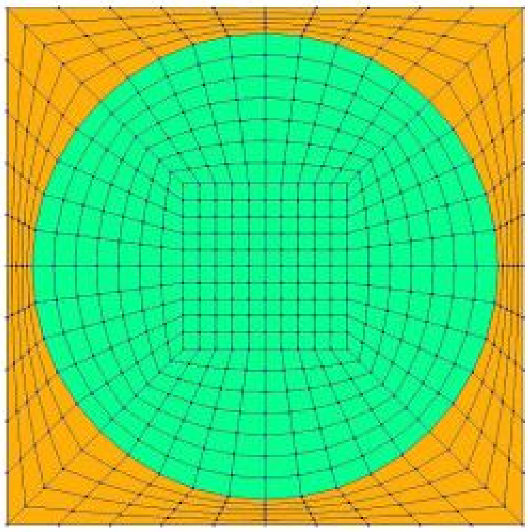
Computationof Viscoelastic Plate properties of a woven composite Corrugated Sandwich Sheet using Abaqus SwiftComp GUI, Texgen4SC and Swift Comp 2.1

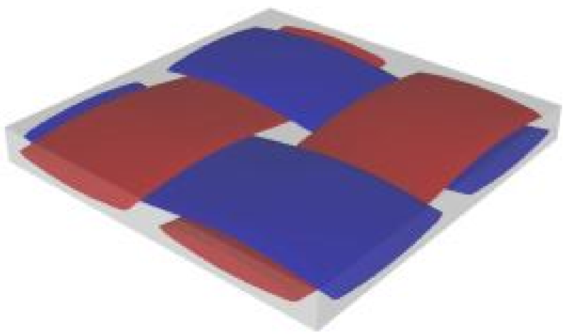
Viscoelastic Plate Properties of a Corrugated Sandwich Sheet

In this example, we want to compute the Viscoelastic effective properties of a Corrugated Sandwich Sheet fabricated from plain weave composite material made of isotropic viscoelastic matrix and transversely isotropic elastic fiber. The MSG solid model is used to predict the effective viscoelastic properties of a plain weave composite using a three part approach.

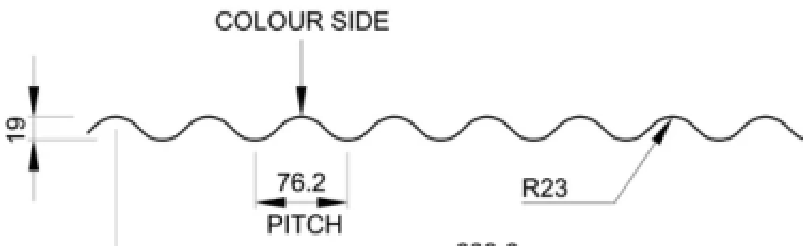
The first part predicts the effective viscoelastic yarn properties based on the elastic fiber and viscoelastic matrix properties at the microscale. The second part takes the effective yarn properties and matrix properties to predict the viscoelastic properties of weave composites. The third part takes the effective weave properties to predict the viscoelastic properties of the Corrugated Sandwich Sheet.

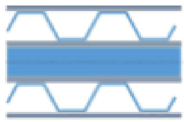


Yarn



Weave



Corrugated Sheet model 

Corrugated Sandwich Sheet example

The fiber properties are defined as transversely isotropic elastic by means of engineering constants and the matrix properties are given by means of the Prony coefficients with a constant Poisson's ratio equal to 0.33 as specified in the table below.

Fiber properties defined as transversely isotropic elastic

E1 (MPa)	E2 (MPa)	G12 (MPa)	G23 (MPa)	v12	v23
233,000.0	15,000.0	8,963.0	5639	0.23	0.33

Prony coefficients and relaxation times for the matrix

s	∞	1	2	3	4	5	6	7
λ	-	10^3	10^5	10^6	10^7	10^8	10^9	10^10
E (MPa)	1,000.0	224.1	450.8	406.1	392.7	810.4	203.7	1486.0

Material Properties

We will use a square pack 2D SG with fiber volume fraction equal to $v_f = 0.64$.

Software Used

We will use TexGen4SC 2.0, SwiftComp 2.1 and Abaqus CAE with the Abaqus SwiftComp GUI for this tutorial. TexGen4SC 2.0 will be used to run the viscoelastic homogenization of the fiber-matrix square pack micro structure and also for the viscoelastic homogenization of the plain weave laminate. Abaqus CAE will be used to model the sheet and to run the viscoelastic homogenization while SwiftComp runs in the background.

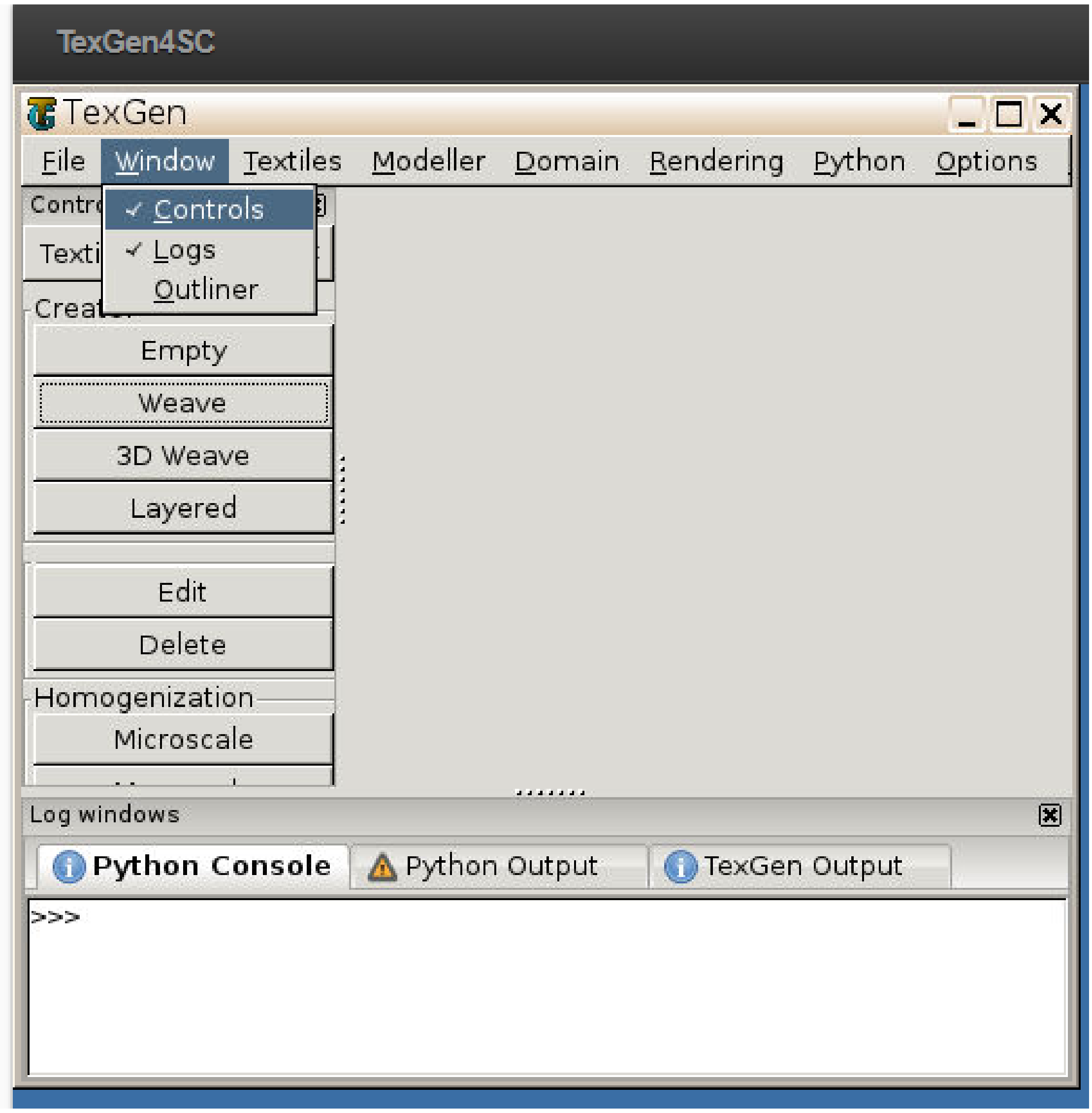
Solution Procedure

The problem is solved in the following three steps:
Part 1- Micro-scale analysis of the square-pack fiber matrix micro structure using Texgen4SC.
Part 2- Meso-scale analysis of the plain weave laminate using Texgen4SC.
Part 3- Macro-scale analysis of the Corrugated Sandwich Sheet using Abaqus CAE with the Abaqus SwiftComp GUI and SwiftComp 2.1.

Part 1- Micro-scale analysis of the square-pack fiber matrix micro structure using Texgen4SC.

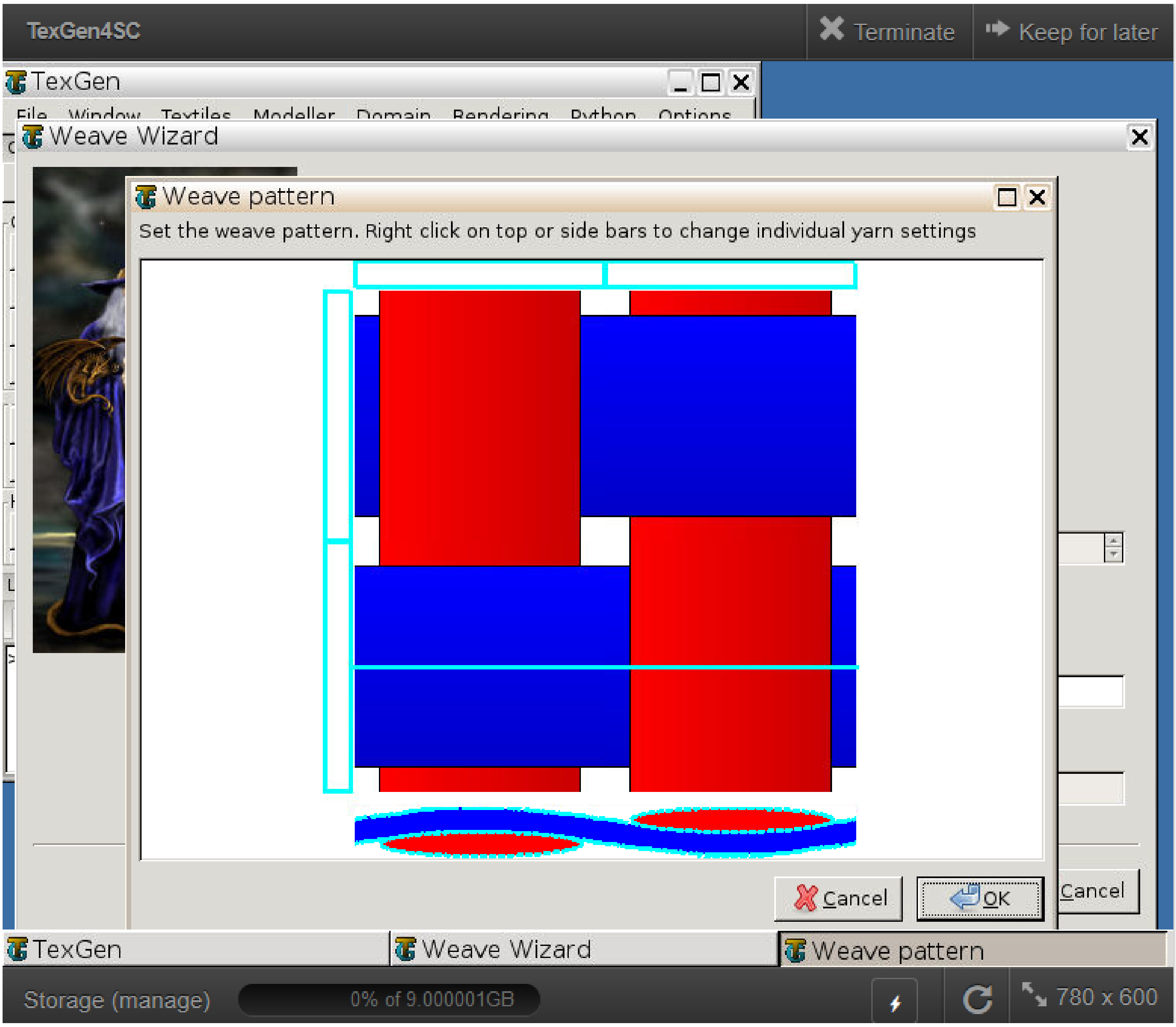
TexGen4SC 2.0 provides a function to let users import the material properties from a text file. Refer to the Predict viscoelastic plate properties of a single-layer plain weave laminate tutorials for more details regarding preparation of the materials text file.

