Pro/MECHANICA WF4.0

Inertia Relief

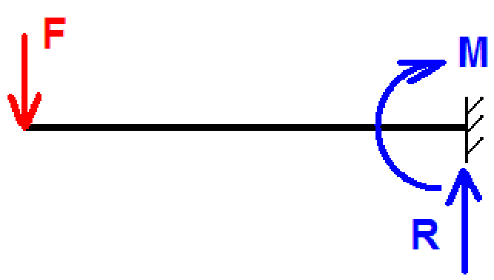
General

- Inertia Relief is an advanced option in Mechanica that allows running unconstrained models in static analysis
- Typical applications:
    - Modeling of an aircraft in flight
    - Automobile on a test track
    - Satellite in space
    - Analyzing parts in a mechanism with forces in joints extracted from rigid body dynamics simulation

Equilibrium in Static Analysis

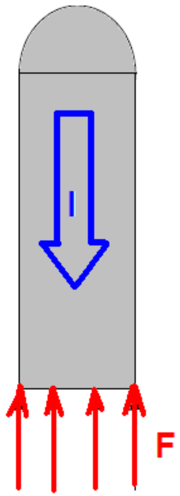
- In static stress analysis, the model is assumed to be in static equilibrium
- Types of equilibrium:
  - The model is brought into equilibrium by reaction forces that equalize the applied loads (Example 1 below)
  - The model is brought into equilibrium by body mass forces (inertia) (Example 2 below)

Example 1: Cantilever beam



Applied force F is balanced by reactions R and M in the constraint

Example 2: Rocket in flight



- Applied thrust force F is balanced by inertia force I
- Constraints do nor participate in equilibrium hence unnecessary

How Inertia Relief works ? (1)

- In essence, when Inertia Relief is activated, the inertia (mass) of the model is used to resists the applied loads
  - **The assumption is made that the model is in a state of static equilibrium even though it is not constrained**
- The following steps are done by Mechanica behind the scenes:
  - Body loading (both translational and rotational in general case) is calculated and automatically applied so it exactly balances all the external applied loads
  - The 3-point constraints are applied in such a manner that they don't restrain the model's deformation (so called "3-2-1 principle"). How those points are picked is not controlled by the user.

How Inertia Relief works ? (2)

Step 1:

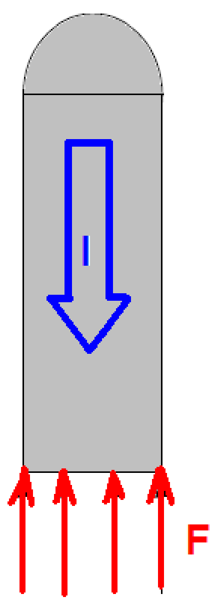
• Body force **I** (magnitude, direction, and distribution through the model) is computed and applied

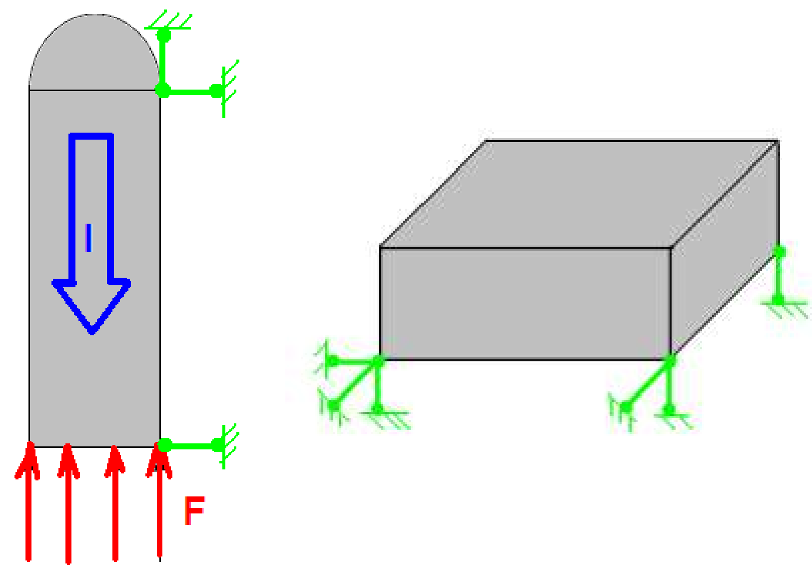
Step 2:

