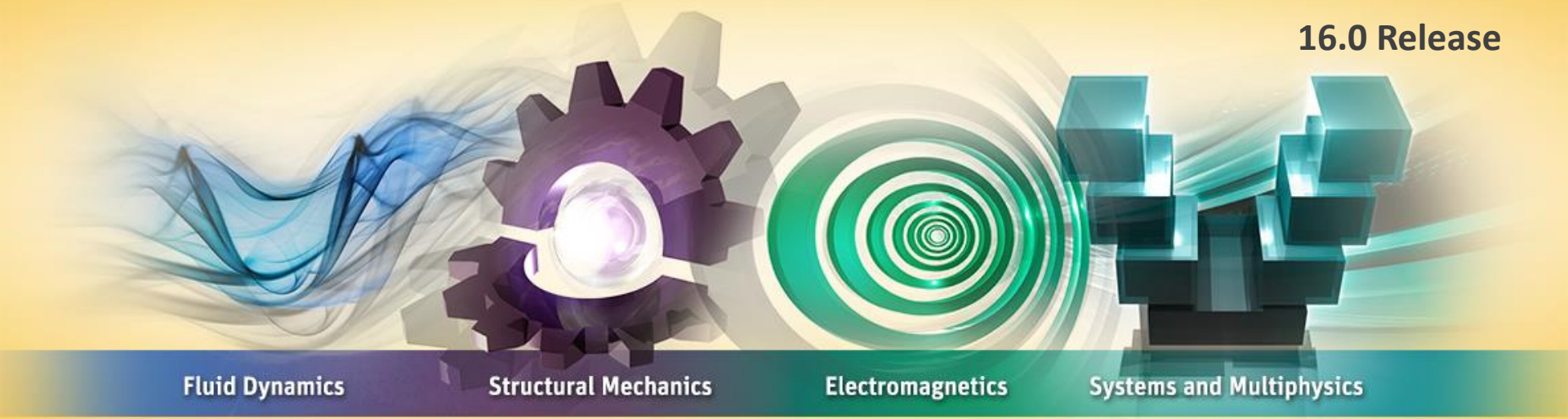
Lecture 11
Results and Post Processing

16.0 Release



Introduction to ANSYS Mechanical

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Chapter Overview

In this chapter controlling the display of results and the detection of potential results errors due to poor mesh quality will be covered:

A. Demonstration
B. Section Planes
C. Probe Tool
D. Charts
E. Scoping Results
F. Coordinate systems
G. Linearized Stress
H. Error Estimation
I. Convergence
J. Stress Singularities
K. Convergence and Scoping
L. Workshop 11.1 – Results Processing
M. Appendix

Chapter Overview

In this chapter controlling the display of results and the detection of potential results errors due to poor mesh quality will be covered:

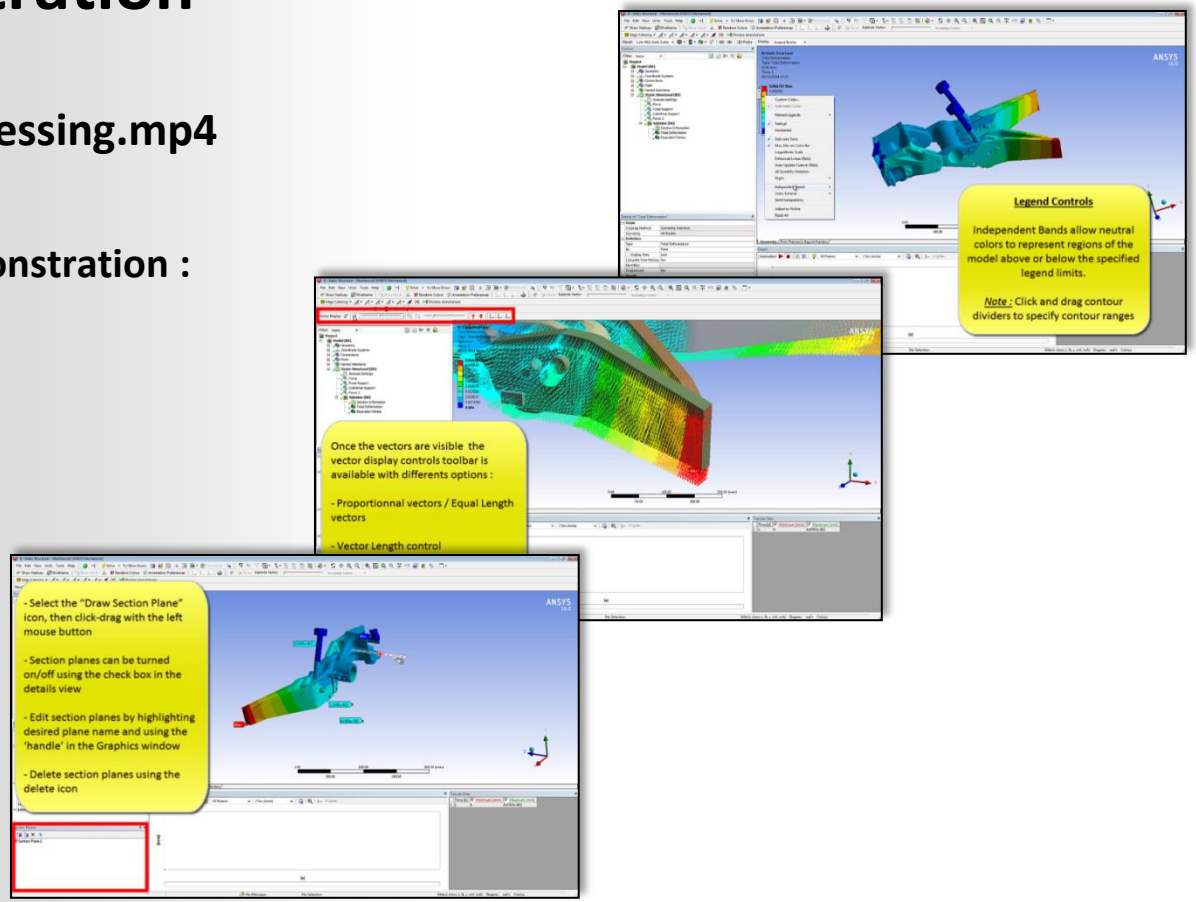
A Demonstration video showing post processing tools is available with this training material.

The Lecture covers features which do not appear in the video.

A. Demonstration

Demonstration : 04_Post_Processing.mp4

- **What you can learn in this demonstration :**
  - **Viewing Results**
  - **Legend Controls**
  - **Contour Controls**
  - **Post-processing Utilities**
  - **Scoping Results**
  - **Exporting Results**

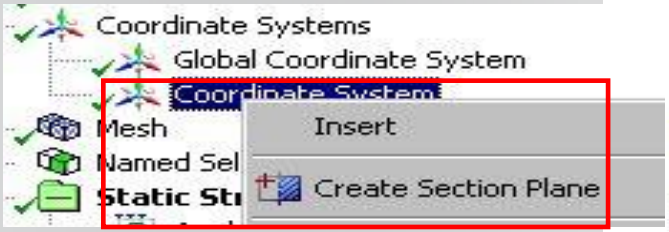


B. Section planes

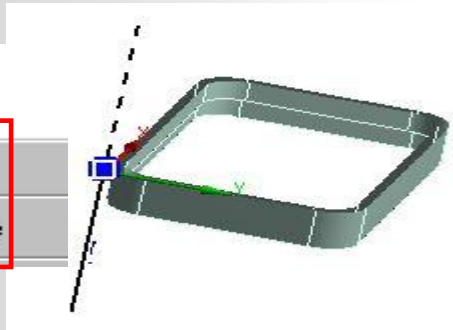
Section Planes are used to slice the model for viewing.

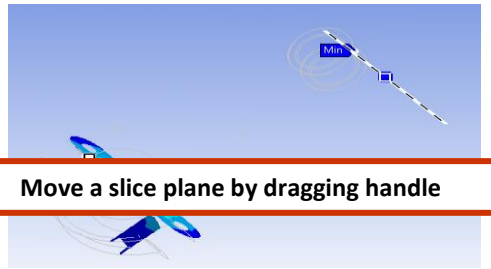
- **Select the “Draw Section Plane” icon, then click-drag with the left mouse button.**
- **Section planes can be turned on/off using the check box in the details view.**
- **Delete section planes using the delete icon.**
- **Edit section planes by highlighting desired plane name and using the ‘handle’ in the Graphics window.**
- **Can use local coordinate systems to automatically create a section plane (XY plane).**

Click on one side of bar to cap view



RMB



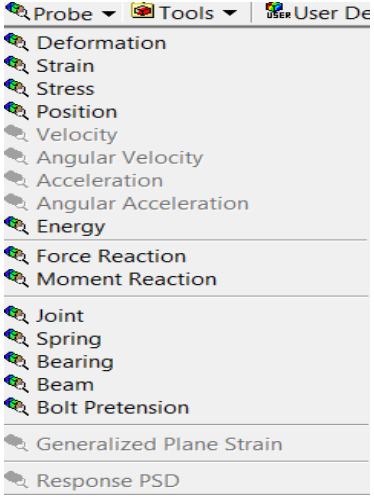


Move a slice plane by dragging handle

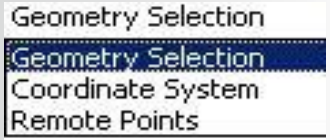
C. Probe tool

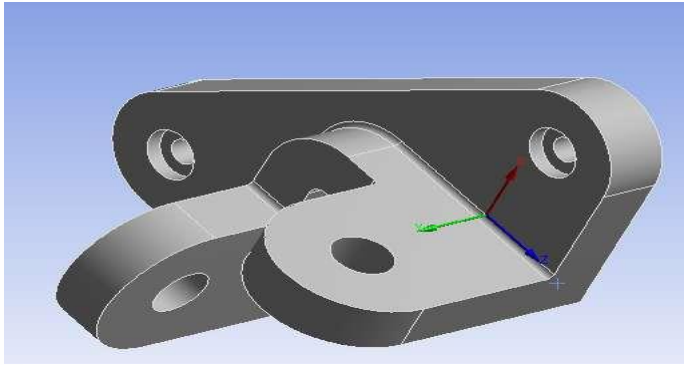
The Probe Tool:

- **Can be scoped to numerous entities depending on the probe type and results can be made parametric.**
- **The orientation of the result item can be with respect to global or local coordinate systems.**



Details of "Deformation Probe"	
Definition	
Type	Deformation
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
P Z Axis	
Maximum Value Over Time	
Z Axis	
Minimum Value Over Time	
Z Axis	
Information	

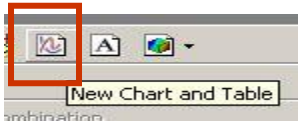


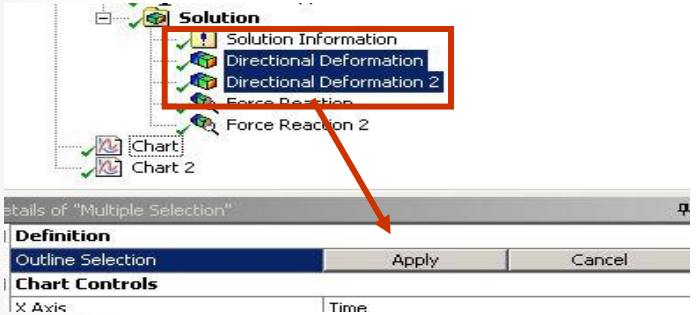


D. Charts

Combine results data from multiple steps (static or transient) into charts and/or tables:

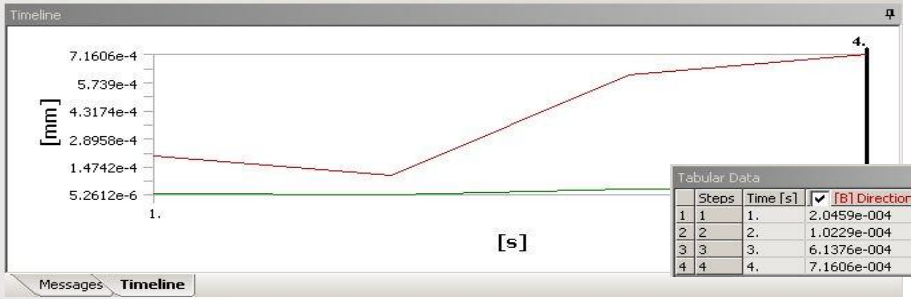
- **Select "New Chart and Table" icon.**
- **From the details "Apply" the desired result(s).**
  - **Use the CTRL key to select multiple results.**
- **Select desired display items in details.**





