Lessons and Tricks Learned in Using ANSYS

v1.3 – Part 2

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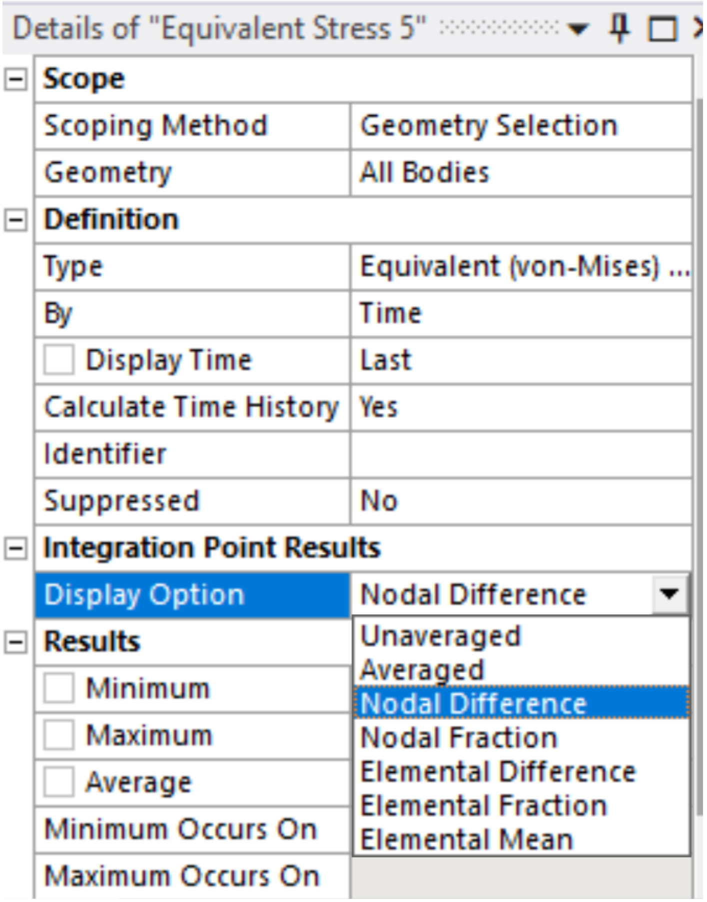
Outline

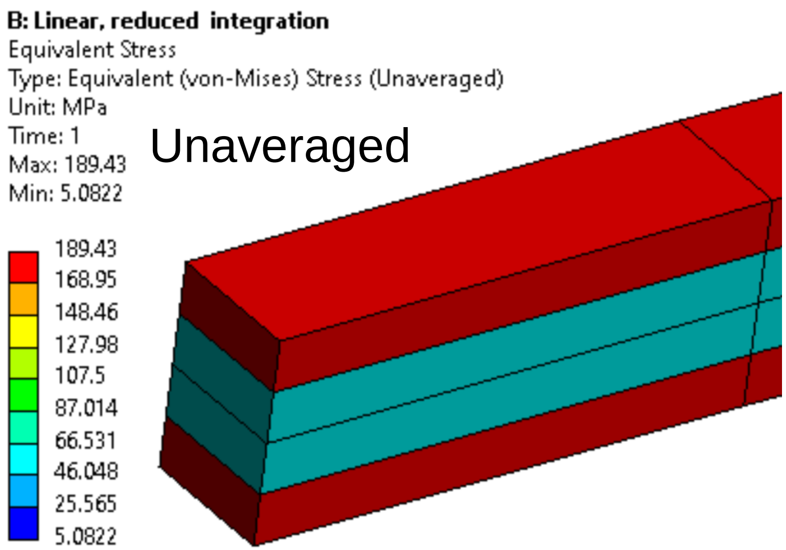
1. Meshing – Quality, Virtual Topology, Multizone, Sweep, and Size of Problem
2. Boundary Conditions
3. Coordinate Systems
4. Selection
5. User Defined Results
6. Penetration, Legends, Rendering Quality, and Material Designer
7. APDL and Celsius
8. Maxwell

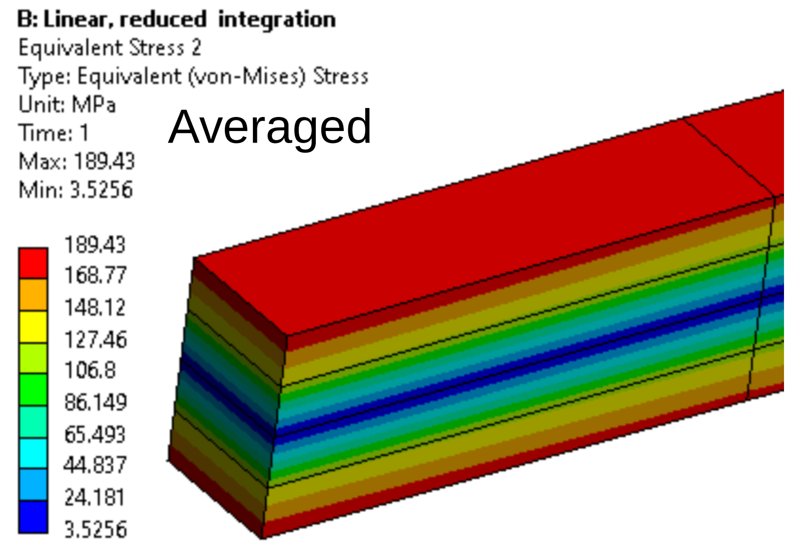
Tricks Learned – Mesh Quality

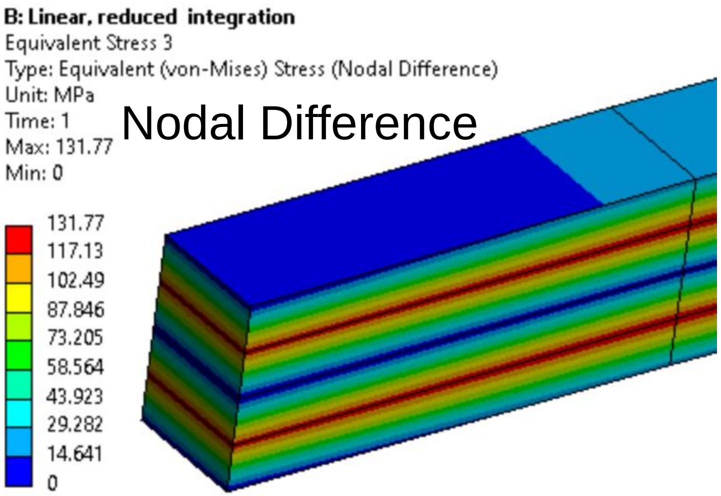
1. Display Option under Integration Point Results, Details could be used to determine the mesh quality. Nodal Difference and Elemental Difference are particularly useful.

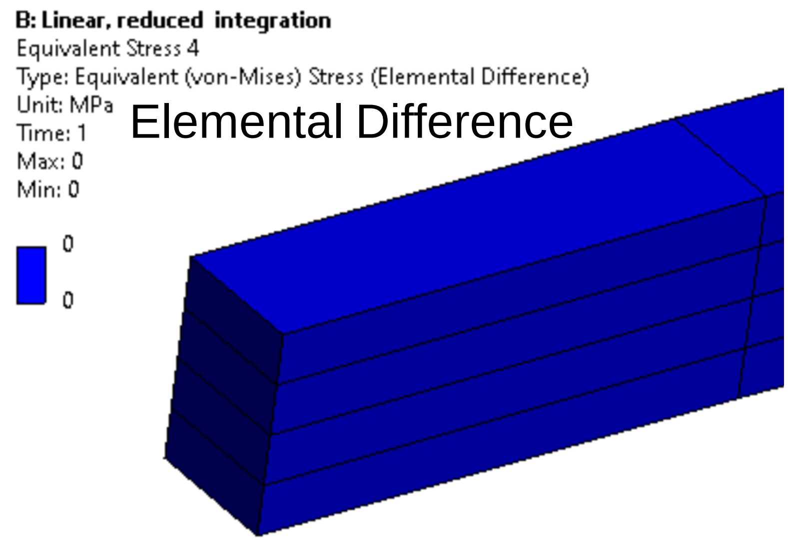


Example – Poor Mesh Quality









Tricks Learned – Element Quality

2. The Element Quality option provides a composite quality metric that ranges between 0 and 1. A value of 1.0 indicates a perfect cube or square while a value of 0 indicates that the element has a zero or negative volume.

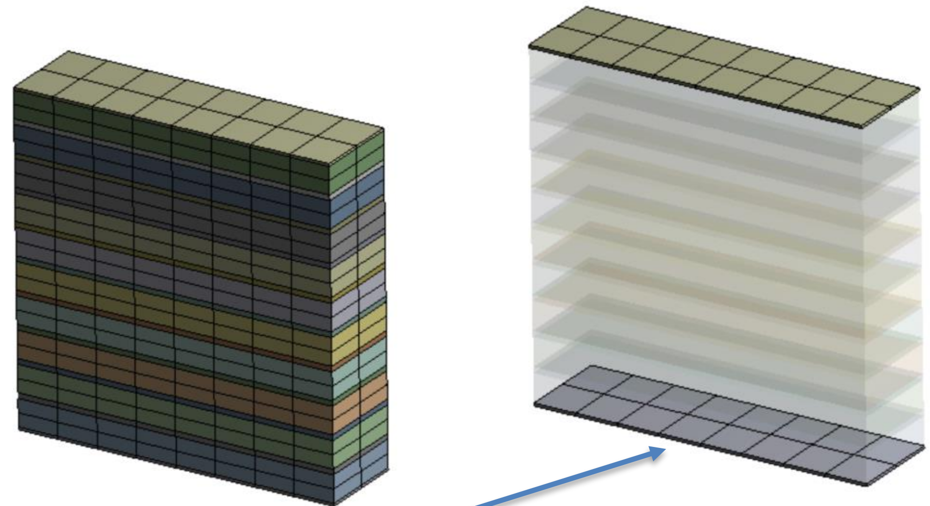
2D $$Quality = C\left(area / \sum (EdgeLength)^2 \right)$$

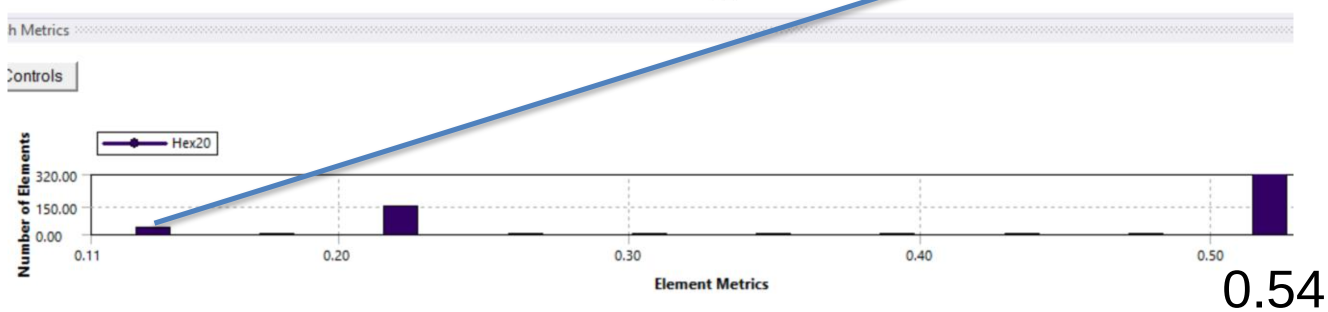
3D $$Quality = C\left[volume / \sqrt{\left[\Sigma(Edge\ length)^2\right]^3} \right]$$

Element	Value of C
Triangle	6.92820323
Quadrangle	4.0
Tetrahedron	124.70765802
Hexagon	41.56921938
Wedge	62.35382905
Pyramid	96

Example – Element Quality

Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	0.11456
Max	0.54205
Average	0.42303
Standard Deviation	0.16272



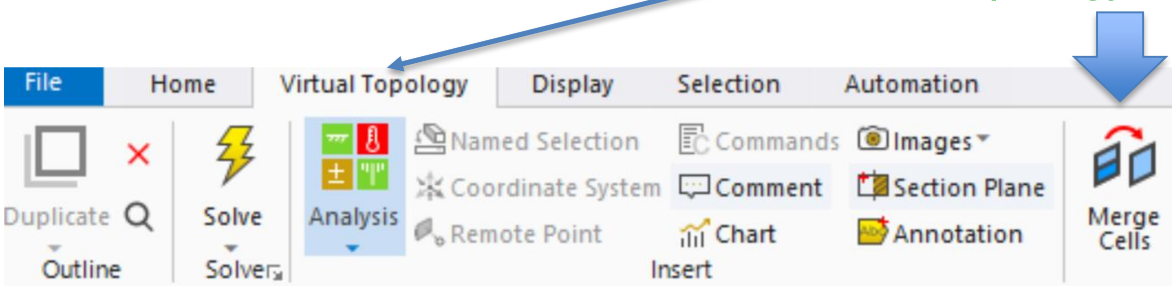


Min element quality = 0.11 due to two layers of 0.015 mm gaskets. Gaskets are special elements and can be very thin.