• 3-point constraints are applied. The points are picked automatically

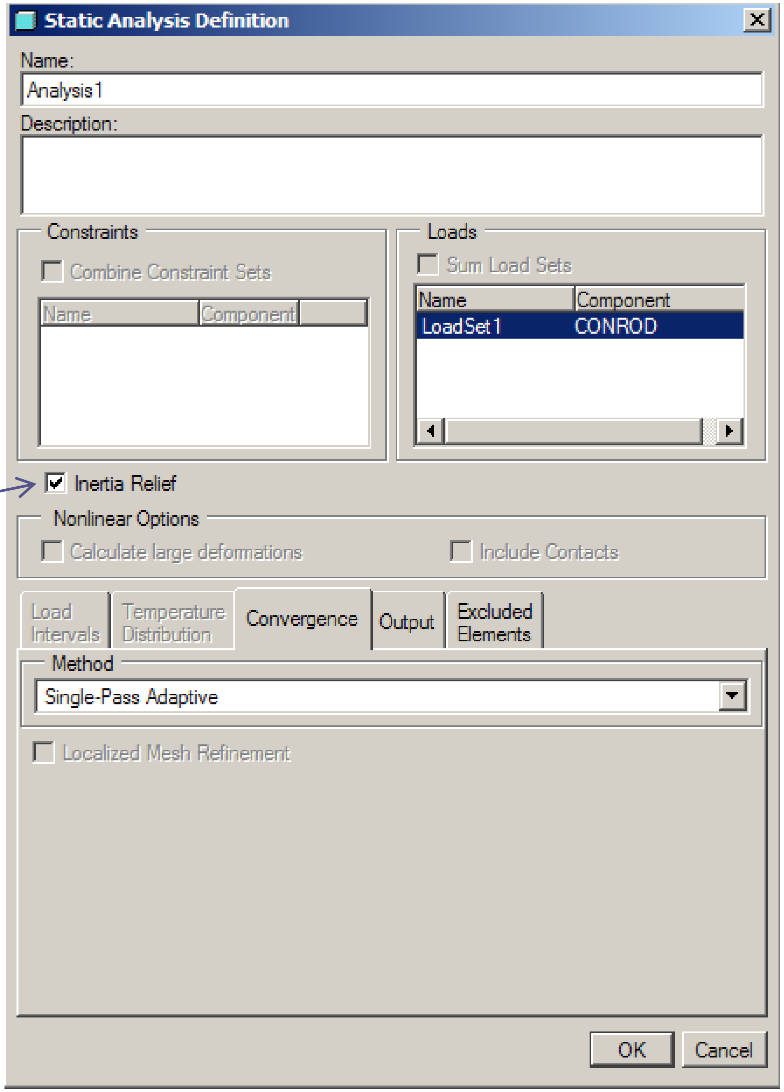
• The choice of points doesn't affect stress results

• However, it does affect how displacements are displayed – the point with 3 constraints defines the "zero-displacement" point in the model





Interface



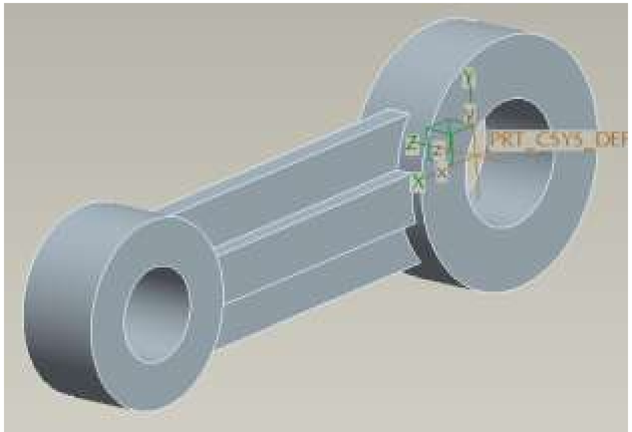
Check this box to activate *Inertia Relief* option