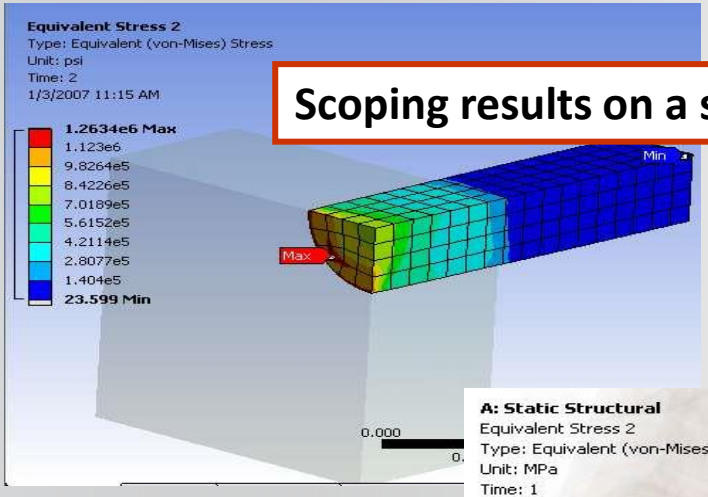
Details of "Multiple Selection"

Definition		
Outline Selection	Apply	Ca
Chart Controls		
X Axis	Time	
Axis Labels		
X-Axis		
Y-Axis		
Report		
Content	Chart And Tabular Data	
Caption		
Input Quantities		
Time	X Axis	
Output Quantities		
[A] Directional Deformation (Min)	Omit	
[B] Directional Deformation (Max)	Display	
[C] Directional Deformation 2 (Min)	Omit	
[D] Directional Deformation 2 (Max)	Display	

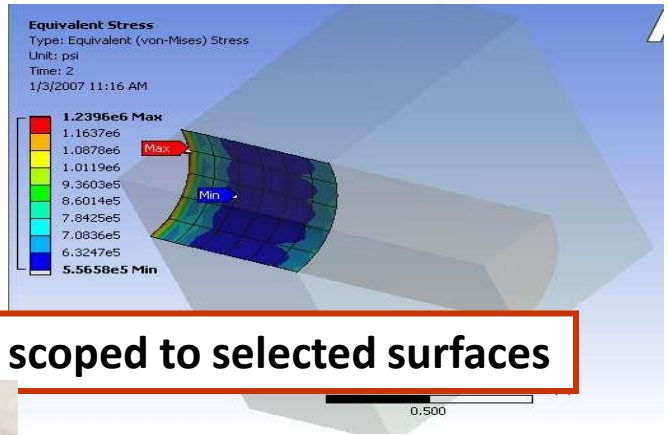


E. Scoping Results

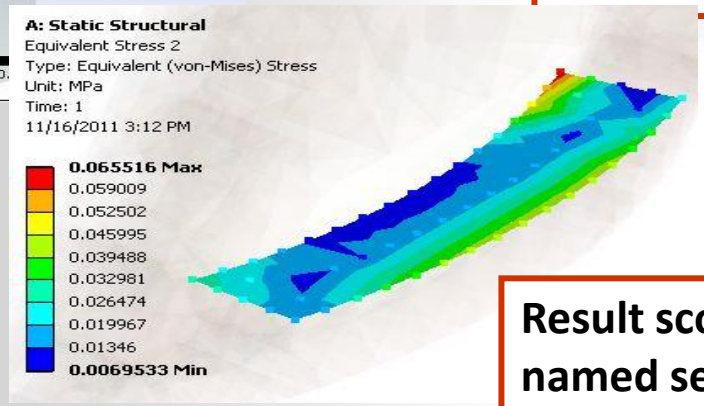
Some examples of scoping results on surfaces/parts:



Scoping results on a single part



Result scoped to selected surfaces

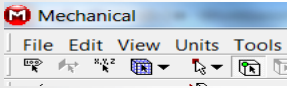


Result scoped to a nodal named selection

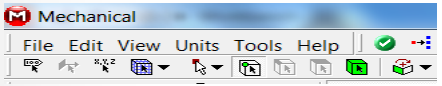
… Scoping Results

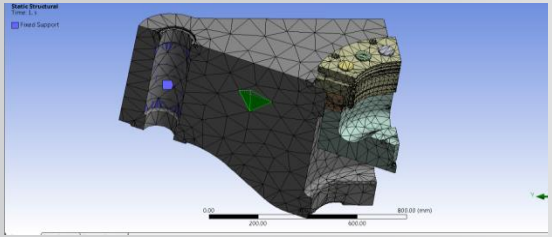
We can now also scope results to elements and nodes directly via the GUI.

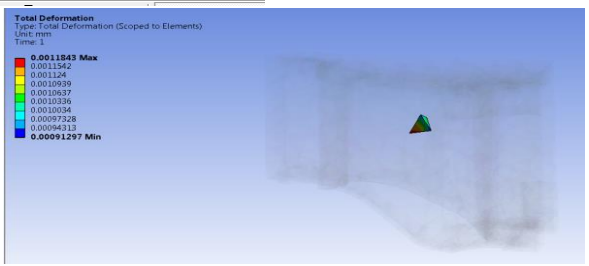
1) **Select mesh as the select type:**

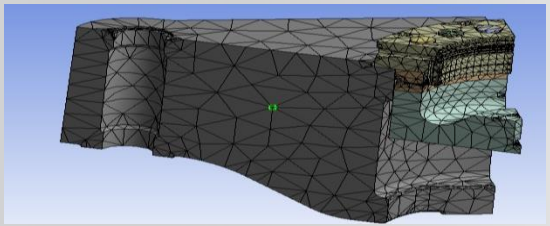


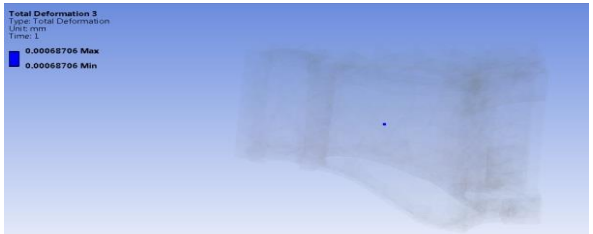
2) **Two geometry selection options remain, the rest disappear; vertex refers to nodes and body selection refers to elements.**





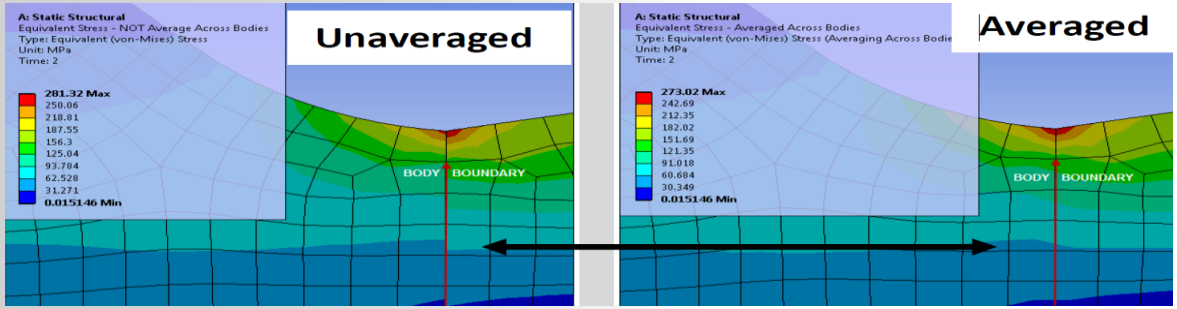






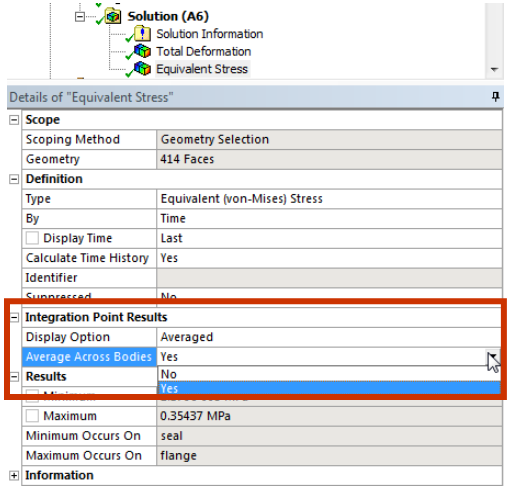
… Scoping Results

Contour plots across multi-body parts are available.



When you select Averaged as the display option.

Setting this property to Yes (the default value is No) allows to average the results across separate bodies the model.



F. Coordinate Systems

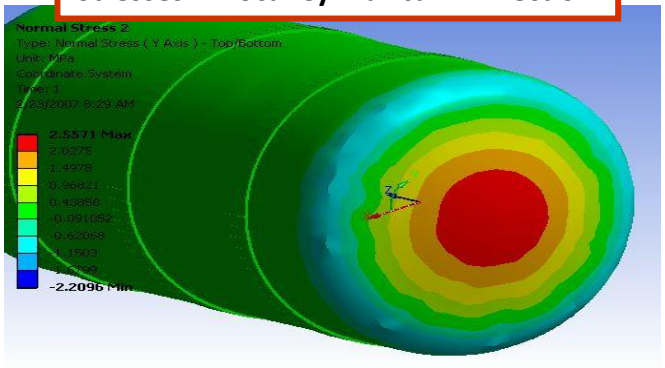
Results containing directional components can be transformed into a local coordinate system:

- **In result details select coordinate system from the drop down list.**

Details of "Normal Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Normal Stress
Orientation	X Axis
By	Time
Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Global Coordinate System
Identifier	Coordinate System
Suppressed	Coordinate System 3
	Solution Coordinate System

Stresses in Local Cylindrical Y-Direction

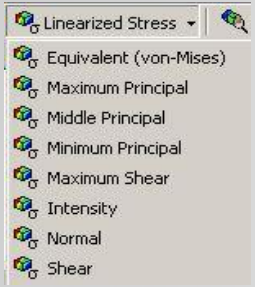


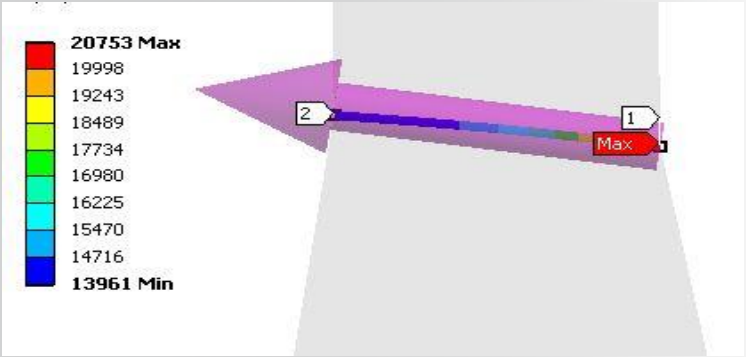
Details of "Normal Stress 2"

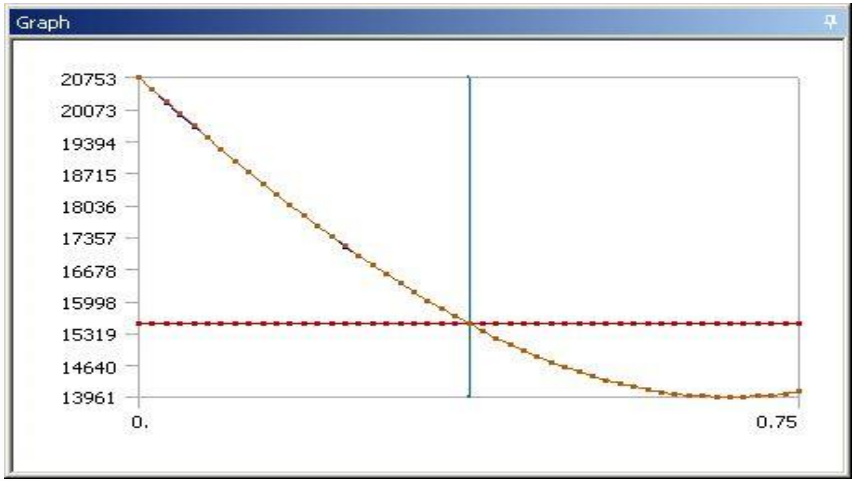
Scope	
Geometry	All Bodies
Definition	
Type	Normal Stress
Shell	Top/Bottom
Orientation	Y Axis
Coordinate System	Cylindrical System

G. Linearized Stress

Using the path plot feature a linearized stress calculation can be plotted (commonly used various structural codes such as ASME).