Tricks Learned – Virtual Topology

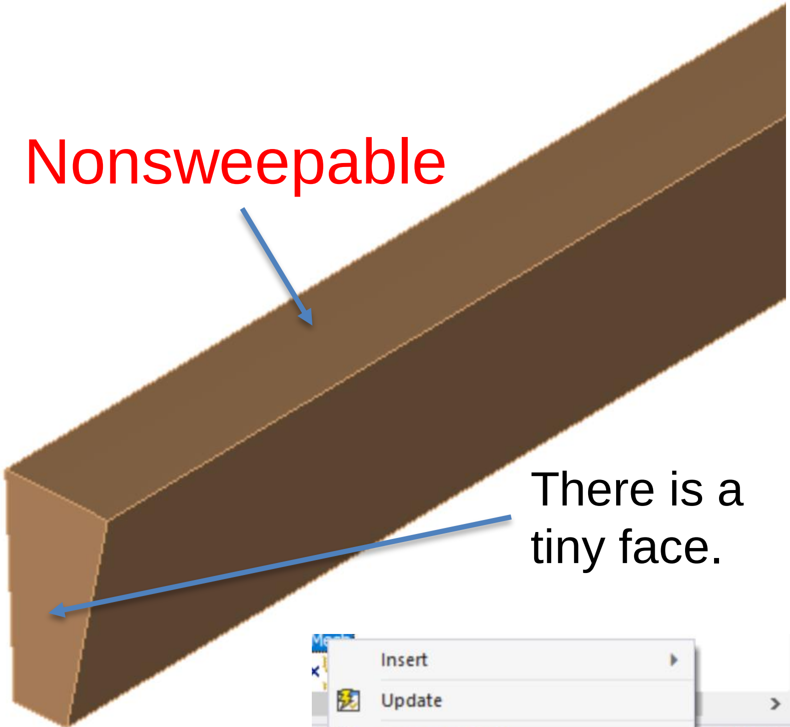
3. Virtual topology can convert a nonsweepable body into a sweepable body. It basically stitches multiple edges into one continuous edge or multiple faces into one face.

Virtual Topology -> Merge Cells



Example – Virtual Topology

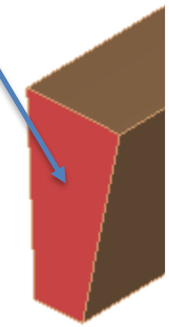
Nonsweepable



There is a tiny face.

One virtual face

Definition	
Method	Automatic
Behavior	High
Advanced	
Generate on Update	Yes
Simplify Faces	Yes
Merge Face Edges	Yes
Lock Position of Dependent Edge Splits	Yes
Statistics	
Virtual Faces	1
Virtual Edges	0
Virtual Split Edges	0
Virtual Split Faces	0
Virtual Hard Vertices	0
Total Virtual Entities	1

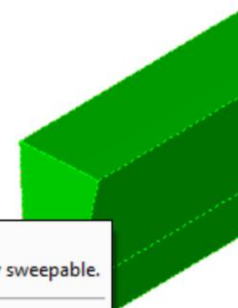


Messages

- Insert
- Update
- Generate Mesh
- Preview
- Show
  - Sweepable Bodies
  - Mappable Faces
  - Suppressed Vertices (Beta)
  - Suppressed Edges (Beta)
  - Defeatured Faces (Beta)
  - Defeatured Edges (Beta)
  - Defeatured Vertices (Beta)
- Create Pinch Controls
- Group All Similar Children
- Clear Generated Data
- Rename F2
- Start Recording
- Force Update Mesh State (Beta)

Sweepable Bodies
Select all bodies that are topologically sweepable.

Press F1 for help.



Sweepable

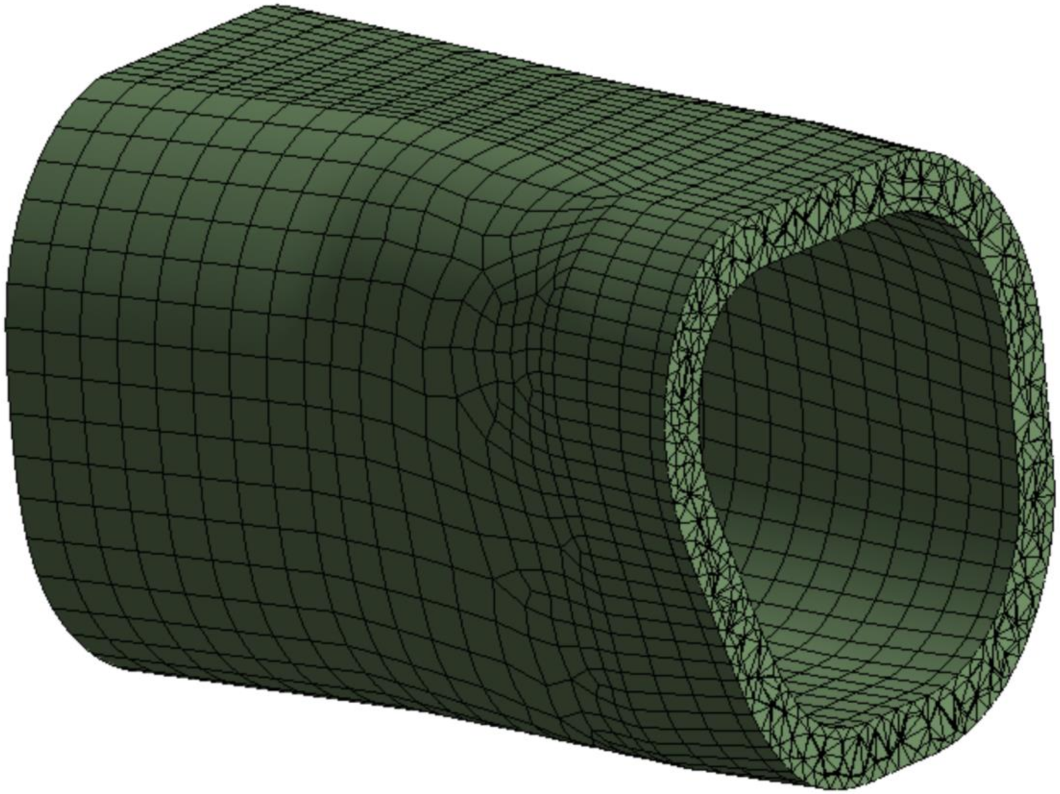
Tricks Learned – Multizone

4. Multizone meshing could be misleading. It may produce low quality elements hidden by beautiful exterior mesh patterns.

Don't use Hexa Core for wall-like structures because they don't have enough volume for Hexa Core.

Definition	
Suppressed	No
Method	MultiZone
Mapped Mesh Type	Hexa/Prism
Surface Mesh Method	Program Controlled
Free Mesh Type	Hexa Core
Element Order	Use Global Setting
Src/Trg Selection	Manual Source
Source Scoping Method	Geometry Selection
Source	1 Face
Sweep Size Behavior	Sweep Element Size
Sweep Element Size	Default
Element Option	Solid

Example – Multizone (Hexa Core)

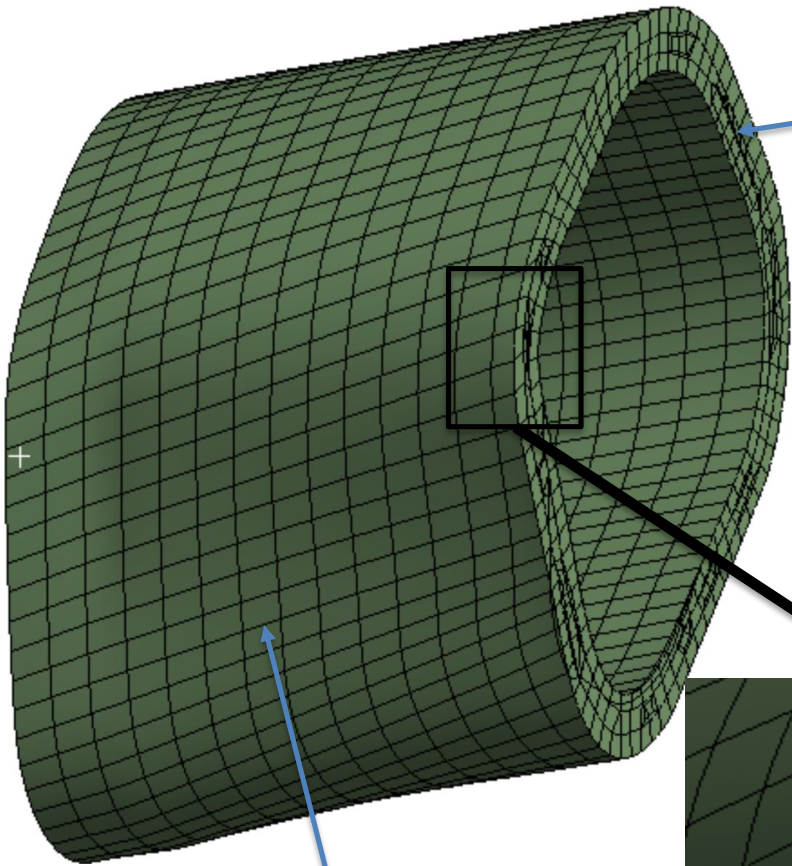


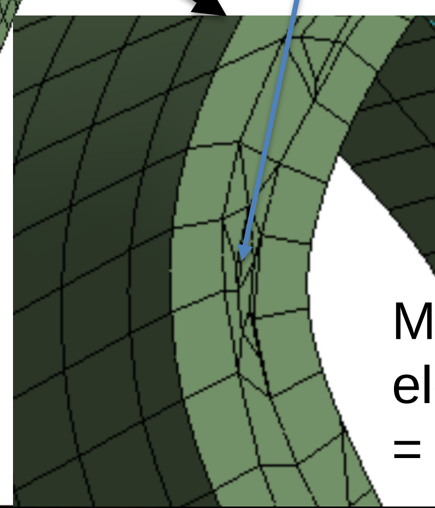
Quality	
Check Mesh Qua...	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	7.7085e-002
Max	0.99993
Average	0.56484
Standard Devi...	0.1648
Inflation	
Advanced	
Statistics	
Nodes	62089
Elements	38827

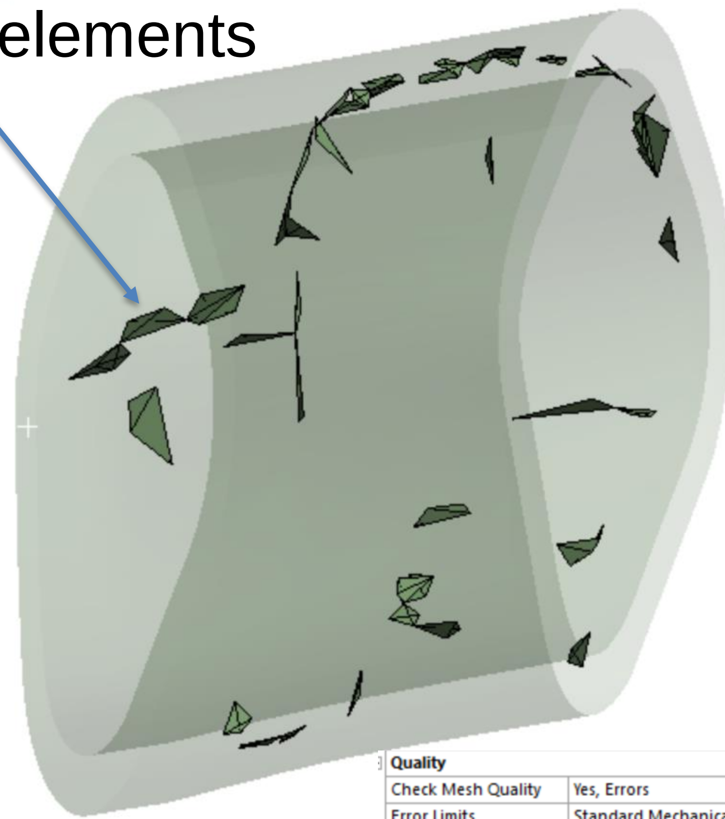
Uniform exterior mesh has a messy interior. Minimum element quality = 0.077. Since this is a wall-like structure, it doesn't have enough interior volume to generate a hexa core.