Exercises

Exercise #1: Tension of a Connecting Rod

1.Open ***conrod.prt***

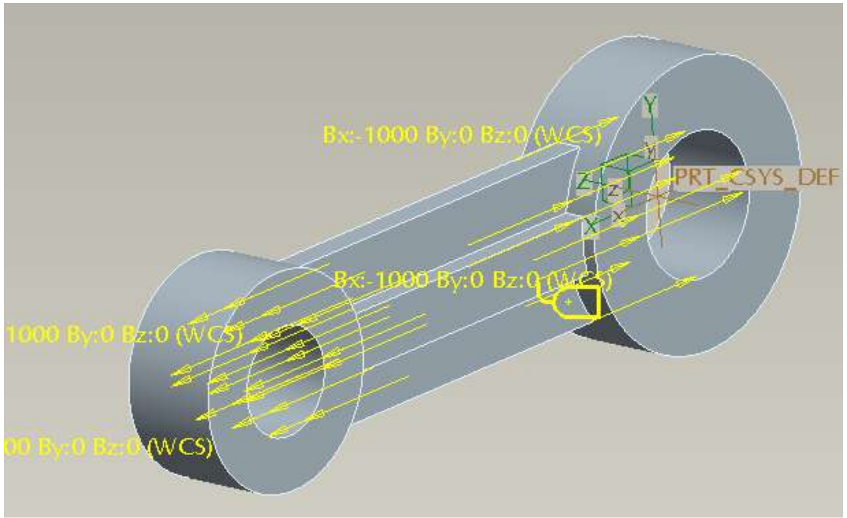
2.Start *Mechanica*. Assign STEEL to the part



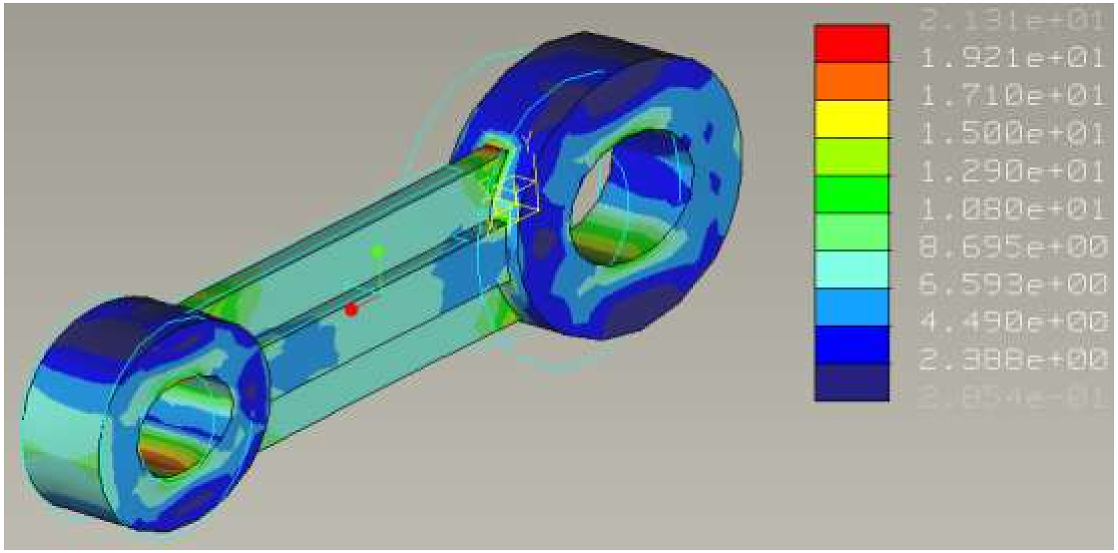
3.Apply 1,000N Bearing Loads to both holes – in +X-direction on the smaller hole, and in –X-direction on the large hole.