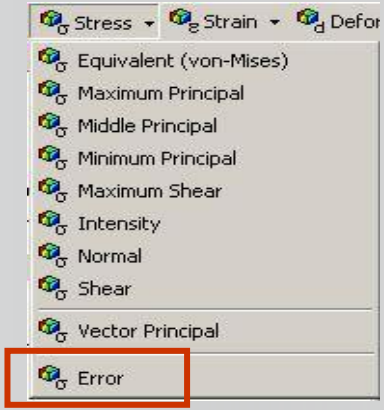


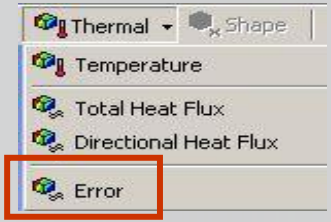


H. Error Estimation

You can insert an Error result based on stresses (structural), or heat flux (thermal) to help identify regions of high error.

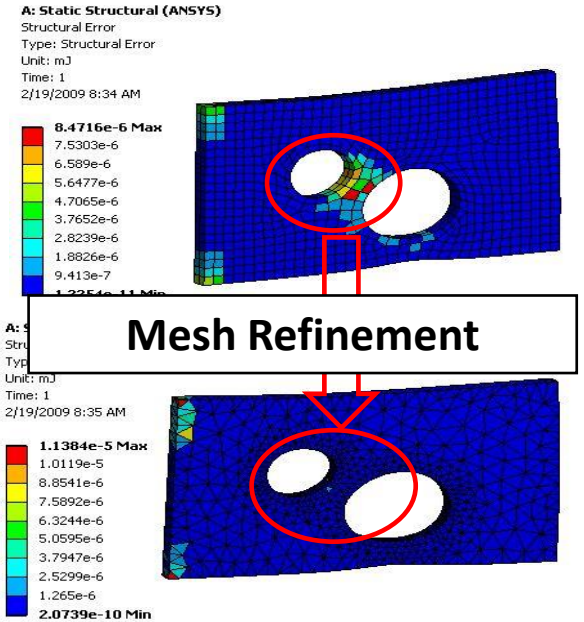
- **These regions can indicate where the model could benefit from a more refined mesh.**





Error plots are used to identify regions where large energy changes occur between adjacent elements.

The actual energy value in the legend is of little significance on its own.

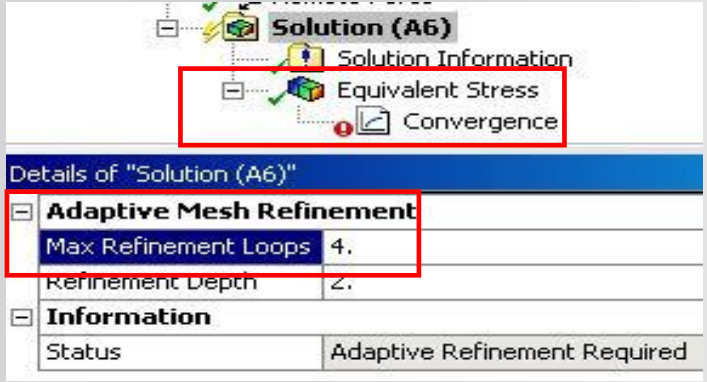


I. Convergence

In most finite-element analyses as the mesh is refined one expects to get mathematically more precise results. How much refinement is "enough" usually requires experience and engineering judgment. The Mechanical application has a convergence tool that can help assess the mesh quality.

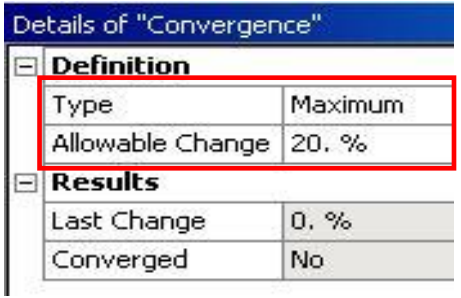
Obtaining an *optimal mesh* requires:

- **Having criteria to determine if a mesh is adequate.**
- **Adding more elements only where they're needed.**



Attach convergence to a result item and set the "allowable change" in the convergence details.

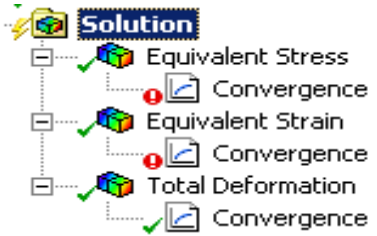
Specify maximum number of iterations in the Solution details.

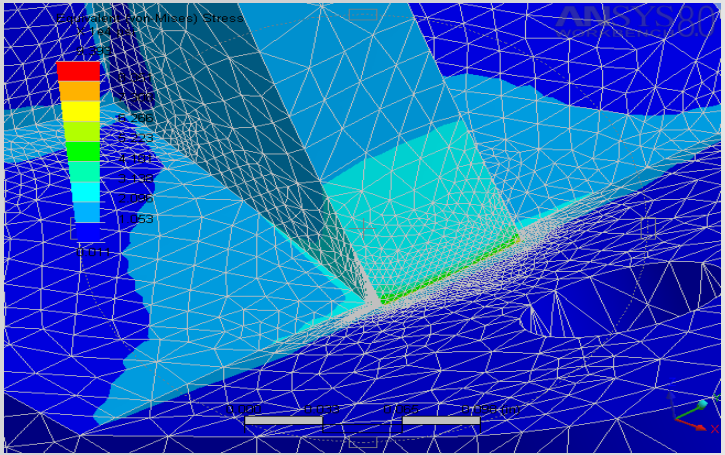


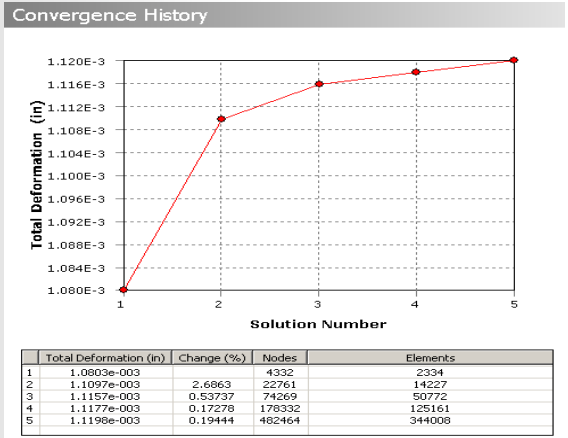
… Convergence

After the solution is complete one can view the results normally:

- **The Convergence history shows the trend for each refinement loop.**
- **Displaying elements in the results plot shows the last mesh (the mesh branch always displays the original mesh).**
- **Symbol next to convergence branch indicates success or failure.**

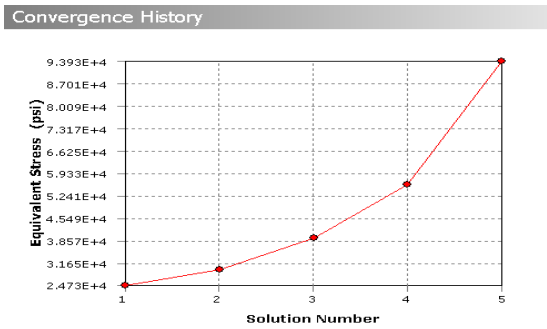






	Total Deformation (in)	Change (%)	Nodes	Elements
1	1.0803e-003		4332	2334
2	1.1097e-003	2.6863	22761	14227
3	1.1157e-003	0.53737	74269	50772
4	1.1177e-003	0.17278	178332	125161
5	1.1198e-003	0.19444	482464	344008

Convergence



	Equivalent Stress (psi)	Change (%)	Nodes	Elements
1	24733		4332	2334
2	29650	18.082	22761	14227
3	39431	28.317	74269	50772
4	55933	34.609	178332	125161
5	93934	50.712	482464	344008

Divergence

… Convergence

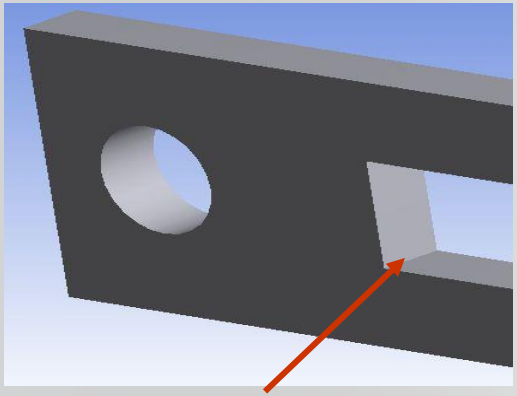
Convergence tool cannot be used if:

- **The model contains mesh connection object**
- **You have an upstream or a downstream analysis link**
- **You import loads in the analysis**

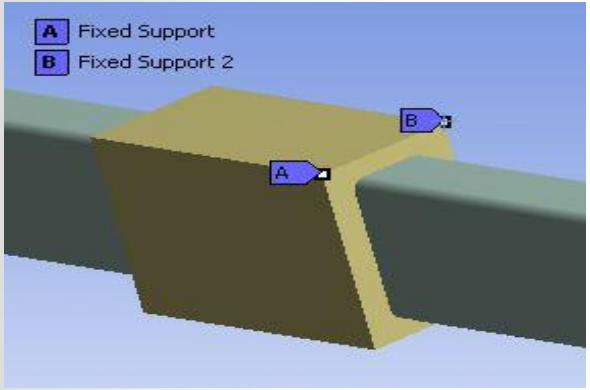
To use Convergence, you must set ”Calculate Stress” to ”Yes” under Output Controls in the Analysis Settings details panel.

J. Stress Singularities

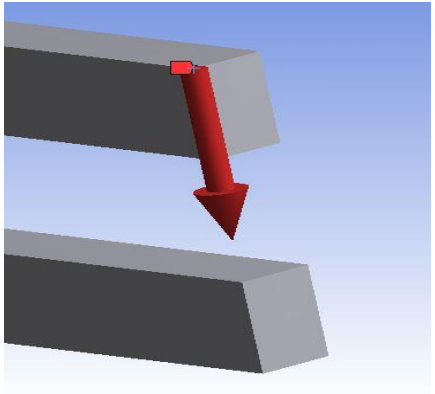
In structural analysis there are several situations that can cause singularities. These "artificial" hot spots can adversely affect both error plots and convergence.



Crude Geometry



Point Constraints



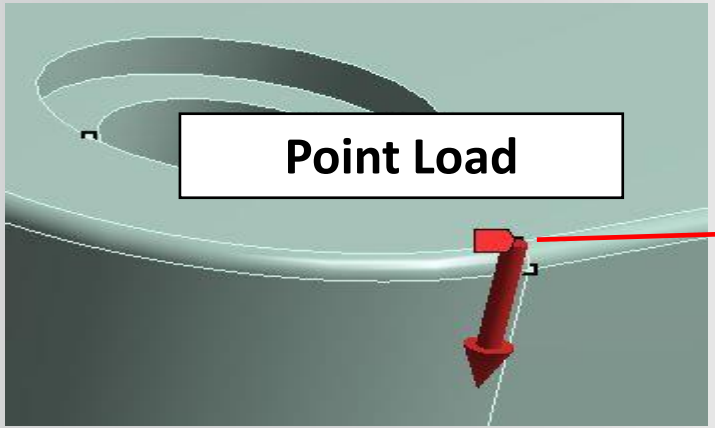
Point Loads

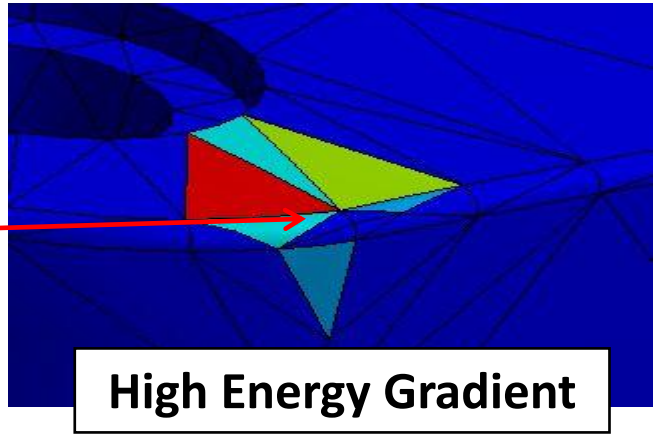
$$\sigma = \frac{Force}{Area}$$

As Area ⇨ Zero $\sigma \Rightarrow \infty$

… Stress Singularities

Consider the affect on error plots when a singularity is present. This situation will also cause a convergence monitor to "chase" the singularity.