Example – Multizone (Hexa Dominant)

Low quality elements







Beautiful mesh pattern with hidden low quality elements

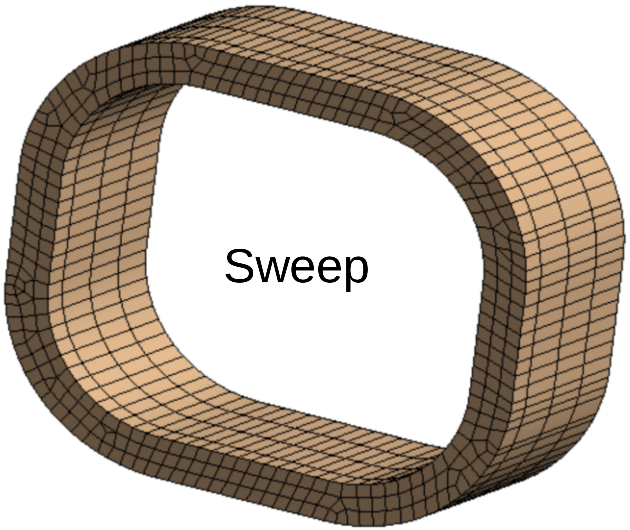
Minimum element quality = 0.0087

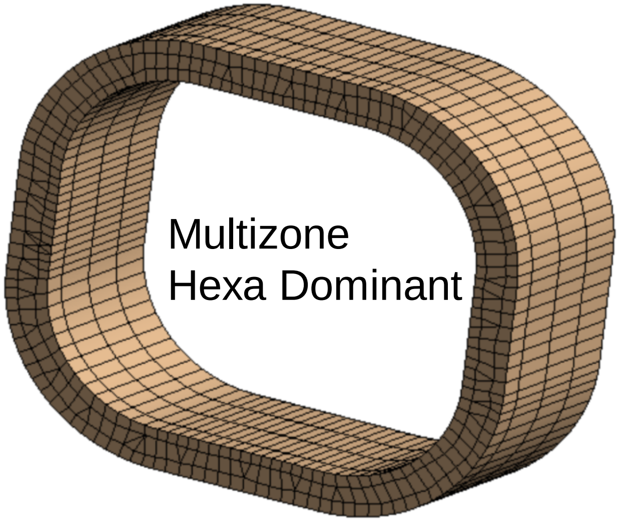
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	8.7416e-003
Max	0.9991
Average	0.6283
Standard Deviation	0.20354
Inflation	
Advanced	
Statistics	
Nodes	45092
Elements	11376

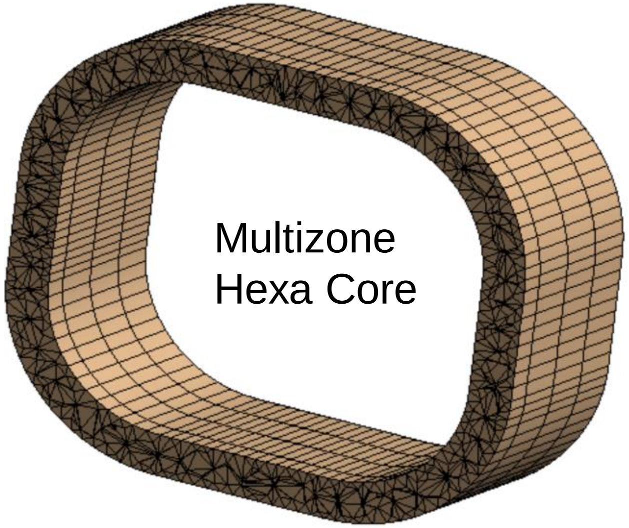
Tricks Learned – Sweep vs Multizone

5. Sweep is better than Multizone’s Hexa Dominant or Hexa Core. Sweep produces high quality elements with less number of nodes and elements. Sweep is not noticeably better than Multizone if Multizone’s Free Mesh Type is turned off.

Example – Sweep vs Multizone







Quality	
Check Mesh Qua...	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	0.22127
Max	0.46856
Average	0.38987
Standard Devi...	3.7645e-002
Inflation	
Advanced	
Statistics	
Nodes	10632
Elements	7728

Min element quality = 0.22

Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	2.5324e-003
Max	0.93991
Average	0.358
Standard Deviation	0.13171
Inflation	
Advanced	
Statistics	
Nodes	11611
Elements	10792

Min element quality = 0.0025

Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	1.9814e-002
Max	0.99712
Average	0.40559
Standard Deviation	0.1479
Inflation	
Advanced	
Statistics	
Nodes	13549
Elements	56673

Min element quality = 0.020

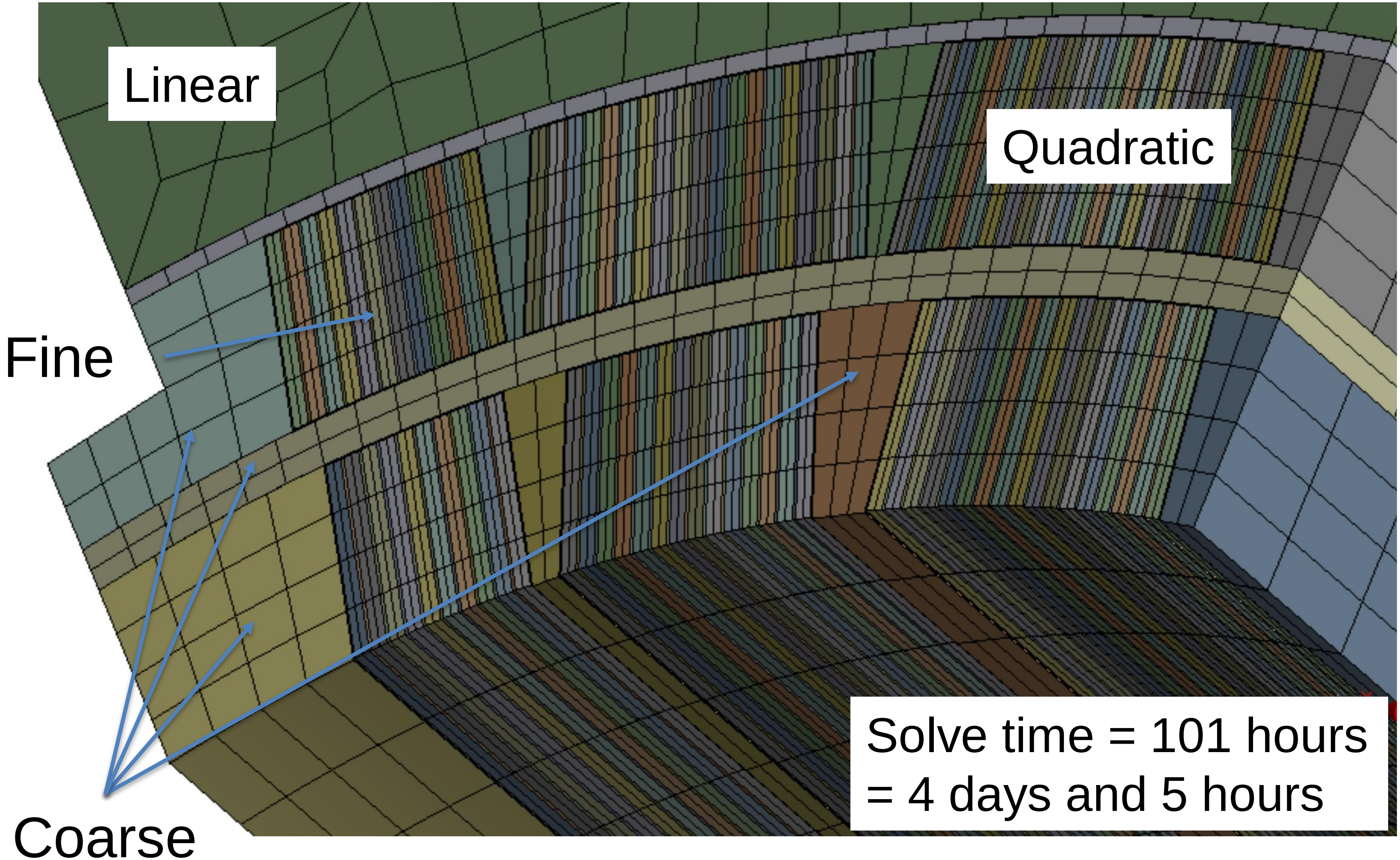
Tricks Learned – Control Problem Size

6. Properly define mesh sizes at the interested areas and use coarse meshes in unimportant regions.

It is tempting to think “the finer the mesh the better” and therefore not to pay attention to the size of the FEA problem as the computer is powerful and has a lot of RAM.

This strategy has four issues: (1) stress concentration could produce misleading maximum stress in linear elastic analysis; (2) a long solve time would make debugging very difficult; (3) the waiting could quickly become intolerable; (4) this strategy may reveal a lack of understanding of which area is the most important.

