Workshop 02: C-Shape Profile Fast Cure Simulation

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Workshop 02: C-Shape Profile Fast Cure Simulation

- In this Workshop, we will model the curing of a C-shape composite profile made from Carbon fiber prepreg.
- The problem is identical to the one in Workshop 01. The difference is that the fast instead of the full solution method is used.
- A fast solution method is possible for relatively thin laminates (<5 mm thick) where a uniform temperature distribution can be assumed. In that case the transient thermal analysis can be executed in three linear steps, directly imported in the Static Structural Analysis System.
- Using ACCS with a fast cure simulation, in conjunction with ACP, you will predict the mean process outputs like material state, degree of cure and Glass transition temperature.
- In a Static Structural analysis you will forecast the process induced distortions according to the thermal conditions of the curing cycle that the manufacturer recommends.

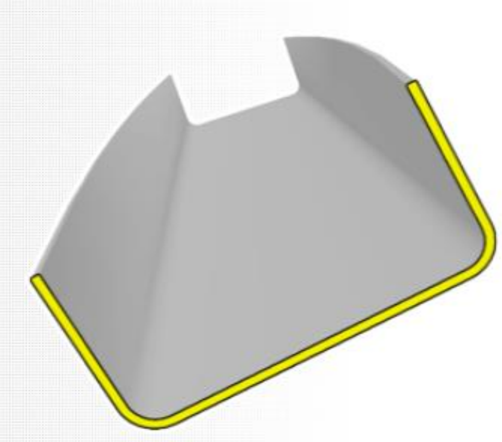
Background

C-Shape Profile: Problem Description

- During the curing of composite parts, residual stresses develop during the cure resulting in distorted components

Mismatch between in-plane and through-thickness CTE

Tool-part interaction



Cure shrinkage

Cure gradients, variable gelation and vitrification times

Asymmetry

Enthalpy (exotherm)

Understanding the influence of the process parameters play an important role in the shape and quality of the final part.

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Material Characterization

- During curing of thermosetting composites, the resin undergoes cross-linking reactions that lead to an increase of material density and reduction in volume.
- When monomers link into larger molecules they release energy in the form of heat. The exothermic heat of polymerization causes huge problems in processing especially in the case of thick laminates.
- Many thermo-mechanical properties are needed to solve the kinetic models that are available in ACCS.
- <u>Differential Scanning Calorimetry (DSC)</u>
  - Test performed to determine: Glass transition temperature (Tg), curing state (α) Total heat of cure (HR) and heat capacities (Cp)
  - Analytical models are obtained by empirical fitting of the DCS data.

Workshop

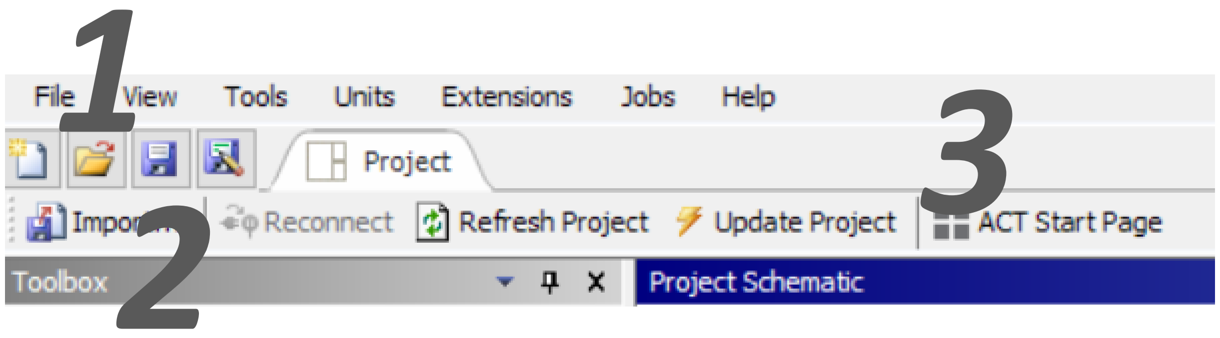
Setting up the Transient Thermal Analysis

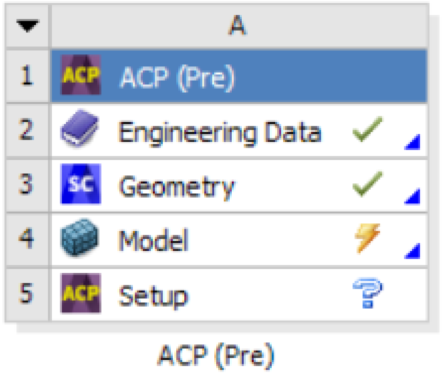
Workshop 02: C-Shape Profile Fast Cure Simulation

- This Workshop focuses on the fast cure and distortion simulation of a quarter C-shape made of [0 90 90 0] AS4-8552 plies.
- The material properties needed for the curing simulation are complex and should be empirically measured. In this case we use a dummy material of the ANSYS material library.
- The thermal analysis is not performed on its own but is performed during the mechanical analysis.
- It is considered that every point of the part follows exactly the manufacturer’s recommended cure cycle.
- The spatial and temporal temperature distribution obtain from the thermal analysis is then used to compute thermal expansion effects, material properties evolution and cure shrinkage.
- The mechanical analysis considers that the part is lying inside a cylindrical mould and the mould-part interface is modelled by a frictionless support condition.
- The Support Remover allows simulating the opening of the mould by removing the frictionless support condition at the last step of the analysis. Additional constraints are added to block any rigid body motions of the part.