Follow the step-by-step procedure to solve the problem.
 # Step 1.1. Create the plain weave pattern using TexGen4SC 2.0. Launch TexGen4SC 2.0 on cdmHUB, then Go to window-> controls-> “Weave” to create mesoscale plain weave SG.



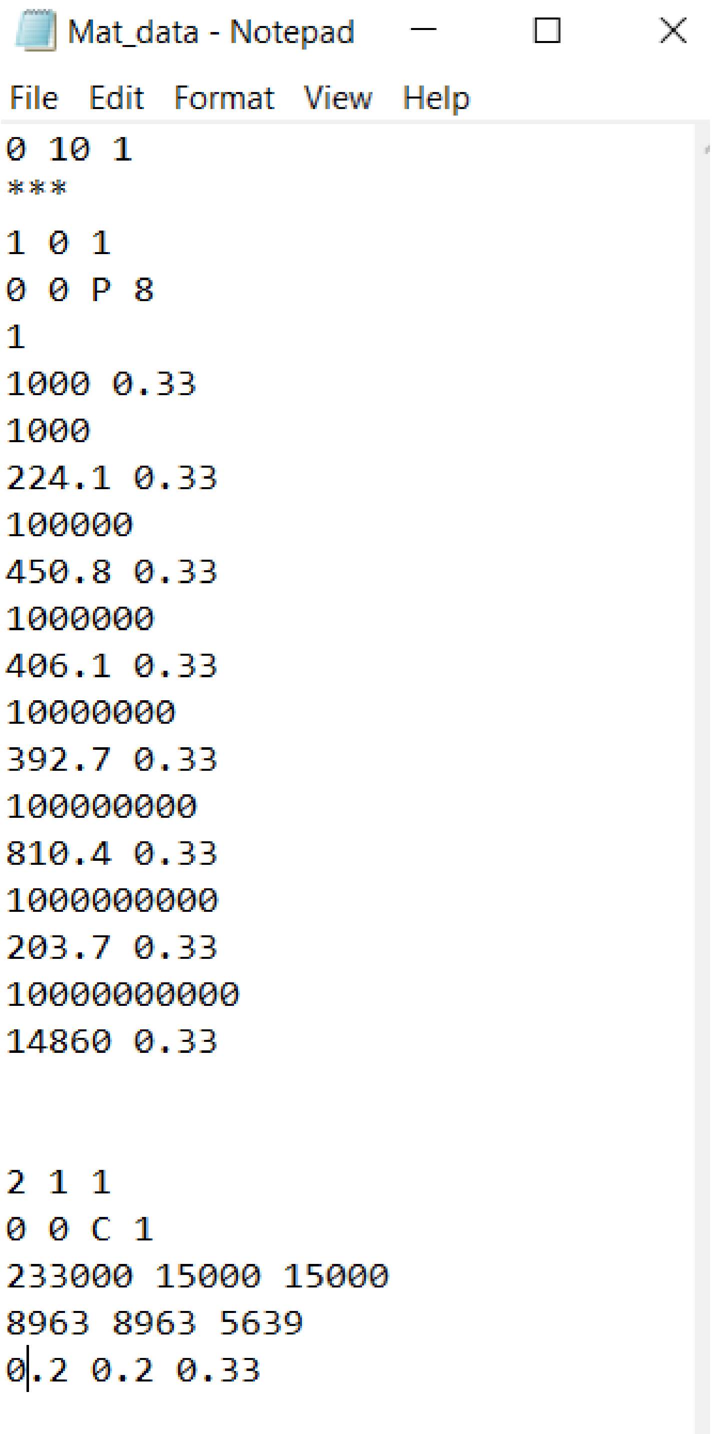
Weave Wizard

Step 1.2. Keeping the geometric properties as required, Click on the upper-right and lower-left squares to get the woven pattern.



Weave Pattern

Step 1.3. Upload the .txt file containing matrix and fiber properties to the current session, using any FTP app, for example, FileZilla, to set up connection with the current session. Refer to the[Predict viscoelastic plate properties of a single-layer plain weave laminate]() Tutorials for more details.



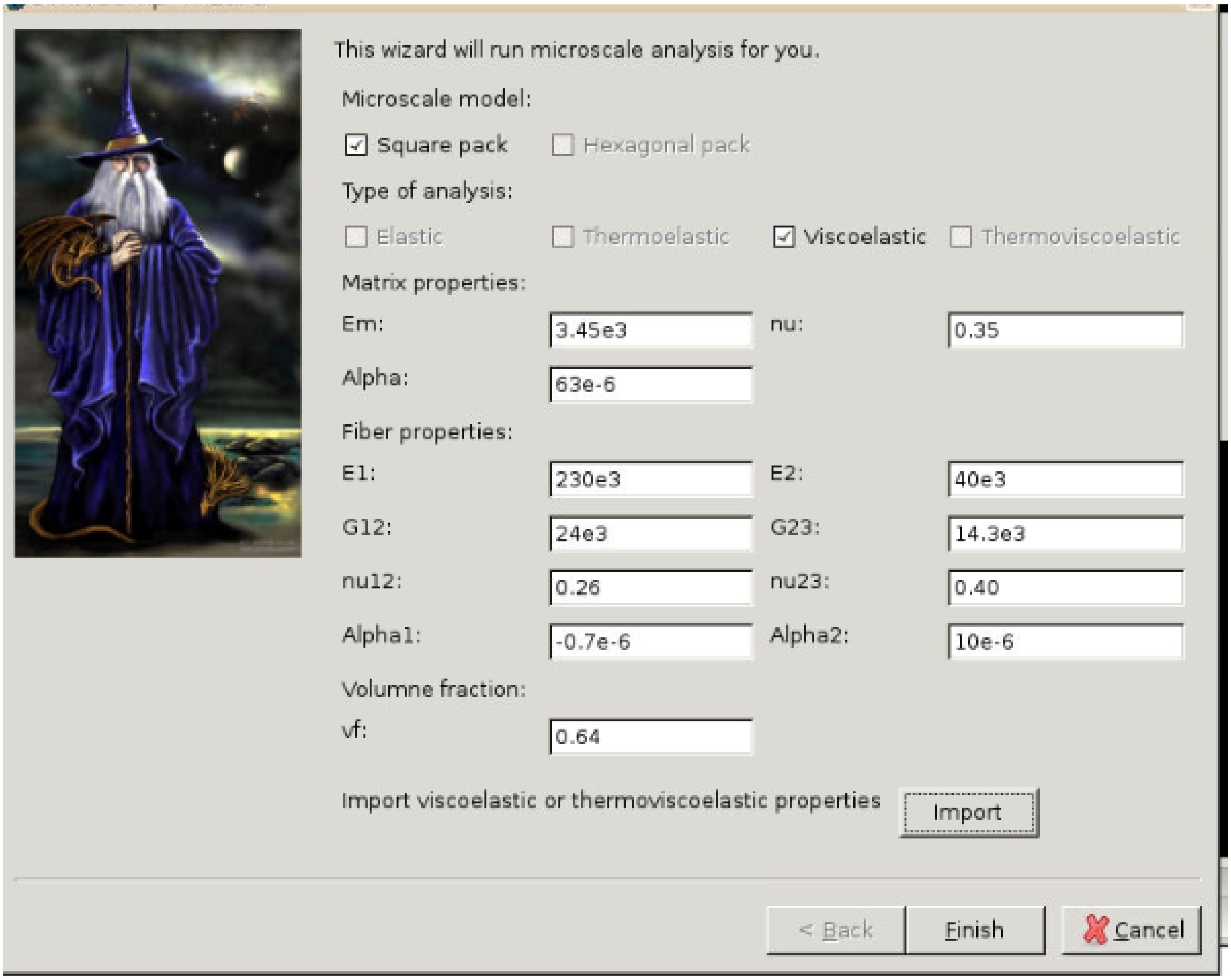
Mat_data - Notepad

File Edit Format View Help

```
0 10 1
***
1 0 1
0 0 P 8
1
1000 0.33
1000
224.1 0.33
100000
450.8 0.33
1000000
406.1 0.33
10000000
392.7 0.33
100000000
810.4 0.33
1000000000
203.7 0.33
10000000000
14860 0.33


2 1 1
0 0 C 1
233000 15000 15000
8963 8963 5639
0.2 0.2 0.33
```