Example – Control Problem Size

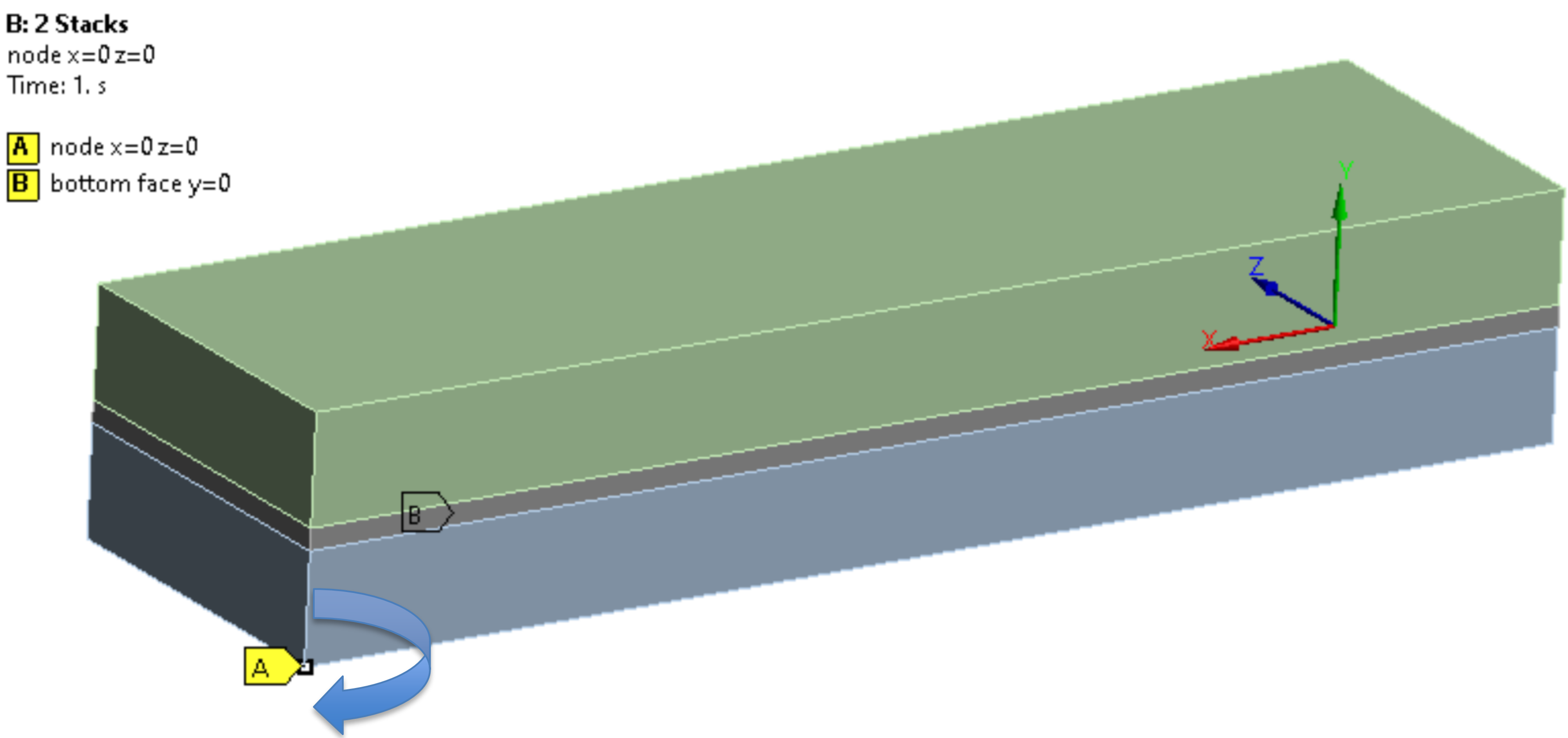


Tricks learned – Constrained BC

7. Under-constrained bodies produce rigid body movements. To find them, fix every body except the suspicious ones and run analysis under gravity. If no solution, identify the direction that is not constrained.

8. Over-constrained bodies produce incorrect reaction forces and stresses.

Example – Under-constrained

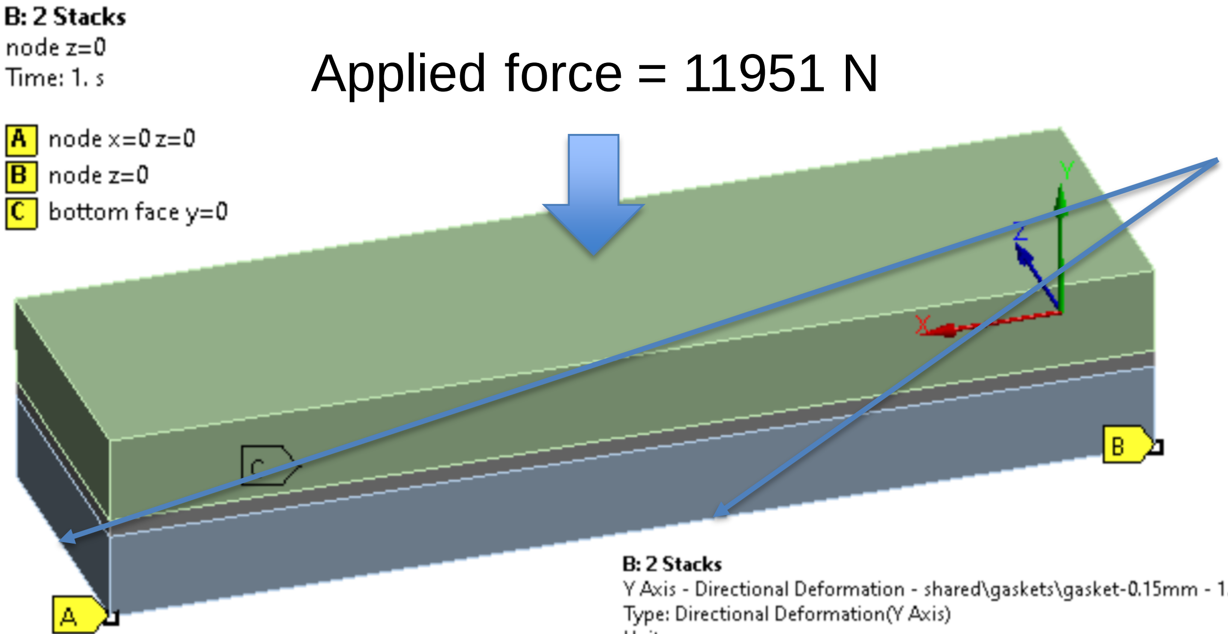


The problem is not properly constrained: although there is no movement in X, Y and Z, it can rotate along Y at Vertex A.

Example – Properly constrained

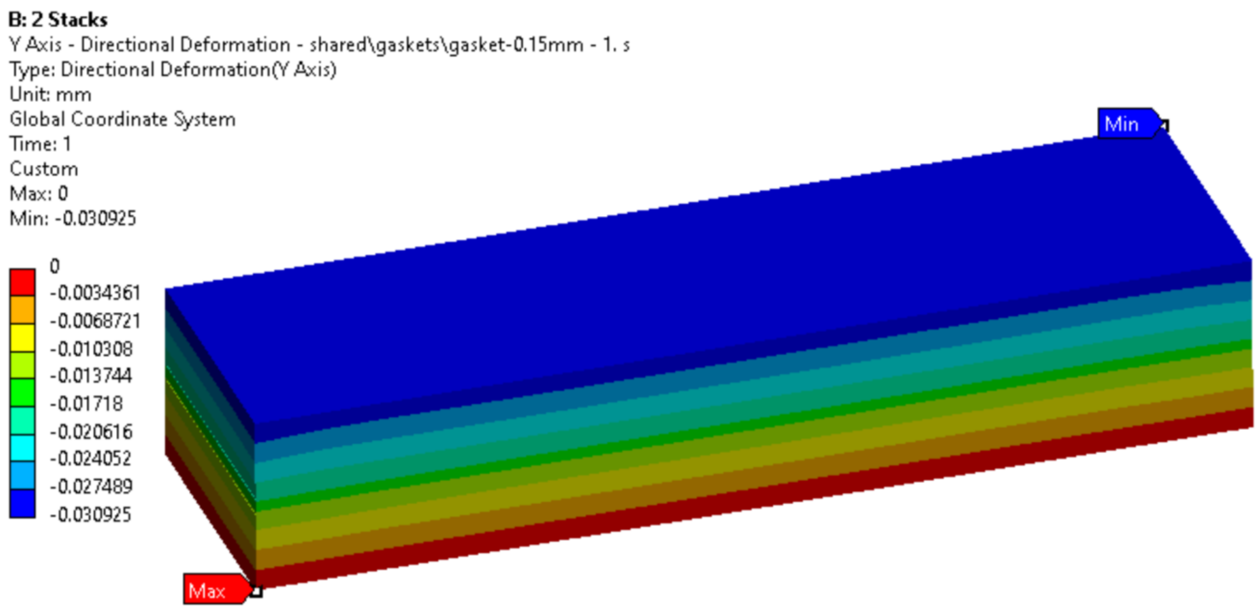
Applied force = 11951 N

Free to move in X and Z



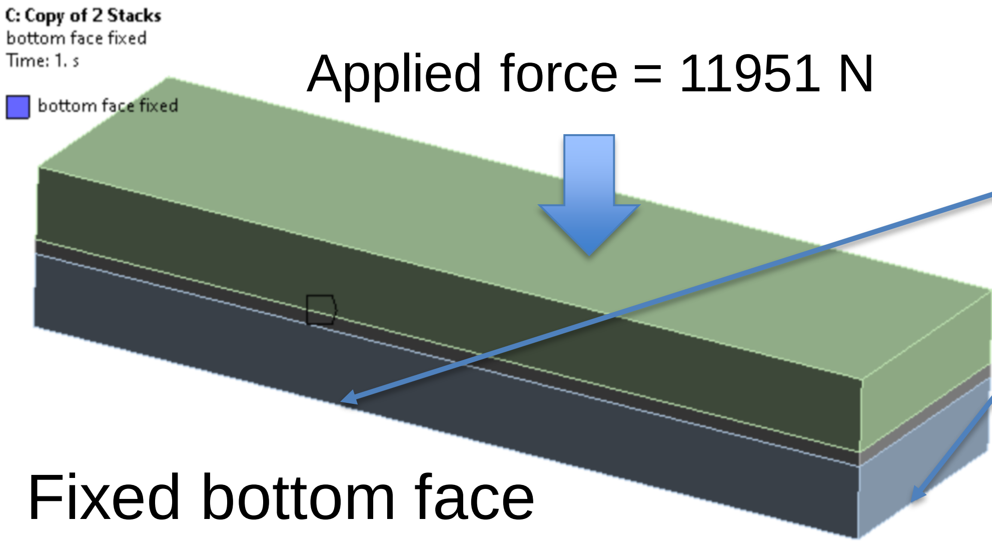
Reaction force = 11951 N

You may turn on Weak Spring to prevent rigid body movements.