Workshop 02: C-Shape Profile Fast Cure Simulation
Opening the Model

Start ANSYS Workbench and Open Archive



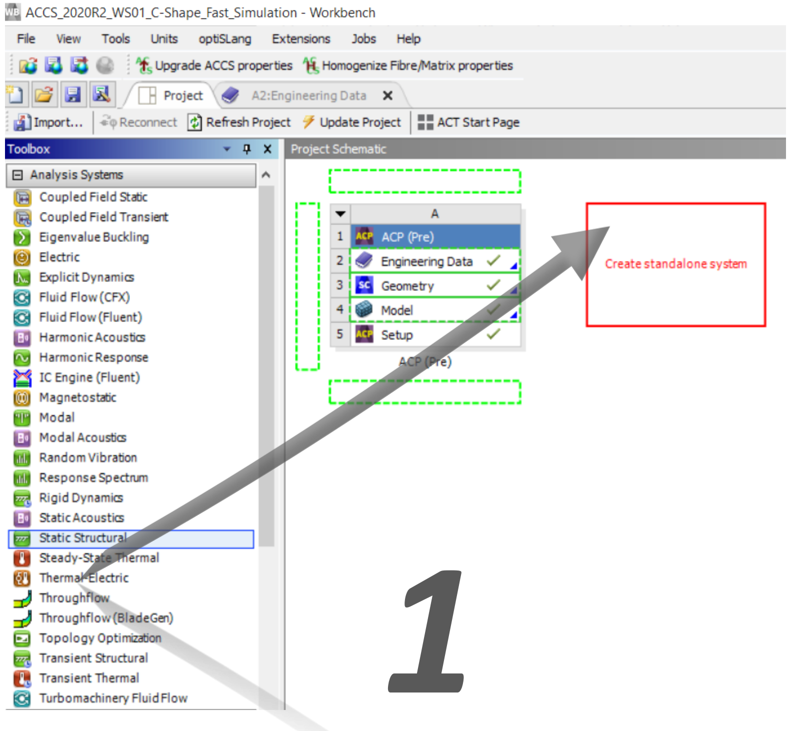


1. Start ANSYS Workbench and open the archive `ACCS_`*`<Release>`*`_WS02_C-Shape_Fast_Simulation.wbpz`
2. Save the Workbench project
3. Update the project

Workshop 02: C-Shape Profile Fast Cure Simulation
Opening the Model

The composite model is already built in. In order to learn how to setup a composite structure like this, you should do the ACP training course.

1. Because this model is a thin wall composite structure you will use the fast cure simulation. Drag and drop a “Static Structural" Analysis System to the "Project schematic".



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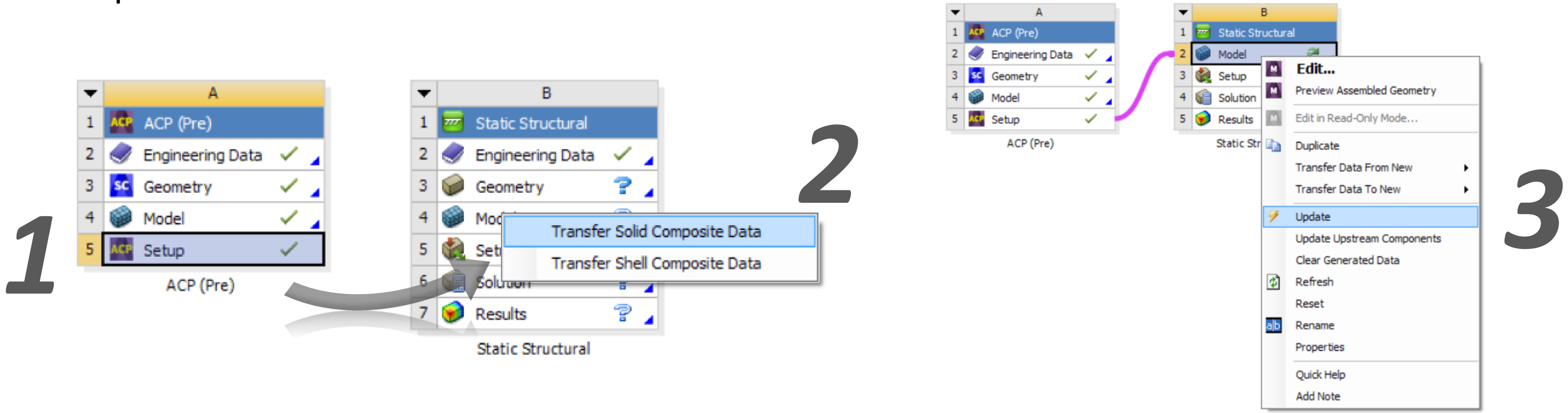
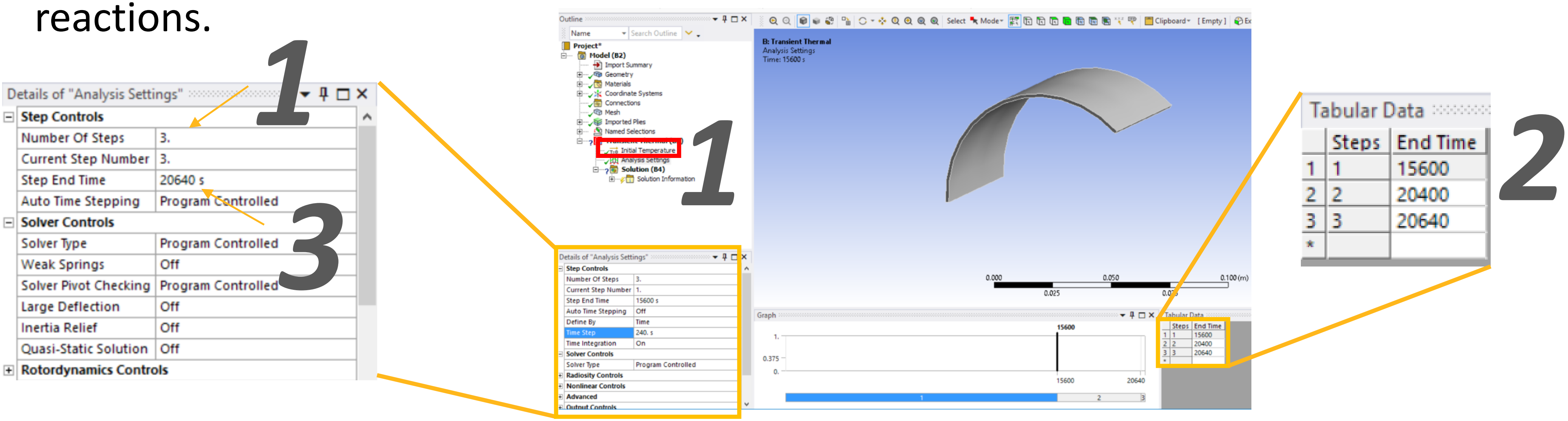
1. Drag and Drop Setup of "ACP (Pre)“ (cell A5) onto Model of the new Static Structural Model (cell B4).
2. Select “Transfer Solid Composite Data”.
3. Right click in the Setup cell of the Static Structural and Update the project.
4. Open the Mechanical model



Workshop 02: C-Shape Profile Fast Cure Simulation

Now we set the number of steps and the time steps of the curing cycle

1. Click in “Analysis Settings” and set the Number Of Steps to 3 which are the same as the no. of steps of the autoclave process.
2. Then in the “Tabular Data” tab, start editing the “End Time” of step 3 to 20640 s, edit then step 2 to 20400 s and finally step 1 to 15600 s.
3. Let the “Auto Time Stepping” to “Program Controlled”. After solved, you can choose if you need shorter time steps to capture better the dynamics of the chemical reactions.

