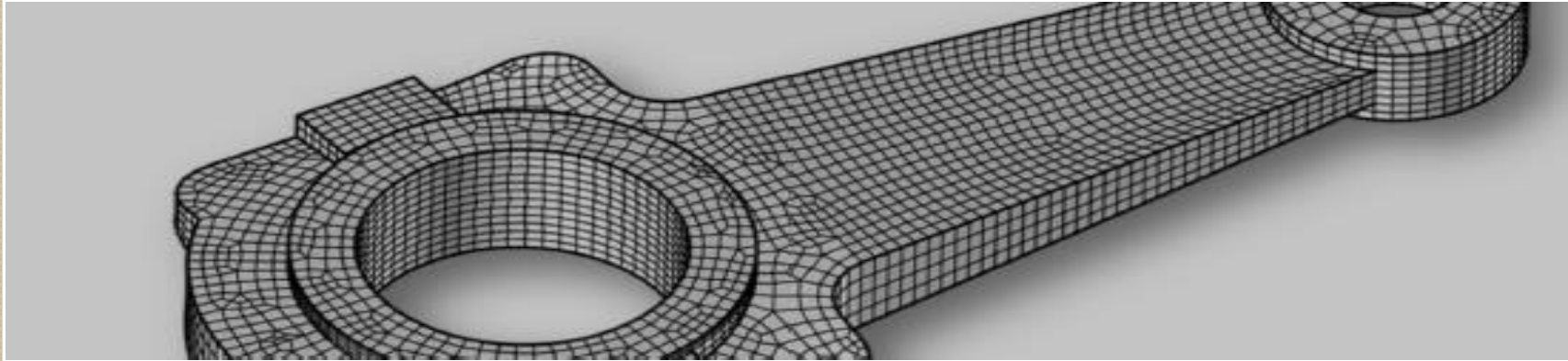


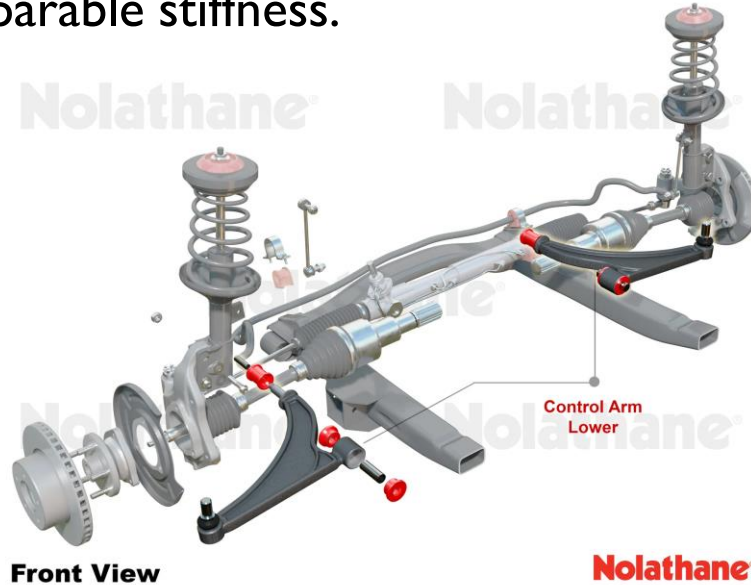
01DWRMZ - Materials and production process simulation

Teamwork I: Design of the lower arm of an automotive suspension



Exercise Object

The objective of the exercise is the **structural analysis** of the **lower control arm** of an **automotive suspension** and its redesign in **composite material**, with the goal of reducing weight keeping a comparable stiffness.



Exercise Requests

The requirements of the exercise are three:

- 1) Model the structure with **3D brick elements** in **steel** and compute the **equivalent stress** and the **maximum deflection**.
- 2) Model the structure with **shell elements** in **steel** and compare the results with the previous model.
- 3) Model the structure with **shell elements** in **composite** material – named **Epoxy Carbon UD (230 GPa) prepreg** in engineering data – and redesign the structure to keep the **same maximum deflection** and **rotation** (or lower) obtained with the steel, but reducing the **weight**. Verify also the satisfaction of the **Tsai-Hill criterion**. Choose the best design solution in terms of **number** of plies, **thickness** and **direction** of the fibers.



Create the Geometry

Step 1.

Create the sketch in **design modeler**.

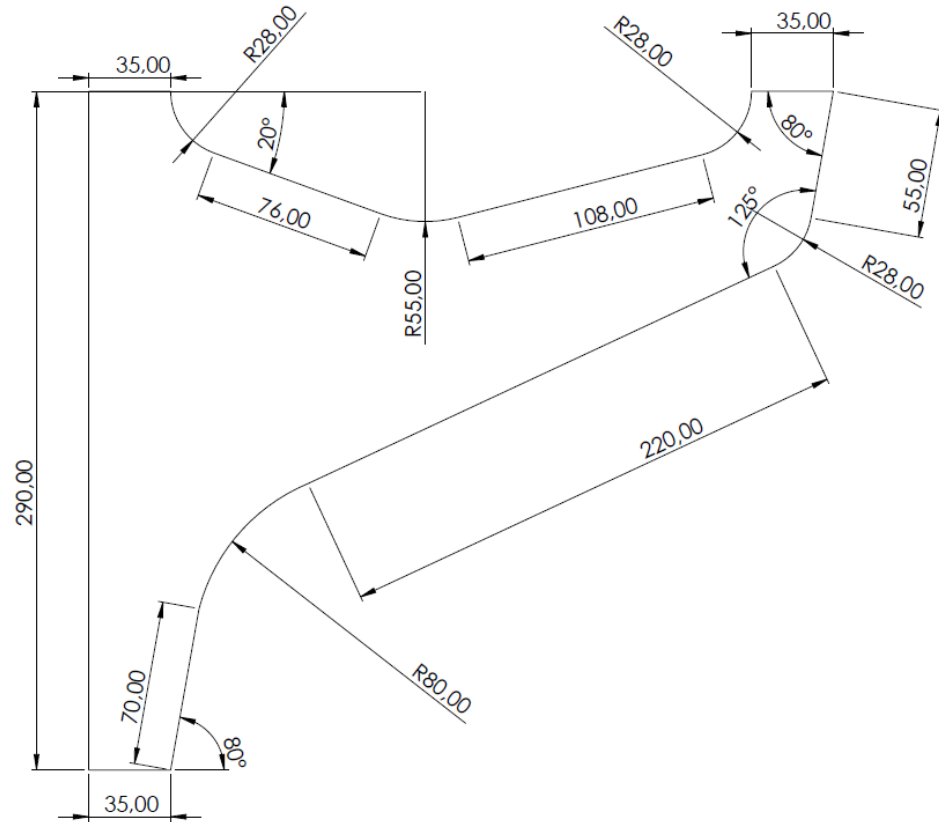
HINT: Use arc by 3 points to create the arcs.