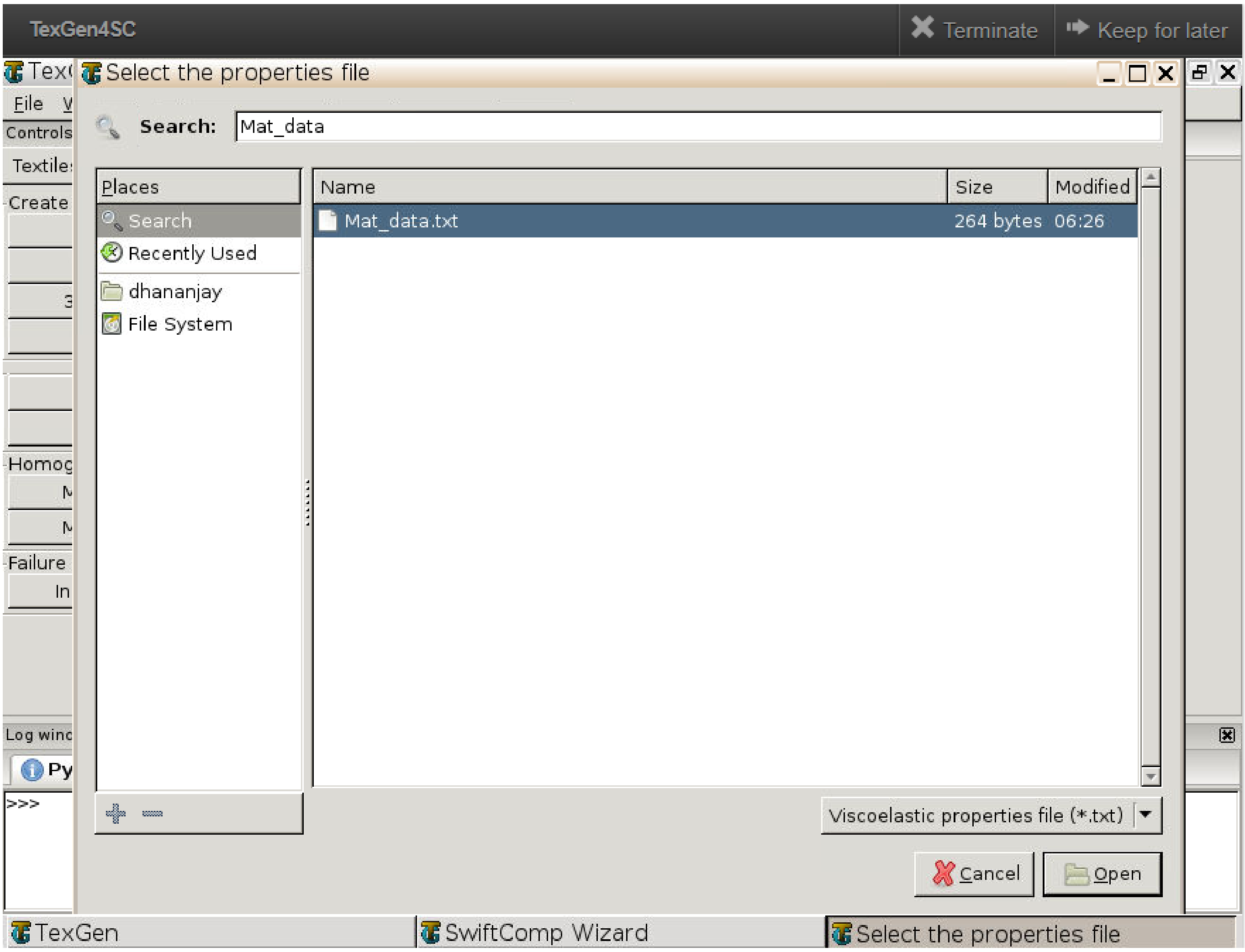
Importing Material properties text file

 # Step 1.4. Once you uploaded the .txt file, click “Microscale” under “Homogenization” tab for yarn property calculation. Select “Viscoelastic” as the type of analysis. Set fiber volume fraction to 0.64.



Homogenization

 # Step 1.5. Ignore the matrix and fiber properties in the window, since the material properties will be imported from the uploaded file.



Property file

Step 1.5. Click “Import” and select the uploaded .txt file and Click “Finish”. Now a .sc file (micro.sc) will be generated that SwiftComp will take as the input. SwiftComp will run on the cloud to calculate viscoelastic properties of yarns, e.g., effective microscale properties. In the pop-up window, you will find the analysis results.

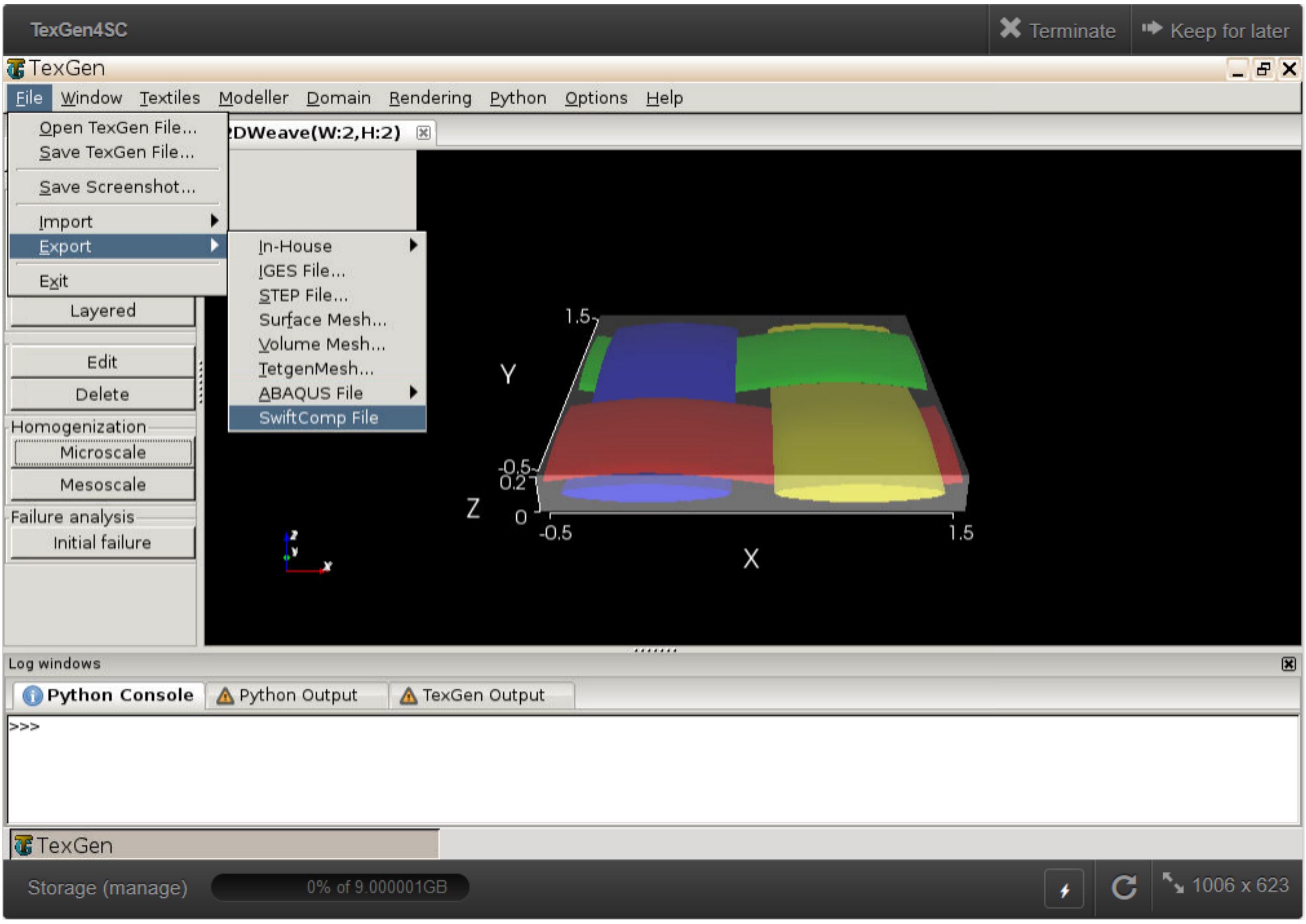
micro.sc.k

```
#---------------------------------------------------------#
Effective Viscoelastic Properties at Time: t =       1.0000000E+000

The Effective Stiffness Matrix
-------------------------------------------
      1.5905452E+005     6.9429652E+003     6.9429633E+003    -9.2747546E-004     0.0000000E+000     0.0000000E+000
      6.9429652E+003     1.9819295E+004     7.6742466E+003    -1.1722393E-002     0.0000000E+000     0.0000000E+000
      6.9429633E+003     7.6742466E+003     1.9819291E+004     9.8404582E-003     0.0000000E+000     0.0000000E+000
     -9.2747546E-004    -1.1722393E-002     9.8404582E-003     6.0440591E+003     0.0000000E+000     0.0000000E+000
      0.0000000E+000     0.0000000E+000     0.0000000E+000     0.0000000E+000     8.1507328E+003    -9.4817636E-005
      0.0000000E+000     0.0000000E+000     0.0000000E+000     0.0000000E+000    -9.4817636E-005     8.1507330E+003

The Effective Compliance Matrix
-------------------------------------------
      6.4288881E-006    -1.6234922E-006    -1.6234917E-006     4.8102178E-013     0.0000000E+000     0.0000000E+000
     -1.6234922E-006     5.9765115E-005    -2.2572976E-005     1.5241626E-010     0.0000000E+000     0.0000000E+000
     -1.6234917E-006    -2.2572976E-005     5.9765126E-005    -1.4133404E-010     0.0000000E+000     0.0000000E+000
      4.8102178E-013     1.5241626E-010    -1.4133404E-010     1.6545173E-004     0.0000000E+000     0.0000000E+000
      0.0000000E+000     0.0000000E+000     0.0000000E+000     0.0000000E+000     1.2268836E-004     1.4272360E-012
      0.0000000E+000     0.0000000E+000     0.0000000E+000     0.0000000E+000     1.4272360E-012     1.2268835E-004

The Engineering Constants (Approximated as Orthotropic)
-------------------------------------------------------------
 E1  =       1.5554789E+005
 E2  =       1.6732169E+004
 E3  =       1.6732166E+004
 G12 =       8.1507330E+003
 G13 =       8.1507328E+003
 G23 =       6.0440591E+003
 nu12=       2.5253079E-001
 nu13=       2.5253072E-001
 nu23=       3.7769485E-001


Effective Density =       0.0000000E+000
#---------------------------------------------------------#
Effective Viscoelastic Properties at Time: t =       1.0000000E+001

The Effective Stiffness Matrix
-------------------------------------------
      1.5905361E+005     6.9426822E+003     6.9426803E+003    -9.2679192E-004     0.0000000E+000     0.0000000E+000
      6.9426822E+003     1.9818548E+004     7.6740087E+003    -1.1709267E-002     0.0000000E+000     0.0000000E+000
```

Micro scaleResuts

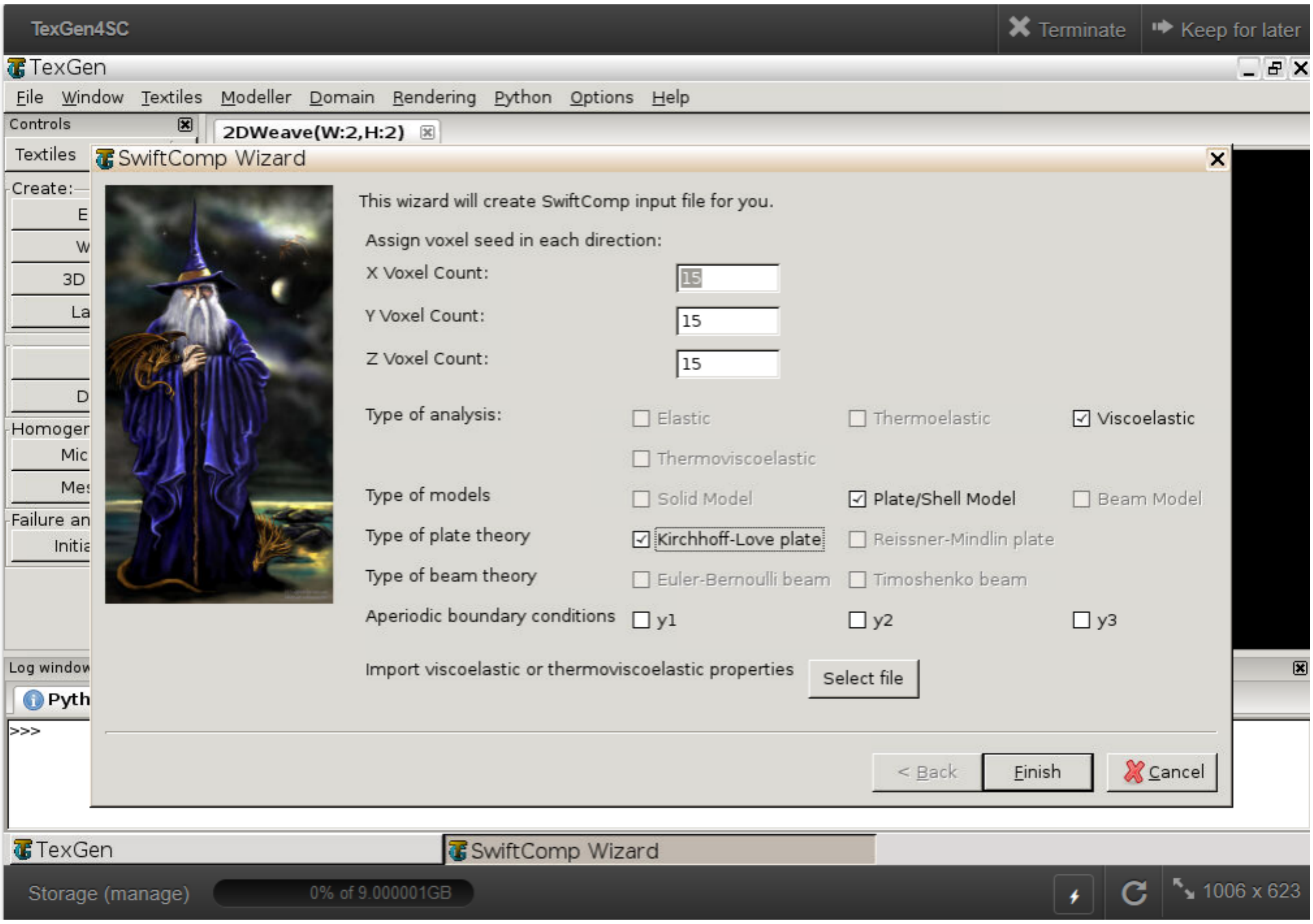
Part 2- Meso-scale analysis of the plain weave laminate using Texgen4SC.