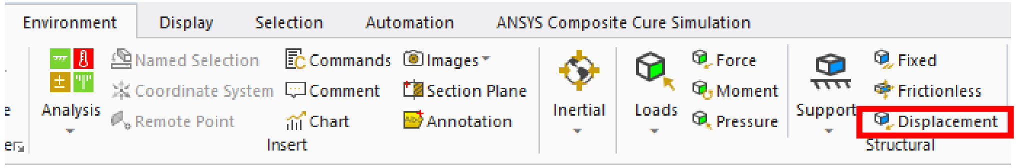


Workshop 02: C-Shape Profile Fast Cure Simulation

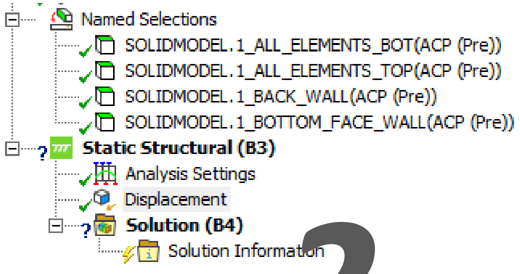
The degree of freedom (DOF) should be defined according to the process. The part is fist laminated in a mold and then released from it.

Fix the displacement in Y direction:

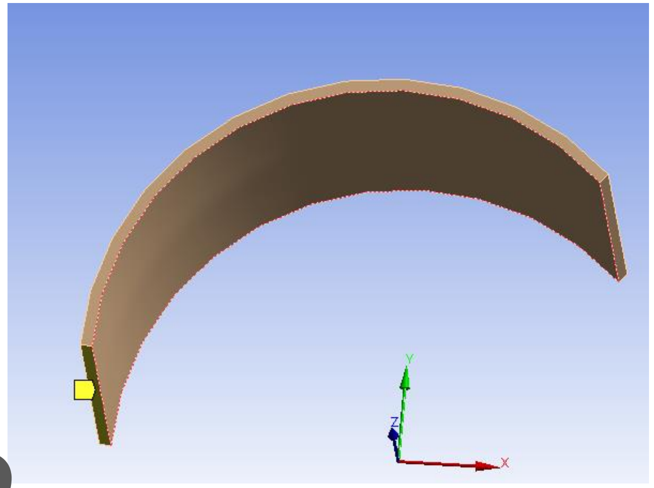
1. Add a “Displacement” condition.
2. Scope the Named Selection named SOLIDMODEL.1_BOTTOM_FACE_WALL
3. Specify the “Y Component” to 0.



1



2



Details of "Displacement"

Scope	
Scoping Method	Named Selection
Named Selection	SOLIDMODEL.1_BOTTOM_FACE_WALL(ACP (Pre))
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	Free
Y Component	0. m (ramped)
Z Component	Free
Suppressed	No

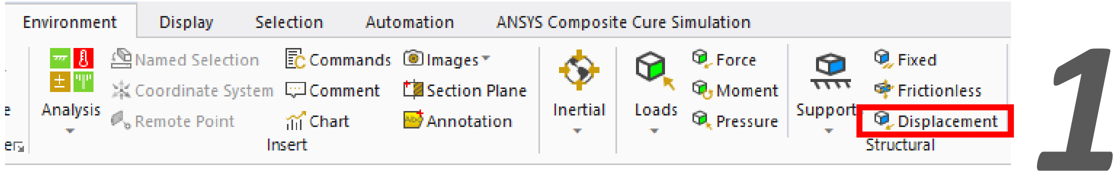
2

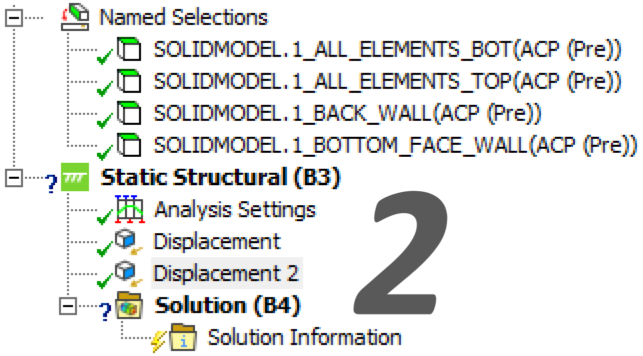
3

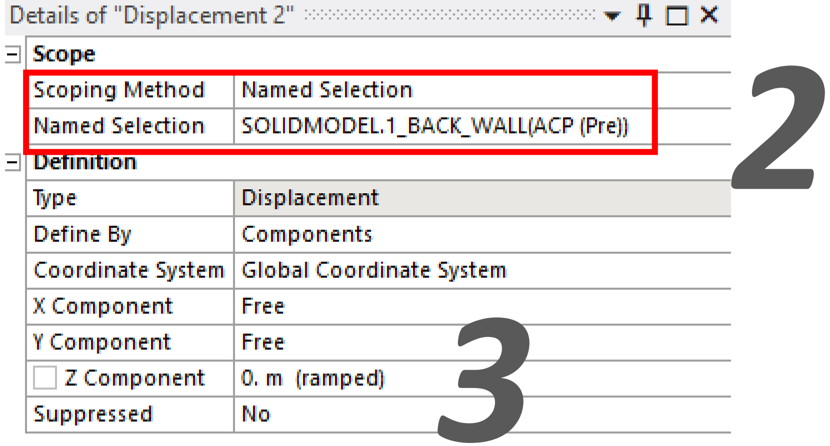
Workshop 02: C-Shape Profile Fast Cure Simulation

Fix the displacement in Z direction:

1. Add another "Displacement" condition.
2. Select the Named Selection named SOLIDMODEL.1_BACK_WALL
3. Specify the "Z Component" to 0.

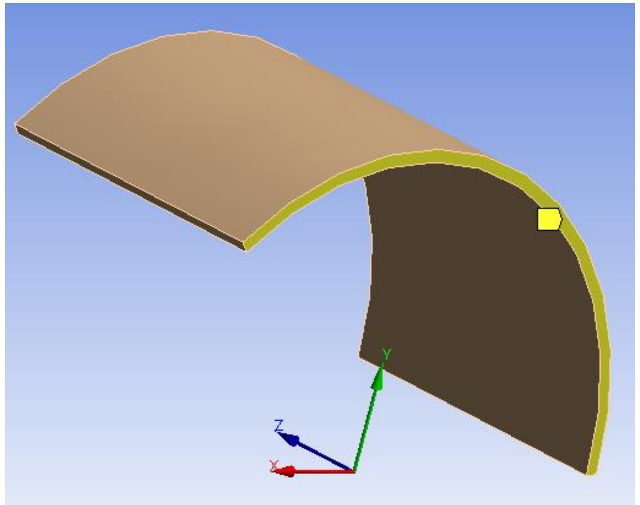






Details of "Displacement 2"

