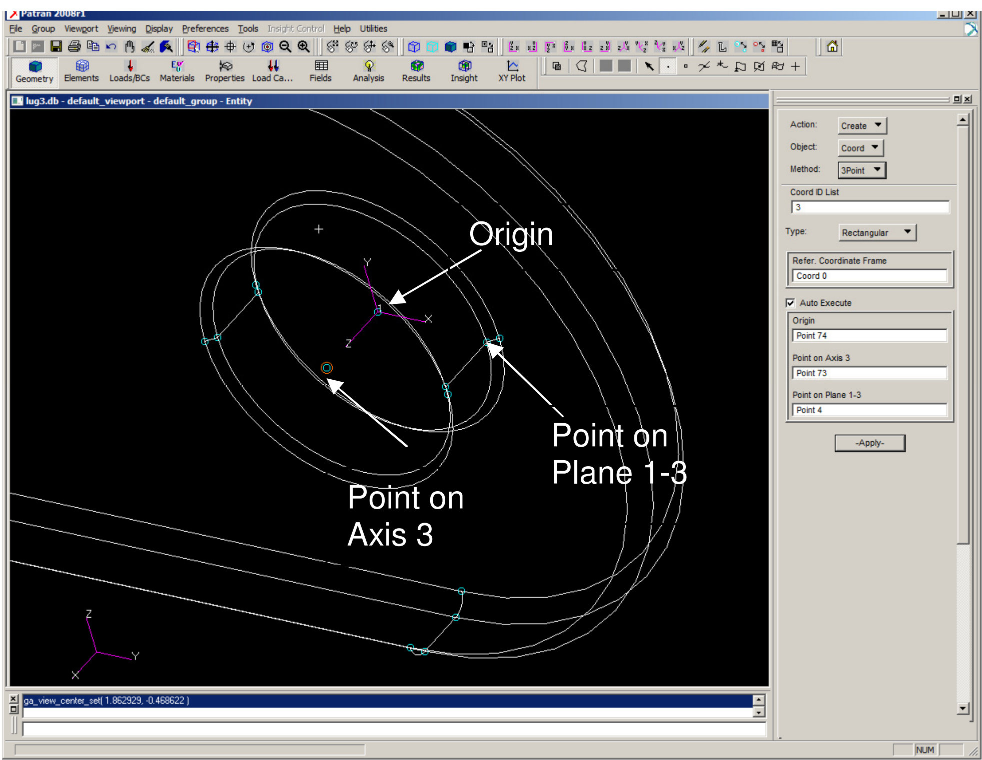


To apply the load, first a rectangular coordinate system is created at the center of the hole. Next, a cylindrical coordinate system is created rotated 25 degrees.

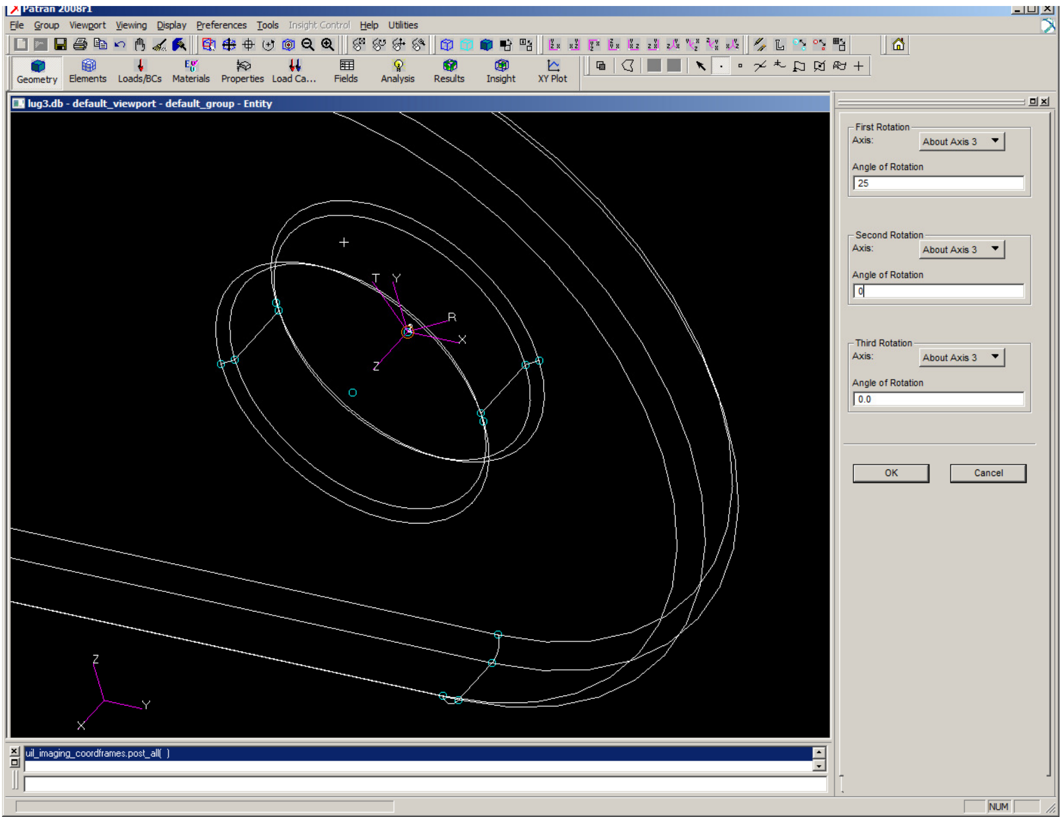
Geometry, Create, Point, ArcCenter is first used to create two points on the hole axis:



The first coordinate system is created by *Geometry, Create, Coord, 3Point* using origin, point on Axis 3 and point on Plane 1-3 as shown:



The second coordinate system is created using *Geometry, Create, Coord, Euler*. The coordinate system type is set as **cylindrical**, and a 25 degree rotation about the Z-axis of the first coordinate system is specified:



With the desired coordinate system created, a field can now be defined. A pressure load can be created to apply normal pressure to selected surfaces (in this case the cylindrical surfaces) with the magnitude controlled by the field.

Fields, Create, Spatial, PCL Function

Recall,

$p = A\ Cos(\theta),\ \ -\pi/2 \leq \theta \leq \pi/2, \quad else\ p=0$

$$A = \frac{2P}{\pi \cdot R \cdot t}$$

For our case, R=0.375in, t=0.20in and P=2,500lbs.

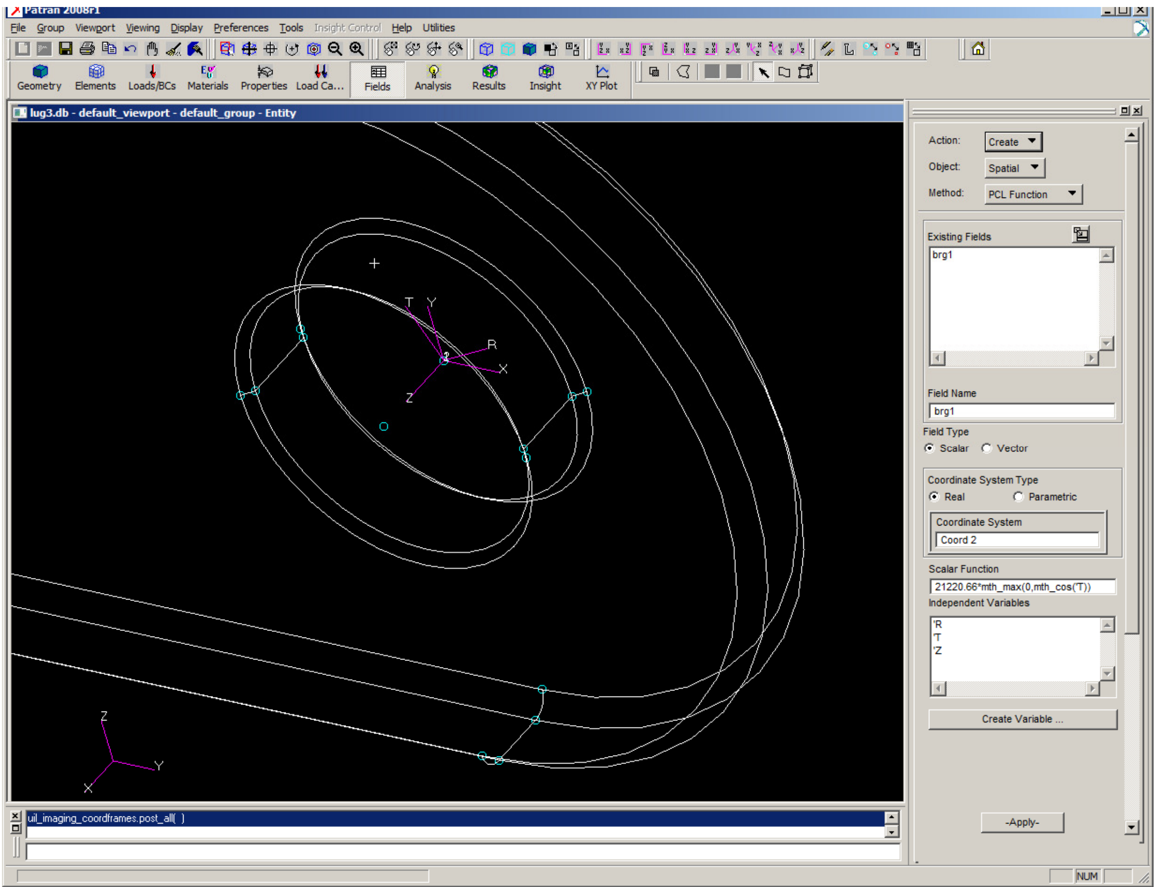
Thus, A = 2*2,500 / (π * *0.375 * 0.20) = 21,220.66*

The field can reference the created cylindrical coordinate system. Conveniently when θ is outside the target 180 degree range, the value of *p*, becomes negative. PATRAN has a math function for *cos*, and another function for *max*.