HINT: Use constraint -> tangent and select two lines to make them tangent.

HINT: Use constraint -> perpendicular and select two lines to make them perpendicular.

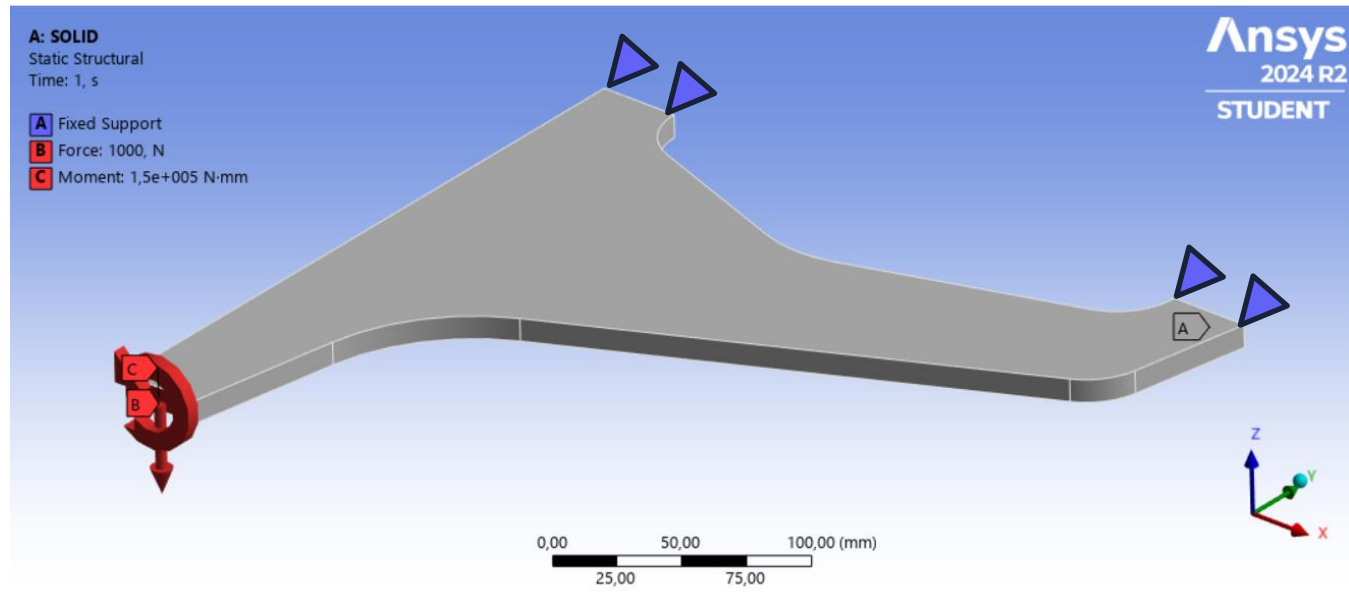
Step 2.

Extrude the geometry to obtain a **10mm thick plate**.