 # Step 2.1. Go to “File->Export->SwiftComp File” to generate the .sc file for mesoscale analysis.

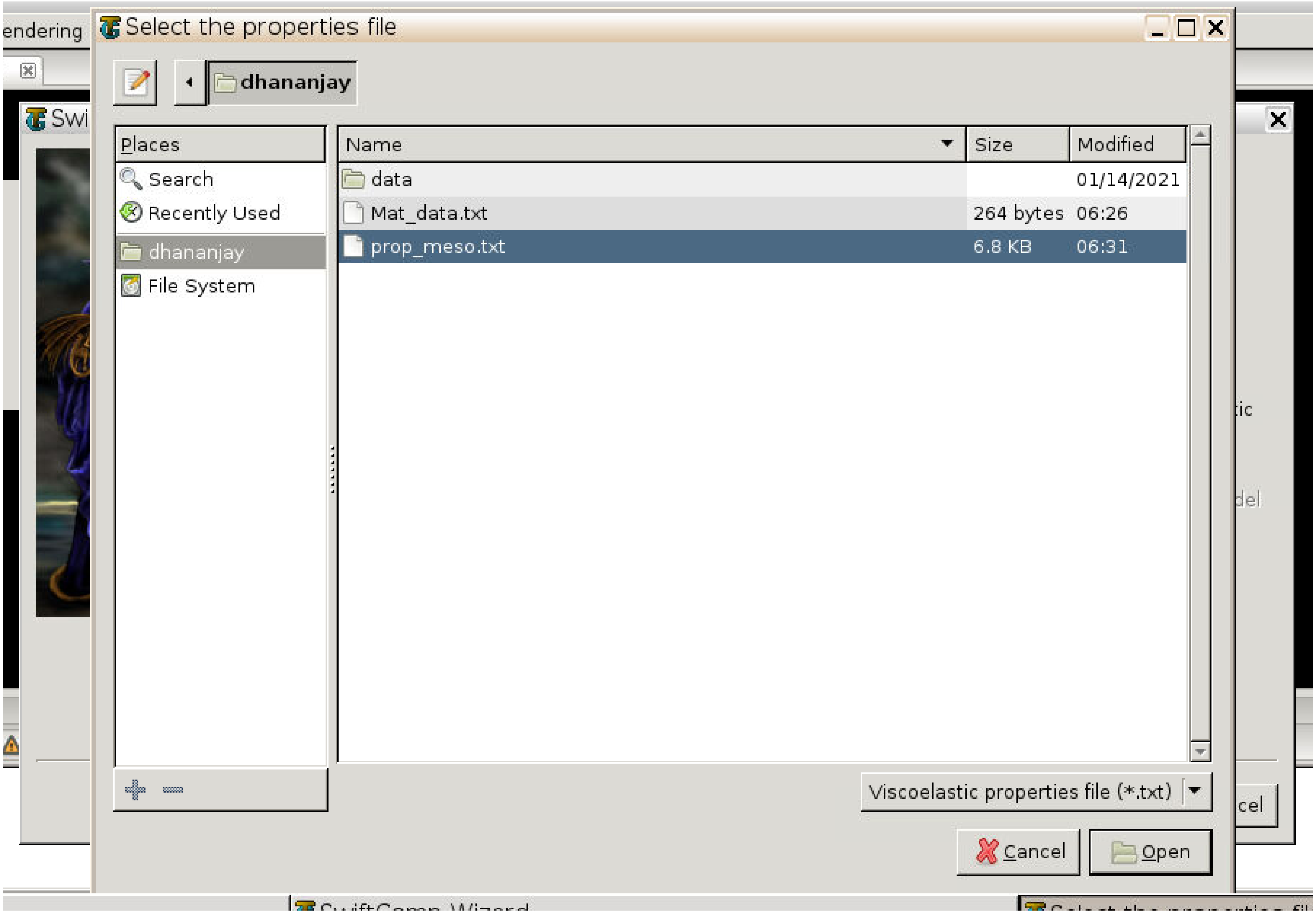


weave mesh

 # **Step 2.2.** Define the voxel mesh, Select “Viscoelastic” as Type of analysis and Select “Plate/Shell model” and “Kirchhoff-Love plate”. Click “Select file” and select “prop_meso.txt” which is automatically generated during microscale analysis, and will be used as part of mesoscale analysis input file.



SwiftComp Wizard



Property file

Step 2.3. Save the .sc (SwiftComp input file) file with a filename of your choice. Click “Mesoscale” in “Homogenization” tab, which will call SwiftComp to calculate fabric properties.

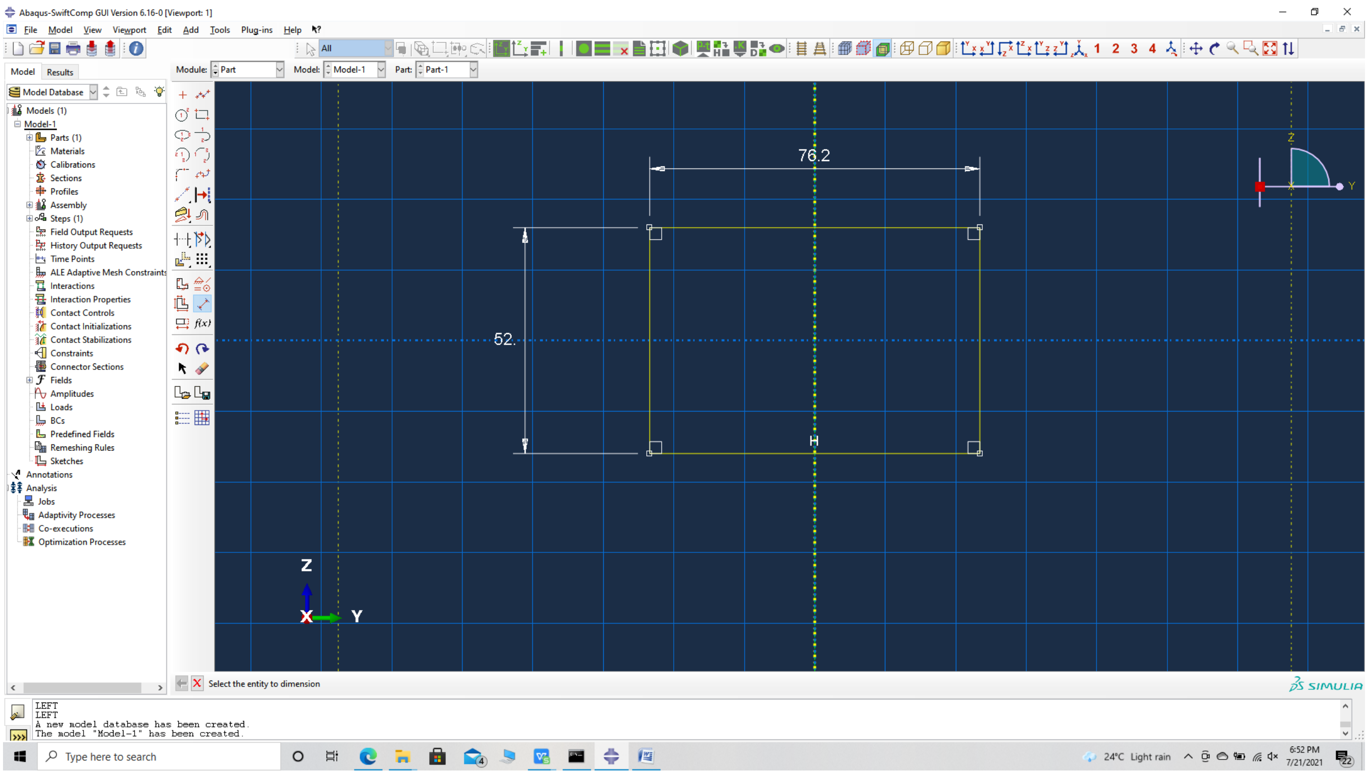
```
micro.sc.k   Trac_Boom_Meso.sc.k
#------------------------------------------------------------#
Effective Viscoelastic Properties at Time: t =       1.0000000E+000

The Effective Stiffness Matrix
-----------------------------------------------
      1.0296956E+004    2.2829771E+003   -2.2146829E-003    2.7663528E-004    9.0027160E-006   -3.0232876E-003
      2.2829771E+003    1.0296954E+004    1.0873695E-002   -1.6574217E-004    3.7136883E-004    3.2771317E-003
     -2.2146829E-003    1.0873695E-002    1.5220751E+003   -3.4197595E-002    3.4230130E-002    3.5042926E-006
      2.7663528E-004   -1.6574217E-004   -3.4197595E-002    2.0573200E+001    3.1276517E+000   -1.2141517E-006
      9.0027160E-006    3.7136883E-004    3.4230130E-002    3.1276517E+000    2.0573195E+001    3.1289359E-006
     -3.0232876E-003    3.2771317E-003    3.5042926E-006   -1.2141517E-006    3.1289359E-006    4.8755161E+000

The Effective Compliance Matrix
-----------------------------------------------
      1.0213682E-004   -2.2645146E-005    3.1033909E-010   -1.6486571E-009    6.1418505E-010    7.8555807E-008
     -2.2645146E-005    1.0213684E-004   -7.6253595E-010    1.4378770E-009   -2.0510858E-009   -8.2694558E-008
      3.1033909E-010   -7.6253595E-010    6.5699787E-004    1.2880402E-006   -1.2889424E-006   -4.7036635E-010
     -1.6486571E-009    1.4378770E-009    1.2880402E-006    4.9756897E-002   -7.5643228E-003    1.7242583E-008
      6.1418505E-010   -2.0510858E-009   -1.2889424E-006   -7.5643228E-003    4.9756910E-002   -3.3813307E-008
      7.8555807E-008   -8.2694558E-008   -4.7036635E-010    1.7242583E-008   -3.3813307E-008    2.0510649E-001

In-Plane Properties
--------------------------------------------------------------
 E1  =       4.8953942E+004
 E2  =       4.8953933E+004
 G12 =       7.6103748E+003
 nu12=       2.2171383E-001
 eta121=       4.7235935E-007
 eta122=      -1.1606369E-006

Flexural Properties
--------------------------------------------------------------
 E1  =       3.0146574E+004
 E2  =       3.0146567E+004
 G12 =       7.3132741E+003
 nu12=       1.5202561E-001
 eta121=       8.4066490E-008
 eta122=      -1.6485732E-007


Effective Density =       0.0000000E+000
#------------------------------------------------------------#
```