Defining the function as:

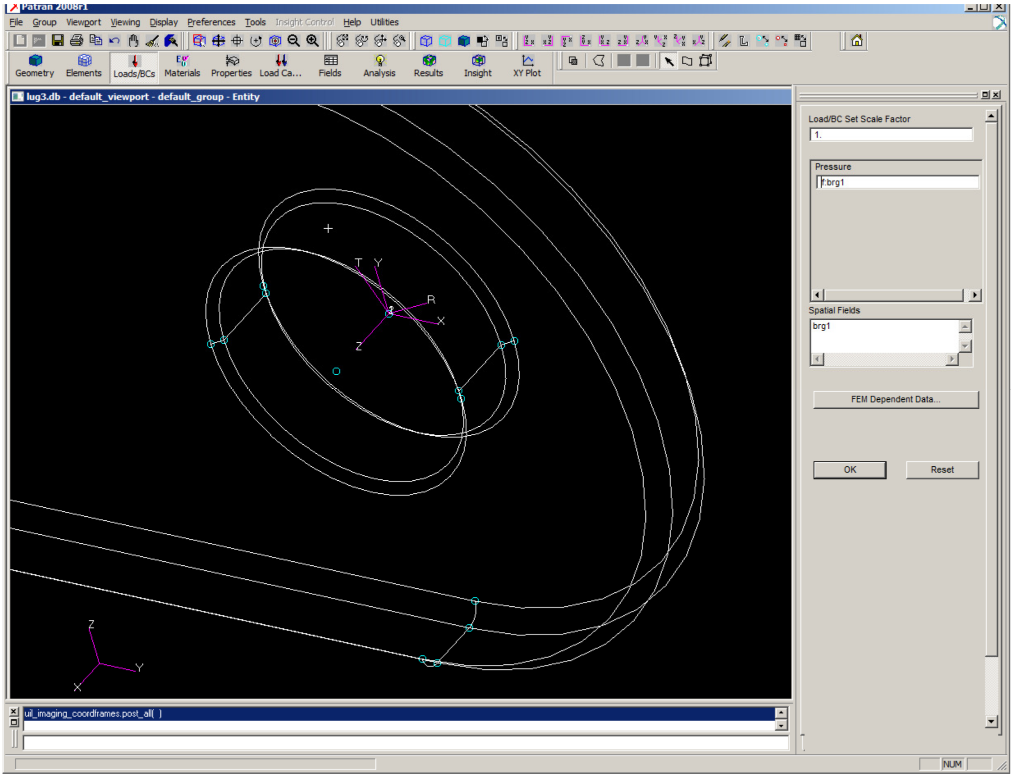
21220.66 * *mth_max(0, mth_cosr('T'))*

Will properly define the field (Note: mth_max() may not function in PATRAN versions earlier than 2008R1).



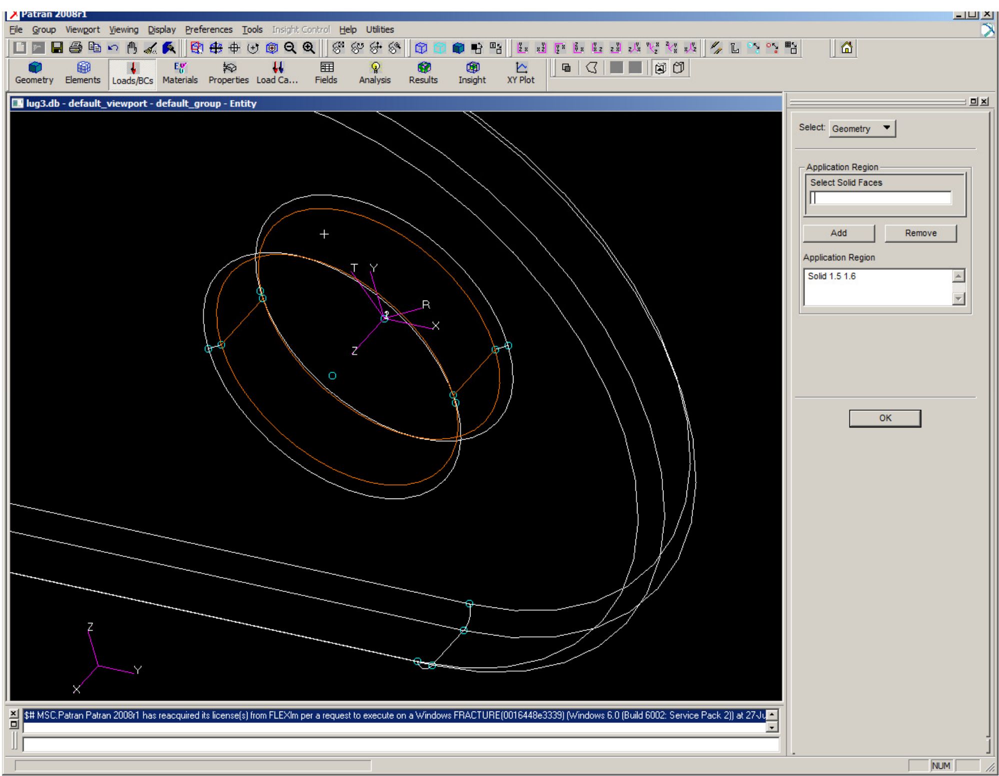
Finally, the field must be used while creating boundary conditions.