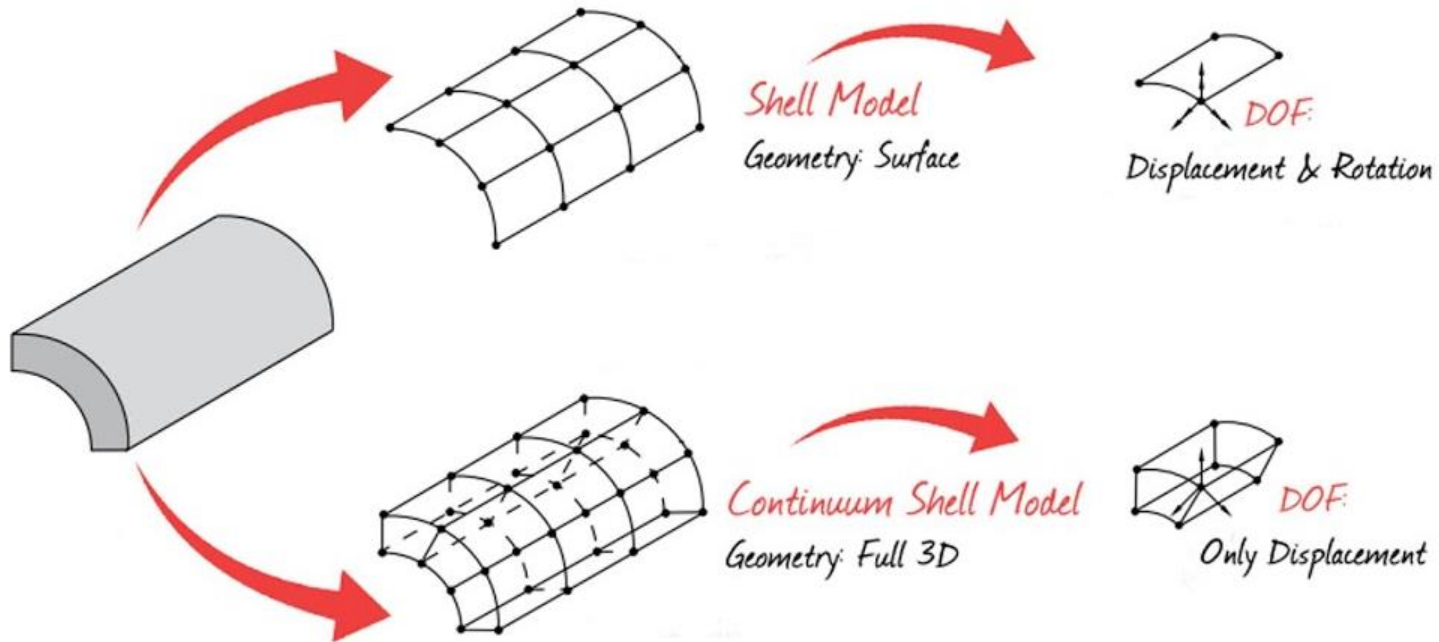
Apply Load and Constraint

Fully constrain the two ends connecting to the chassis. Apply a downward **force** equal to the **1000N** in the **z-direction** and a **clockwise moment** about the **y-axis** equal to **150000Nmm** on the wheel's edge.



SHELL Elements

Shell elements are used to model **thin structures** without the need to rely on solid elements, with the advantage of having **lighter models** that are **less computationally demanding**.

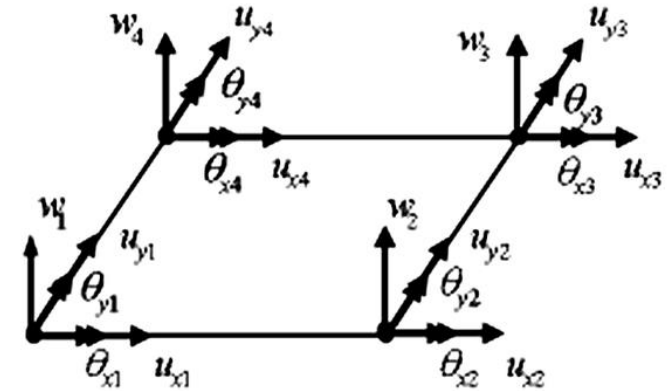
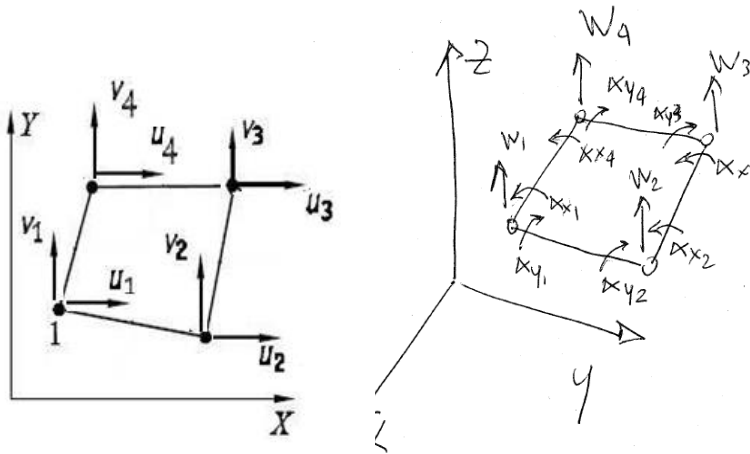


SHELL Elements

Shell elements can withstand **in-plane loads** (tension and compression) as well as **out-of-plane bending** loads.

- a) Plate membrane (ux, uy) + b) plane flexural (uz, rotx, roty) →

6 d.o.f. per node, considering also the torsional stiffness



SHELL Elements

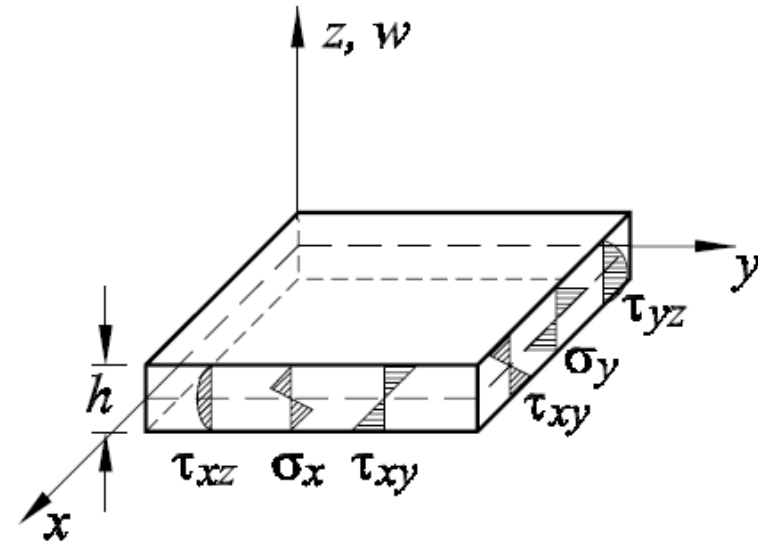
Thin plate will be considered (one dimension can be neglected); the following hypotheses hold:

- 1) stress component σ_{zz} normal to the reference plane can be neglected with respect to σ_{xx} , σ_{yy} , τ_{xy} (plane stress);
- 2) normal displacement w does not vary through the thickness;
- 3) Kirchhoff hypothesis: section normal to the reference plane will remain perpendicular after loading ($\tau_{yz} = \tau_{zx} = 0$). Mindlin hypothesis introduces the contribution of shear to deformation; sections normal to middle plane will not remain perpendicular after loading.

Hypothesis: Linear field.