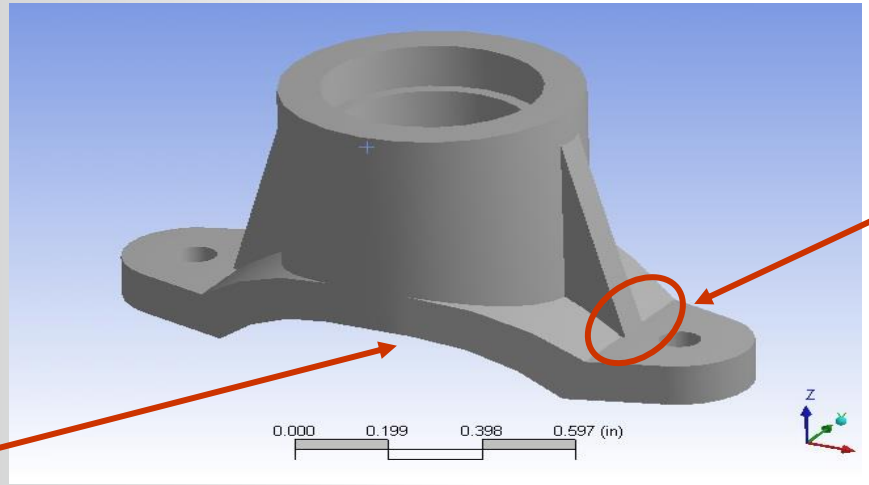
To remedy this we need to either remove the singularity (e.g. more realistic loads and/or geometry) or we need to avoid the problem areas. We avoid singularities by scoping convergence results.

K. Convergence & Scoping

A useful technique to avoid stress singularities when using convergence is to scope results away from them.

If a singularity region is not an area of interest, one can scope results to selected part(s) or surface(s) and add convergence controls only to those results.

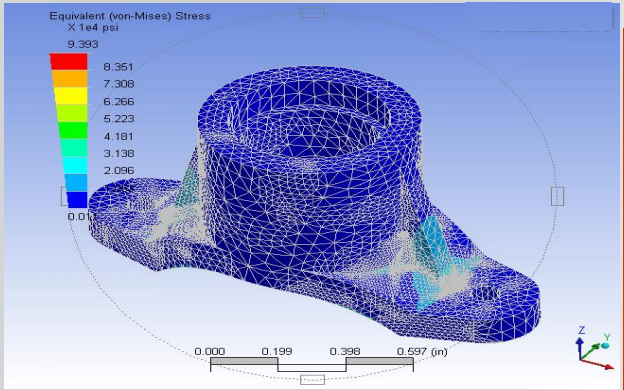
Example:



Possible stress singularity

Region of interest

… Convergence & Scoping Example

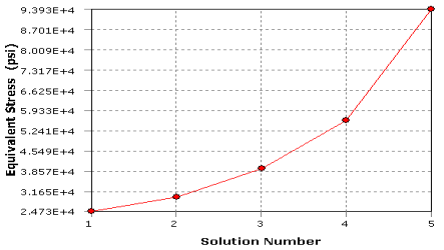


Convergence controls added to the entire model.

Geometric discontinuity causes a stress singularity causing divergence.

Solution becomes very costly by including the stress singularity.

Convergence History



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3	39431	28.317	74269	50772
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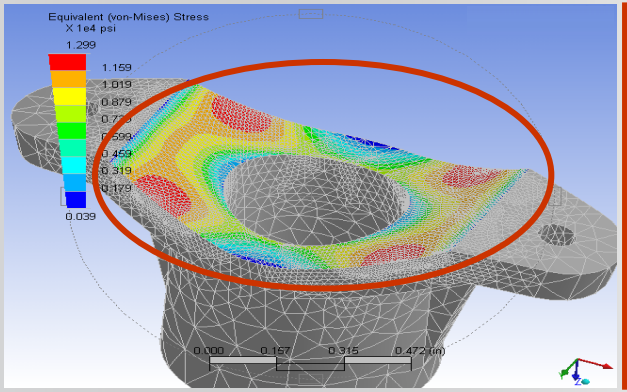
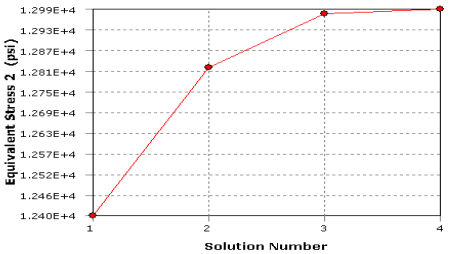


Convergence controls on scoped results allows adaptive refinement only in user-specified locations.

Provides more control over the mesh and the adaptive solution.

Accurate stresses realized in the region of interest.

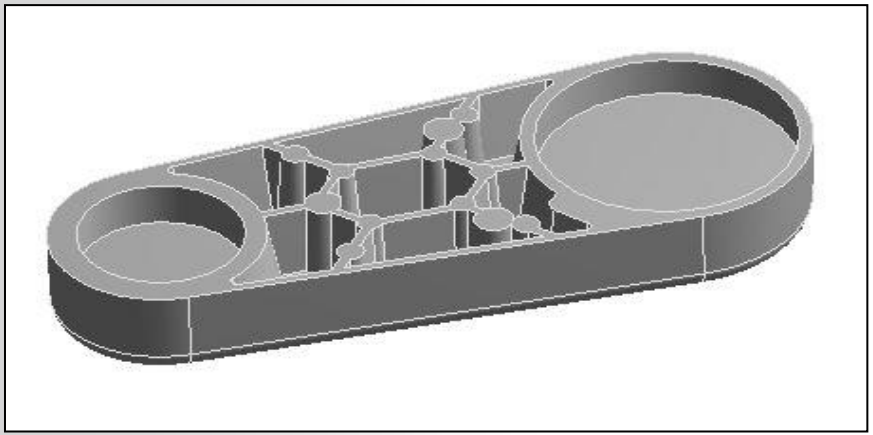
Convergence History



	Equivalent Stress 2 (psi)	Change (%)	Nodes	Elements
1	12397		4308	2313
2	12822	3.3681	19581	12216
3	12976	1.1907	79922	54702
4	12989	0.10441	226308	159669

L. Workshop 11.1

- **Workshop 11.1 – Results Processing**
- **Goal:**
  - **Analyze the mechanical arm shown below and then use some of the advanced postprocessing features to review the stress and estimate the error associated with a default mesh.**

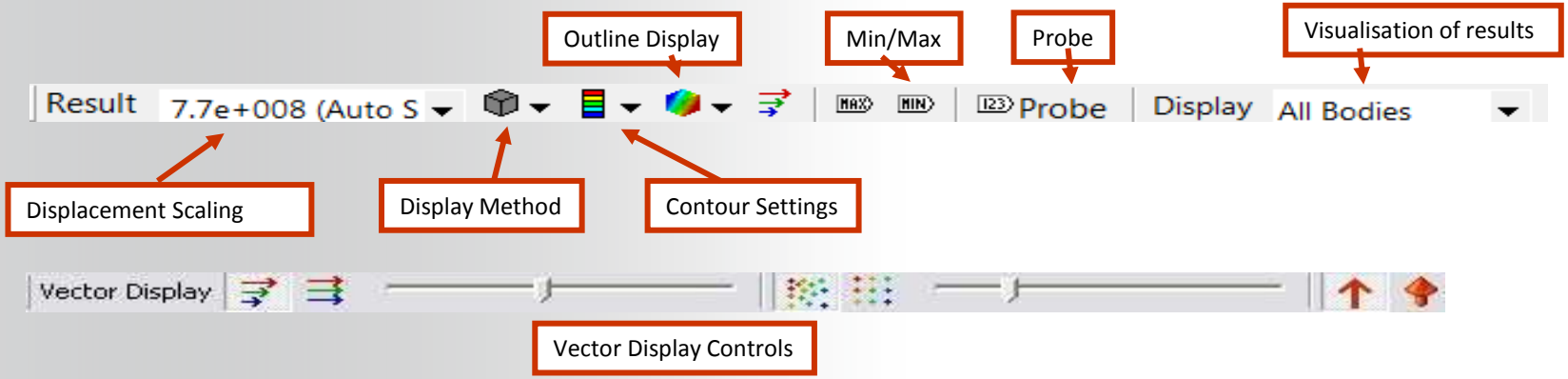


M. Appendix

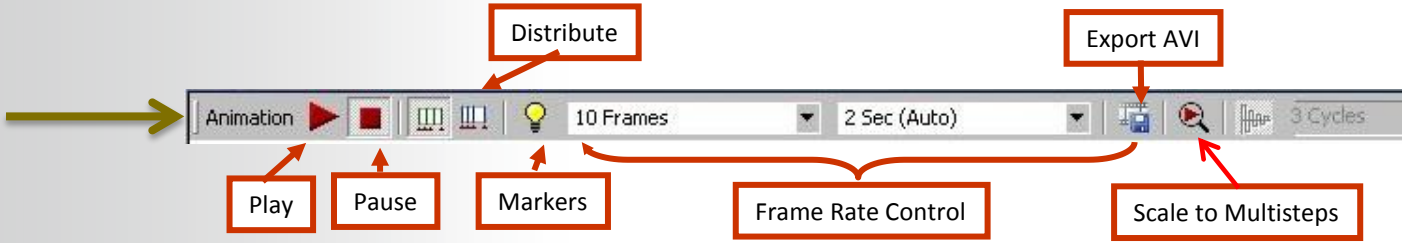
- Viewing Results
- Legend Controls
- Contour Controls
- Alert
- Windows
- Videos
- CE display
- Scoping Results
- Exporting Results

Viewing Results

Multiple ways to view results. Context toolbar allows for alternative ways of view results:



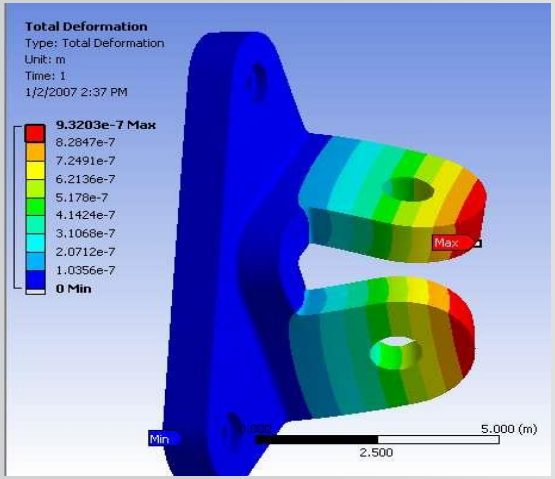
"Timeline" allows users to animate results



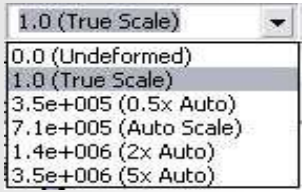
… Viewing Results

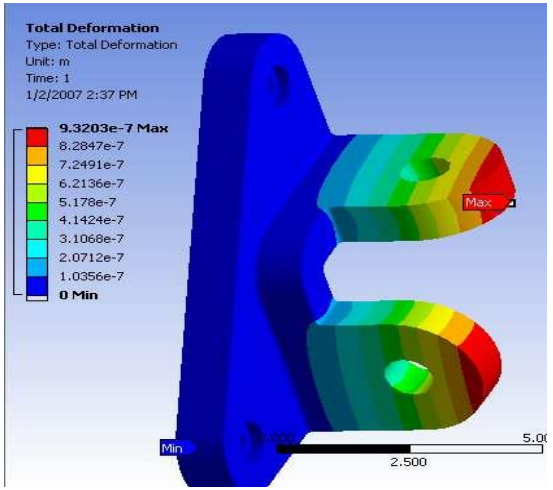
Displacement Scaling:

- In structural analysis a default scale factor “multiplies” actual displacements.
- The scale factor can be changed using several built in values or to a user specified one.