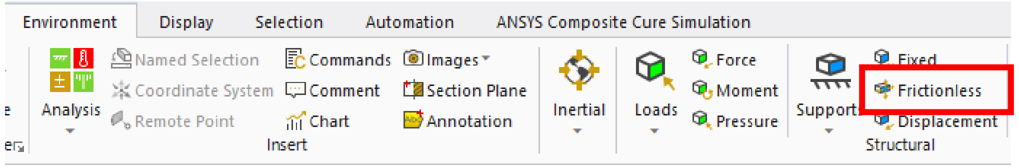
Scope	
Scoping Method	Named Selection
Named Selection	SOLIDMODEL.1_BACK_WALL(ACP (Pre))
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	Free
Y Component	Free
Z Component	0. m (ramped)
Suppressed	No



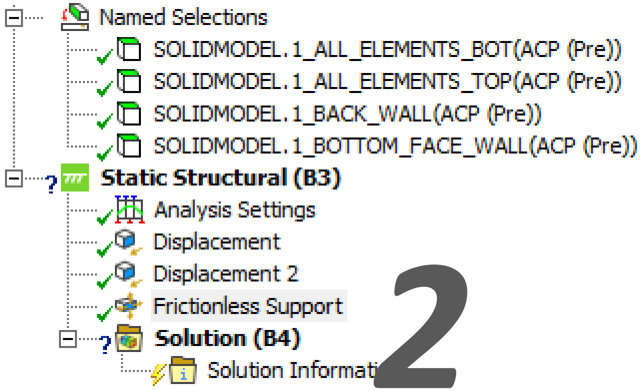
Workshop 02: C-Shape Profile Fast Cure Simulation

Now we are defining the tool surface. Since the tool surface has a special treatment to enable an easy extraction of the part, the best choice of BC is a frictionless support:

1. Add a “Frictionless Support” condition
2. Scope the Named Selection named SOLIDMODEL.1_ALL_ELEMENTS_BOT



1

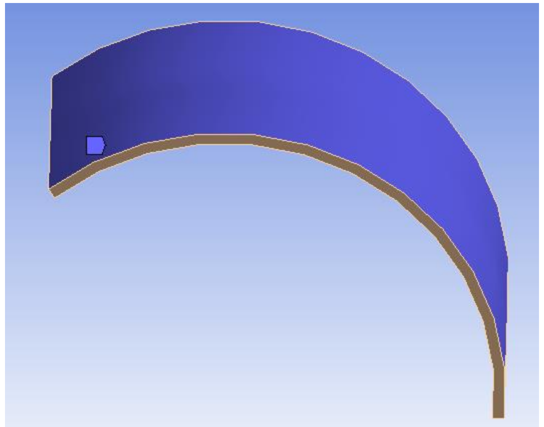


2

Details of "Frictionless Support"

Scope	
Scoping Method	Named Selection
Named Selection	SOLIDMODEL.1_ALL_ELEMENTS_BOT(ACP (Pre))
Definition	
Type	Frictionless Support
Suppressed	No

2



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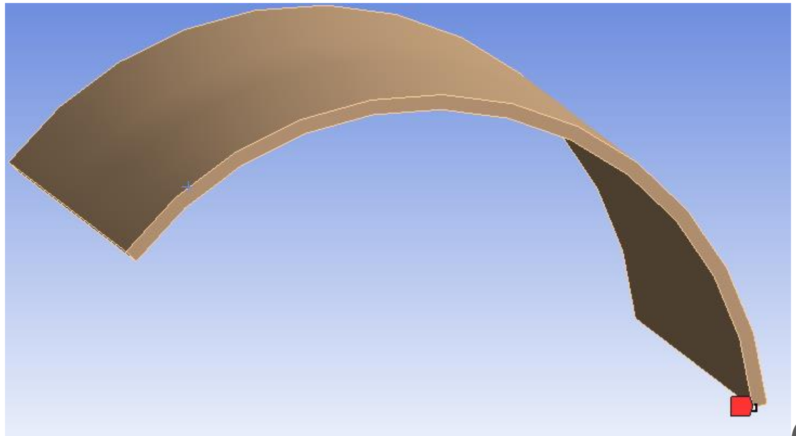
Now all DOF are selected, but once the part is removed from the mold in the last step, the x direction will be undefined, so it is necessary to define it for the last step as follow:

1. Add a Named Selection based in Worksheet
2. specify the vertex at the bottom as shown in the table and name it "Vertex_Bottom"



2

1

Details of "Vertex_Bottom"

Scope	
Scoping Method	Worksheet
Geometry	1 Vertex
Definition	
Send to Solver	Yes
Protected	Program Controlled
Visible	Yes
Program Controlled Inflation	Exclude
Statistics	
Type	Manual
Total Selection	1 Vertex
Suppressed	0
Used by Mesh Worksheet	No

2

Worksheet

Vertex_Bottom

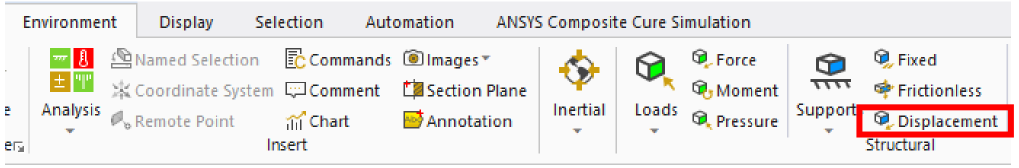
Generate

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)

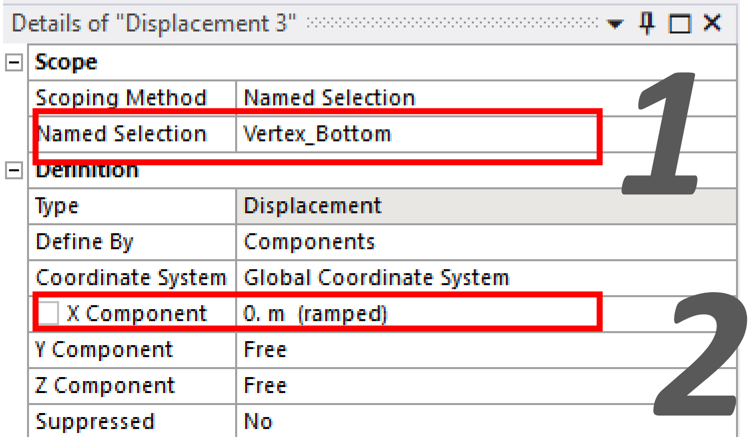
	Action	Entity Type	Criterion	Operator	Units	Value	Lower Bound	Upper Bound	Coordinate System
☑	Add	Vertex	Location X	Equal	m	-4.8e-002	N/A	N/A	Global Coordinate System
☑	Filter	Vertex	Location Z	Range	m	N/A	0.	1.e-003	Global Coordinate System

Workshop 02: C-Shape Profile Fast Cure Simulation

1. Add a "Displacement" and scope it to the "Vertex_Bottom"
2. Specify the X component to "0".
3. Open the Tabular Data tab, select the first three lines, press the right click button, and select "Activate/Deactivate at this step!".