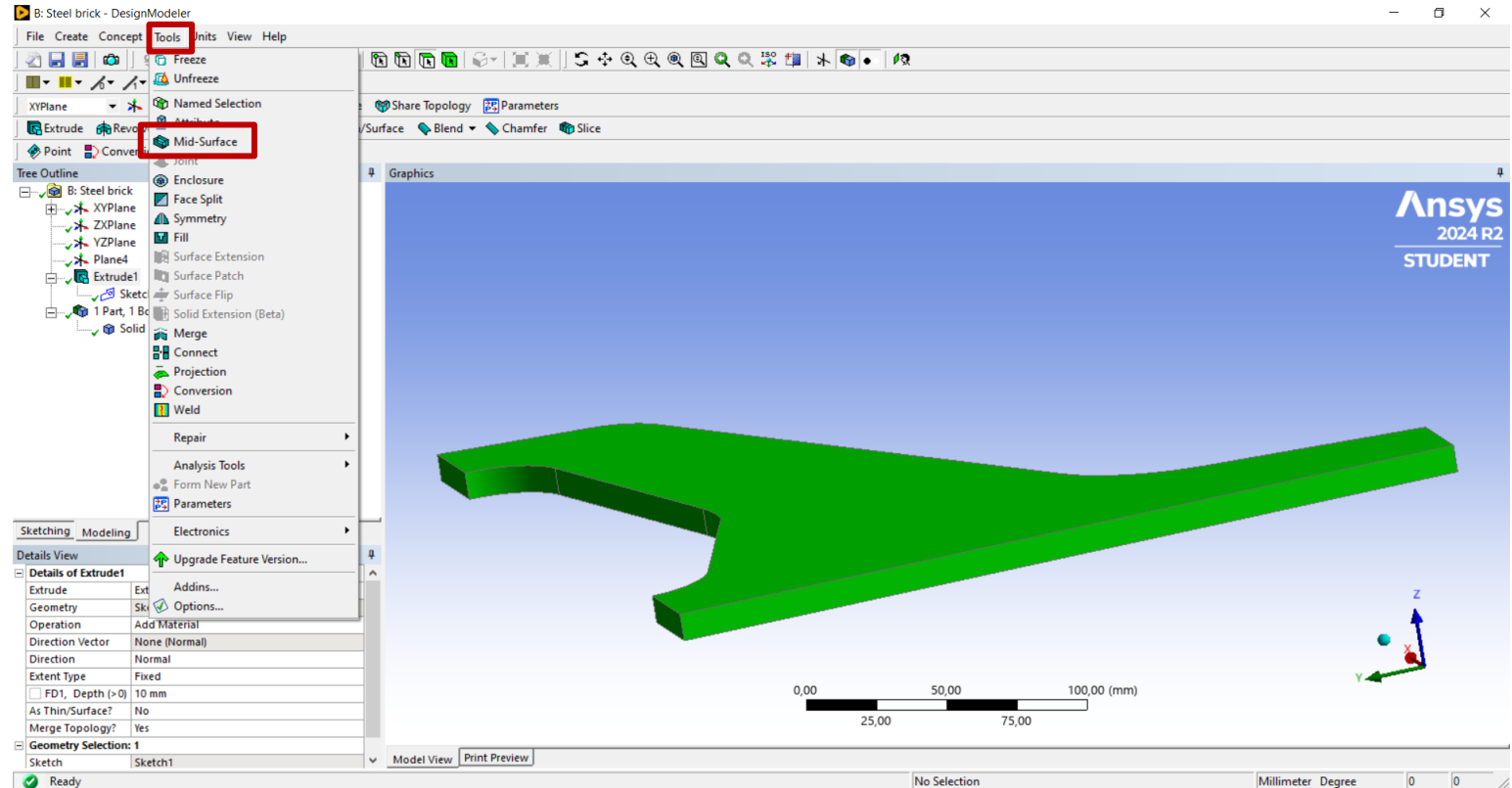
Applied load is normal to the middle plane (reference plane) xy .

$$\sigma_{xx} = \sigma_{yy} = \tau_{xy} = 0 \quad \text{in} \quad z = 0$$



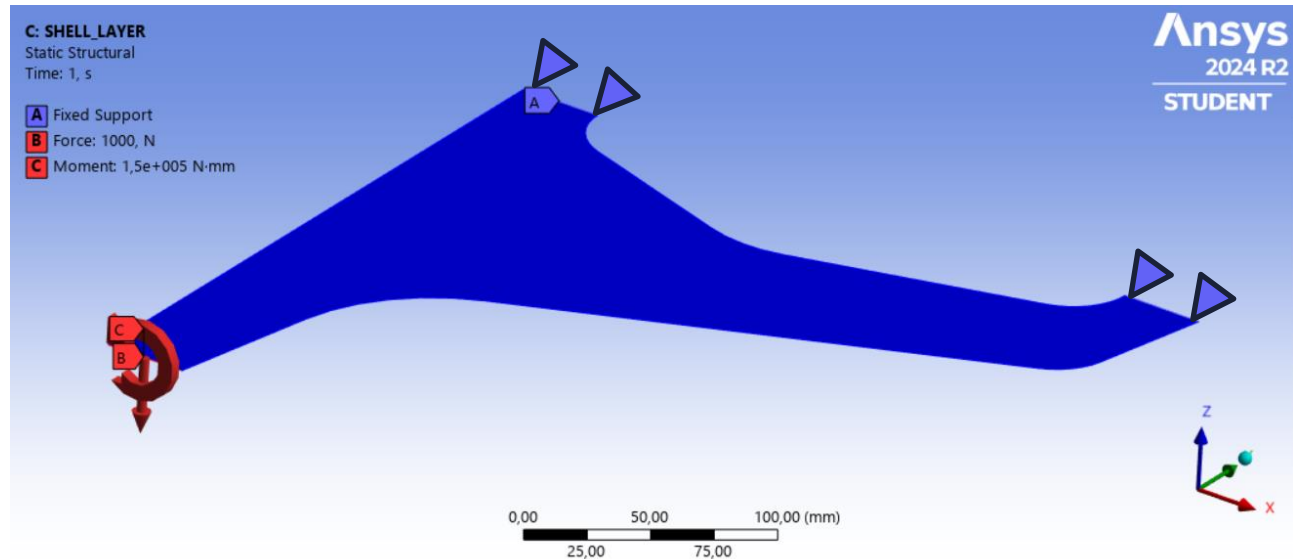
Creation of the Geometry

Create the mid-surface plane from the 3D geometry.