Loads/BCs, Create, Pressure, Element Variable

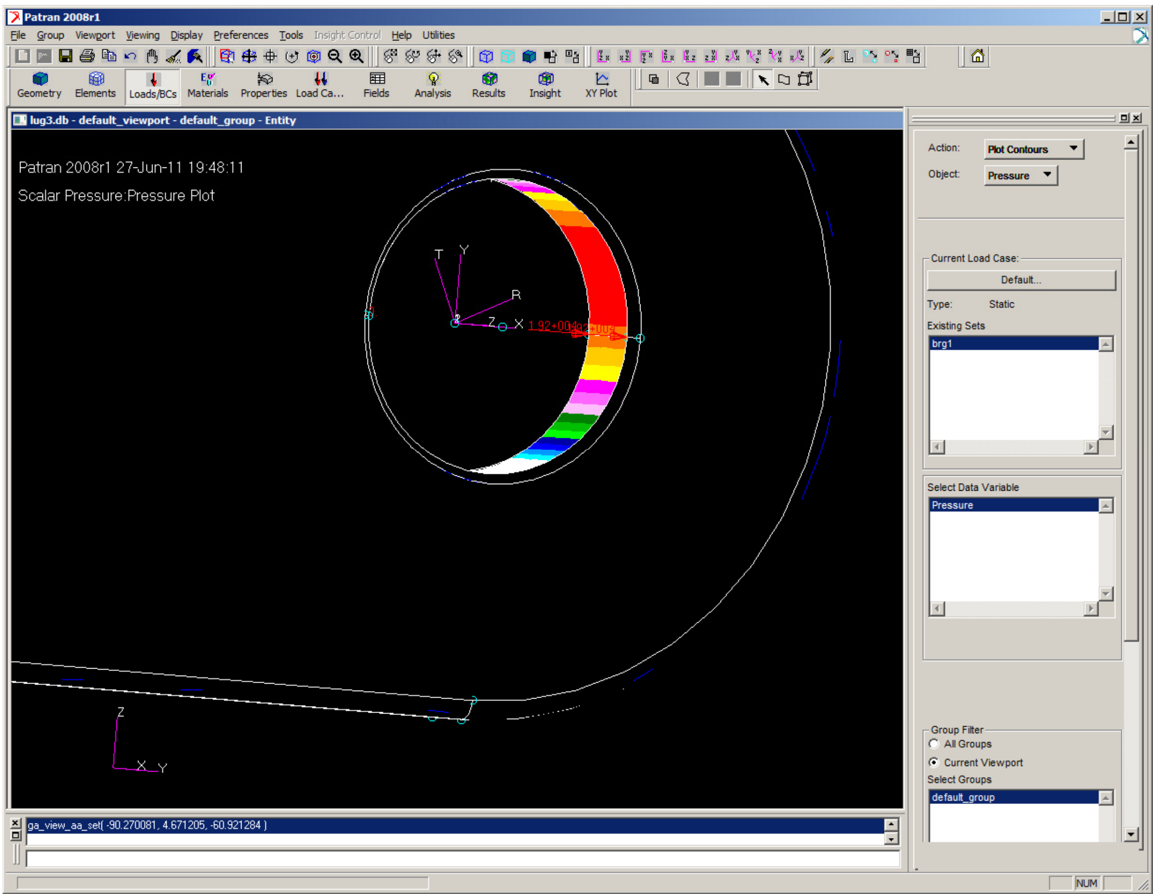


Under *Input Data*, select the previously created field as the value for pressure.

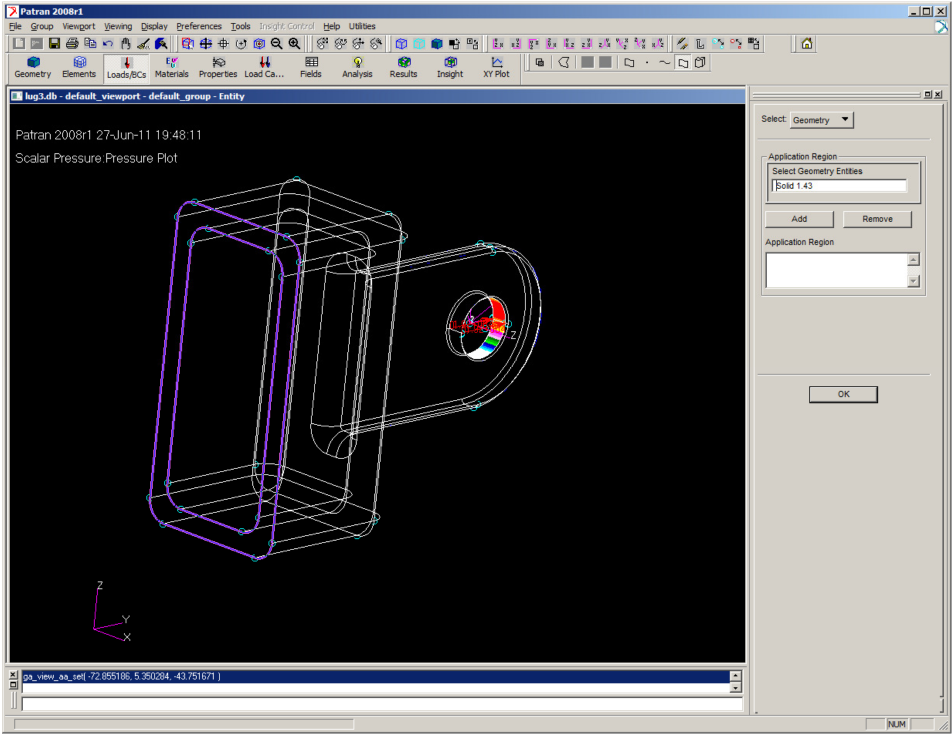
As *Application Region* choose the two cylindrical solid faces:



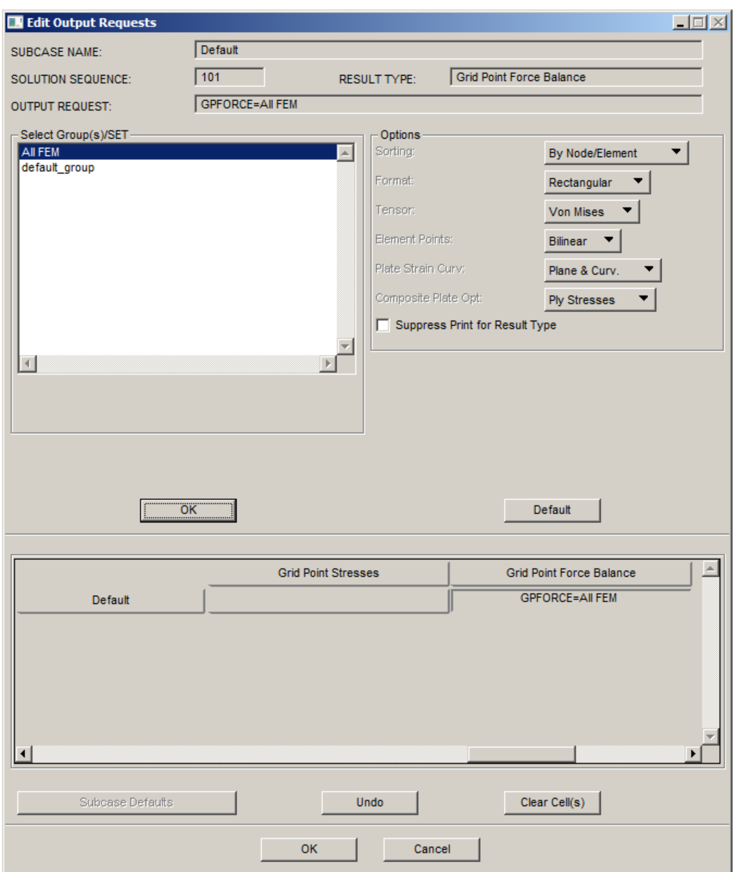
Unfortunately the graphical representation of the load is not overly useful. However, once the solid is meshed (the model was crudely meshed with TET10 elements and a global element length set to 0.1in) one may use *Loads/BCs, Plot Contours, Pressure* to see the load distribution:



For expedience, we may simply ground the end (*Loads/BC, Create, Displacement)* and submit the model to the NASTRAN solver:

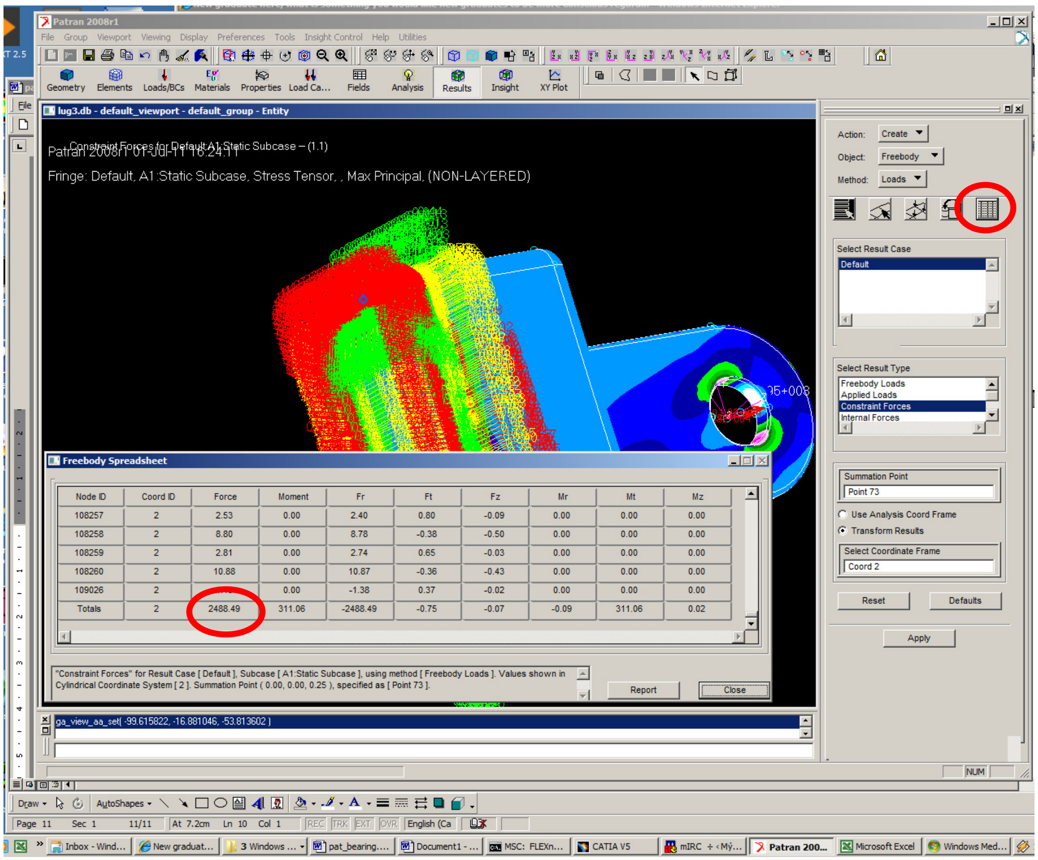


Ensure you select *Grid Point Force Balance* in results selection, through *Global Data, Output Requests*:



Once executed and the results database is attached to the PATRAN session, verify the reaction force with; *Results, Freebody, Loads, Constraint Forces*. Pick one of the points created at the arc centres for *Summation Point*. Choose transform results and the cylindrical coordinate system.

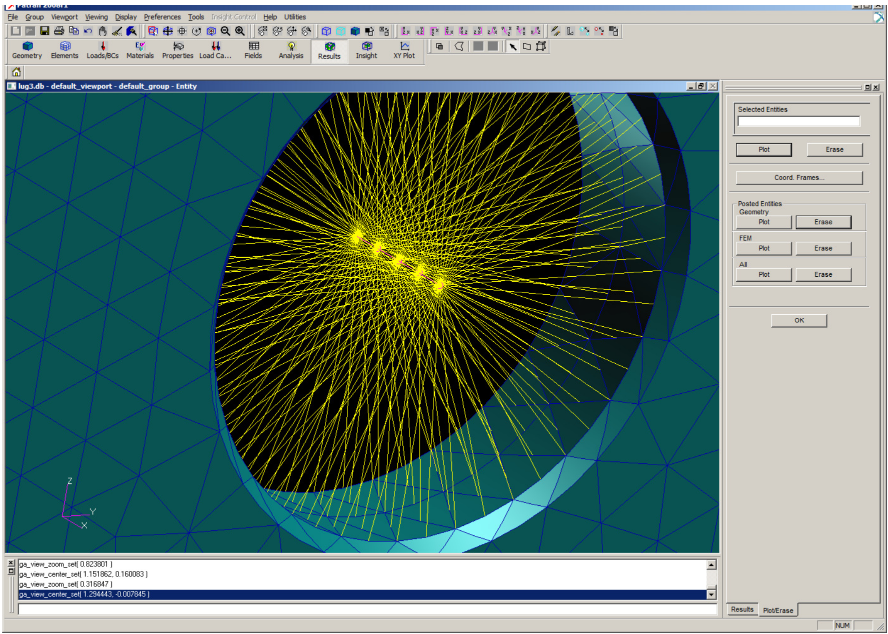
After selecting *Apply*, we may display the spreadsheet (last icon near the top of the menu).



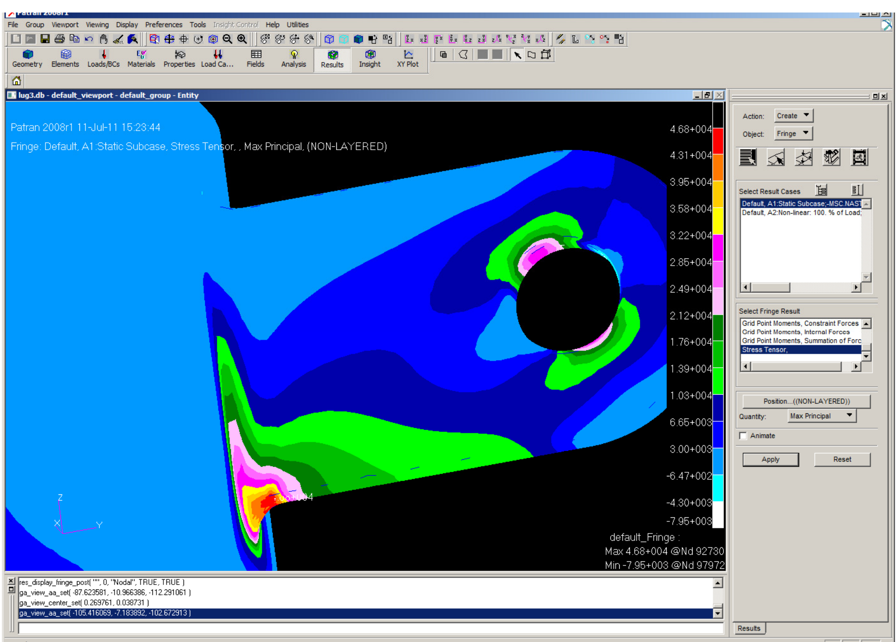
The actual applied load is 2,488 lbs, if the mesh was refined further it would read closer to target, however for our purposes this is sufficient.