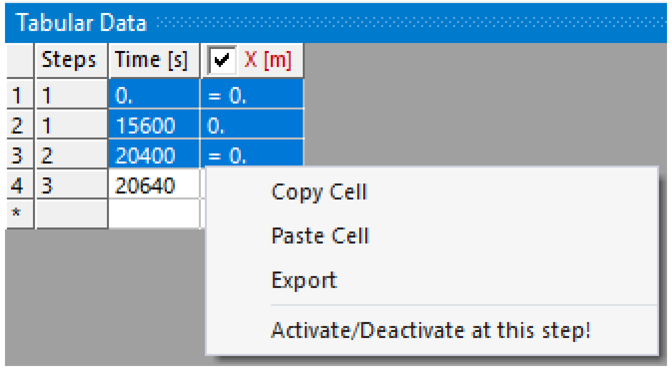


1



1

2



3

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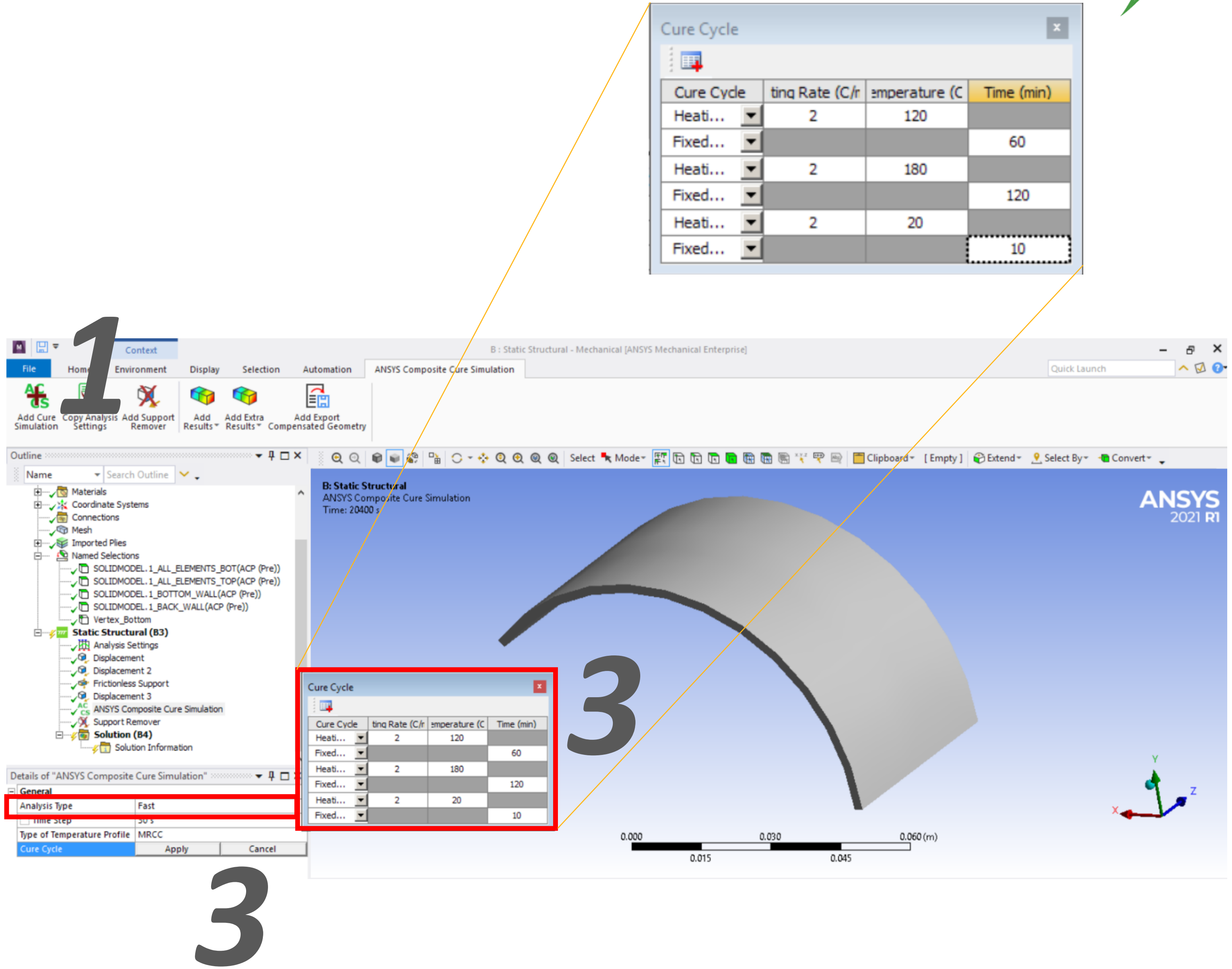
Now we are adding the ACCS material models to calculate the effect of the curing in the final shape of the part.

1. Add the ACCS module
2. Select “Fast” in Analysis Type.
3. Edit the “Cure Cycle” by clicking on “Tabular Data” field, fill-in as illustrated here and then click on “Apply” when done. An ACCS Thermal Load will be created.