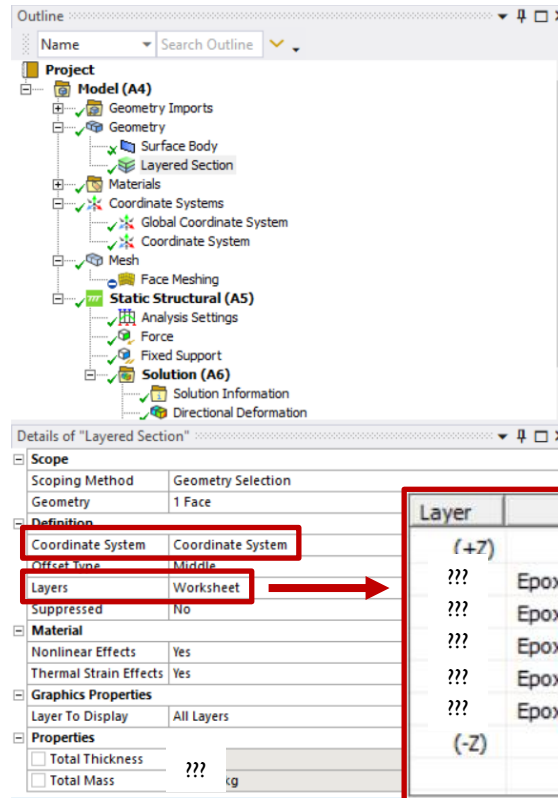
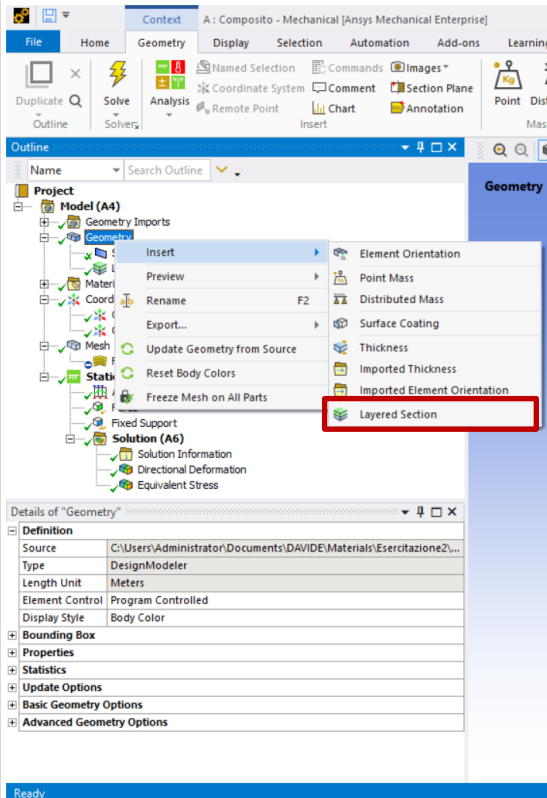
Apply Load and Constraint

Fully constrain the two ends connecting to the chassis. Apply a downward **force** equal to the **1000N** in the **z-direction** and a **clockwise moment** about the **y-axis** equal to **150000Nmm** on the wheel's edge. Now loads and constraints are applied to **lines** rather than **surfaces**.



Setting of the Composite Structure

Insert a new layered section and set the properties.



Choose the **reference system** to align the fibers. 0° is aligned to the x-axis of the chosen system.

Choose the **number of layers**, the **thickness**, the **material**, and the **angle** of the fibers.

Layer	Material	Thickness (mm)	Angle ($^\circ$)
(+Z)			
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
(-Z)			



Setting of the Composite Structure

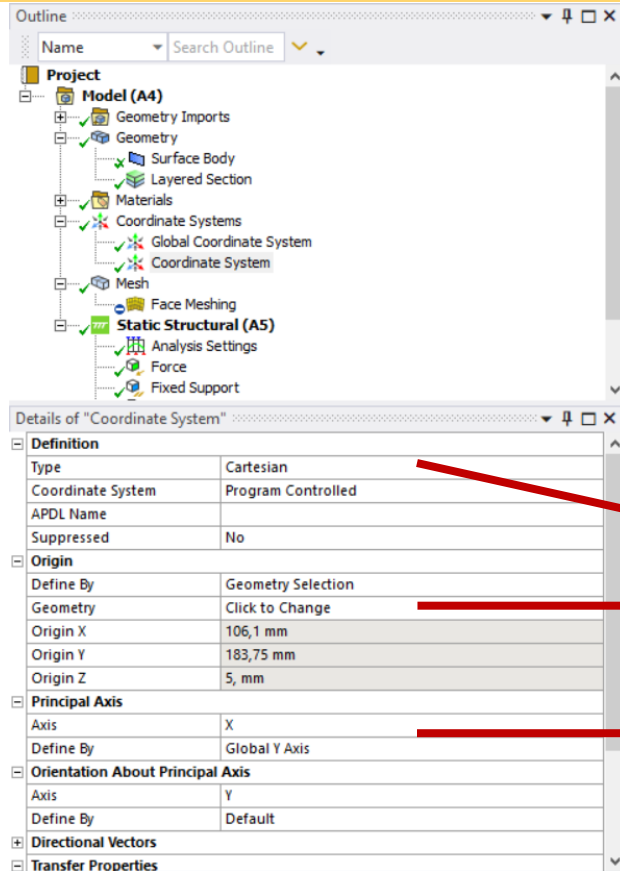
It is suggested to use a symmetric distribution of the layers in terms of angle of the fibers.

To limit the number of layers to be explicitly inserted in the worksheet, consider grouping plies with the same fiber orientation in the same layer, by entering an equivalent thickness value in the “thickness (mm)” field.