Y_{min}= -0.0309 mm

Example – Over-constrained



Applied force = 11951 N

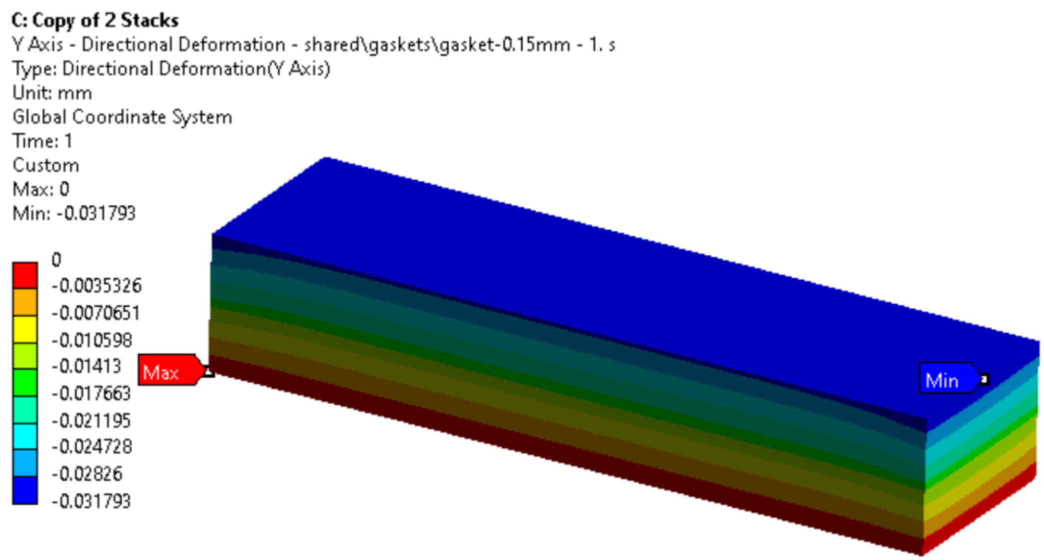
Fixed in X, Y, and Z

Reaction force = 12002 N

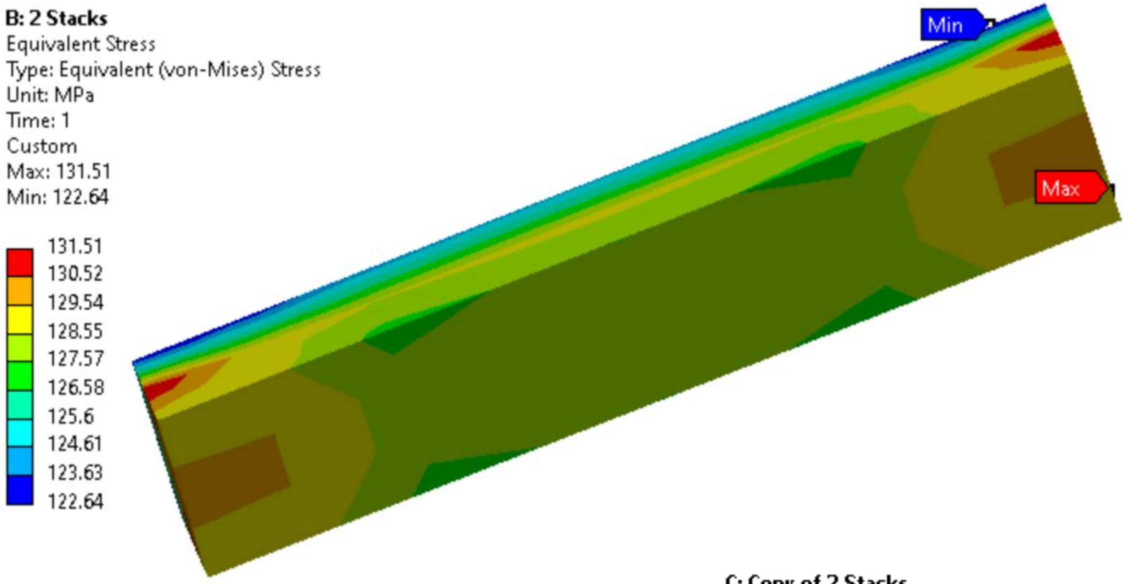
Fixed bottom face
X, Y, Z = 0

Correct Y_{min} = -0.309 mm
But Y_{min}= -0.0318 mm

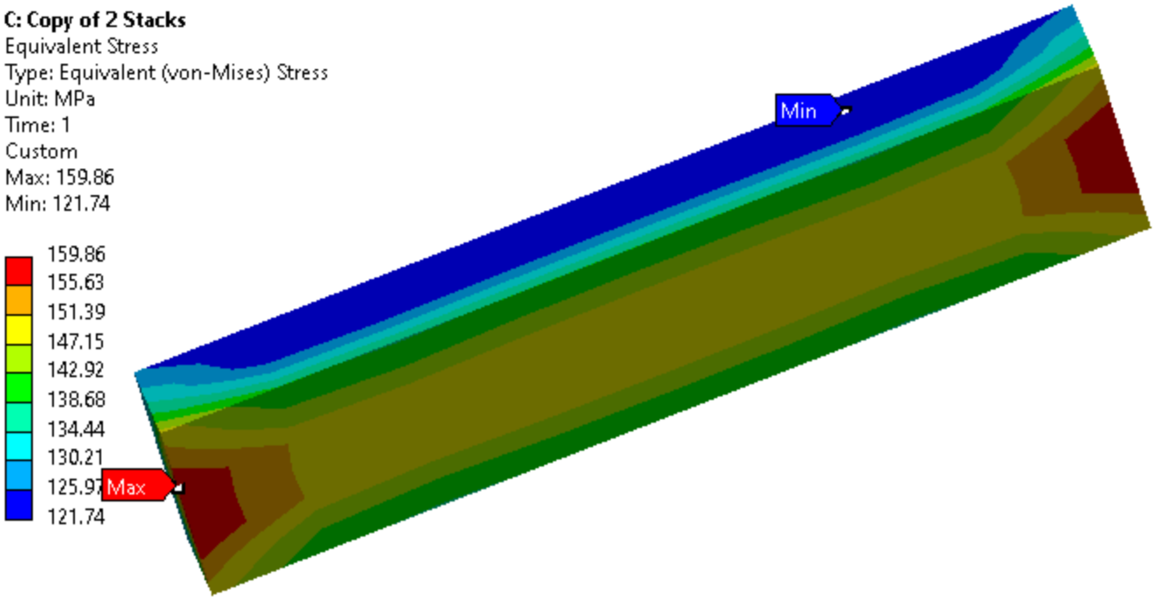
The difference is small. It looks right. However, this is not our intention to have the bottom fully fixed.



Comparison – Properly and Over Constrained



Properly constrained
Max stress = 132 MPa



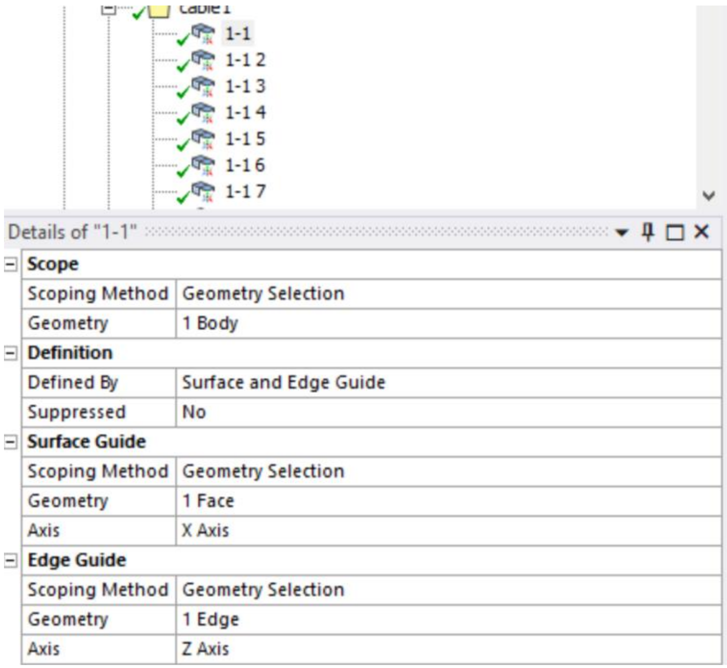
Over constrained
Max stress = 160 MPa

Tricks Learned – Coordinate Systems

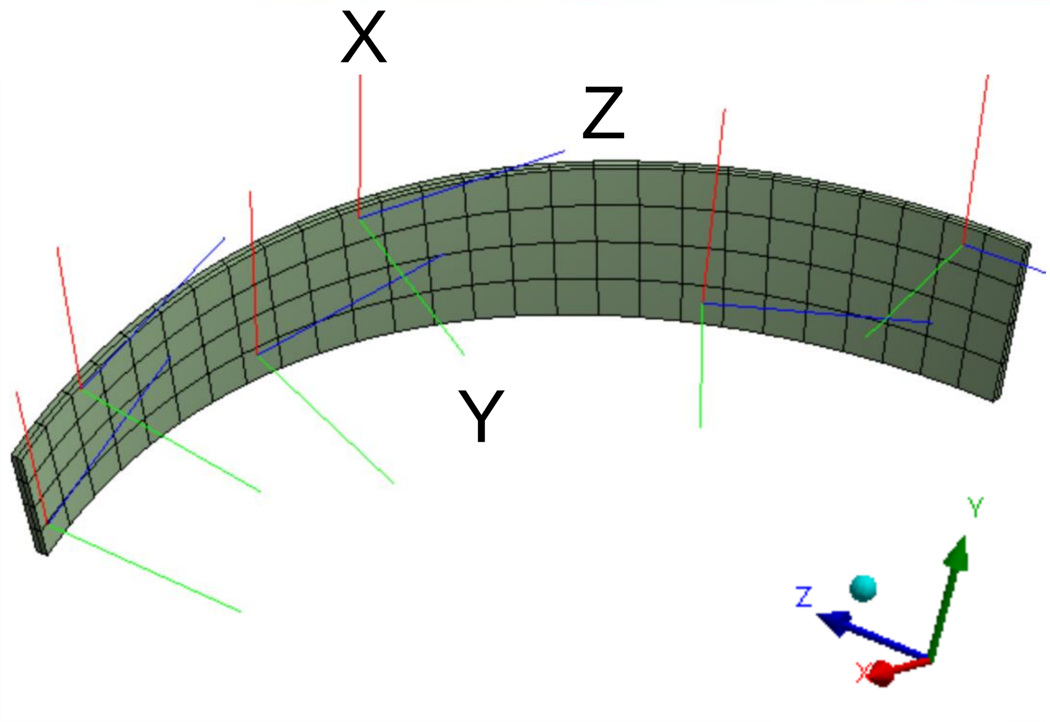
9. The element coordinate system is used for: orthotropic material input; pressure loading input on certain faces of the surface effect elements; output of element quantities, such as stresses, strains, and thermal gradients.

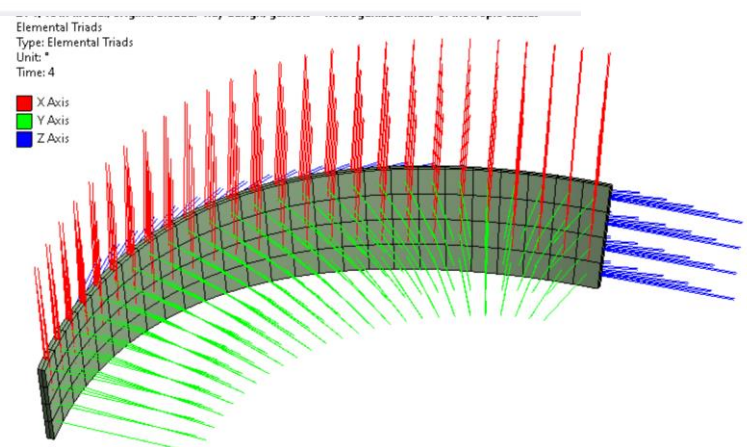
10. While global and local coordinate systems *locate* geometry items, the nodal coordinate system *orients* the degree of freedom directions at each node. Each node has its own nodal coordinate system, which, by default, is parallel to global Cartesian (regardless of the active coordinate system in which the node was defined).

Example – Elemental Coordinate System



Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Defined By	Surface and Edge Guide
Suppressed	No
Surface Guide	
Scoping Method	Geometry Selection
Geometry	1 Face
Axis	X Axis
Edge Guide	
Scoping Method	Geometry Selection
Geometry	1 Edge
Axis	Z Axis





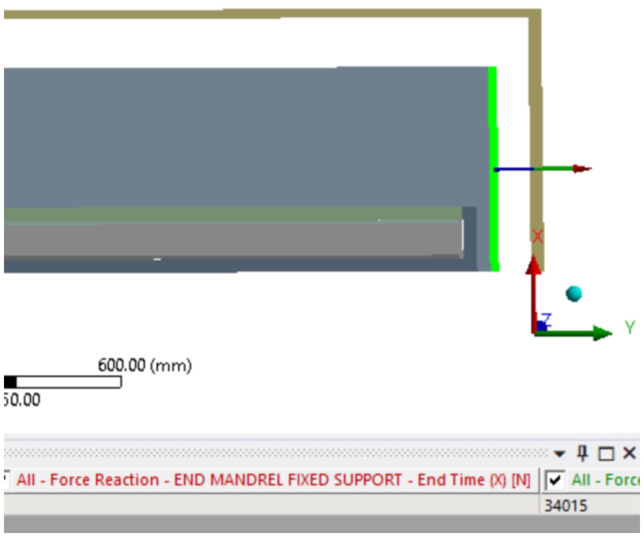
For complicated cases, elemental edges could be used to define coordinate systems.

Lessons Learned – Cylindrical Coordinate Sys

11. For 2D axisymmetric analysis, its default coordinate system is cylindrical coordinate system. When comparing the resultant reaction forces from 2D with those from 3D models, the cylindrical coordinate system must be used in 3D analysis also.