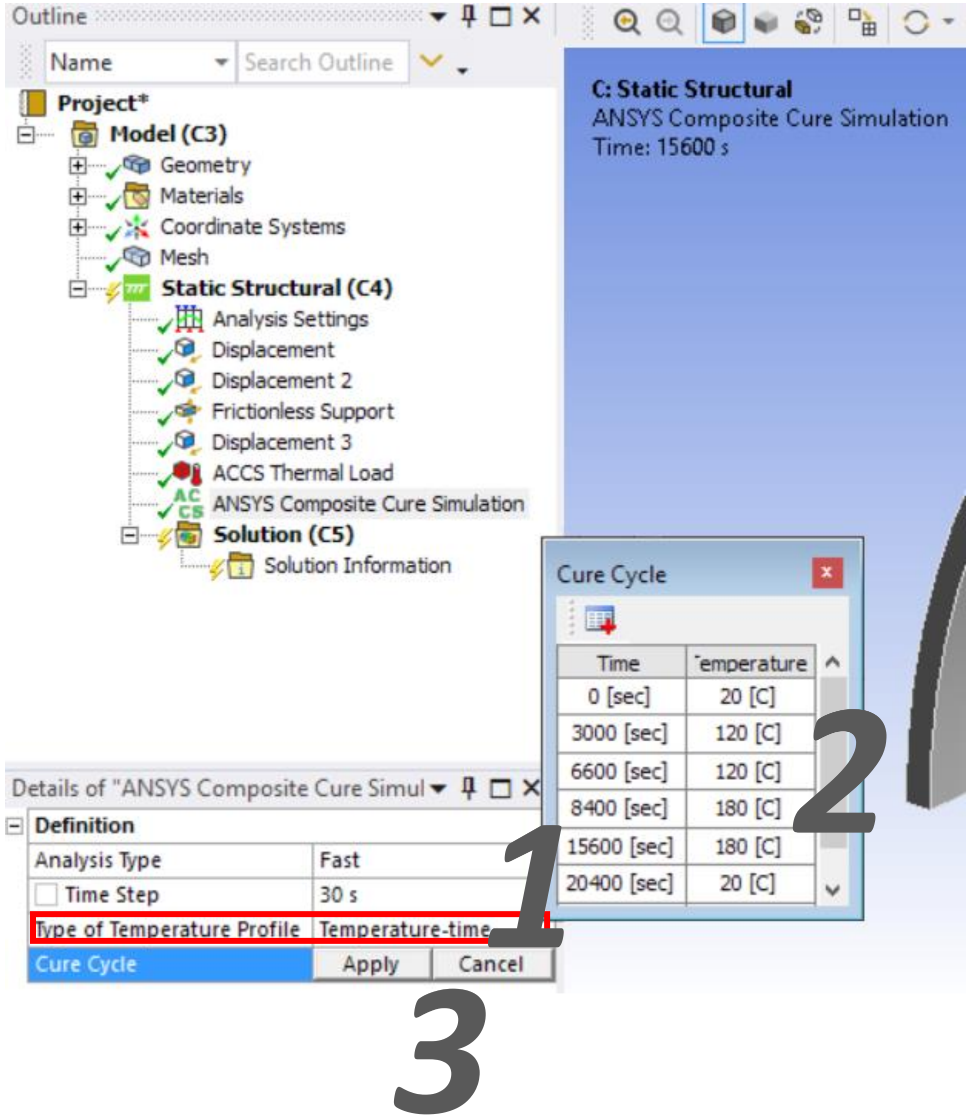


Workshop 02: C-Shape Profile Fast Cure Simulation

If you have the temperature profile defined by time and temperature (defined cure cycle of the resin manufacturer) you can import it as following:

1. Change the "Type of Temperature Profile" to "Temperature-Time". An "Open the Temperature vs time" file. A window will open automatically.
2. Open the cure cycle file, in this case the file is called "AS4-8552_Cure-cycle_Tvst.csv"
3. You can edit the data if needed and then click "Apply" when done.

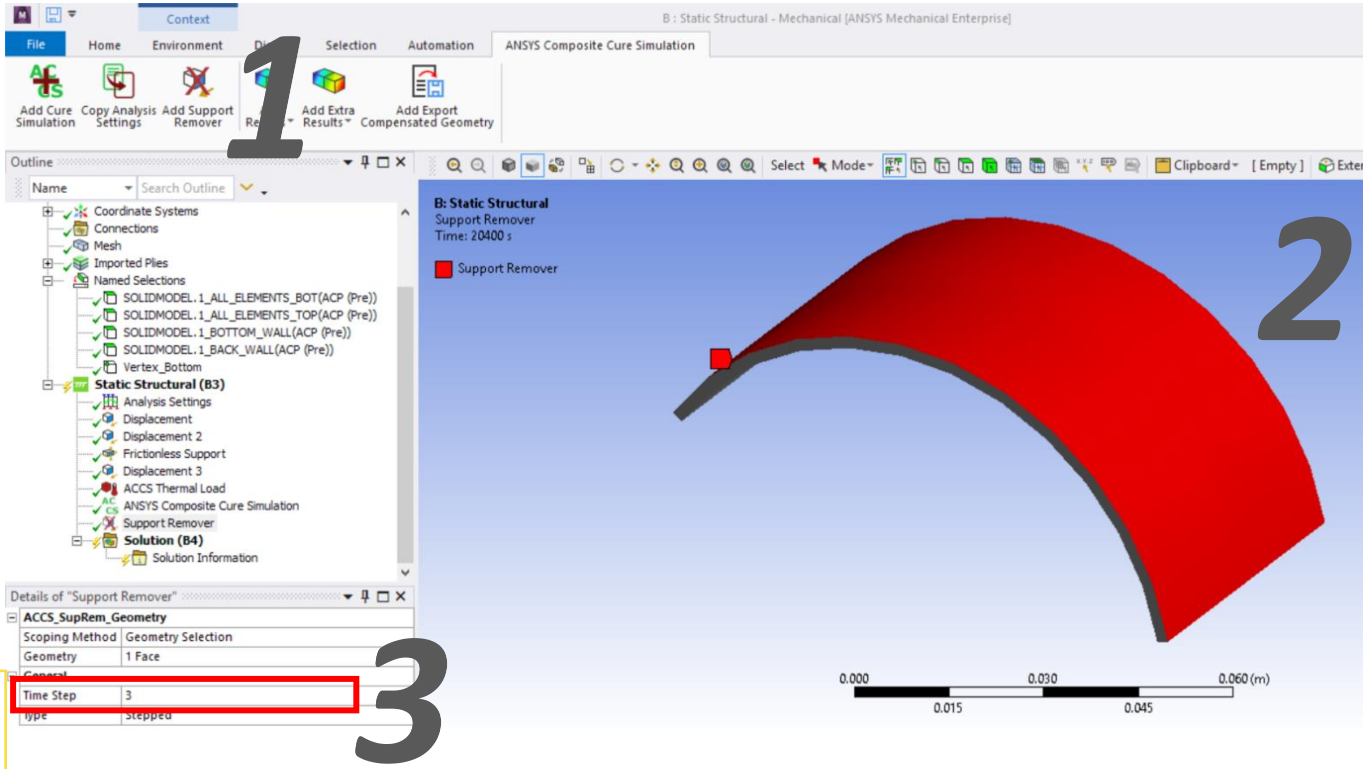
Note: you can manually add points using the button



Workshop 02: C-Shape Profile Fast Cure Simulation

Once the cure cycle is defined, we can define the moment when the part is taken out of the mold.