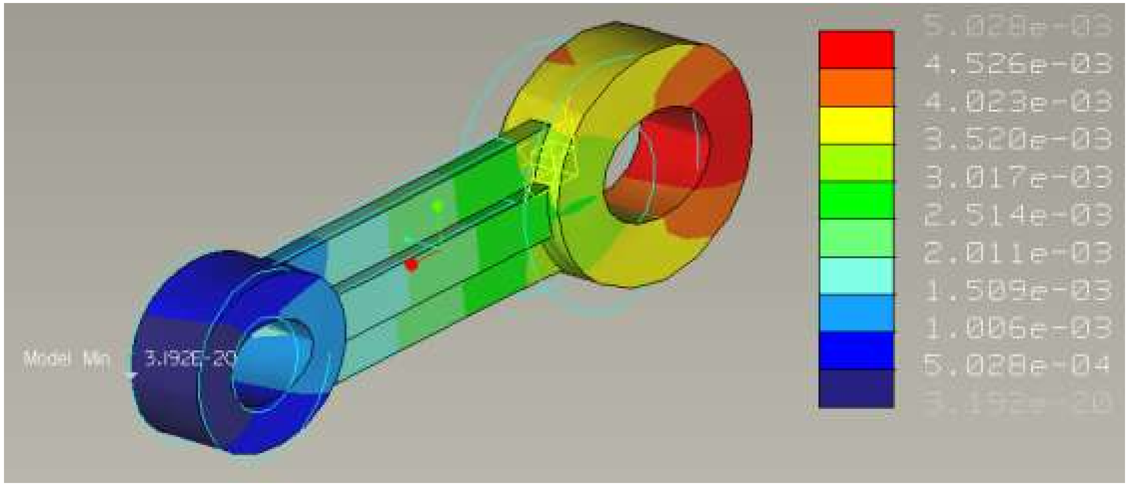
4.Since loads are in equilibrium, no constraints are needed.

5.Create new Static analysis. Make sure you check *Inertia Relief* box; leave all other options as-is. Run analysis.



6.Display *Deformed Von Mises* stress and examine the result. Notice that the model indeed freely deforms under the load, as if fully unconstrained. Can you tell which point Mechanica picked as the “zero-displacement” point?





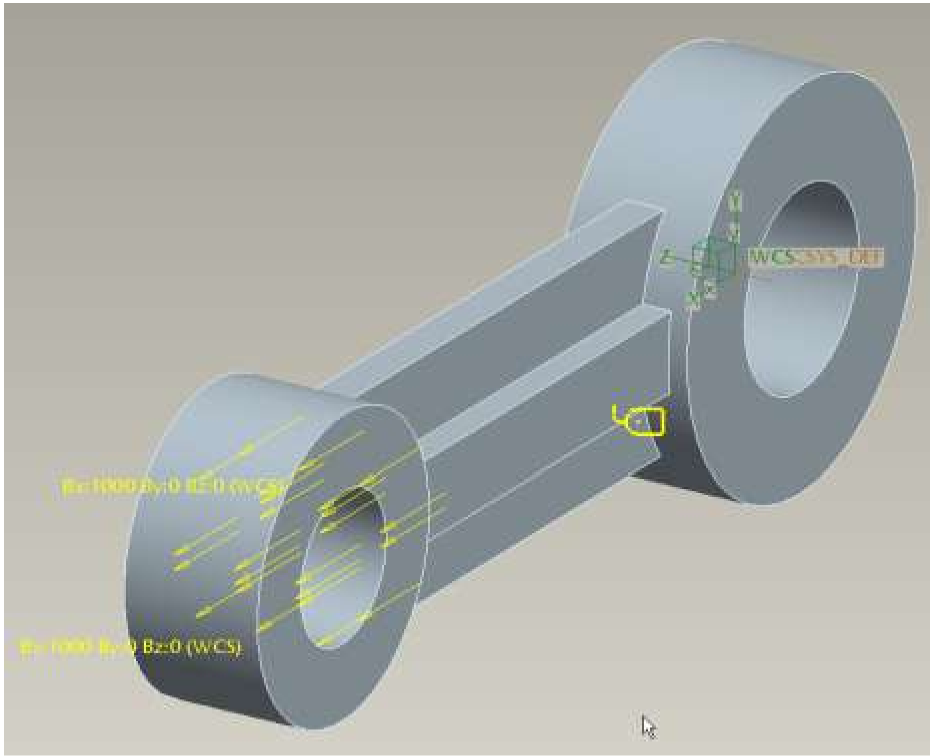
7.Display *Deformed Displacement Magnitude* plot. Click *Info>Model Min* to identify the “zero-displacement” point