Automatic Displacement Scaling





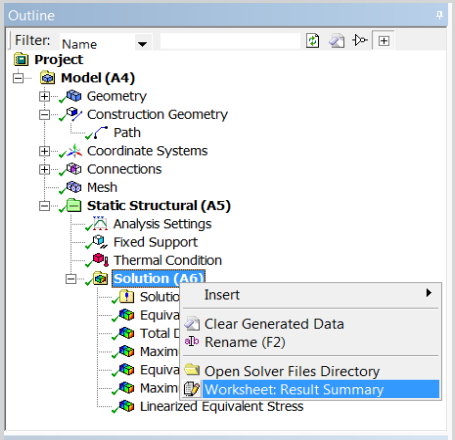
True Scale

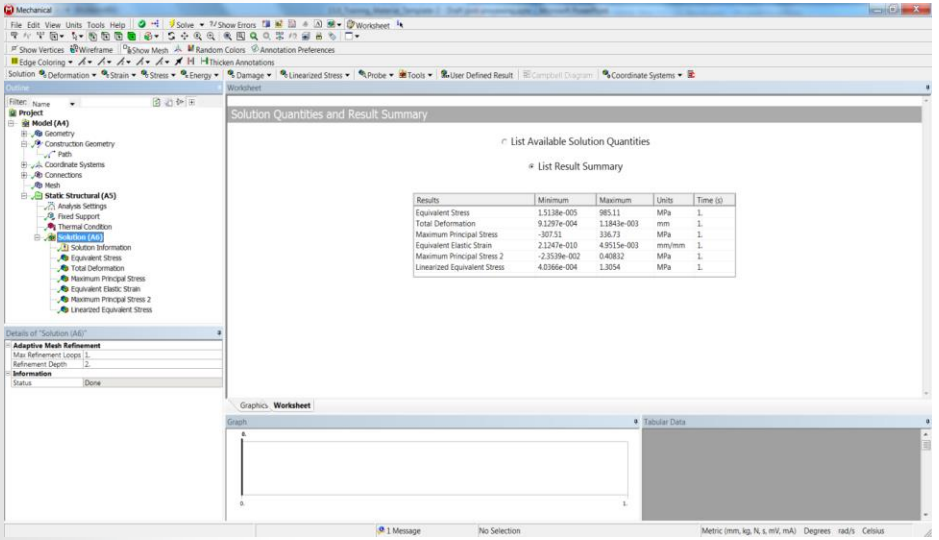
… Viewing Results

We can now view results in a worksheet form.

Multiple Post-Processing entities can be viewed in one go rather than scoping individual entities under the solution branch.

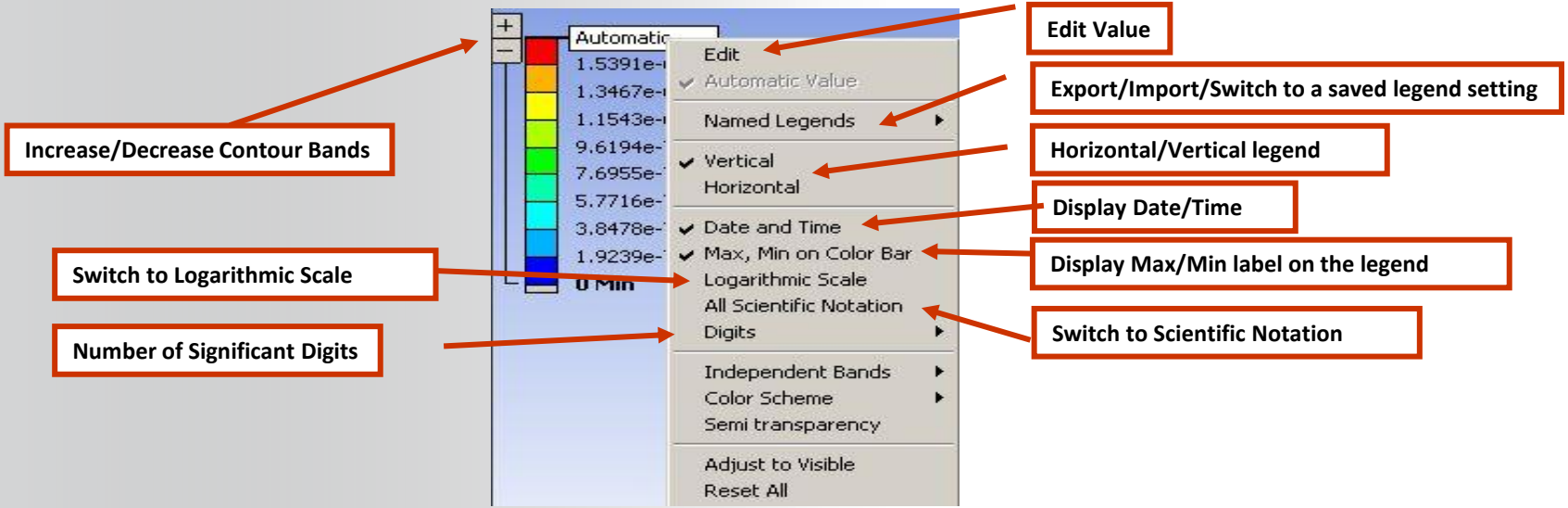
RMB on solution allows users to view worksheet result summary.





Legend Controls

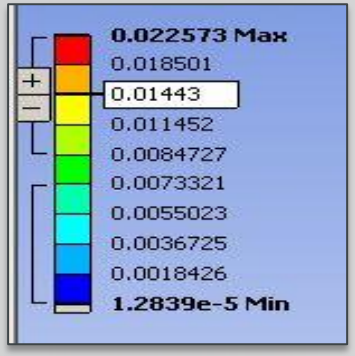
Right Clicking on the legend in the graphics area allows the user to modify the legend display.



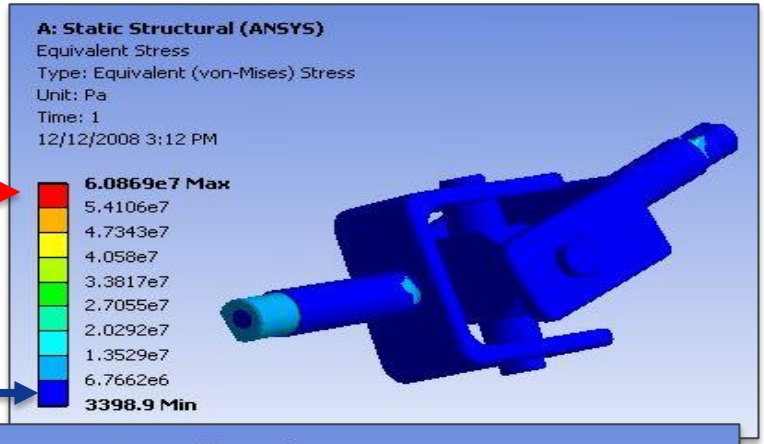
Continued . . .

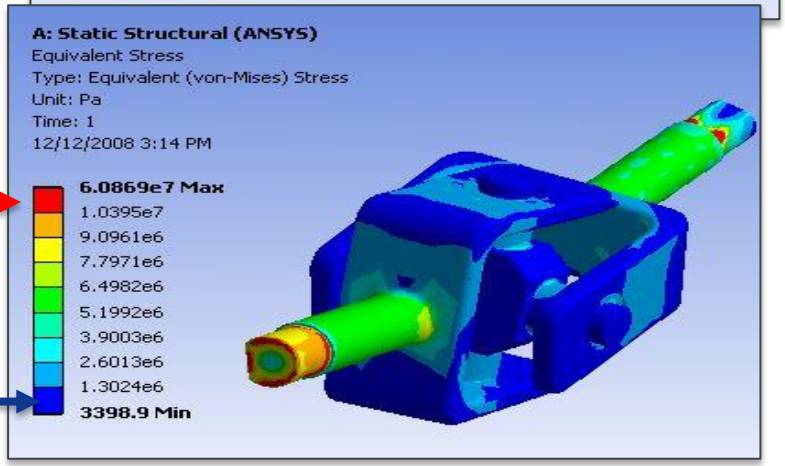
… Legend Controls

The legend bounds can be manipulated to show result distributions more clearly for contour plots.



Max/Min values are unchanged

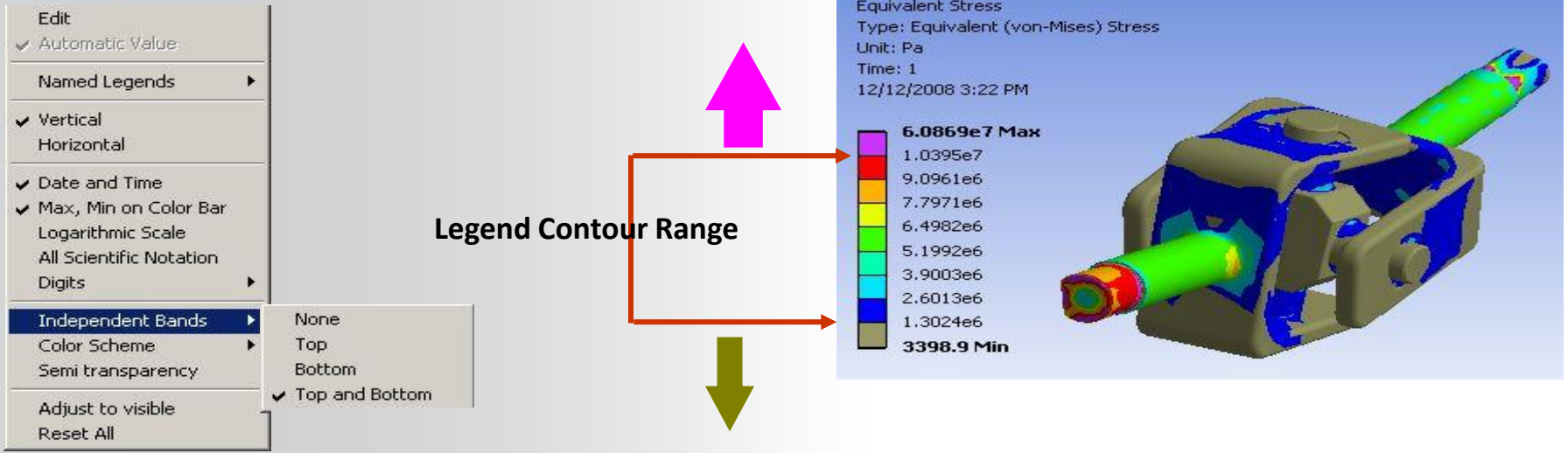




Click and drag contour dividers (or type in values) to specify contour ranges.

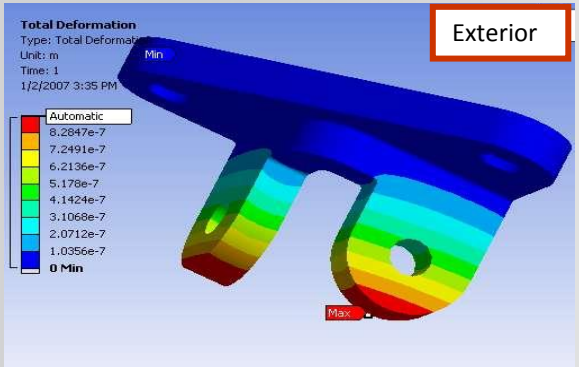
… Legend Controls

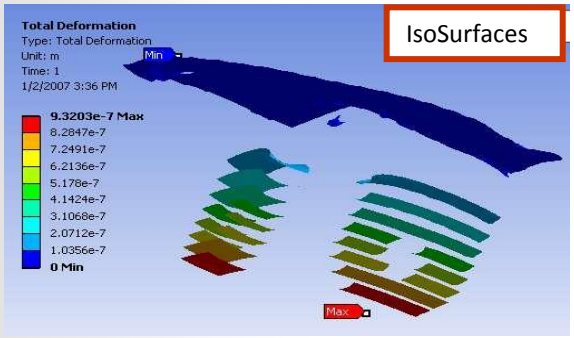
Independent Bands allow neutral colors to represent regions of the model above or below the specified legend limits.

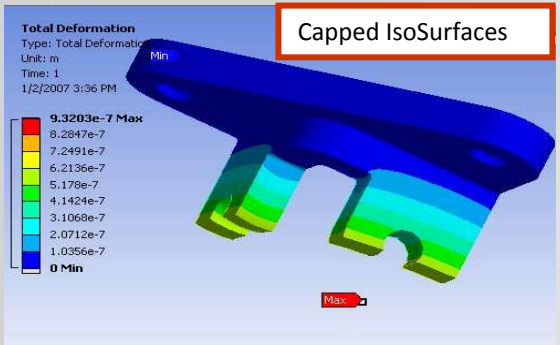


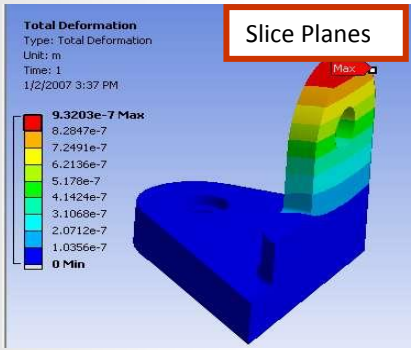
Contour Controls

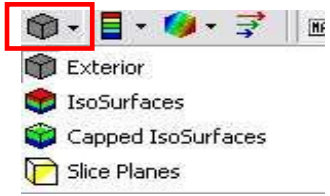
The "Geometry" icon controls the contour display method. Four choices are available:











"Exterior" is the default display option and is most commonly used.

"IsoSurfaces" is useful to display regions with the same contour value.