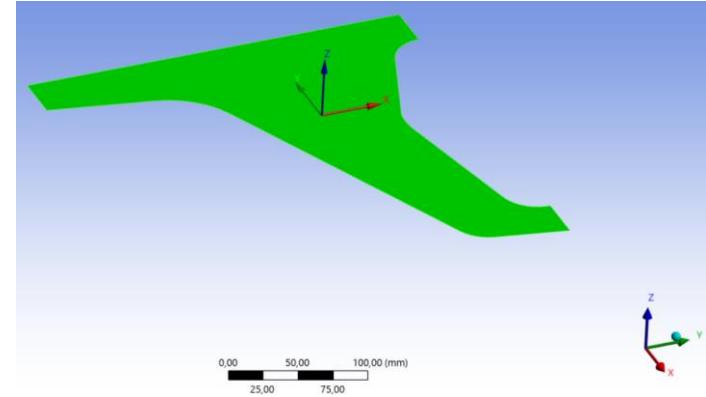
Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
???	Epoxy Carbon UD (230 GPa) Prepreg	??? mm	???
(-Z)			



Setting of the Composite Structure



Creation of a new coordinate system



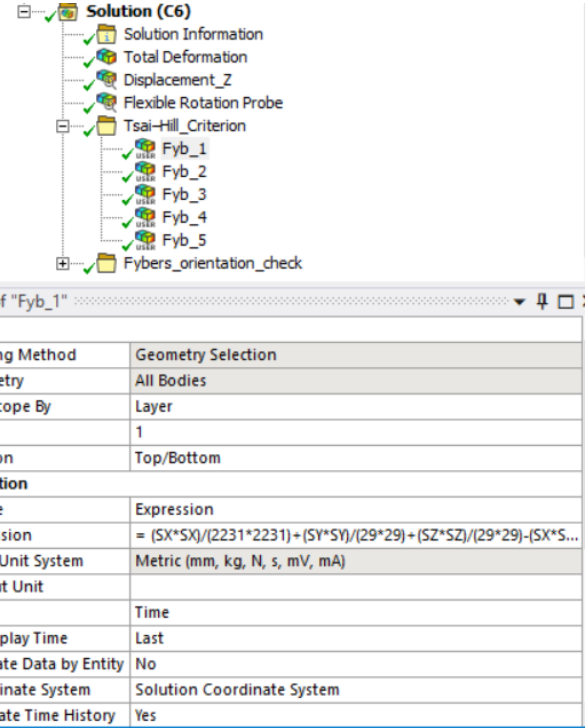
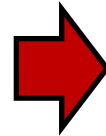
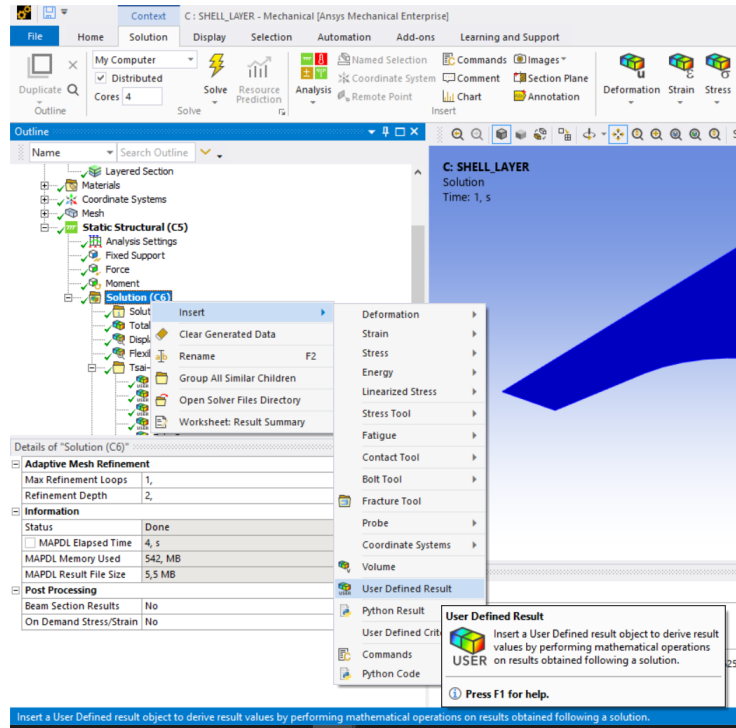
Choose the type of coordinate system

Select the geometry of the local reference system

Define the orientation of the axes of the local system with respect to the global system

Results - Tsai-Hill Criterion

The **Tsai-Hill** is a failure criterion for **anisotropic** materials. This criterion is not implemented in Workbench, so it must be calculated as a **user-defined results**.



Results - Tsai-Hill Criterion

Before computing the criterion, check the **orientation** of the element reference system.

The screenshot displays the Ansys Mechanical Enterprise interface. The main window shows a 3D model of a blue, curved structural component. A red arrow points to a local coordinate system (X, Y, Z) defined at a specific location on the model. The text overlay in red states: "Local reference system used in the definition of the 'layered section' and used to calculate the angle of the fiber (0° aligned to the x-axis of this reference system)".

The left sidebar shows the Outline tree with the following structure:

- Force
- Moment
- Solution (C6)
 - Total C
 - Displacement
 - Flexibility
 - Tsai-Hill
 - Fibers_orientation_check
 - Fibers
 - Fyb_1
 - Fyb_2
 - Fyb_3
 - Fyb_4
 - Fyb_5

The bottom-left pane shows the Details of "Solution (C6)" with the following settings:

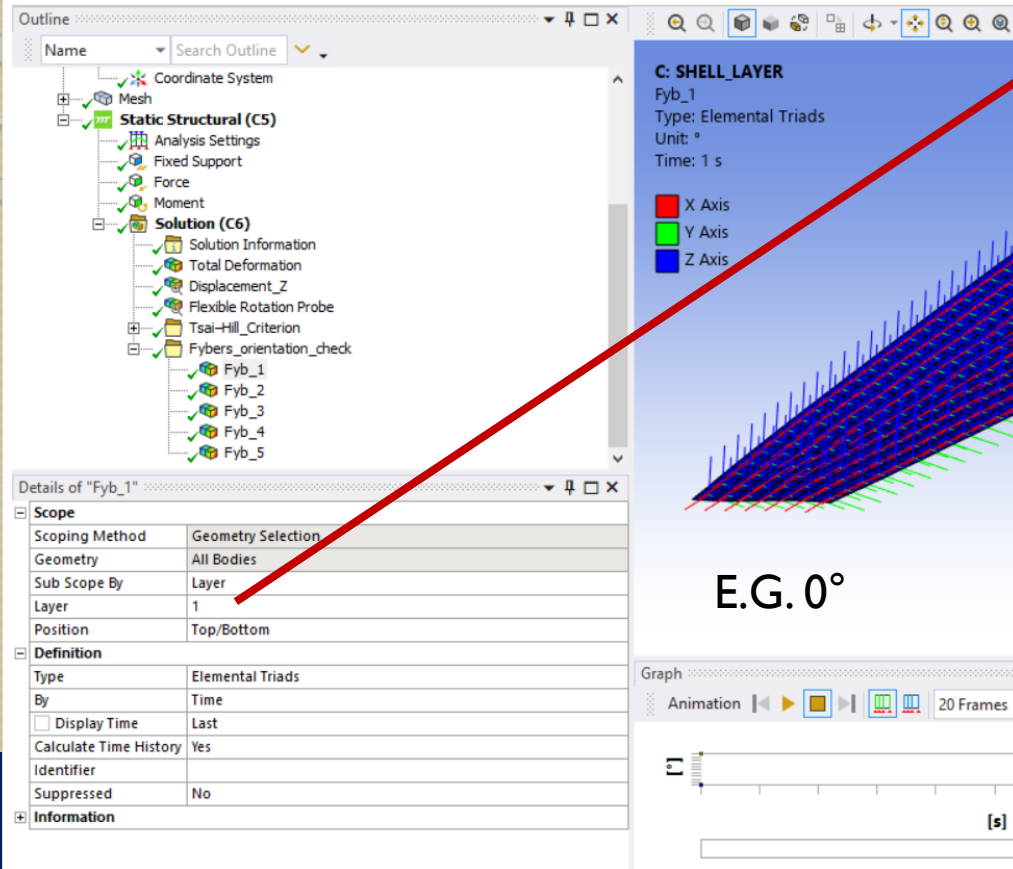
- Adaptive Mesh Refinement
 - Max Refinement Loops: 1
 - Refinement Depth: 2
- Information
 - Status: Done
 - MAPDL Elapsed Time: 4, s
 - MAPDL Memory Used: 542, MB
 - MAPDL Result File Size: 5,5 MB
- Post Processing
 - Beam Section Results: No
 - On Demand Stress/Strain: No

The bottom-right pane shows the Tabular Data table:

Time [s]	Step	Substep
1	1	1

The bottom of the interface shows the "Elemental Triads" dialog box, which states: "At each element centroid, display an XYZ triad aligned with the element's rotated coordinate system, with respect to the global Cartesian coordinate system."

Results - Tsai-Hill Criterion



Outline

Name Search Outline

- Coordinate System
- Mesh
- Static Structural (C5)
 - Analysis Settings
 - Fixed Support
 - Force
 - Moment
- Solution (C6)
 - Solution Information
 - Total Deformation
 - Displacement_Z
 - Flexible Rotation Probe
 - Tsai-Hill_Criterion
 - Fibers_orientation_check
 - Fyb_1
 - Fyb_2
 - Fyb_3
 - Fyb_4
 - Fyb_5

Details of "Fyb_1"

Scope

Scoping Method	Geometry Selection
Geometry	All Bodies
Sub Scope By	Layer
Layer	1
Position	Top/Bottom

Definition

Type	Elemental Triads
By	Time
☐ Display Time	Last
Calculate Time History	Yes
Identifier	No
Suppressed	No