In the next task, we will solve the model now with load on one hole only.

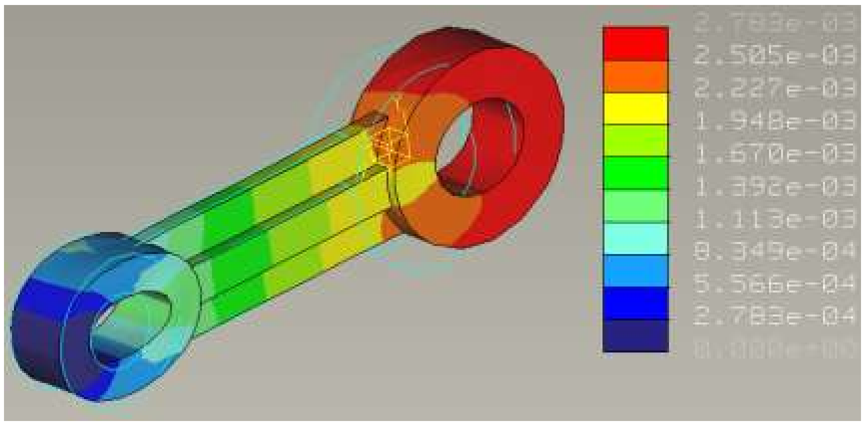
8.Exit Results without saving and return to modeling.

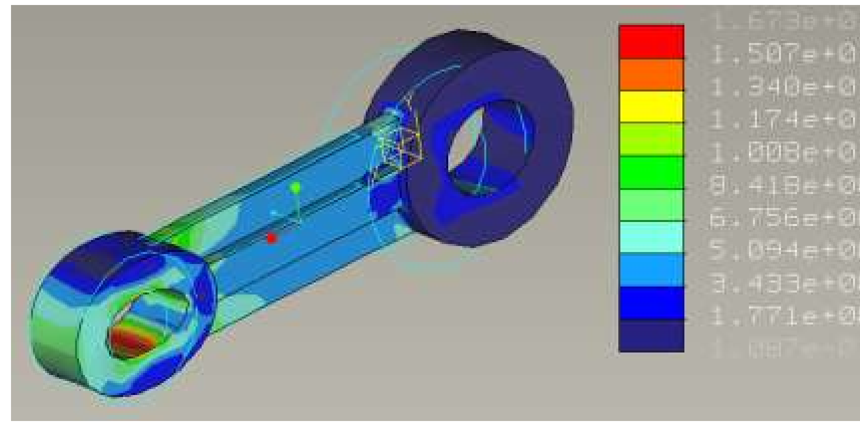
9.Delete the load from the larger hole.

10.Re-run the analysis.



11.Display *Displacement Magnitude* and *Von Mises* stress plots. Notice that the results are now quite different from the 1st analysis. This is because the load at the smaller hole is now balanced by inertia (acceleration) load, which is applied throughout the model, rather than by the load on the larger hole.