Reaction Force on yoke - 2D vs 3D

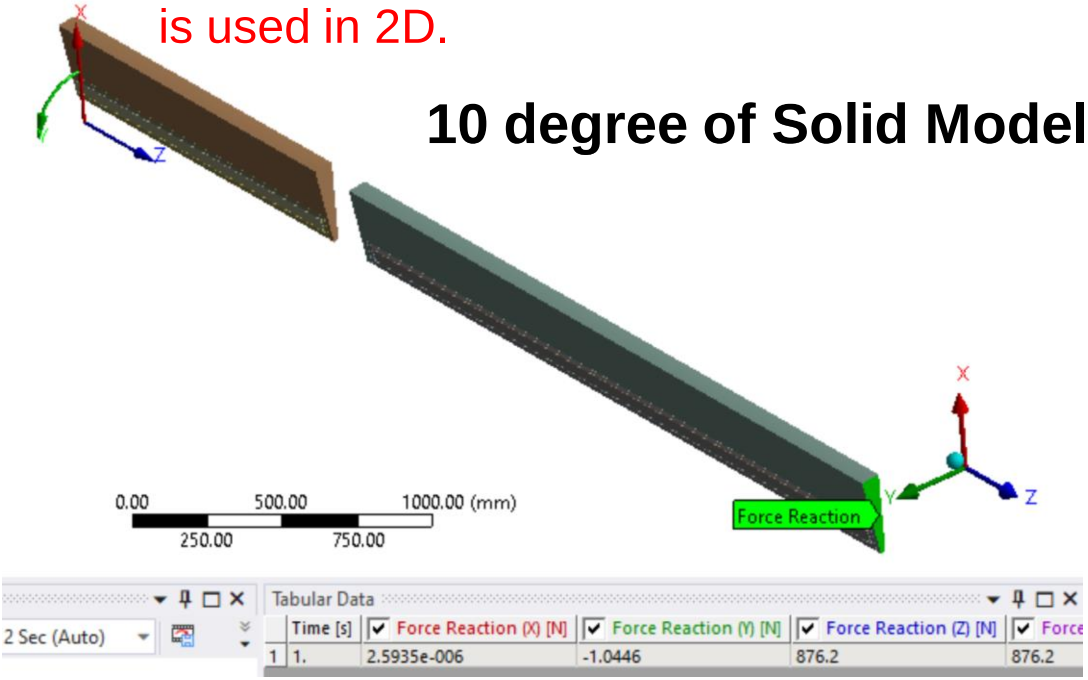
Cylindrical coordinate system is the default in 2D. But it doesn't say it.



F_{2D} = 34,015 N

Cylindrical coordinate system must be used in 3D because cylindrical coordinate system is used in 2D.

10 degree of Solid Model



$F_{3D} = 876.2 \times 36 = 31{,}543$ N

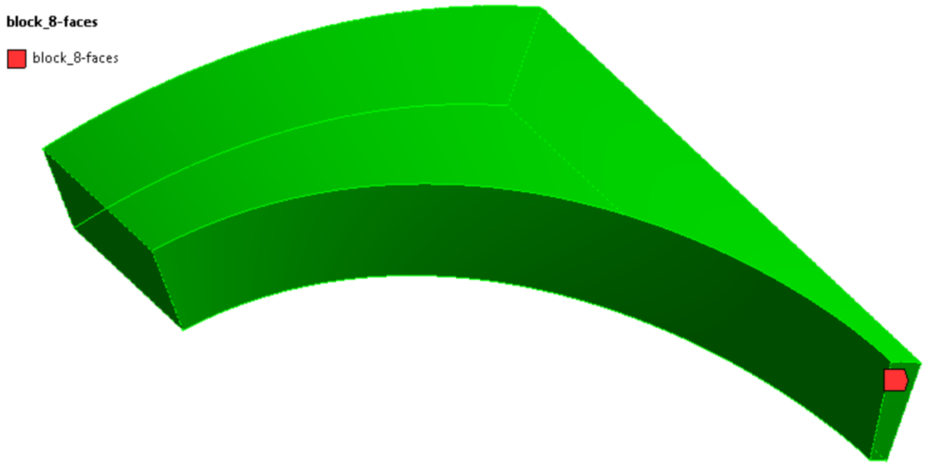
Summary: Forces from 2D and 3D analysis matches more or less. 2D is more accurate because much more fined 2D meshes are used.

Tricks Learned – Use Worksheet Select Tiny Faces

12. Name the body. Convert the body into faces using worksheet. If you get 8 faces for a body with 7 faces, you have one invisible face. Select and name the 7 visible faces. Subtract the 7 faces from the 8 faces using worksheet. You have selected one extremely tiny face. Use *Select Items in Group* to select the tiny face and merge it with the large face using Virtual Topology->Merge Cells. The body is sweepable now.

This procedure is much more complicated than using Extend. However, it does provide a comprehensive picture.

Example – Select Tiny Faces with Worksheet



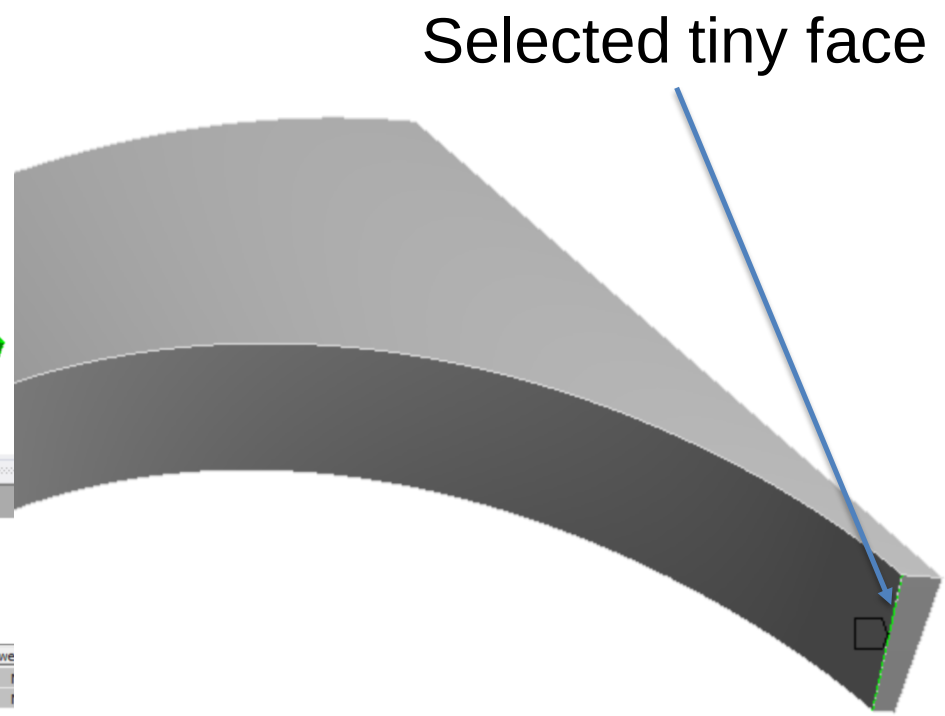
Worksheet

block_8-faces

Generate

Note: Internal comparisons of values that have units are done in the CAD Unit System. See help for more information.
Current CAD Unit System: Metric (m, kg, N, s, V, A)

	Action	Entity Type	Criterion	Operator	Units	Value	Lowe
☑	Add	Body	Named Selection	Equal	N/A	block	
☑	Convert To	Face	N/A	N/A	N/A	N/A	



Worksheet

block_tiny-face

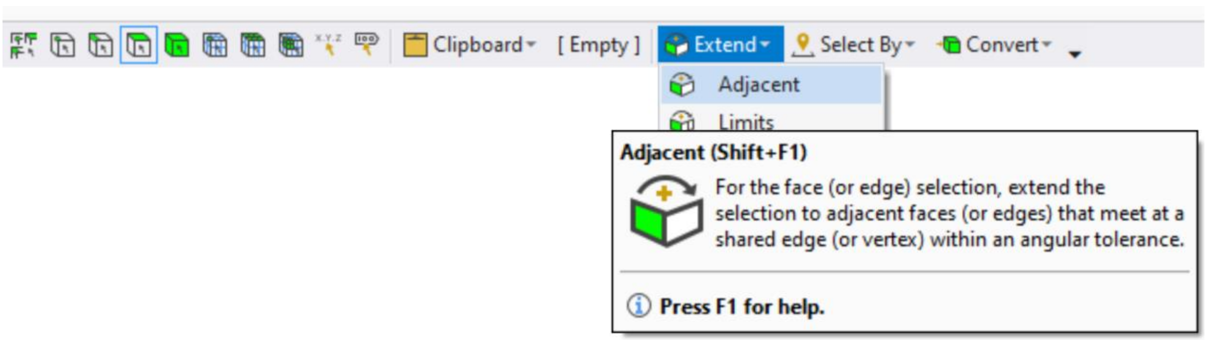
Generate

Note: Internal comparisons of values that have units are done in the CAD Unit System. See help for more information.
Current CAD Unit System: Metric (m, kg, N, s, V, A)

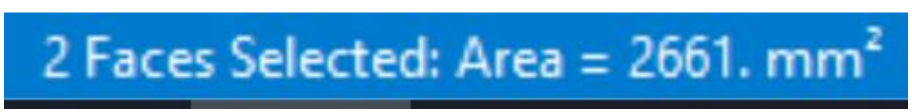
	Action	Entity Type	Criterion	Operator	Units	Value	Low
☑	Add	Body	Named Selection	Equal	N/A	block	
☑	Convert To	Face	N/A	N/A	N/A	N/A	
☑	Remove	Face	Named Selection	Equal	N/A	block_7-faces	

Tricks Learned – Use “Extend” to Select Tiny Faces

13. Use “Extend” to select adjacent tiny faces so that Virtual Topology->Merge Cells can be used to merge them. This is a much simpler procedure than using Worksheet. Watch the bottom status bar; if it says 2 or more Faces Selected you need to Merge Cells.

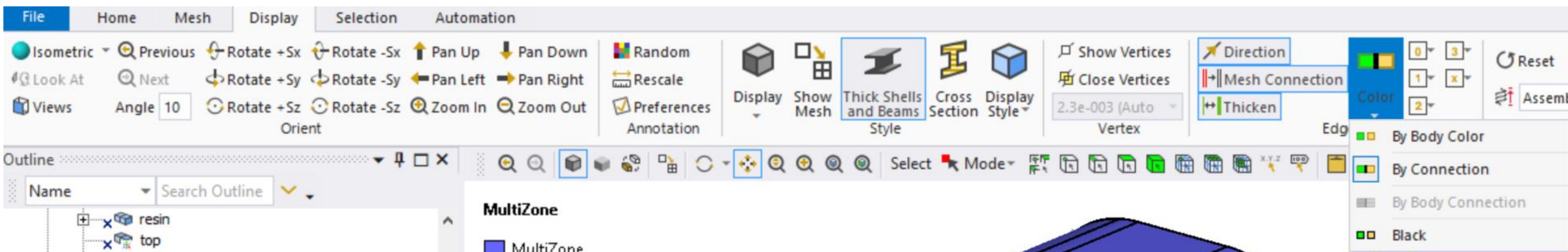


2 Faces Selected

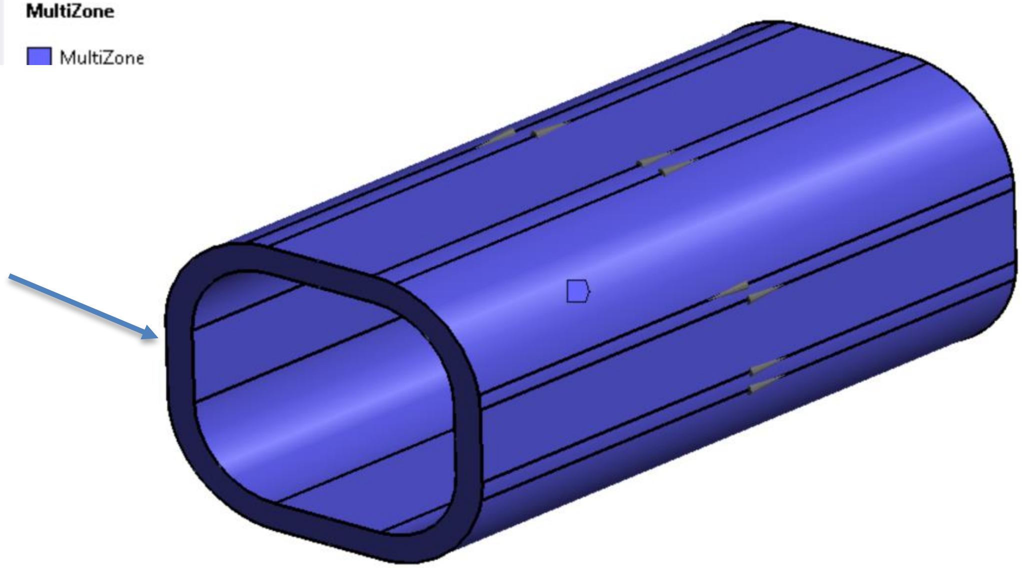


Tricks Learned – Edge Color

14. Edge color indicates connectivity. By Connection -> five categories: free (blue), single (red), double (black), triple (pink) and multiple (yellow). Free means that the edge is not shared by any faces. Single means that the edge is shared by one face.