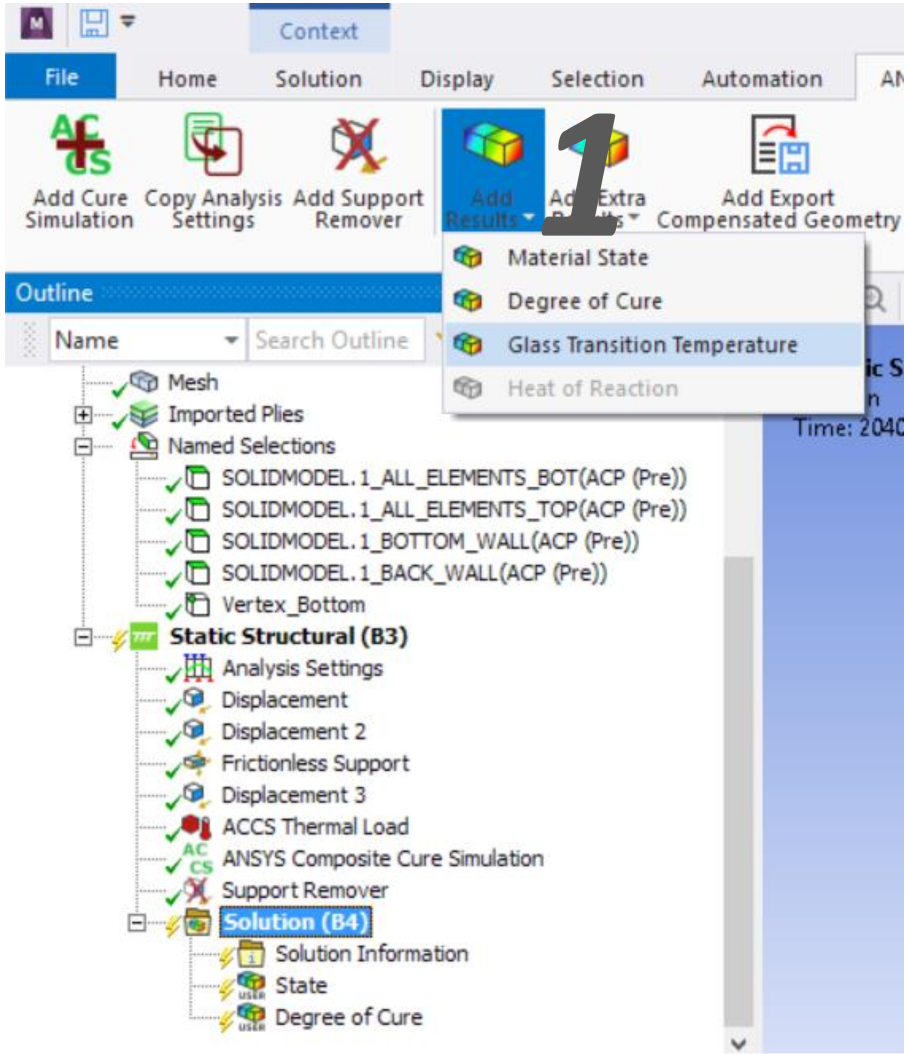
1. In the ACCS menu, Add Support Remover
2. Select the outer face of the part, the one that is in touch with the tool, in this case is the red surface.
3. Select the step no. 3 (the last step of the curing process)

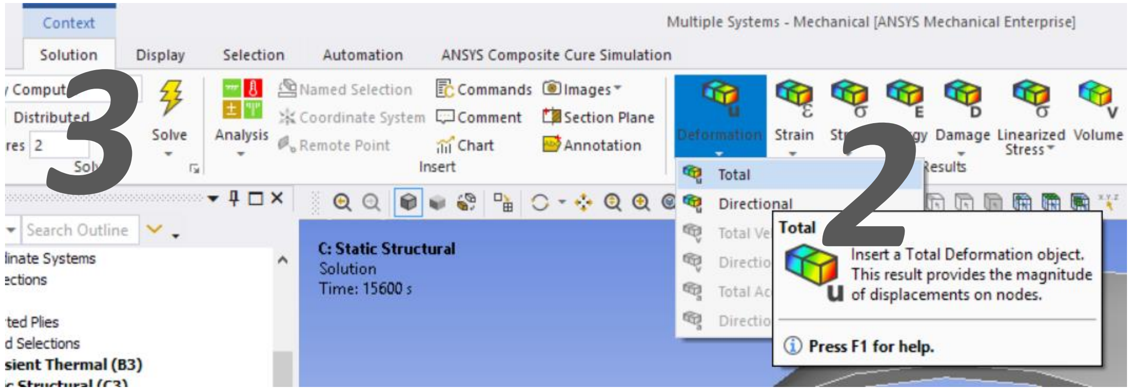


Note: the support remover will remove all the BC that are defined in the nodes of the mapped region.

Workshop 02: C-Shape Profile Fast Cure Simulation

1. Add the ACCS results: Material State, Degree of Cure and Glass Transition Temperature.
2. Add also a "Total Deformation"
3. Run the simulation by clicking the "Solve" button.