Comparison to Non-Linear Solution

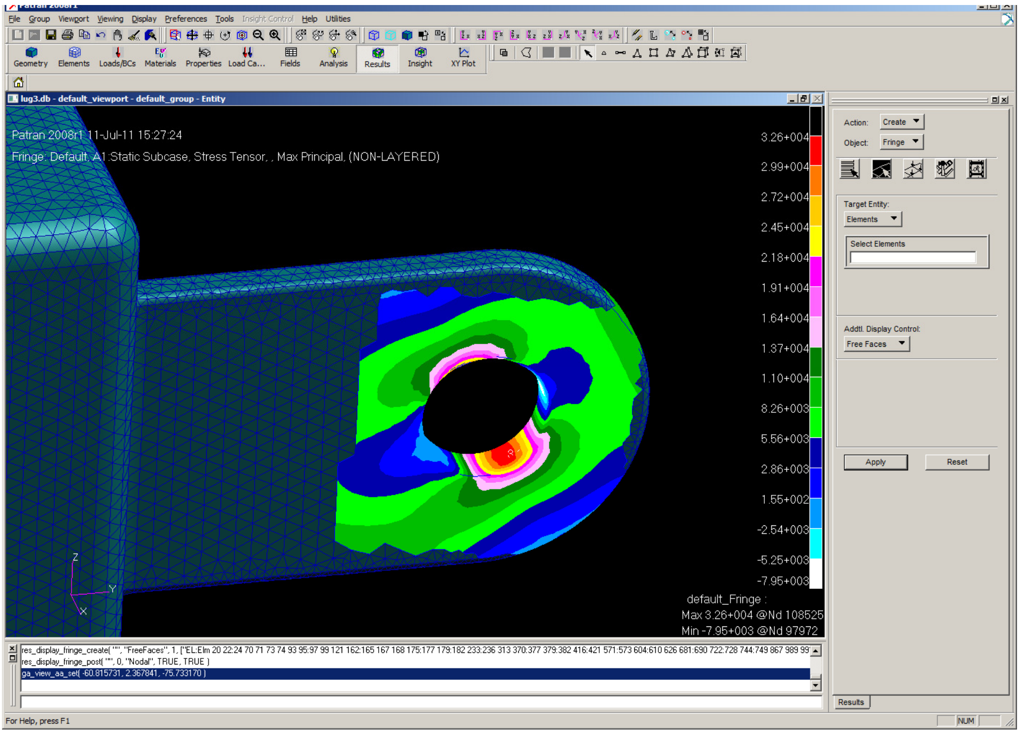
Five nodes were created along the hole axis corresponding to the node locations of the two layers of 10-noded Tets created by the automesher. An RBE2 was used to connect the nodes, then GAP elements created radially to represent the pin. A 2,500lb load was applied to the center point at 25 degrees and the model solved with non-linear statics solution (large displacements OFF).



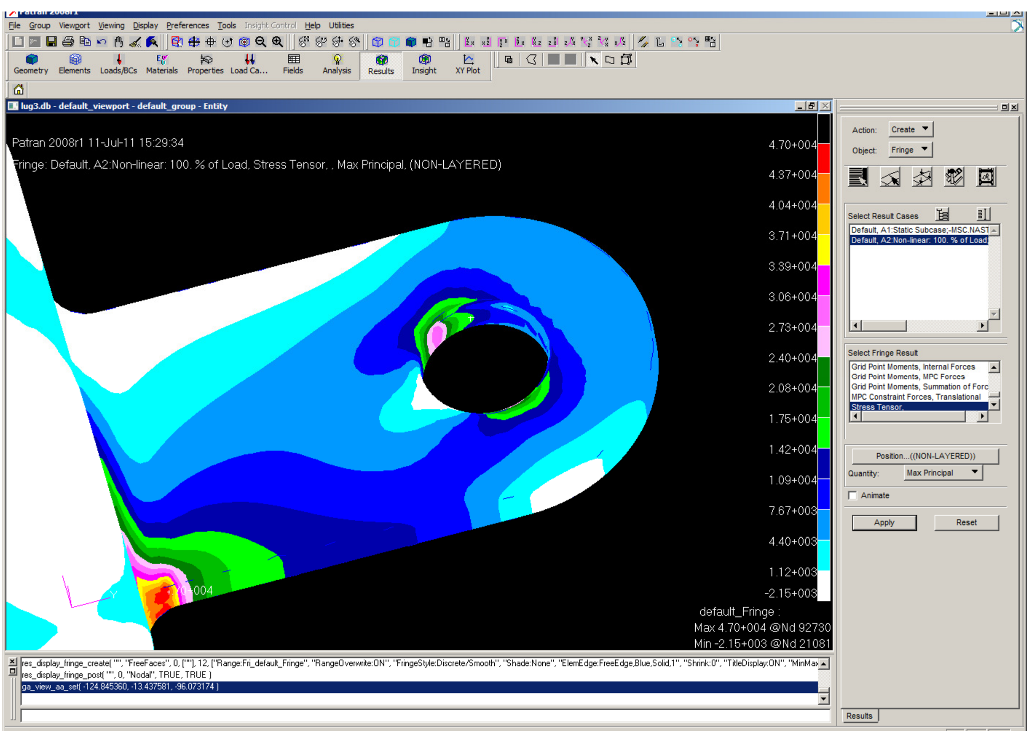
For the linear run, the maximum principal stress was observed at a fillet due to bending, and had value of 46.8ksi:



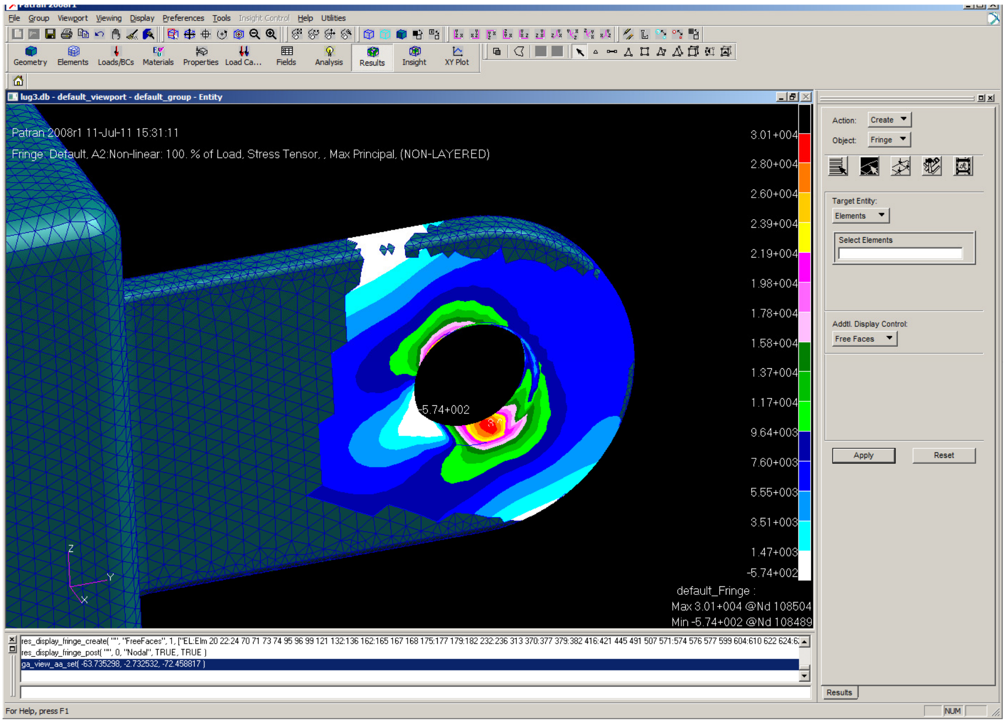
Isolating the hole, a maximum of 32.6ksi is obtained:



By comparison, the non-linear solution presents a maximum stress at the radius of 47.0ksi:

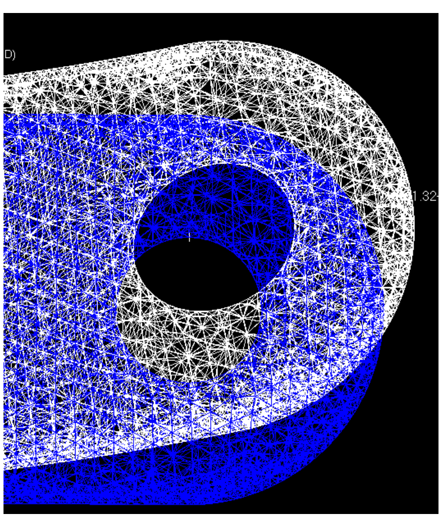


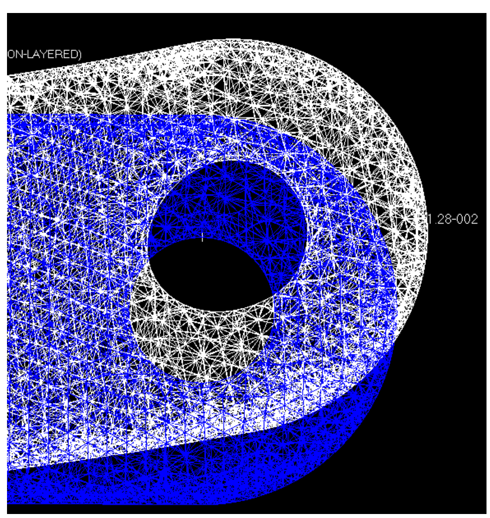
And, the peak stress at the hole is 30.1ksi.



The discrepancy at the radius is explained since as presented earlier the actual load applied by the pressure field was 2,488lbs; thus 2,500/2,488 x 46.8 = 47.0ksi.

The lower stress (30.1ksi versus 32.6ksi) at the hole is due to restraint of ovalization of the hole. In the non-linear run, the GAP elements act as a near-rigid pin keeping the compressed side of the hole round. We can compare the deformation plots:





Conclusion

The simulation of a pinload using a cosine distributed pressure field provides a reasonable approximation of local stress ($K_t\sigma$) useful for fatigue analysis. The value may be slightly conservative since the hole is not maintained round by the support of the pin. The non-linear model presented had zero clearance however between the pin and lug. With normal bolt clearance, the comparison is likely even closer.

The linear solution executed in less than 1/3 the time compared to the non-linear solution. Additionally, the modelling of the radial GAP elements was time consuming. Multiplied in a scenario with multiple holes, the technique may offer additional merit.

Creation of a PCL User Form add-in that takes as input the load and direction vector, and surface list could automate the creation of coordinate systems, field, and load. This activity is suggested for consideration as a future project for FractureProof Research.