Meso Scale Results

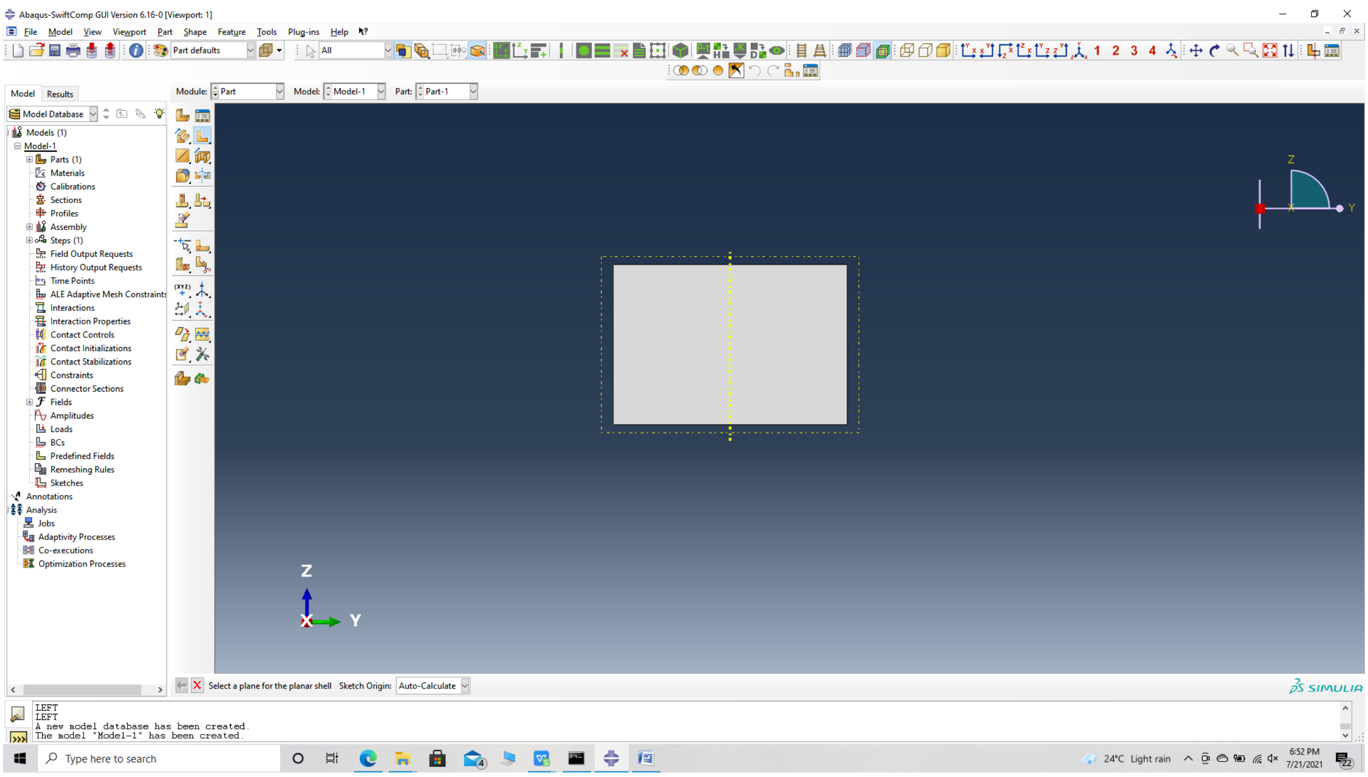
 # Step 2.4. Transfer this file to your local computer for further analysis.

Part 3- Macro-scale analysis of the Corrugated Sandwich Sheet using Abaqus CAE with the Abaqus SwiftComp GUI and SwiftComp 2.1.

 # Step 3.1. Using Abaqus CAE with the Abaqus SwiftComp GUI plugin, Create the part geometry for the Corrugated Sandwich Sheet. Use Set sketch plane for customized SG -> Create planar shell -> Select the plane and vertical axis -> Sketch the rectangle shown and create the part.

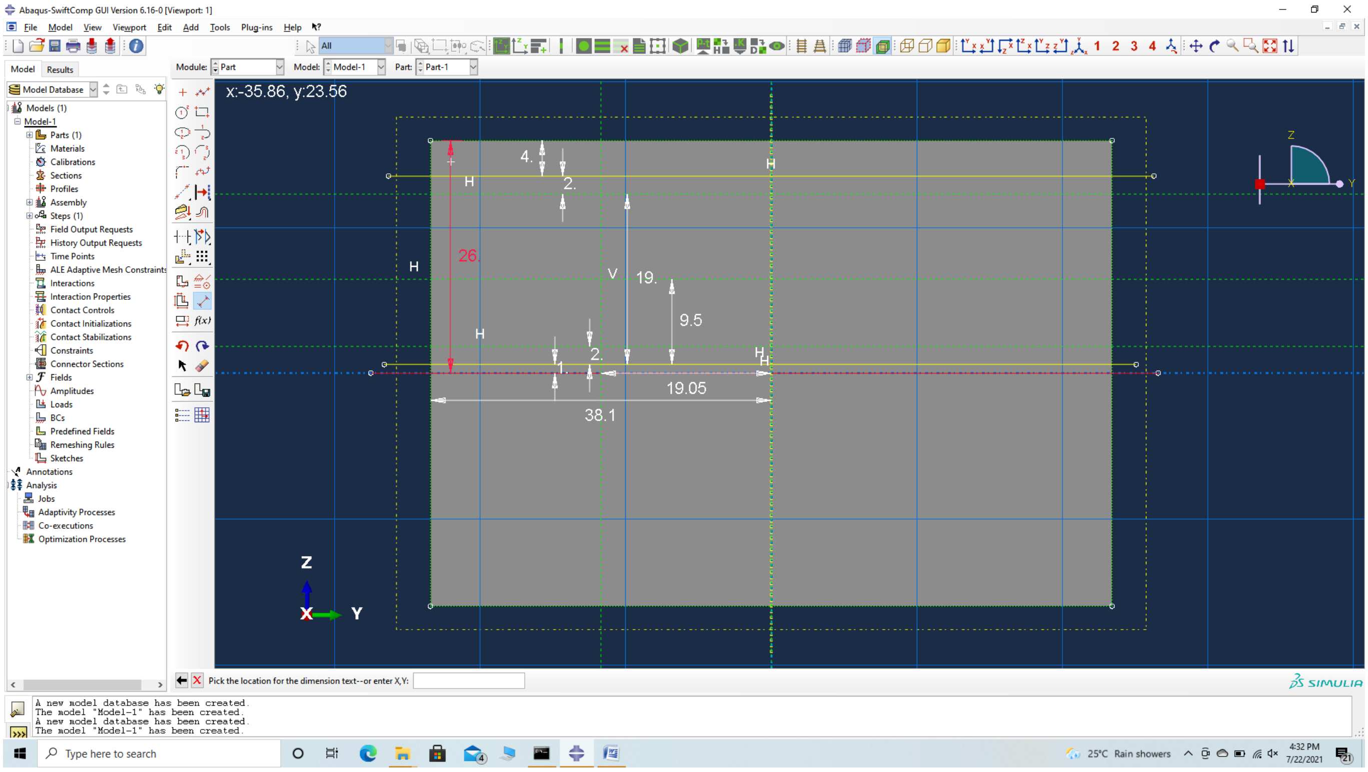


Part Geometry



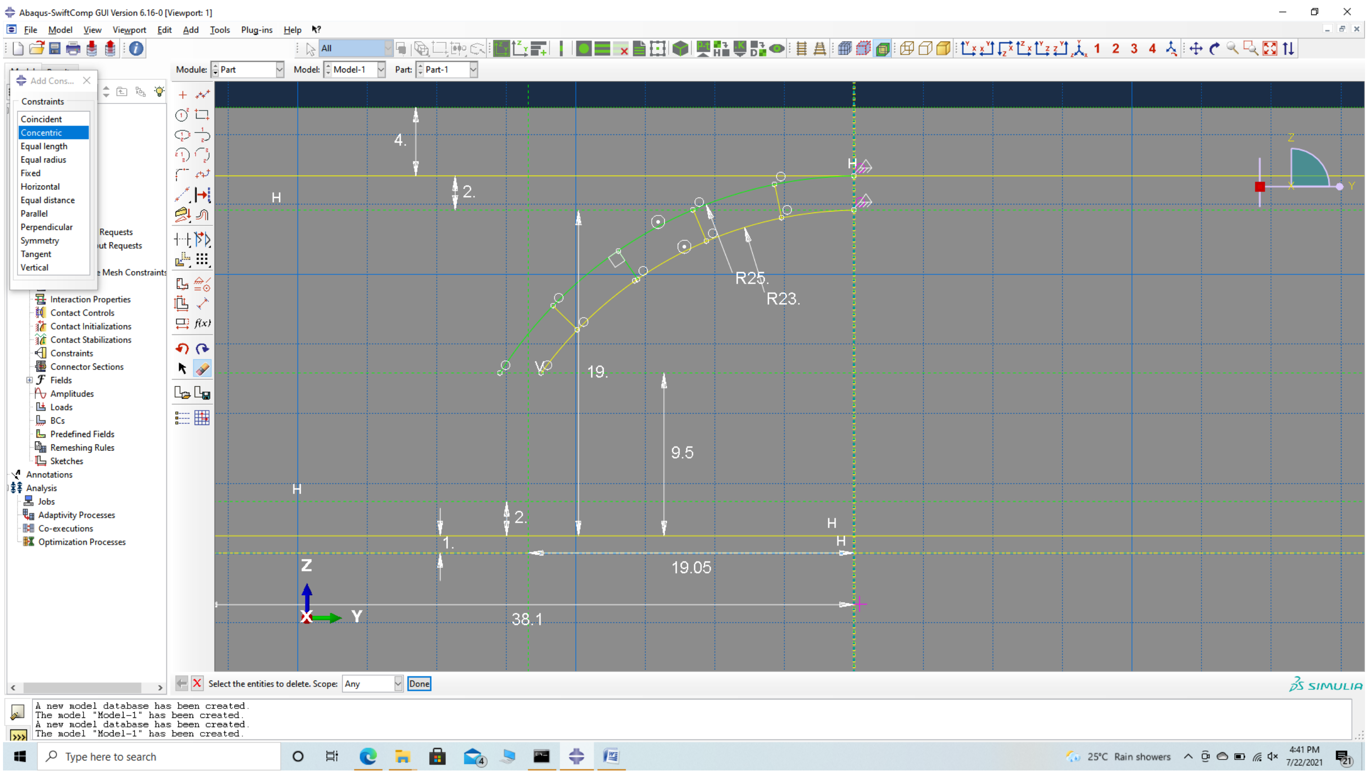
Part Geometry

 # Step 3.2. Partition the part as shown to obtain the required cross-section. We focus on one quadrant and later mirror our partition lines to the other quadrants. Firstly add two horizontal partition lines, three horizontal construction lines, one vertical partition line and one vertical construction line as shown.