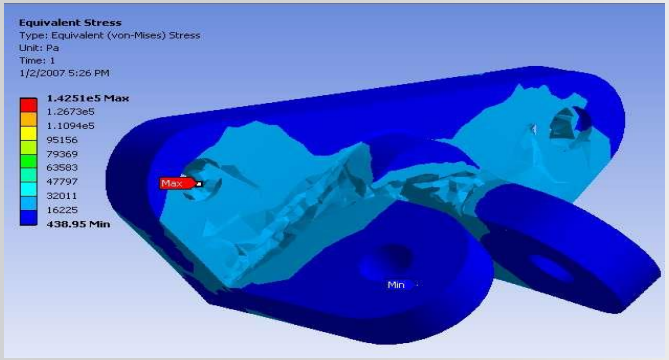
"Capped IsoSurfaces" will remove regions of the model where the contour values are above (or below) a specified value.

"Slice Planes" allow a user to 'cut' through the model visually. A capped slice plane is also available, as shown on the left.

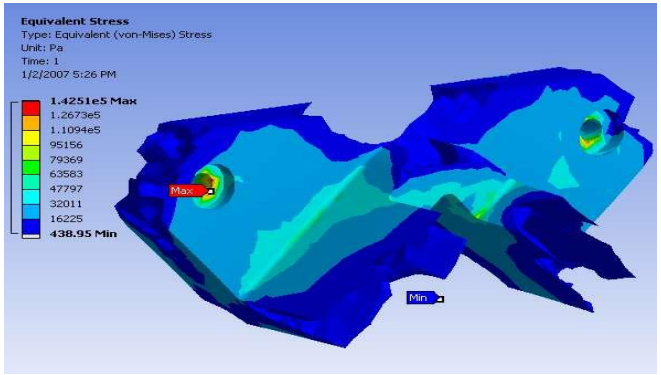
… Contour Controls

Capped IsoSurfaces are manipulated by an independent controller:

- **Icons allow isosurface cap to be top or bottom.**
- **The cap threshold can be controlled via the slider or by typing the value directly**



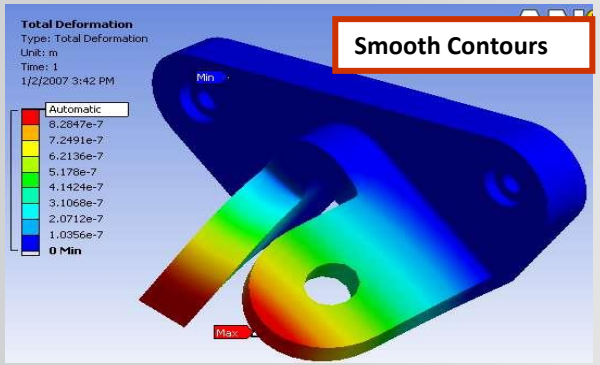
Top Capped Isosurface

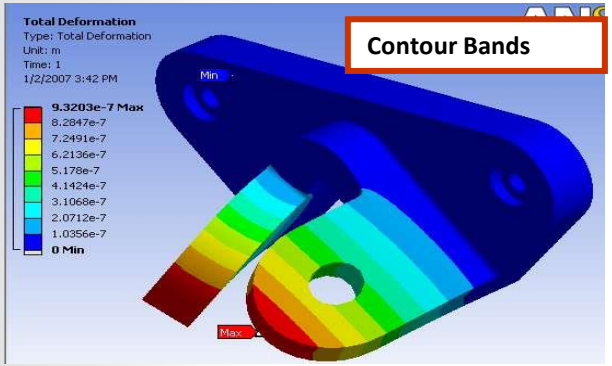


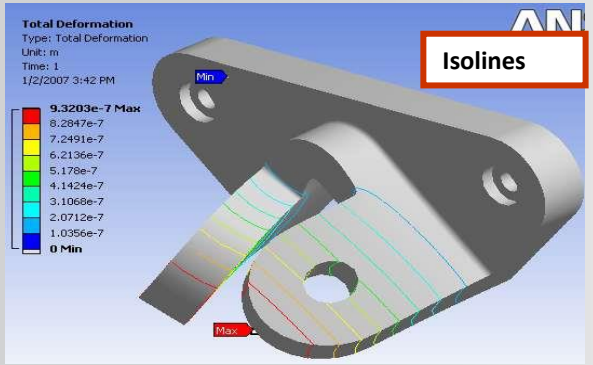
Bottom Capped Isosurface

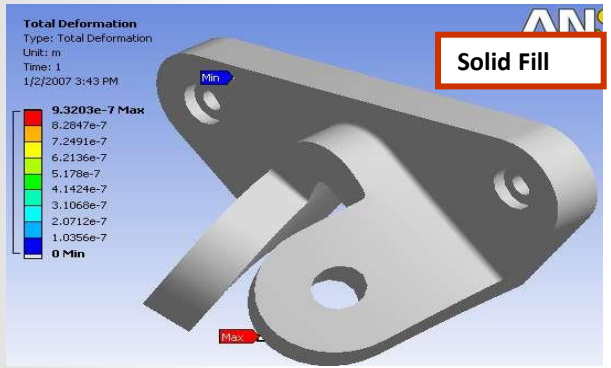
… Contour Controls

The “Contours” icon controls the style of color bands used when plotting results.



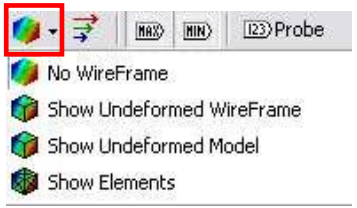


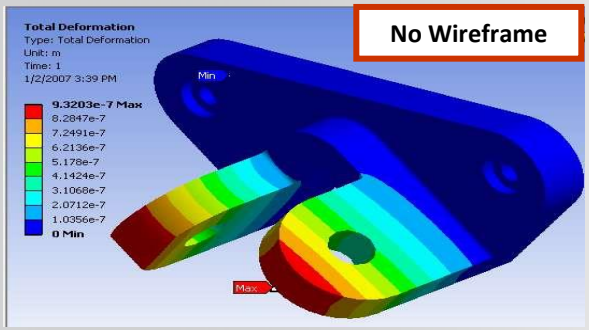


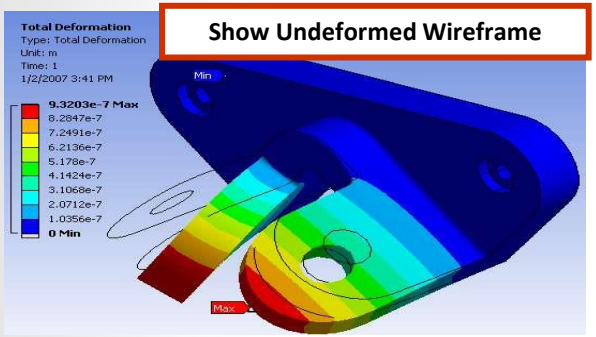


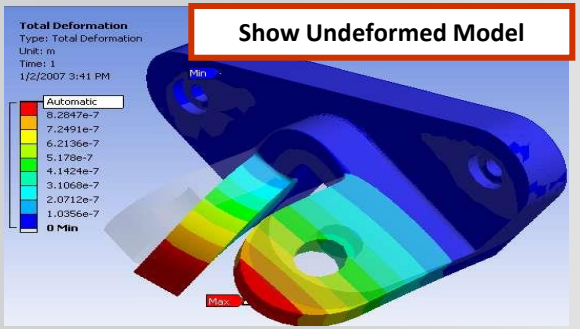
… Contour Controls

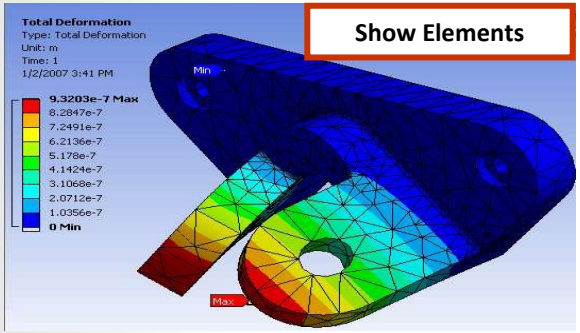
The “Edges” icon controls the display of the undeformed geometry or the mesh.







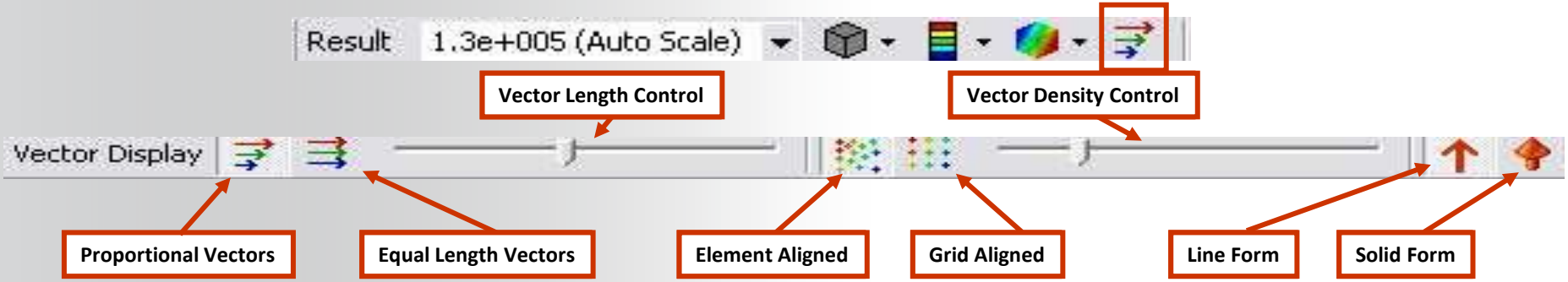


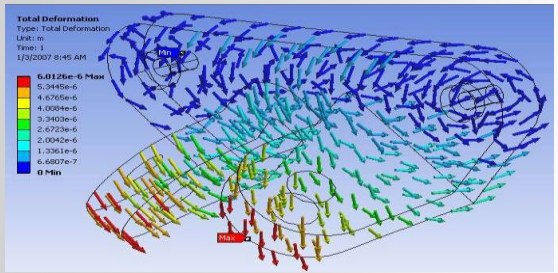


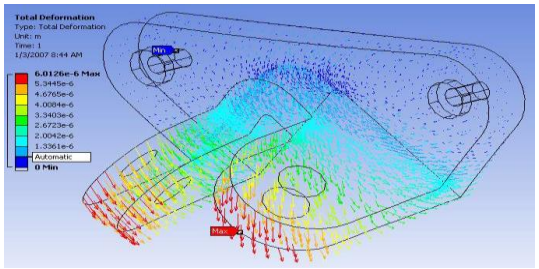
. . . Contour controls

Vector plots can be used to display result quantities defined with directions such as deformation, principal stresses, and heat flux.