Edges are shared by two faces.



Tricks – User Defined Results

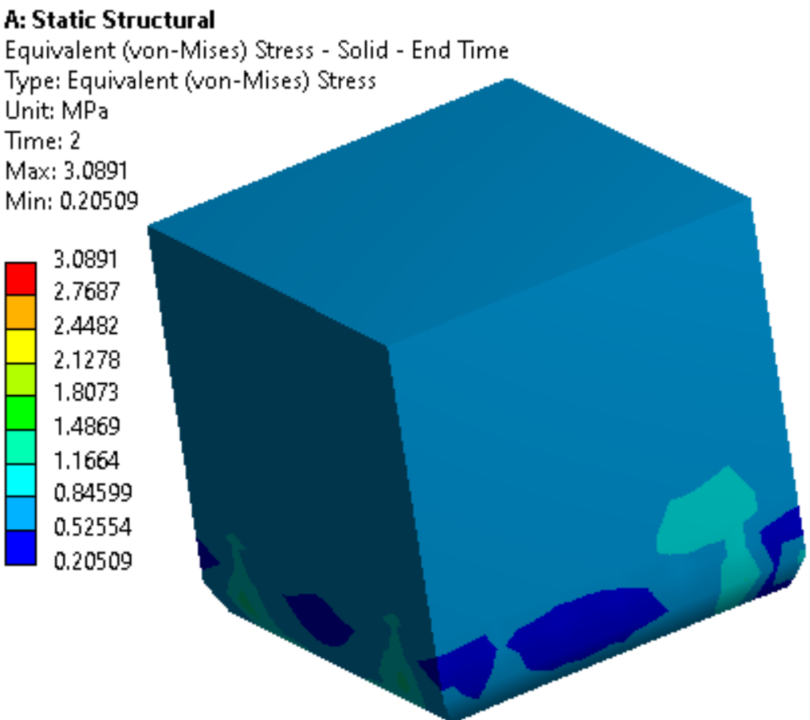
15. Stress components (Sx, Sy, Sz, Sxy, Syz, Sxz) of elements are readily available for users to access. Users can define any results based on these components.

Table 185.1: SOLID185 Homogeneous Structural Solid Element Output Definitions

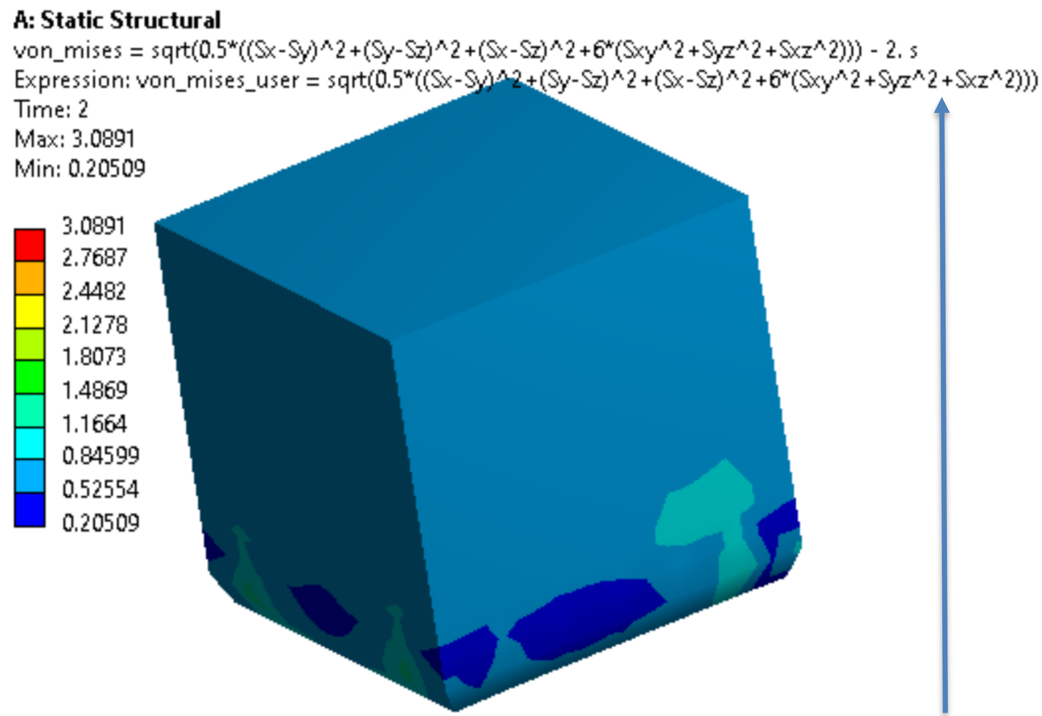
S:X, Y, Z, XY, YZ, XZ	Stresses
S:1, 2, 3	Principal stresses
S:INT	Stress intensity
S:EQV	Equivalent stress
EPEL:X, Y, Z, XY, YZ, XZ	Elastic strains
EPEL:EQV	Equivalent elastic strains [6]
EPTH:X, Y, Z, XY, YZ, XZ	Thermal strains
EPTH:EQV	Equivalent thermal strains [6]
EPPL:X, Y, Z, XY, YZ, XZ	Plastic strains [7]
EPPL:EQV	Equivalent plastic strains [6]

Example – User Defined Results

Built-in von Mises stress



User defined von Mises stress



Type	User Defined Result
Expression	= sqrt(0.5*((Sx-Sy)^2+(Sy-Sz)^2+(Sx-Sz)^2+6*(Sxy^2+Syz^2+Sxz^2)))
Input Unit System	Metric (mm, kg, N, s, mV, mA)

$$\sigma_v^2 = \frac{1}{2}\left[(\sigma_{11}-\sigma_{22})^2+(\sigma_{22}-\sigma_{33})^2+(\sigma_{33}-\sigma_{11})^2+6\left(\sigma_{23}^2+\sigma_{31}^2+\sigma_{12}^2\right)\right]$$

Tricks Learned - Identifiers

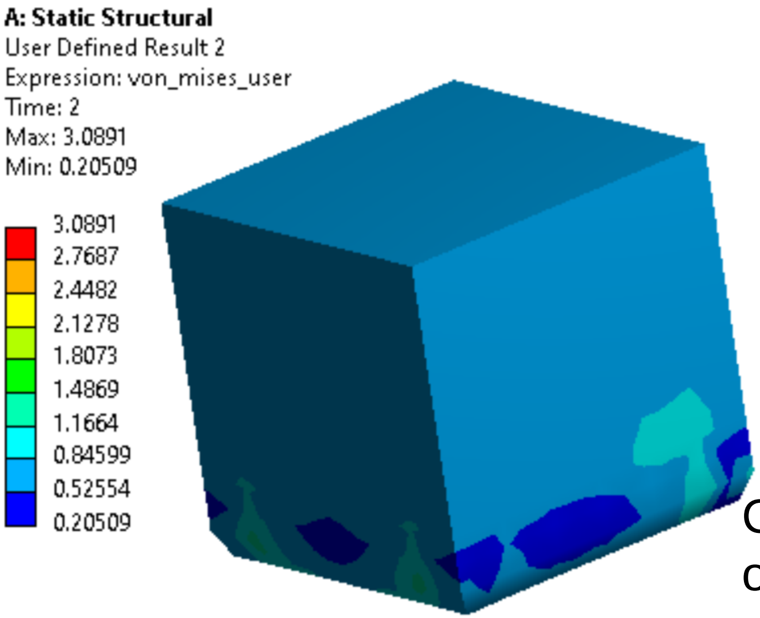
16. Identifiers are user-defined parameters linking to outputs of elements. They can be used to create complicated user defined results.

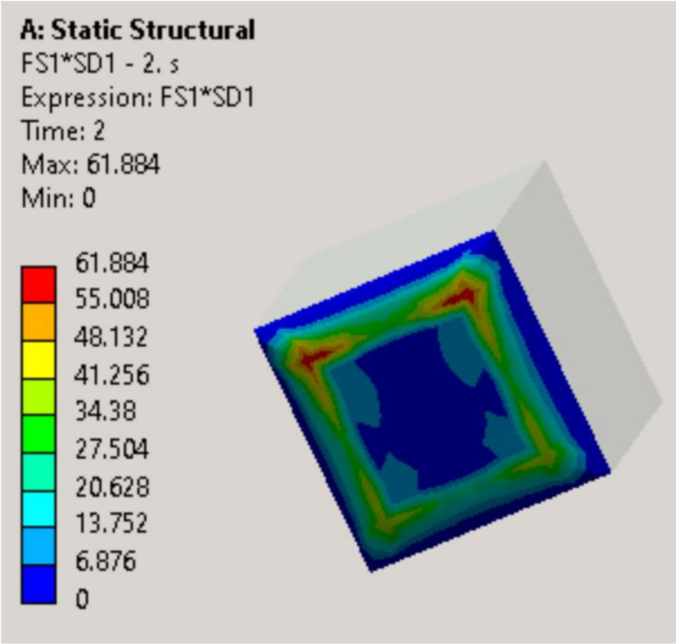
Definition	
Type	Sliding Distance
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	SD1

Definition	
Type	Frictional Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	FS1

Identifiers

Example - Identifiers





Combined result of two user defined identifiers

Definition	
Type	User Defined Result
Expression	= sqrt(0.5*((Sx-Sy)^2+(Sy-Sz)^2+(Sx-Sz)^2+6*(Sxy^2+Syz^2+Sxz^2)))
Input Unit System	Metric (mm, kg, N, s, mV, mA)
Output Unit	
By	Time
Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Yes
Identifier	von_mises_user

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	User Defined Result
Expression	= FS1*SD1
Input Unit System	Metric (mm, kg, N, s, mV, mA)

Identifiers are user-defined parameters.

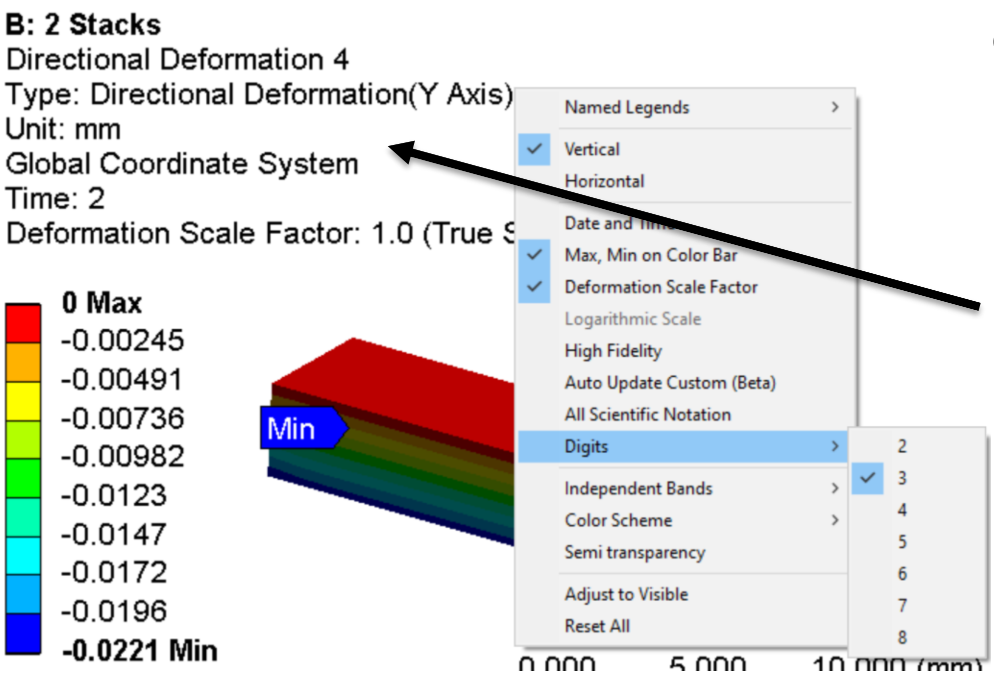
Tricks Learned – Penetration

17. For very thin layers, the penetration tolerance should be much smaller than the layer thickness. Set the penetration tolerance to be small even for bonded contact so that no error will accumulate. Otherwise, the displacement could be wrong.