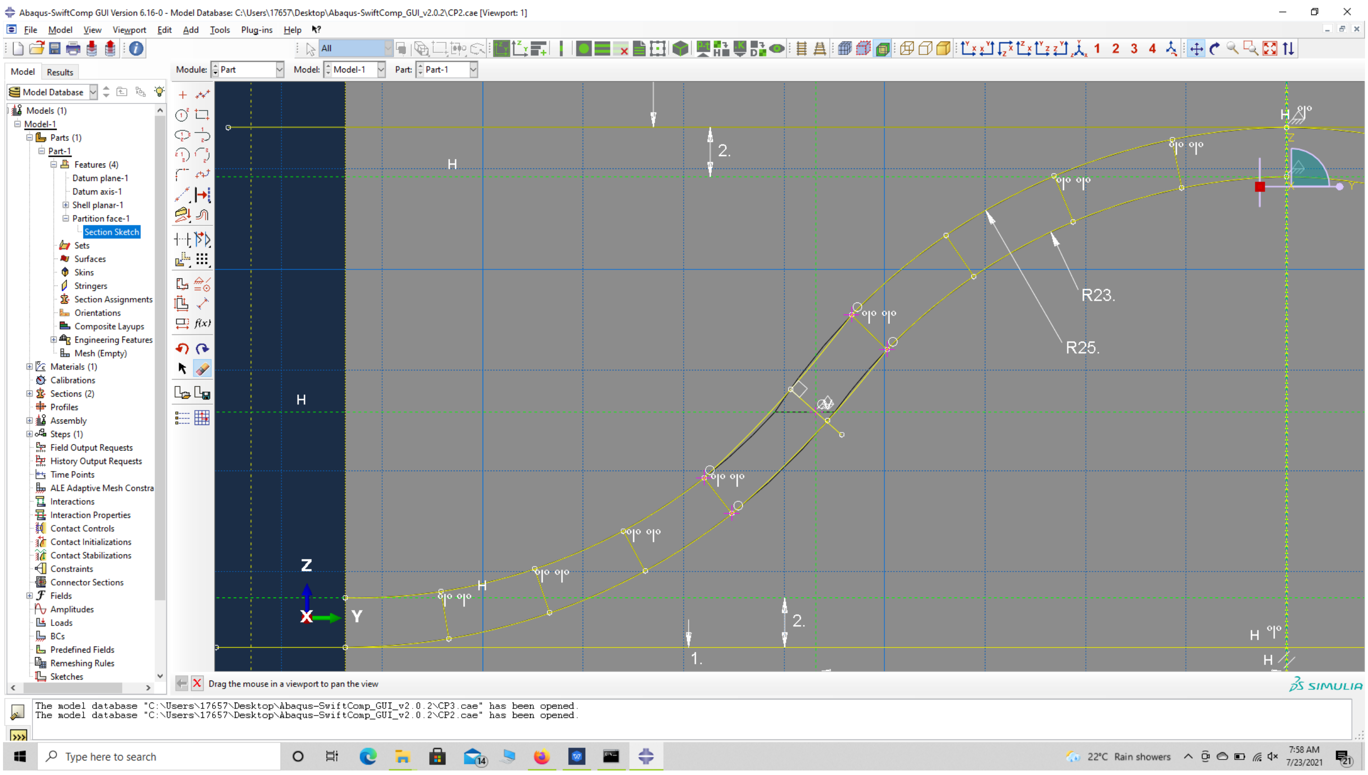
first set of Partitions

 # Step 3.3. Now add two arcs using create arc tru three points as shown. Fix their starting points on the vertical partition, and choose their end points on the second horizontal construction line and choose their third point at random. Constrain their concentricity and set the inner radius as 23 mm. Add partitions to the curves to help add their material properties later.



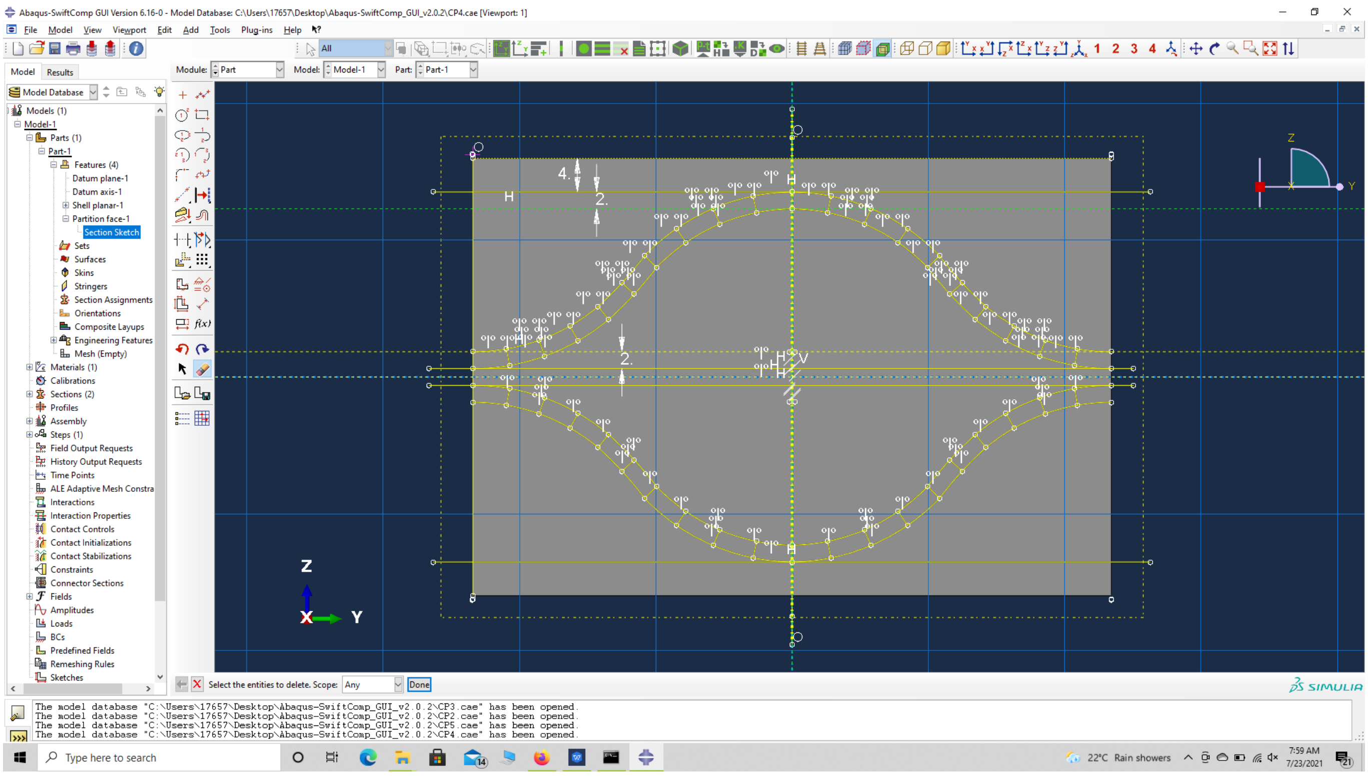
second set of Partitions

 # Step 3.4. Now add the other two arcs of the quadrant as shown. Fix their starting points on the edge, and choose their end points on the second horizontal construction line coinciding with the ends of the previous arcs and choose their third point at random. Constrain their concentricity. Add partitions to the curves to help add their material properties later. Now adjust the meeting of the two pairs of curves to smooth en it by, trimming the sections they meet and replacing it with a new pair of curves which is sectioned so that the section line passes through the intersection of the second horizontal construction line and the vertical construction line as shown.