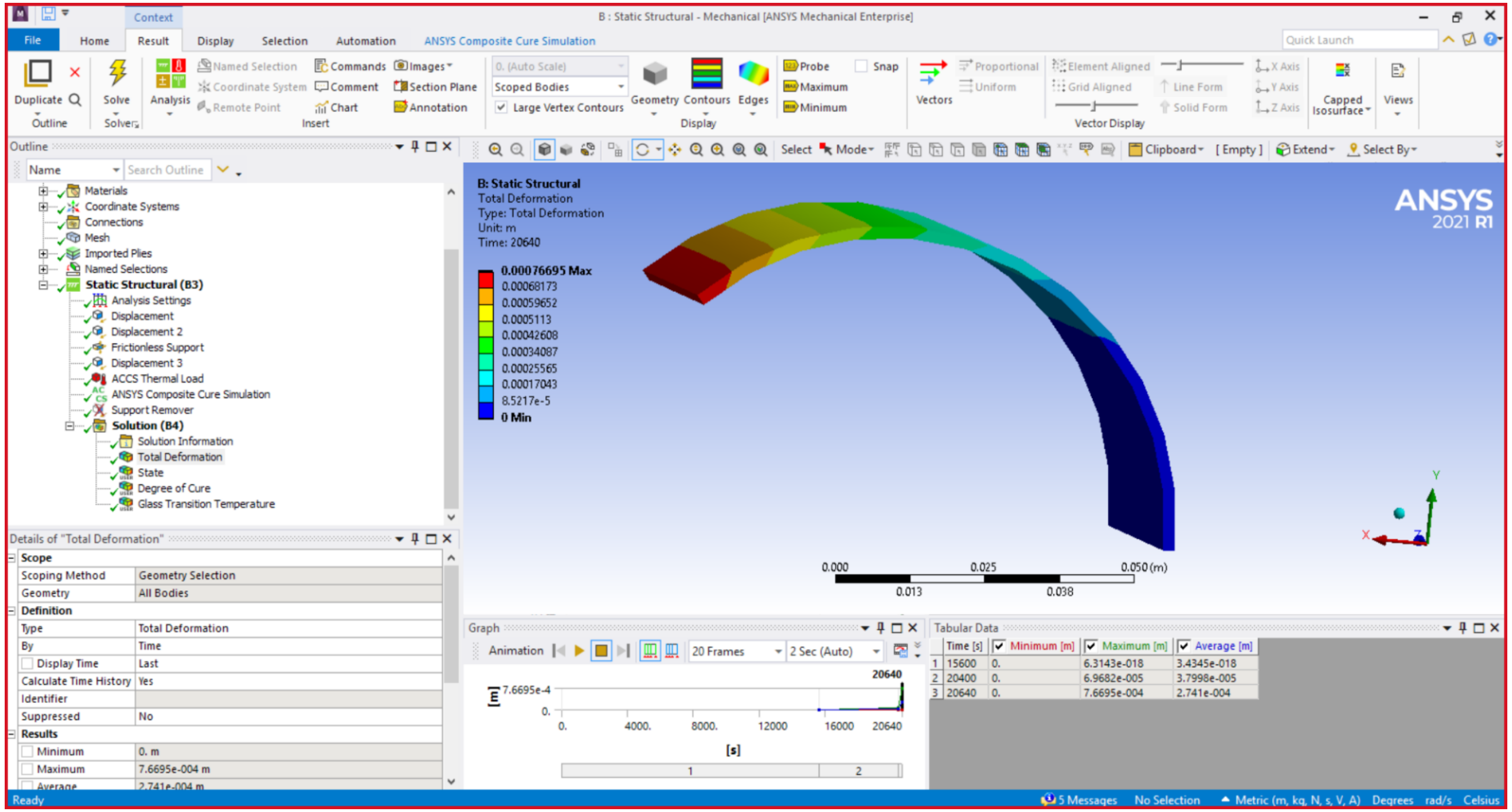


Workshop

Result Analysis

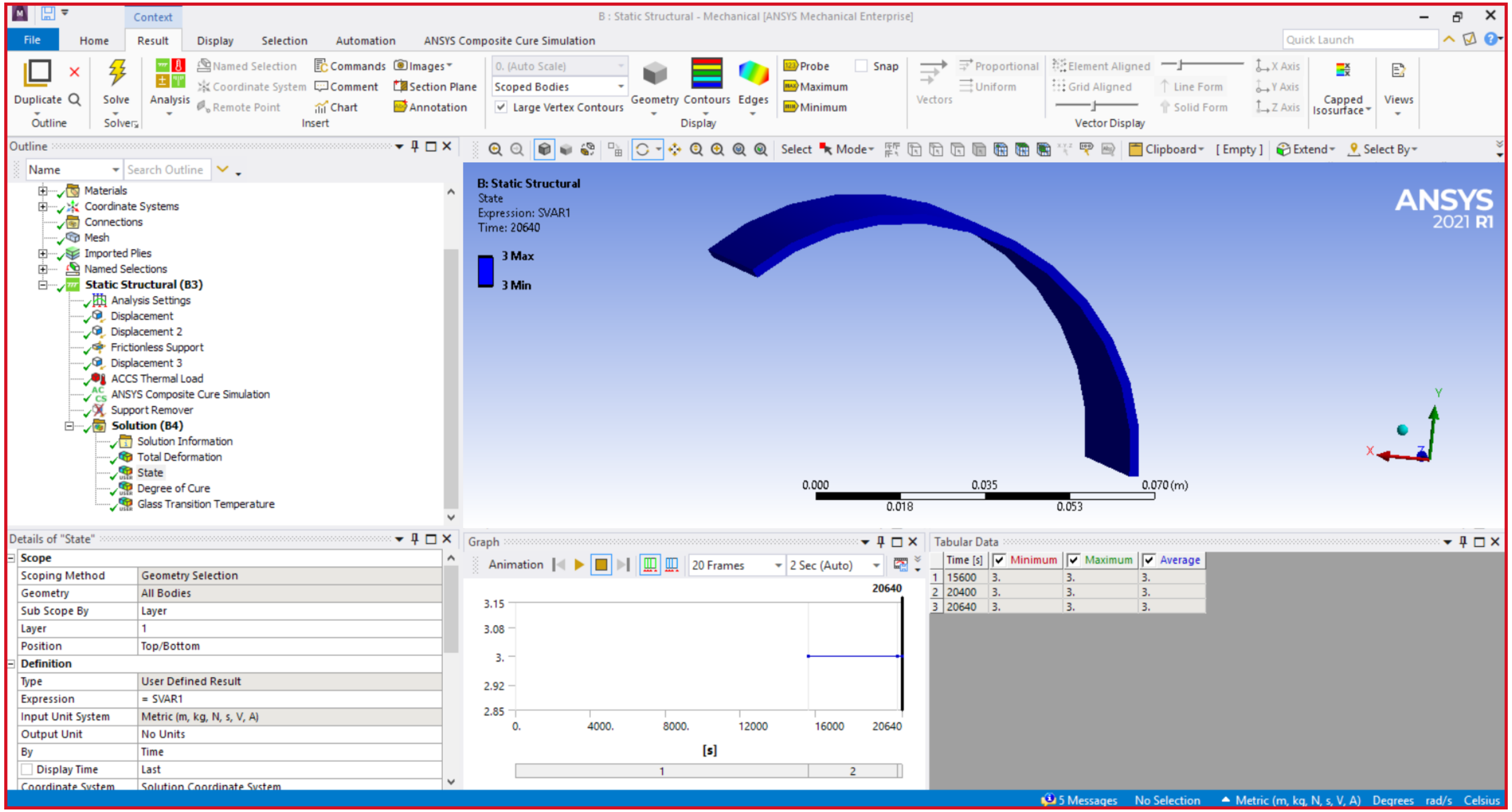
Result Analysis

As you may noticed, the deformations occurred in the last step, when the part is released from the mold. You can try to change the curing parameters to see what has a mayor effect in the process induced distortions (PID).



Result Analysis

Select the Degree of Cure result to display it. 1 means the part is completely cured.



Summary

Summary

In this workshop you learned:

- How to analyze the distortions of the curing process in a composite model build in ACP (Pre) using the fast cure simulation.
- That ACCS solutions use many material properties that can be obtained by a DSC test.
- To set up the curing cycle and the time stepping in a fast cure simulation, either by writing the data directly or by importing the manufacturer cure cycle in a .csv file.
- To define the DOF so the part is freely to deform ones it is released from the mold.
- Add and understand the function of the “Support remover” Boundary condition.