18. Only 99 instantaneous CTE temperature points shall be defined. Anything more will produce an error.

Tricks Learned - Legends

19. For the legend, its font size can be controlled; its number of significant digits can be set; a scientific notation or a regular number format can be used. To control font size, a snippet of Javascript is needed.

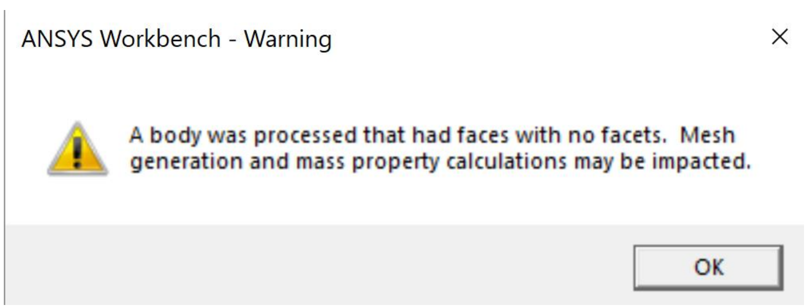


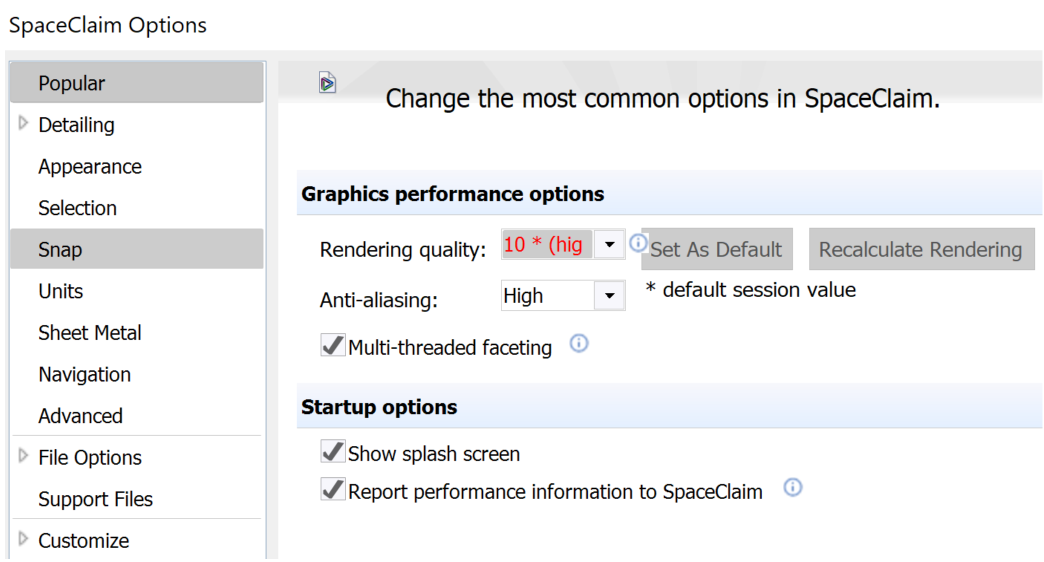
Copy the following text into a text file and rename it as *.js; hit “Automation" on your toolbar; “Run macro", then pick the file you created. This will make the font size in your pictures larger so they are readable in your report (Courtesy of Bill Crahen).

```
DS.Graphics.SetFontStyle( 0, 'Arial', 0, 0, 24, 0, 0 );
DS.Graphics.SetFontStyle( 2, 'Arial', 0, 0, 24, 0, 0 );
DS.Graphics.Redraw(1);
```

Tricks Learned – Rendering Quality

20. Set SpaceClaim Options -> Popular -> Rendering Quality to 10 if there is a warning like: A body was processed that had faces with no facets.





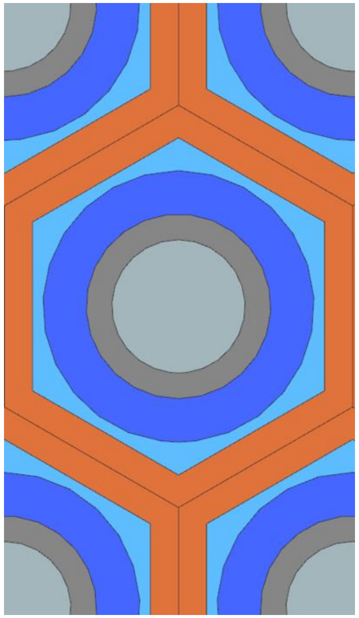
Tricks Learned – Material Designer

21. ANSYS Material Designer is a useful tool to homogenize (average) complex components with multiple composite materials so that the component's material can be represent by an orthotropic material or Hill material.

It supports linear and nonlinear materials.

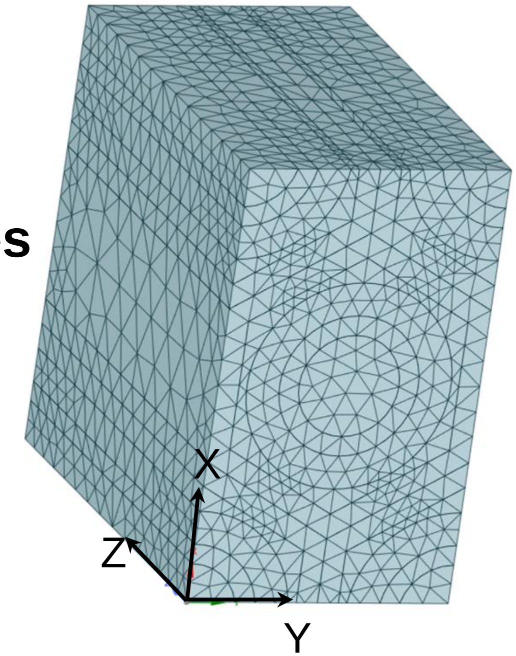
Example – ANSYS Material Designer

Unit cell



Five materials

Detailed Material Designer Model



Computed material properties

Name	Value	Unit
Engineering		
E1	1.2301E+11	Pa
E2	1.2304E+11	Pa
E3	8.0168E+10	Pa
G12	3.2031E+10	Pa
G23	3.4686E+10	Pa
G31	3.3911E+10	Pa
nu12	0.32126	
nu13	0.33797	
nu23	0.33793	

Tricks Learned – APDL Script

22. APDL is powerful. Workbench Mechanical provides us the most commonly used features of ANSYS; APDL enables us to access any feature of ANSYS. For example, defining materials not supported by Mechanical, orienting elemental coordinate systems, and using special features of contacts or elements.

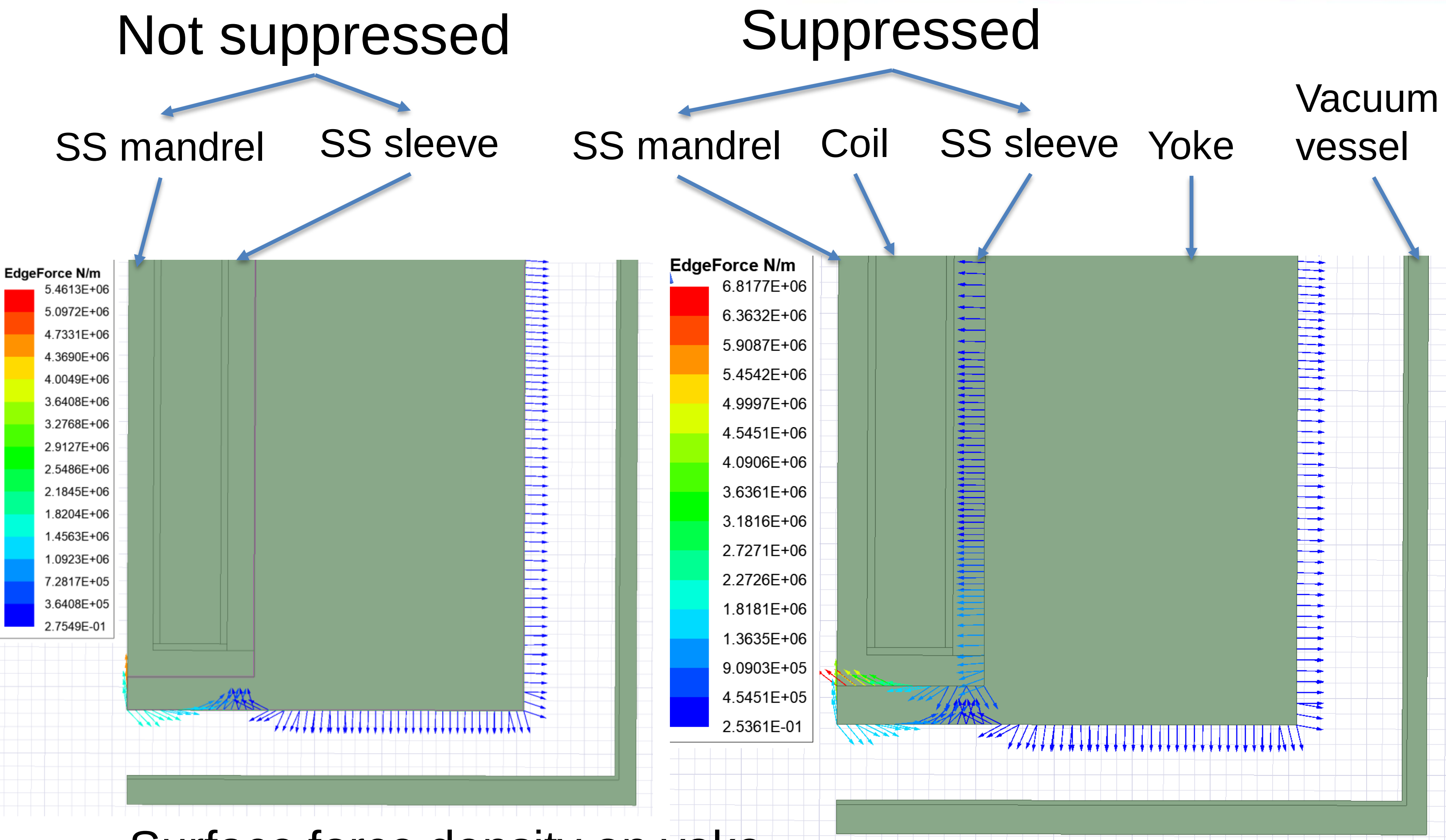
ANSYS APDL may be more powerful than you thought.

23. In APDL scripts, the temperature must be Celsius because the solver uses Celsius.

Lessons Learned – 2D Maxwell

24. Surface force density on the yoke steel doesn't transfer to the 2D analysis if the internal edges of yoke steel touch another material (stainless steel). This material (stainless steel) must be suppressed because it doesn't impact the magnetic field calculation.

2D Maxwell – Not suppressed vs Supressed



Surface force density on yoke