- **Activate vectors for directional quantities using the vector graphics icon:**
- **Once the vectors are visible the vector display controls toolbar is available:**



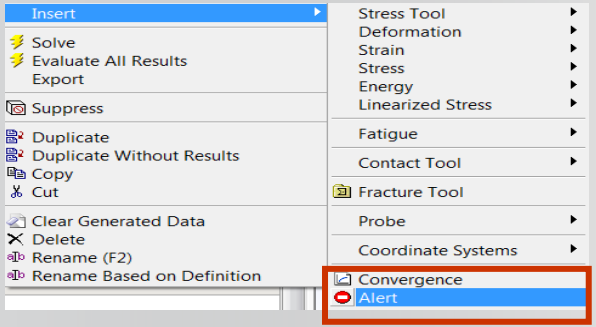


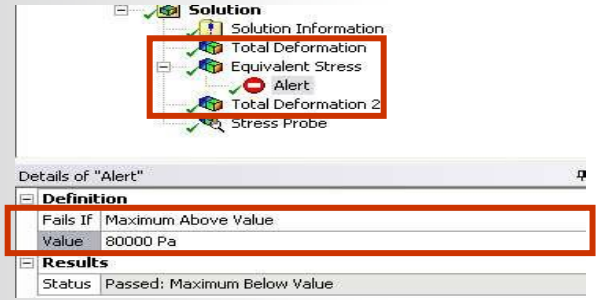


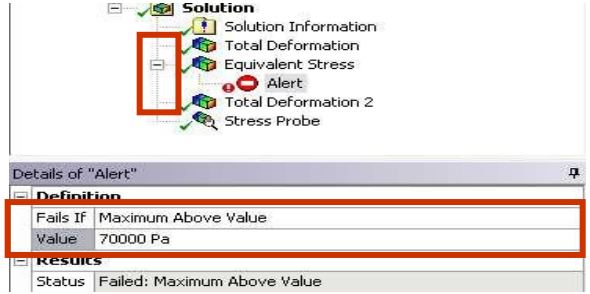
Alert

Alerts are simple ways of check to see if a scalar result quantity satisfies a criterion:

- **Highlight the particular result branch, RMB and insert an Alert.**
- **In the Details view, specify the criterion.**





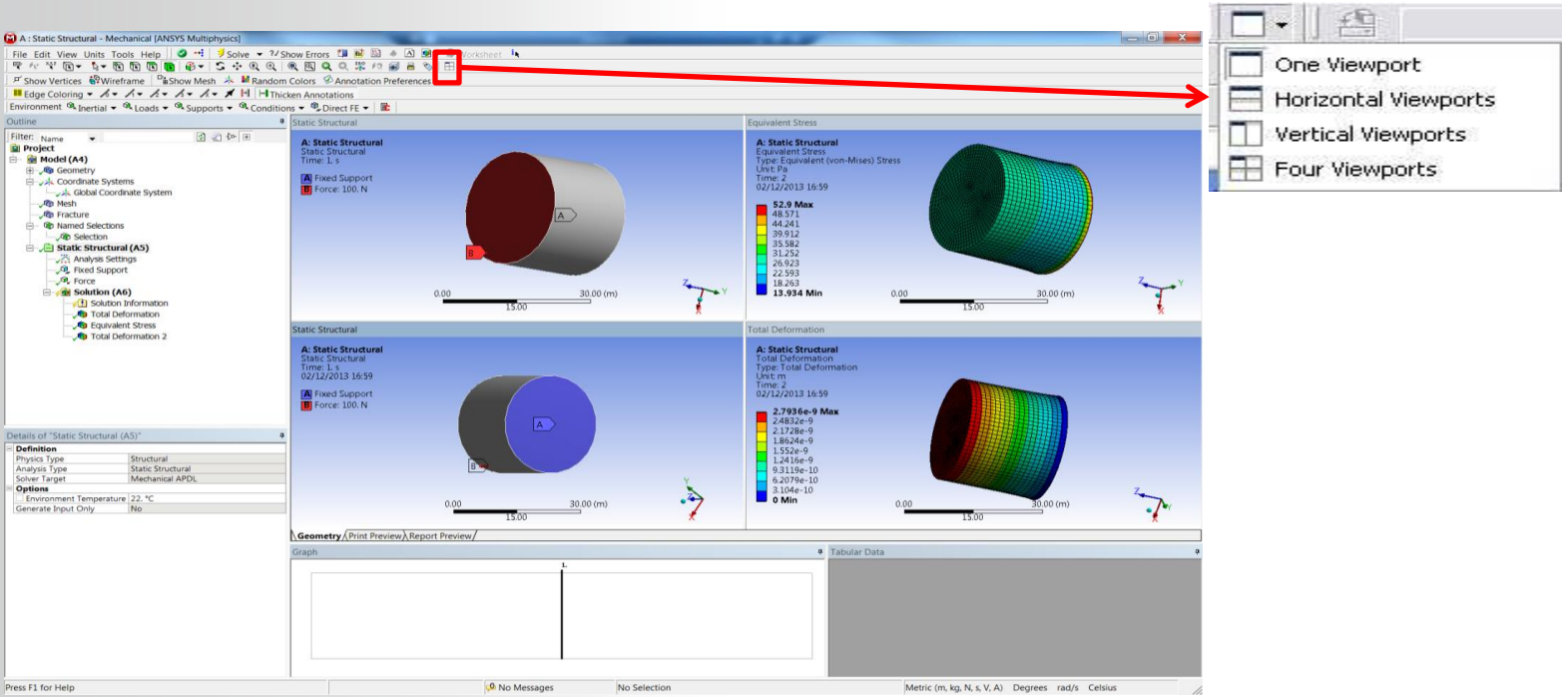


- **In the Outline tree, a green checkmark indicates that the criterion is satisfied. A red exclamation mark indicates that the criterion was not satisfied.**

Windows

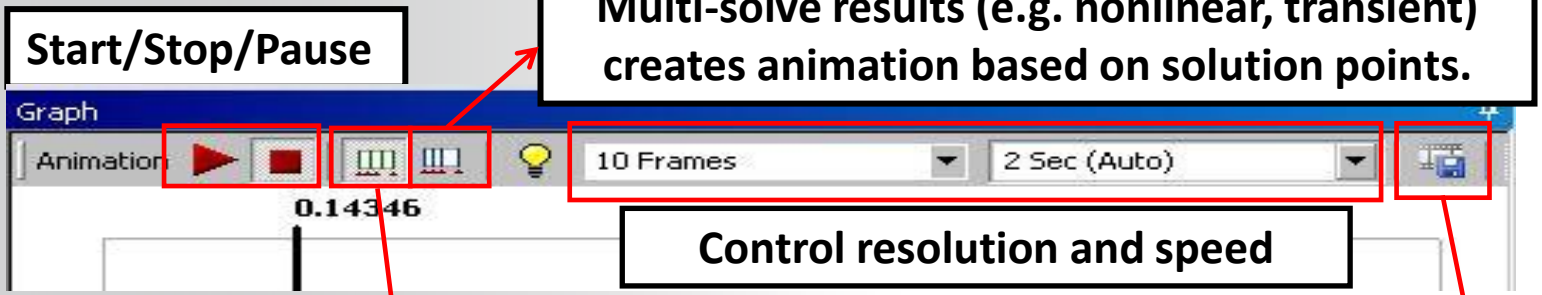
Multiple viewports can be used to display various images at the same time (model or postprocessing data).

- **Useful to compare multiple results, such as results from different environments or multiple mode shapes**



Videos

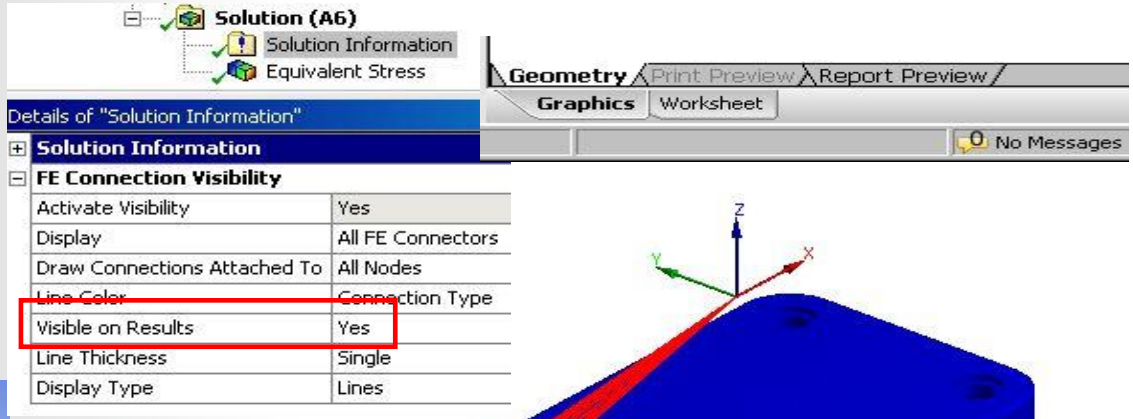
The animation toolbar allows user to play, pause, and stop animations



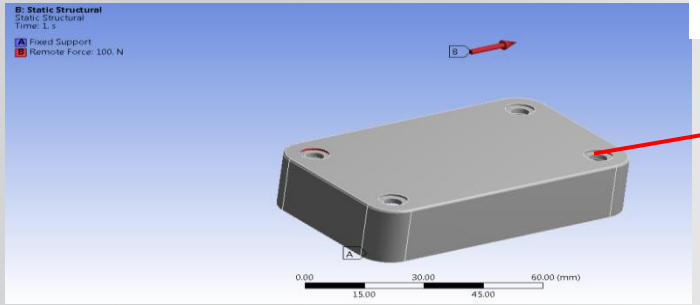
CE display

Various operations in Mechanical result in constraint equations being added to the model (e.g. remote boundary conditions, spot welds, weak springs, etc.)

- **Visibility for these connections is controlled from the Solution Information details and graphics tab.**



Remote Force



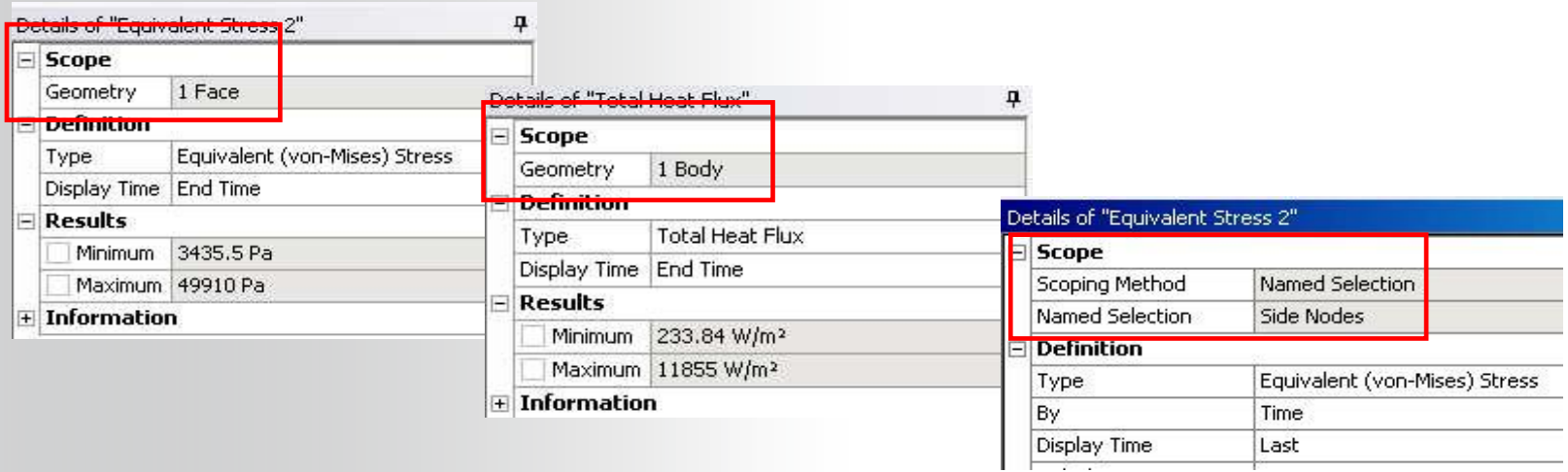
Scoping Results

Limiting the scope of results displays can be useful when postprocessing:

- **Scoping automatically scales the legend to results for selected regions.**

To scope contour results:

- **Pre-select geometry or named selection then request the result of interest.**
- **The non-selected geometry will be displayed as translucent.**

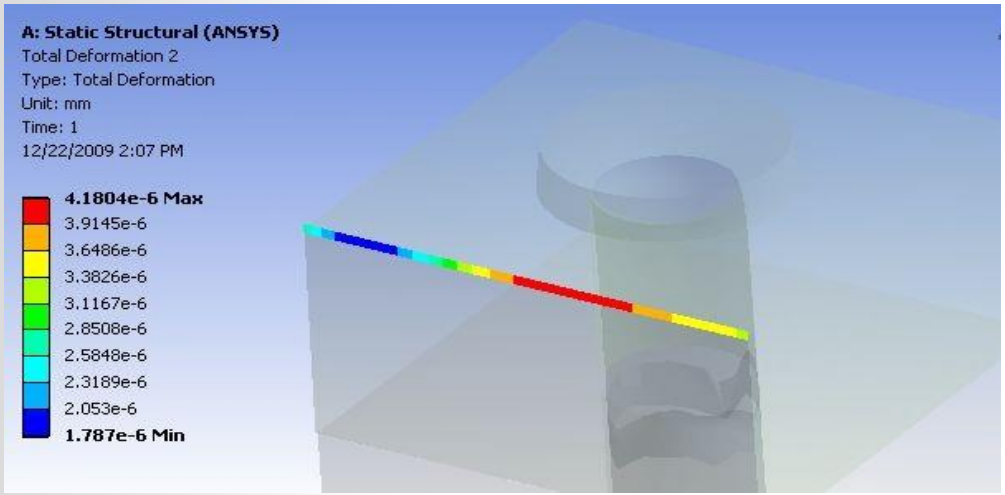


… Scoping Results

Results can be scoped to a single edge (or vertex):