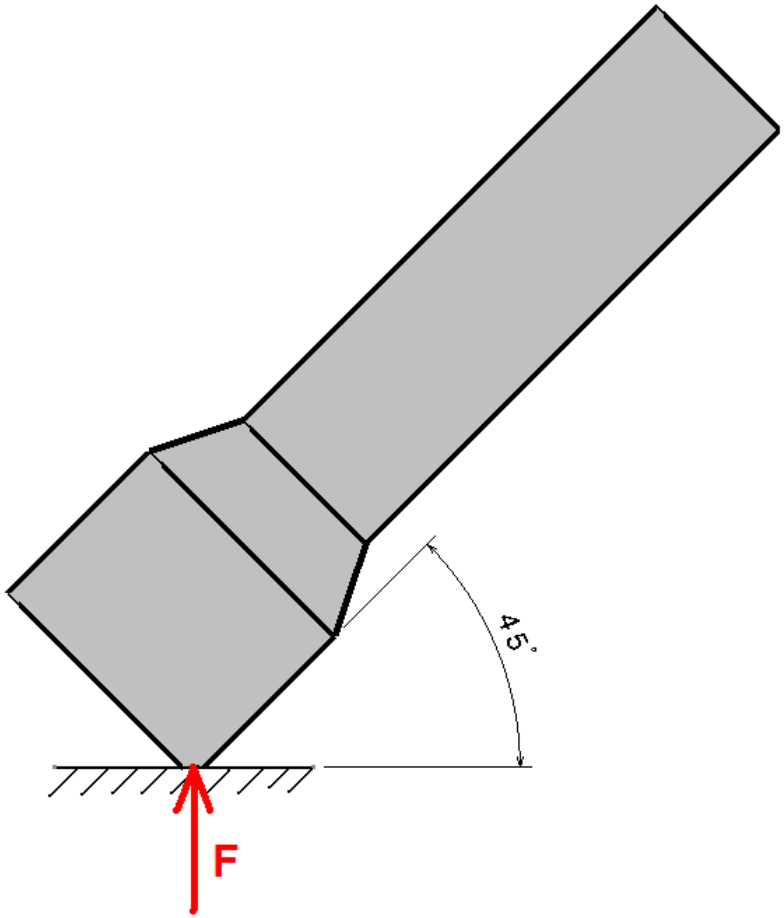
It is critical that *Inertia Relief* is used only if:

- **Either applied loads are already in equilibrium (Free Body Diagram)**
- **Or body (mass) forces actually participate in bringing the model to equilibrium**

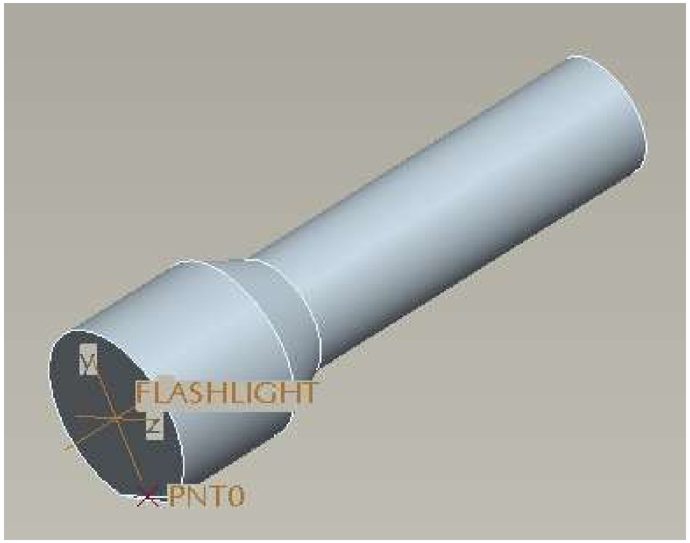
Exercise #2: Drop of a Flashlight on a Floor

- The task is to simulate the following:
  - Flashlight drops on the floor at 45deg angle
  - The estimated force F on impact (given the drop height, flashlight mass, etc) is 50N
  - The model is to be solved with Static analysis