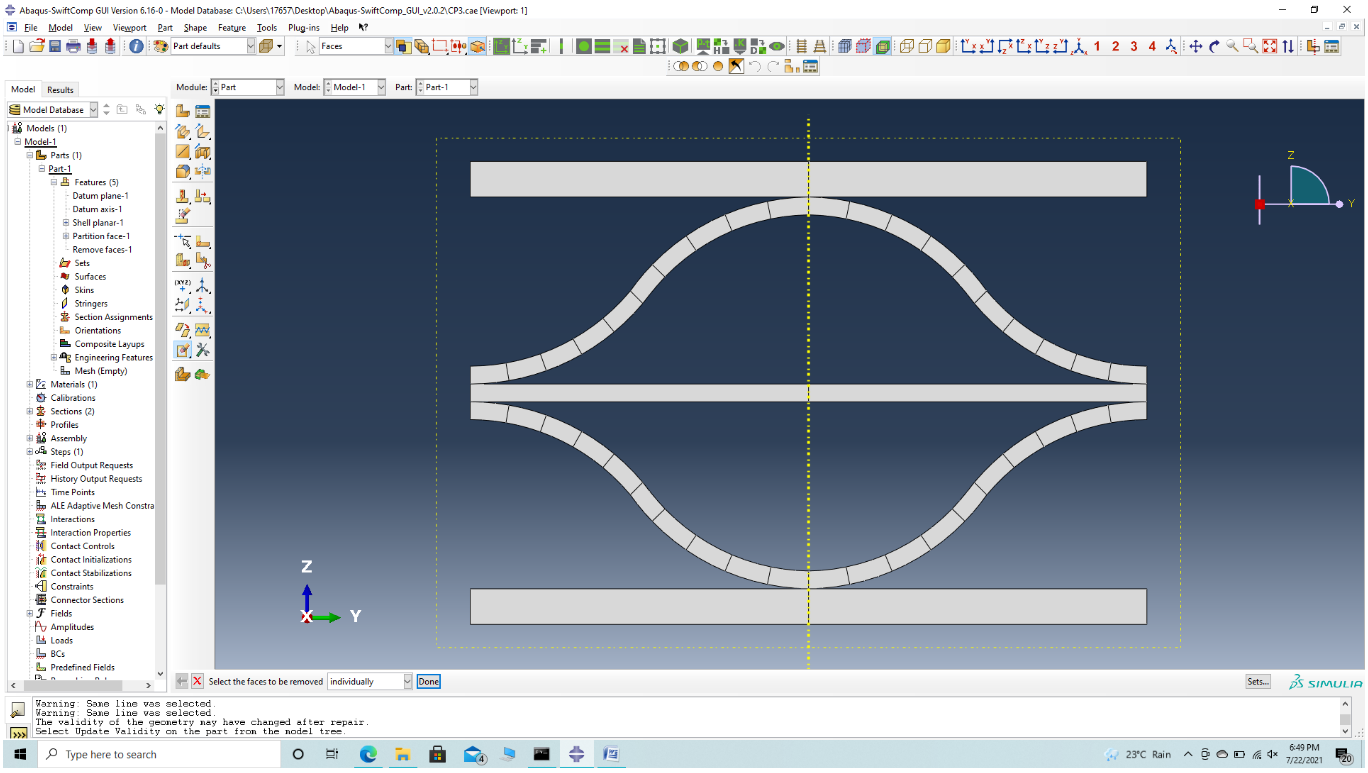
Third set of Partitions

 # Step 3.5. Mirror the partition lines for the other quadrants to have the partition lines shown.



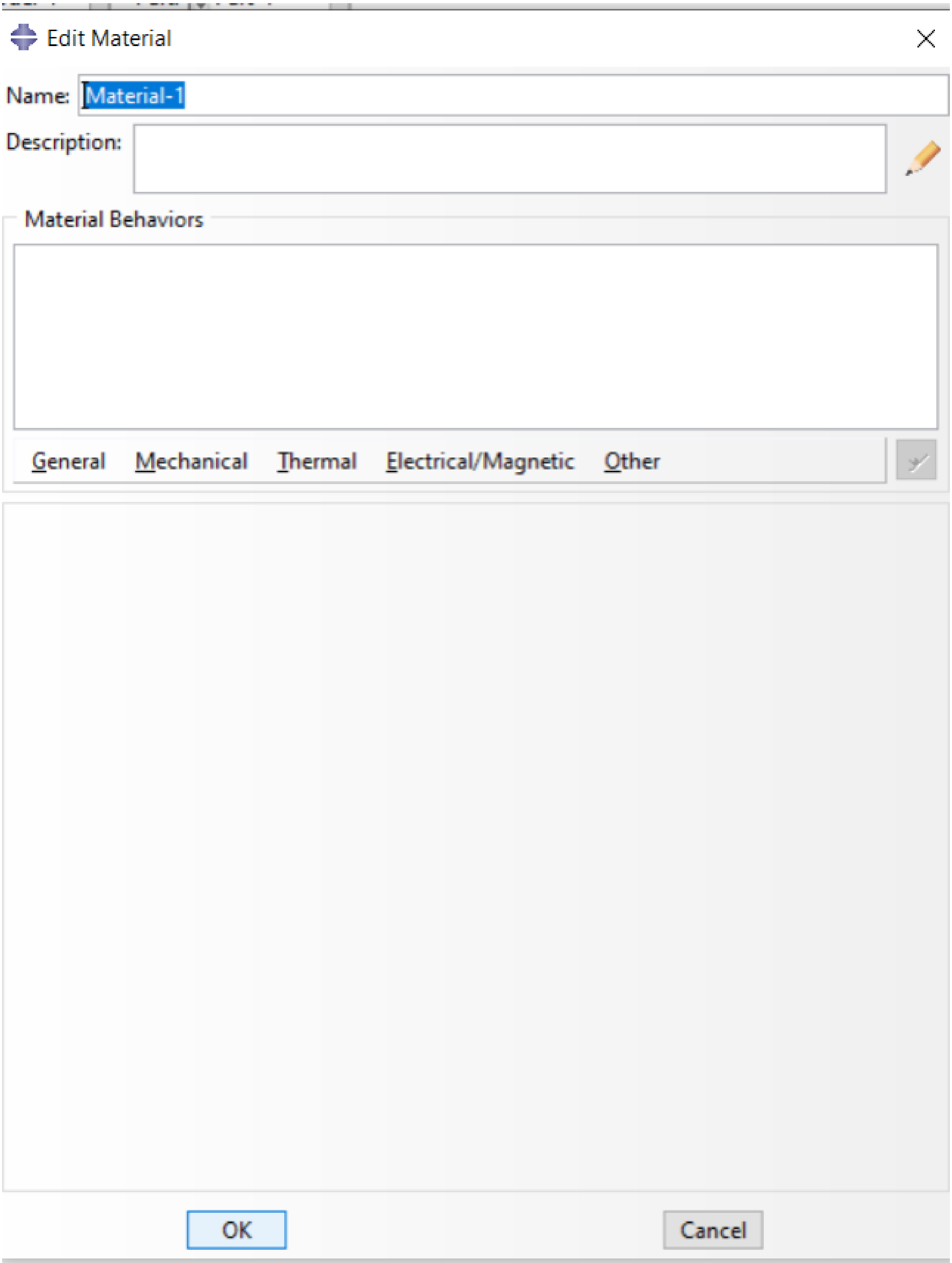
Fourth set of Partitions

 # Step 3.6. Create the part and delete the redundant faces to have the final part shown.



Sandwich corrugated sheet

 # Step 3.7. To enter the material properties for the part, first we need to choose the material properties from the results of the computed effective viscoelastic properties in the previous part. Within the Materials section of Abaqus CAE, we create a dummy material called "Material". Please note that we will not define the material properties using the Abaqus SwiftComp GUI. refer to the [Computation of effective viscoelastic properties with Abaqus SwiftComp GUI] tutorial for more details.

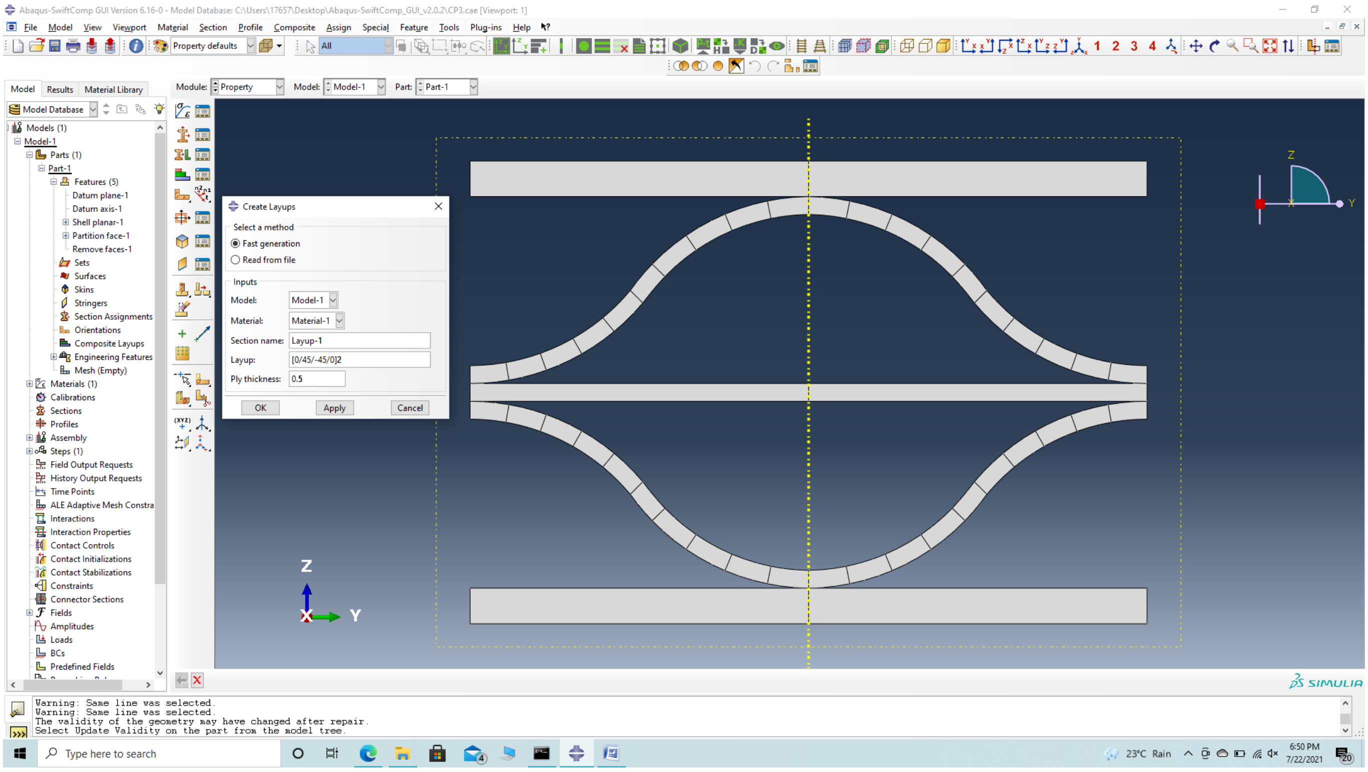

Edit Material
Name: Material-1
Description:
Material Behaviors
General
Mechanical
Thermal
Electrical/Magnetic
Other
OK
Cancel

dd

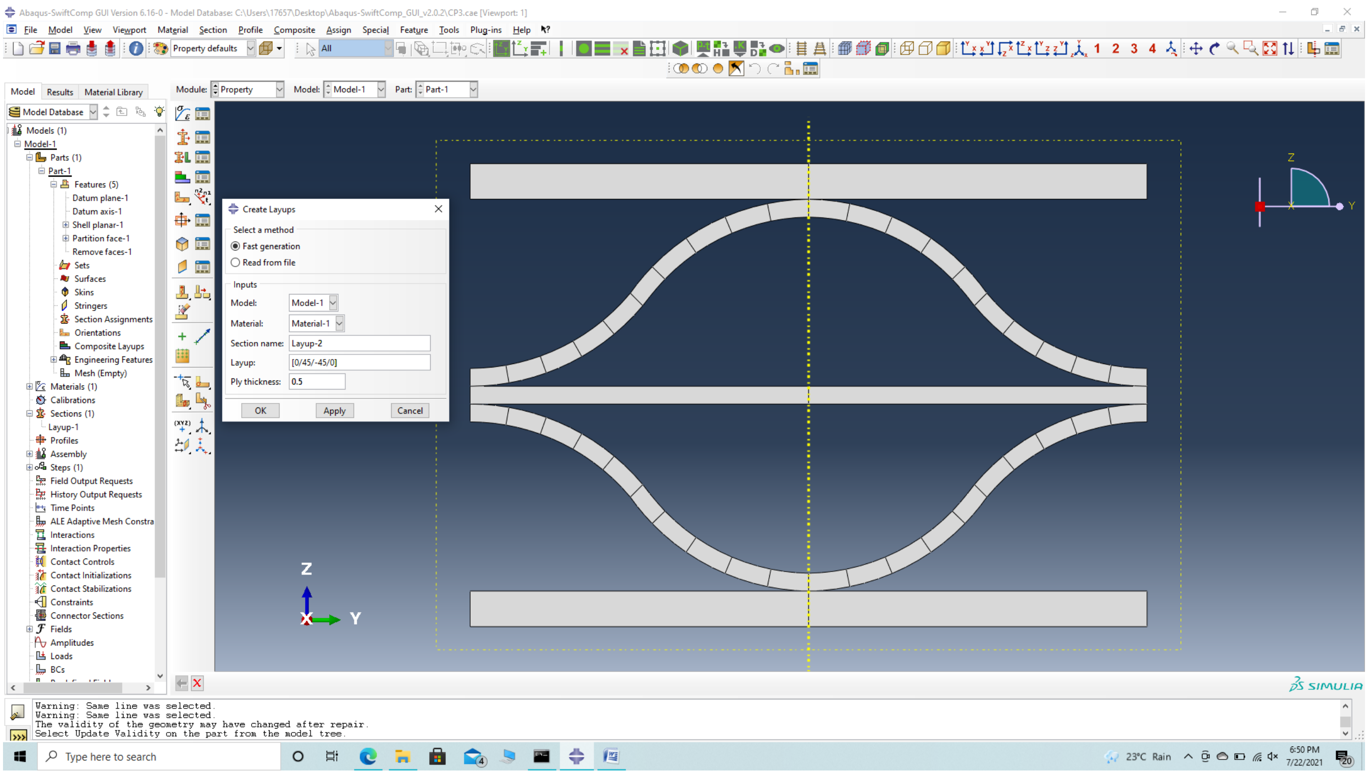
Step 3.8.Import the material properties from the previous step. Since the material properties are given as a time-dependent properties, We will create a text file to input the time-dependent material properties described row wise as –
We will use the in plane engineering constants defined by means of engineering constants unless If we are modelling for flexure, we will use the flexural properties. We will define the material properties in the text file as Orthotropic defined by means of engineering constants. —- E1 (t) —- E2 (t) —- E3 (t) —- nu12 (t) —- nu13 (t) —- nu23 (t) —- G12 (t) —- G13 (t) —- G23 (t) —- Time t for all time intervals.