- **Select edge(s) for results scoping.**

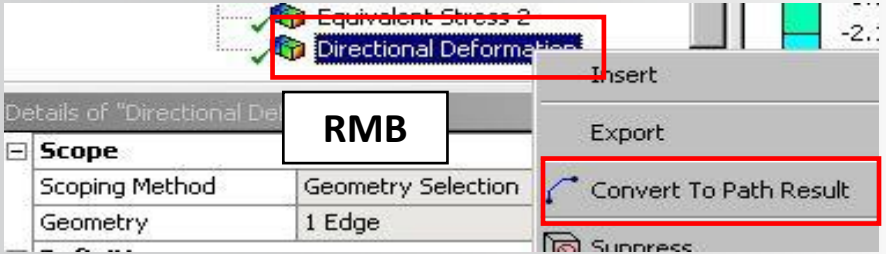
Details of "Total Deformation 2"	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Edge
Definition	
Type	Total Deformation

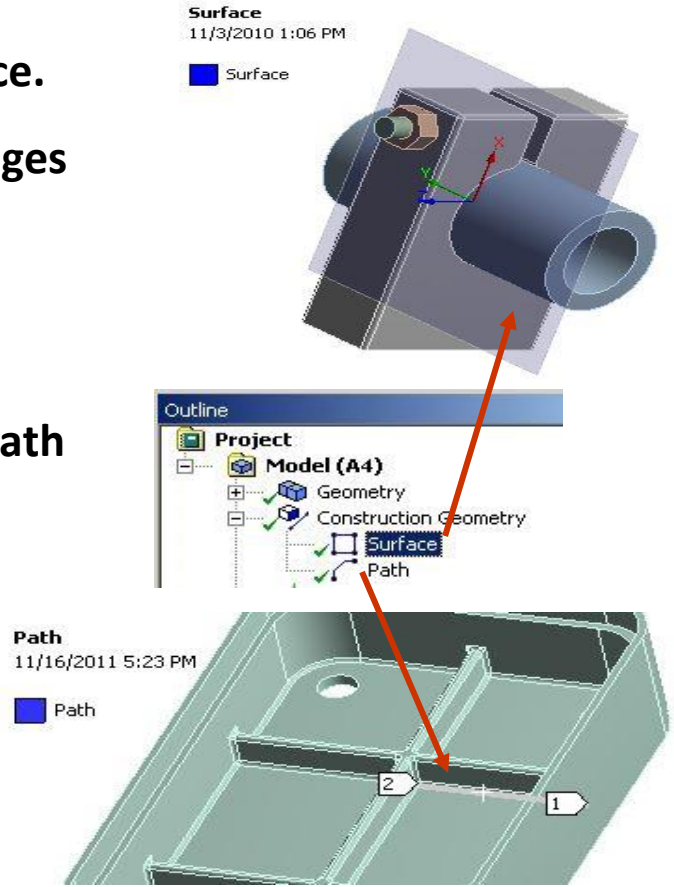


… Scoping Results

Construction geometry consists of either a path or surface.

- **Paths are defined using coordinate systems, model edges or existing points.**
- **Surfaces are located and oriented using coordinate systems.**
- **Existing results scoped to edges can be converted to path plots automatically (RMB).**

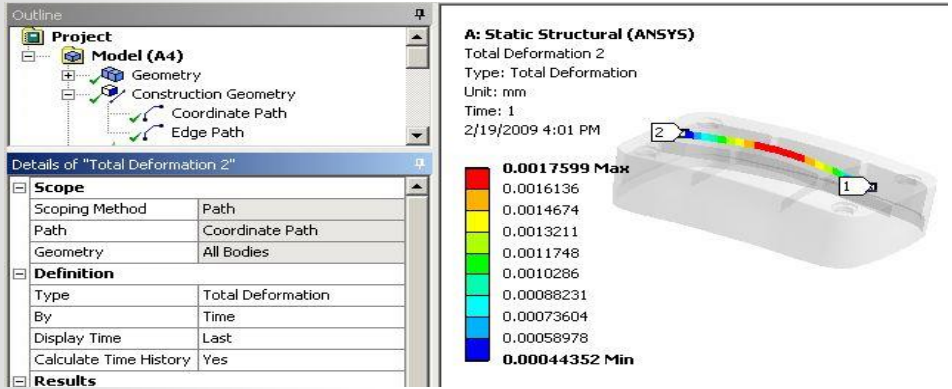




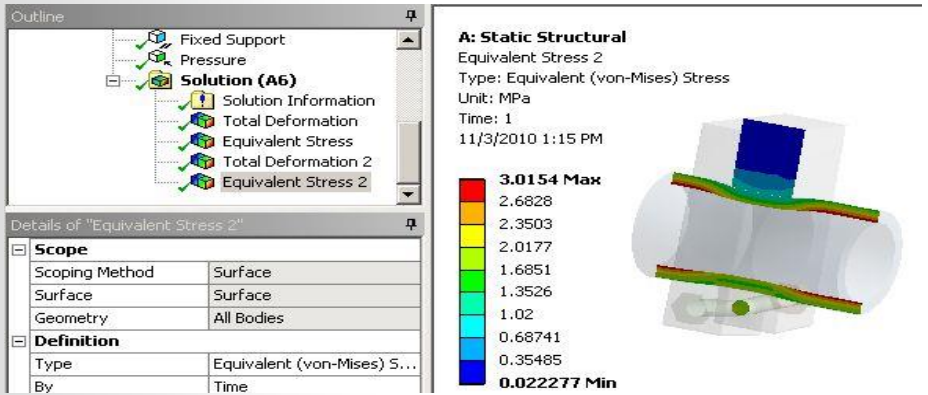
… Scoping Results

Results may be mapped onto construction geometry in the details:

Path Plot Example



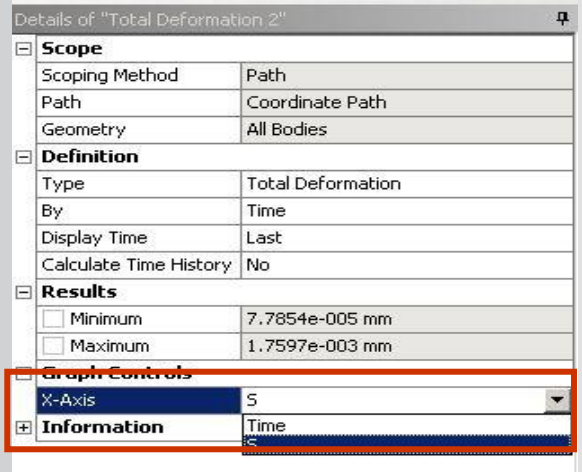
Surface Plot Example

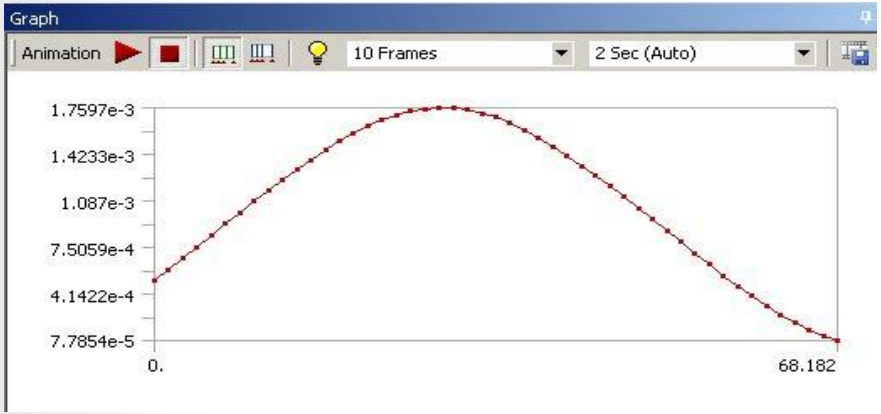


… Scoping Results

Path results may also be displayed in graphical form.

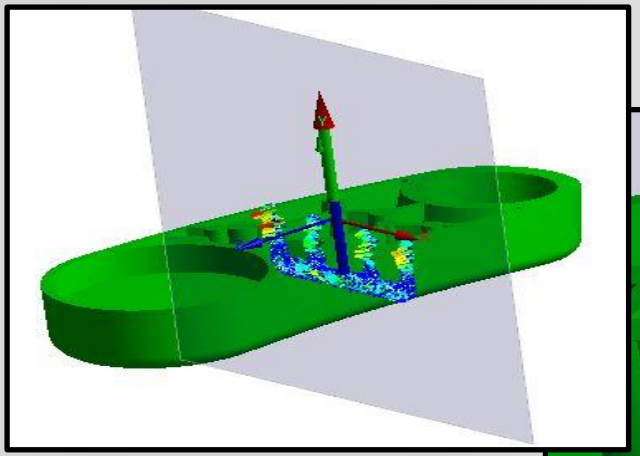
The X axis may be displayed as path location (S) or time (transient analyses).

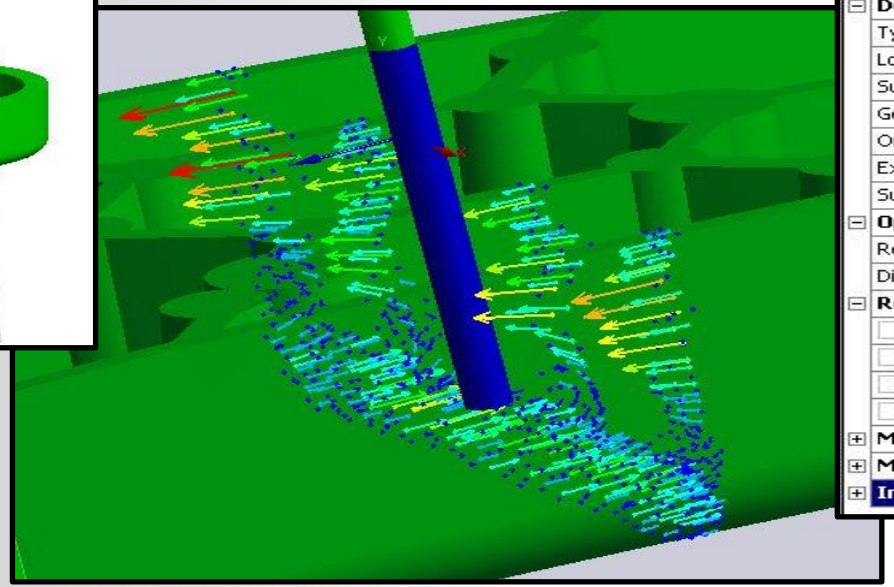


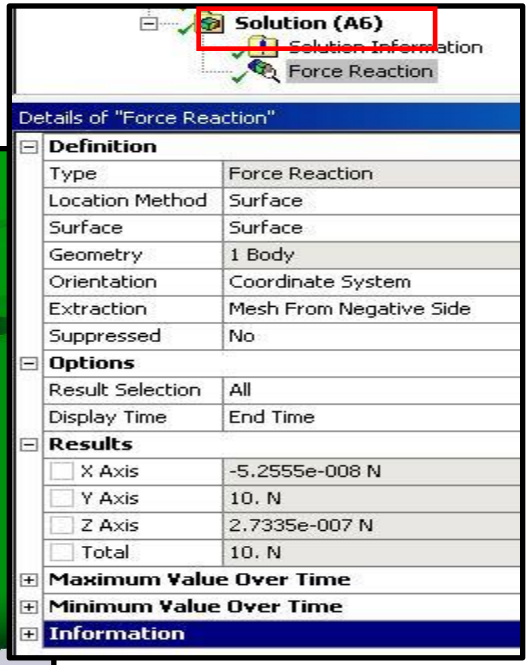


… Scoping Results

In addition to contoured results, a reaction probe can be scoped to a construction surface. Reactions across the surface are displayed and listed in the details.





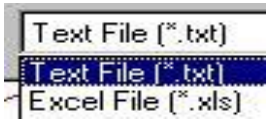


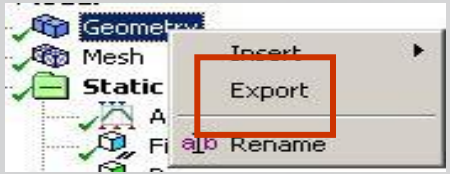
Exporting Results

To export result items, worksheet information and tables:

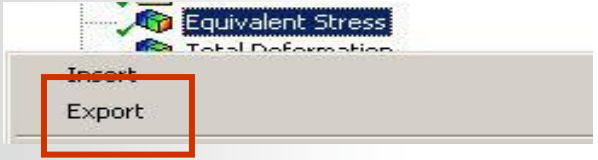
- **Highlight item, RMB > Export**
- **For Worksheet:**
  - **Select the branch and click on the Worksheet tab.**
  - **Right-click the same branch and select “Export”.**

Export as text or Excel .xls file types.





Export Worksheet



Export Results

Export Tables

Note: To include node location information in exports, set the “Include Node Location” option to “Yes” under “Tools menu > Options… > Mechanical: Export”