- To properly simulate the above, consider the following:
  - There are no “natural” constraints in the model, reactions in which would balance the load F
  - Instead, upon the impact, the force F is balanced by inertia forces in the flashlight (dynamic forces due to instantaneous deceleration and rotation of the flashlight)
  - Which all makes it a perfect application for Inertia Relief option

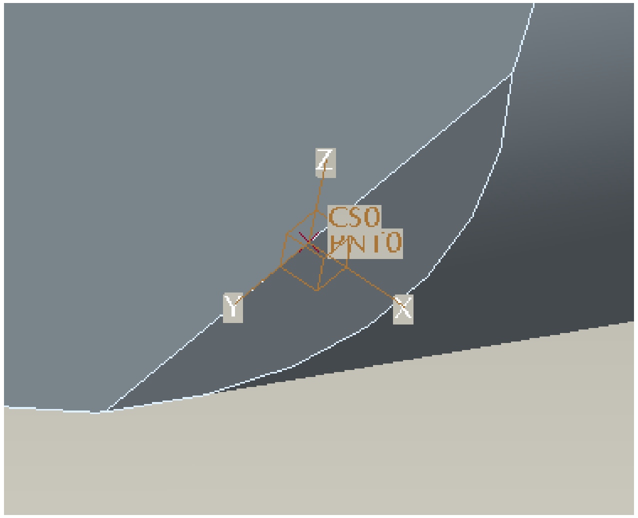


1.Open ***flashlight.prt***

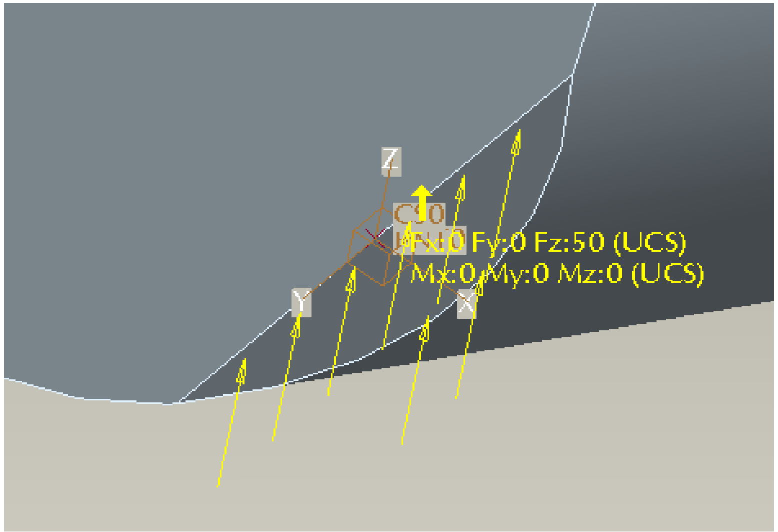


2.Start *Mechanica*. Assign PVC material to the part

3.Create new coordinate system with origin at the point located on the small face at the bottom of the part (this face is in contact with the floor upon impact). Make sure Z-axis is normal to that face and is directed upward.



4.Apply 50N force on that face in +Z-direction of CS0.



5.Create new Static analysis. Make sure you check *Inertia Relief* box; leave all other options as-is. Run analysis.

6.Once the analysis completes, open *Run Status* window and scroll down to *Resultant Load on Model*. Notice that resultant loads "excluding inertia relief" are non-zeroes (actually, the magnitude is 50N), while final resultant loads are almost zeroes i.e. the model loading has actually been brought into equilibrium by Mechanica.

```
Resultant Load on Model:
   in global X direction:  3.304345e-02
   in global Y direction:  3.305183e-02
   in global Z direction: -3.299588e-08

Resultant Load on Model (excluding inertia relief):
   in global X direction:  3.535534e+01
   in global Y direction:  3.535534e+01
   in global Z direction:  0.000000e+00
```

7.Display *Displacement Magnitude* and *Von Mises* stress plots and study the results.