Information

C: SHELL_LAYER

Fyb_1

Type: Elemental Triads

Unit: °

Time: 1 s

X Axis

Y Axis

Z Axis

E.G. 0°

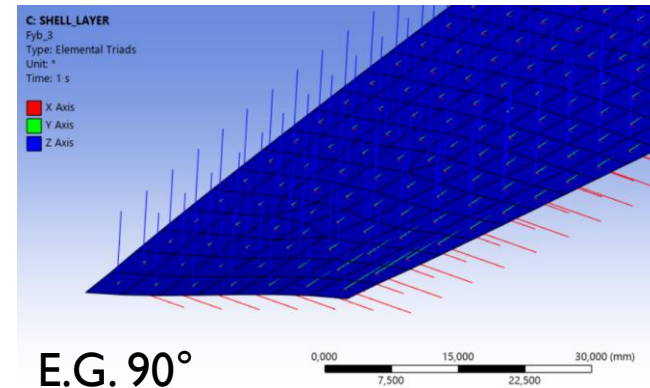
Graph

Animation

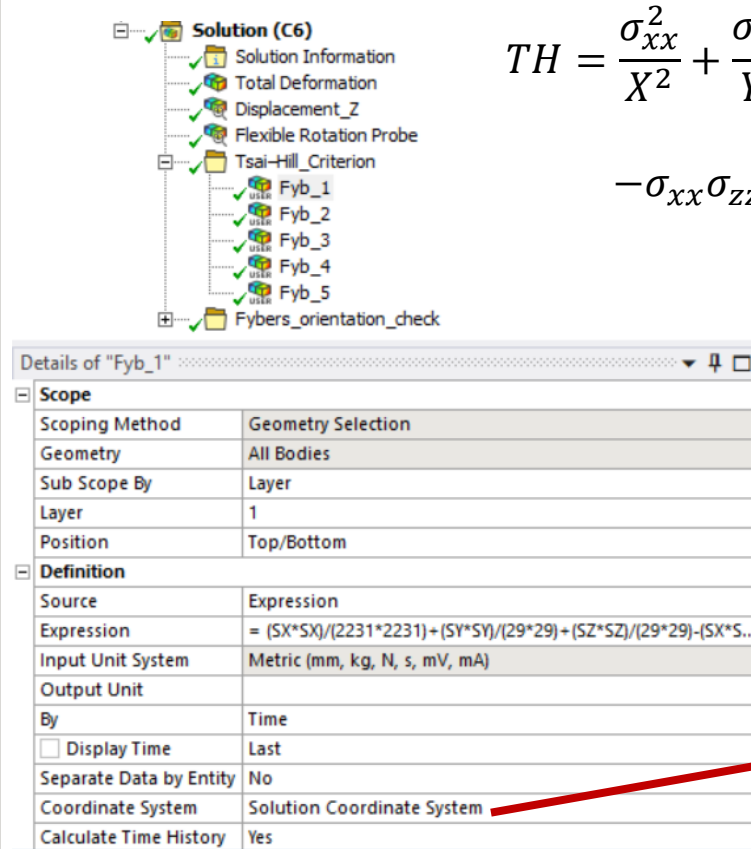
20 Frames

[s]

Select the layer number and verify that the element reference system shown has the x-axis aligned to the fiber direction specified in the worksheet of the layered section



Results - Tsai-Hill Criterion



Details of "Fyb_1"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Sub Scope By	Layer
Layer	1
Position	Top/Bottom
Definition	
Source	Expression
Expression	= (SX*SX)/(2231*2231)+(SY*SY)/(29*29)+(SZ*SZ)/(29*29)-(SX*S...
Input Unit System	Metric (mm, kg, N, s, mV, mA)
Output Unit	
By	Time
☐ Display Time	Last
Separate Data by Entity	No
Coordinate System	Solution Coordinate System
Calculate Time History	Yes

$$TH = \frac{\sigma_{xx}^2}{X^2} + \frac{\sigma_{yy}^2}{Y^2} + \frac{\sigma_{zz}^2}{Z^2} + \frac{\tau_{xy}^2}{Q^2} + \frac{\tau_{yz}^2}{R^2} + \frac{\tau_{xz}^2}{S^2} - \sigma_{xx}\sigma_{yy}\left(\frac{1}{X^2} + \frac{1}{Y^2} - \frac{1}{Z^2}\right) - \sigma_{xx}\sigma_{zz}\left(\frac{1}{X^2} - \frac{1}{Y^2} + \frac{1}{Z^2}\right) - \sigma_{yy}\sigma_{zz}\left(-\frac{1}{X^2} + \frac{1}{Y^2} + \frac{1}{Z^2}\right)$$

Where X,Y,Z,Q,R and S are the **tensile stress limits** in X,Y and Z and the **shear stress limits** XY,YZ and XZ, reported in **Engineering data**.

Write the **expression of the criterion**.

To make the cartesian directions following the fiber orientation:

Choose the **Solution coordinate system**, with the x-axis keeping aligned to the direction of the fiber.

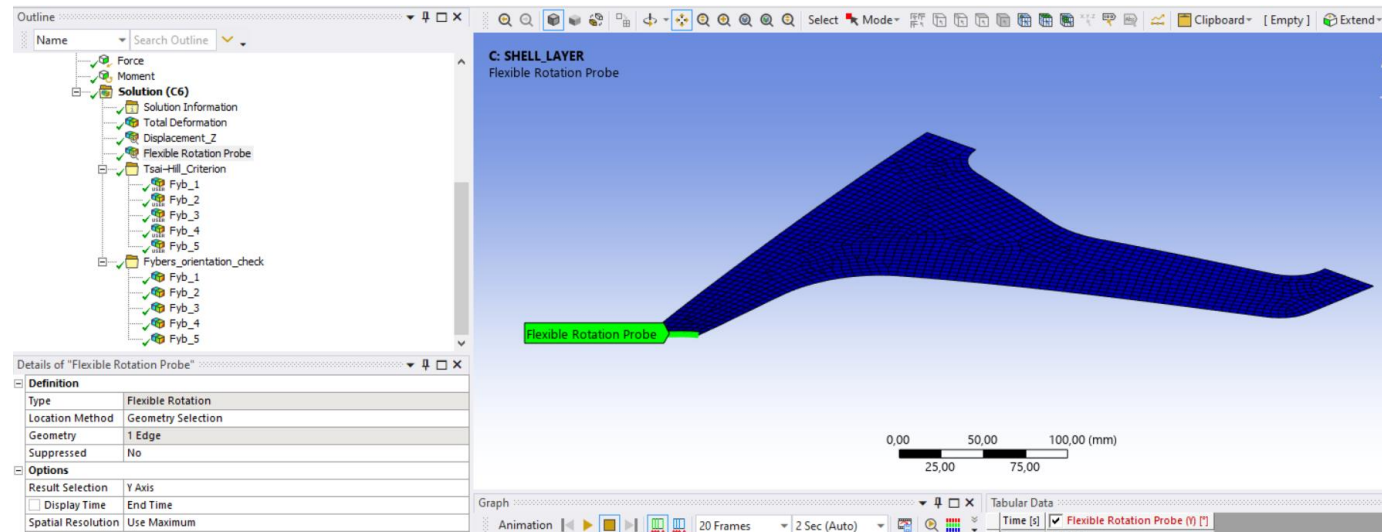


Comparison of the results with the steel case study

For **each layer** in the composite, **verify** that the Tsai-Hill criterion is **satisfied**, namely **$TH < 1$** .

Verify also the **stiffness** of the structure: the **maximum deflection** and the **rotation** of the wheel's edge must be equal or less than the **steel** case study.

Rotation can be quantified with **probe** (insert->probe -> flexible rotation).



Content of the Report

A report describing the activity is due by the end of course. The report must contain the following:

- Objectives of the exercise;
- Description of the numerical model;
- Requested results;
- Critical analysis of the results;
- Conclusions;