(Image(CS3.81.png, desc="Material properties file") failed - File not found)

Step 3.9. Now go to New Layups and add the material, section name, Layup and thickness to create the required layup. This can be repeated if we have multiple layups. We will use (0/45/-45/0)2 and (0/45/-45/0) as the laminate for the sheet.

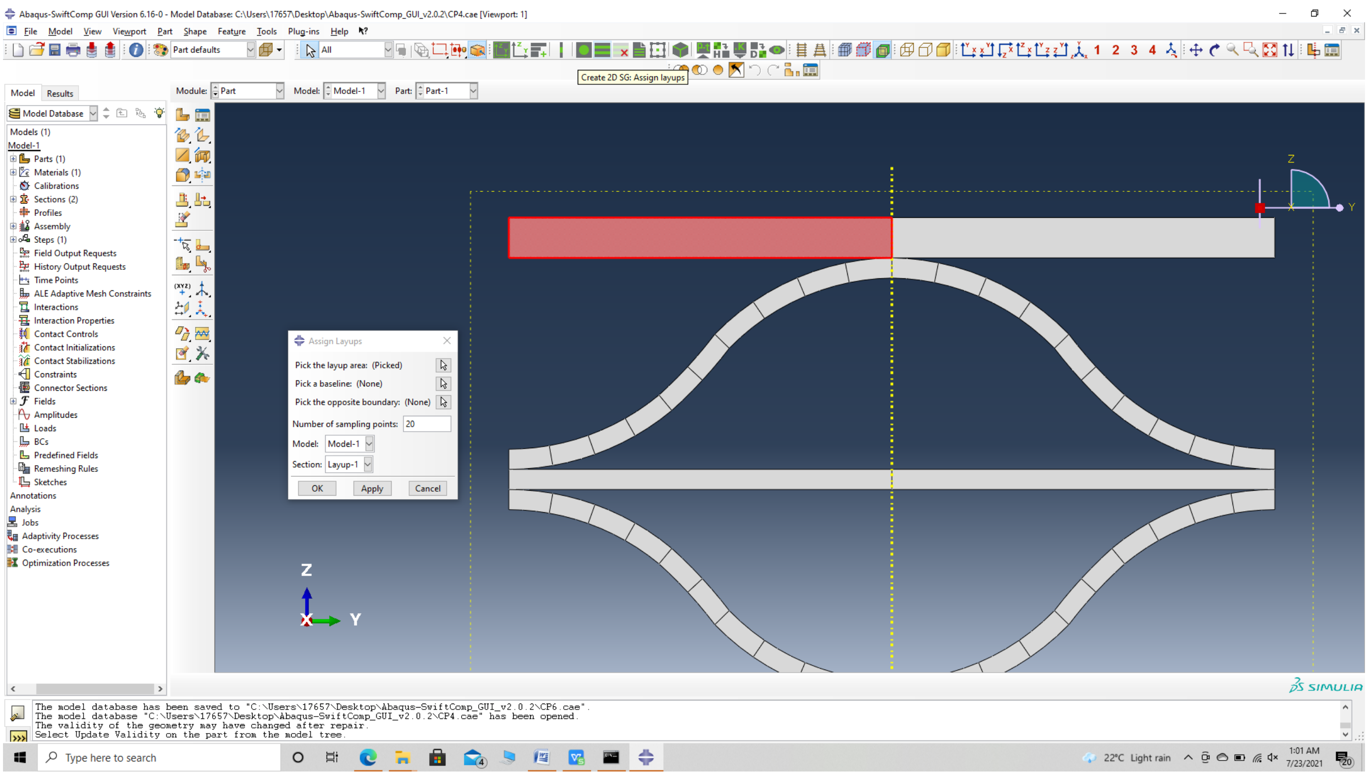


First Layup

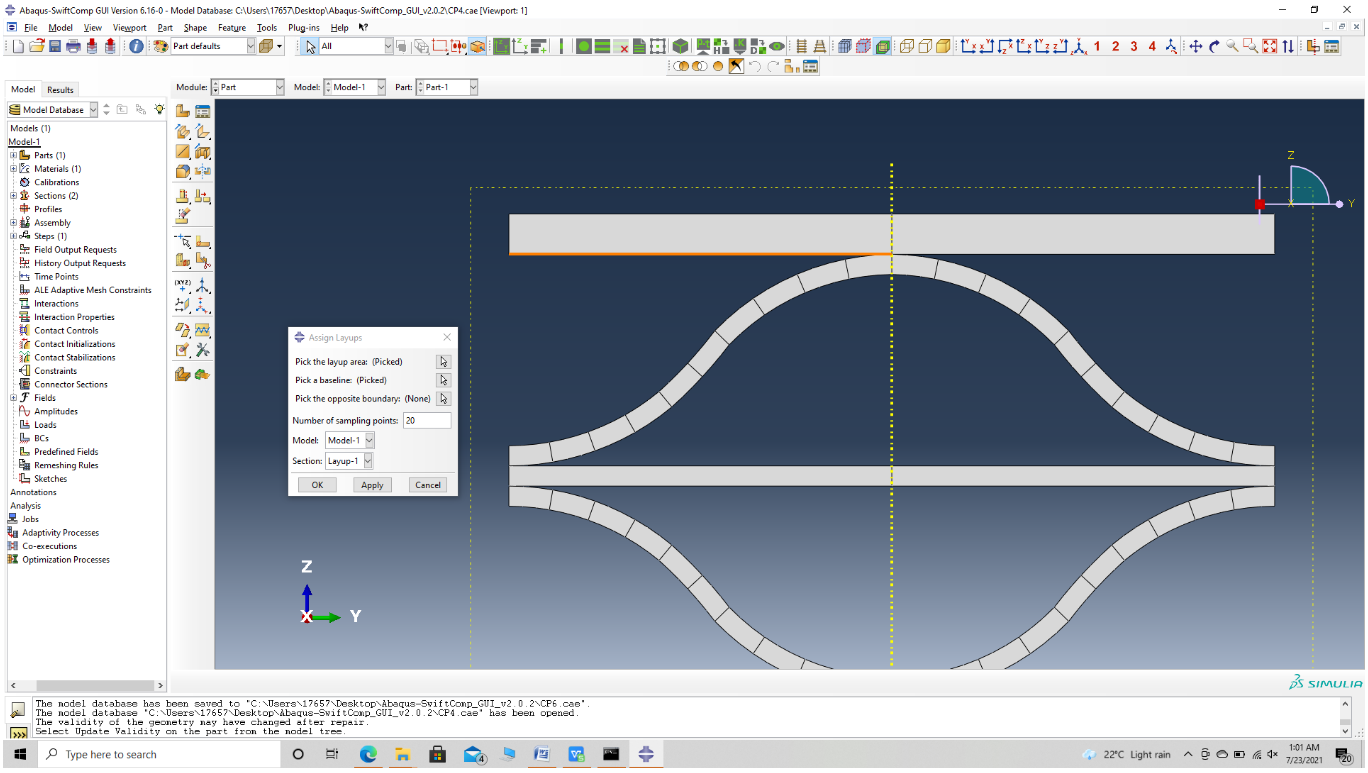


Second Layup

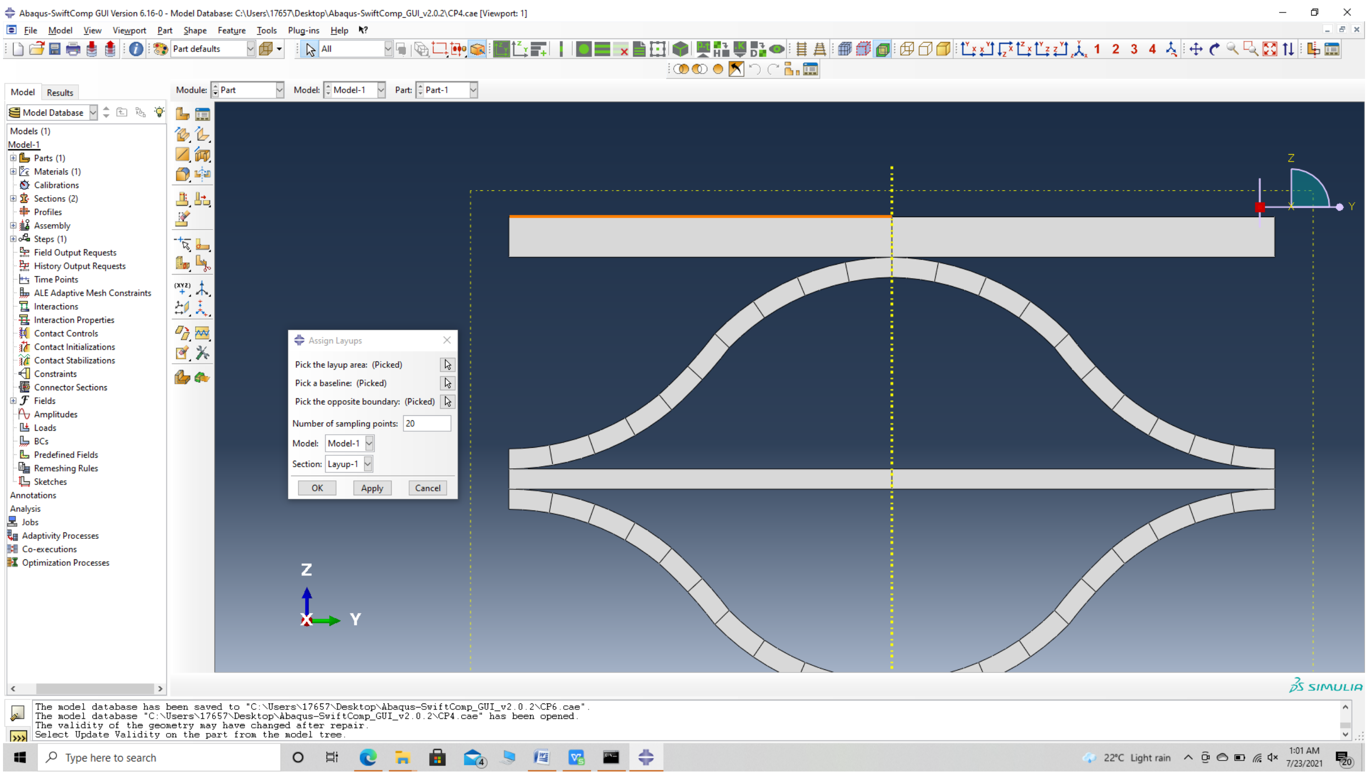
‘ # *Step 3.10.* To assign the layup, go to Create 2D SG: Assign Layups and the pick the baseline, the line opposite to the baseline and the area between the two picked line for the right flange as shown and then hit Ok. Do this for all sections



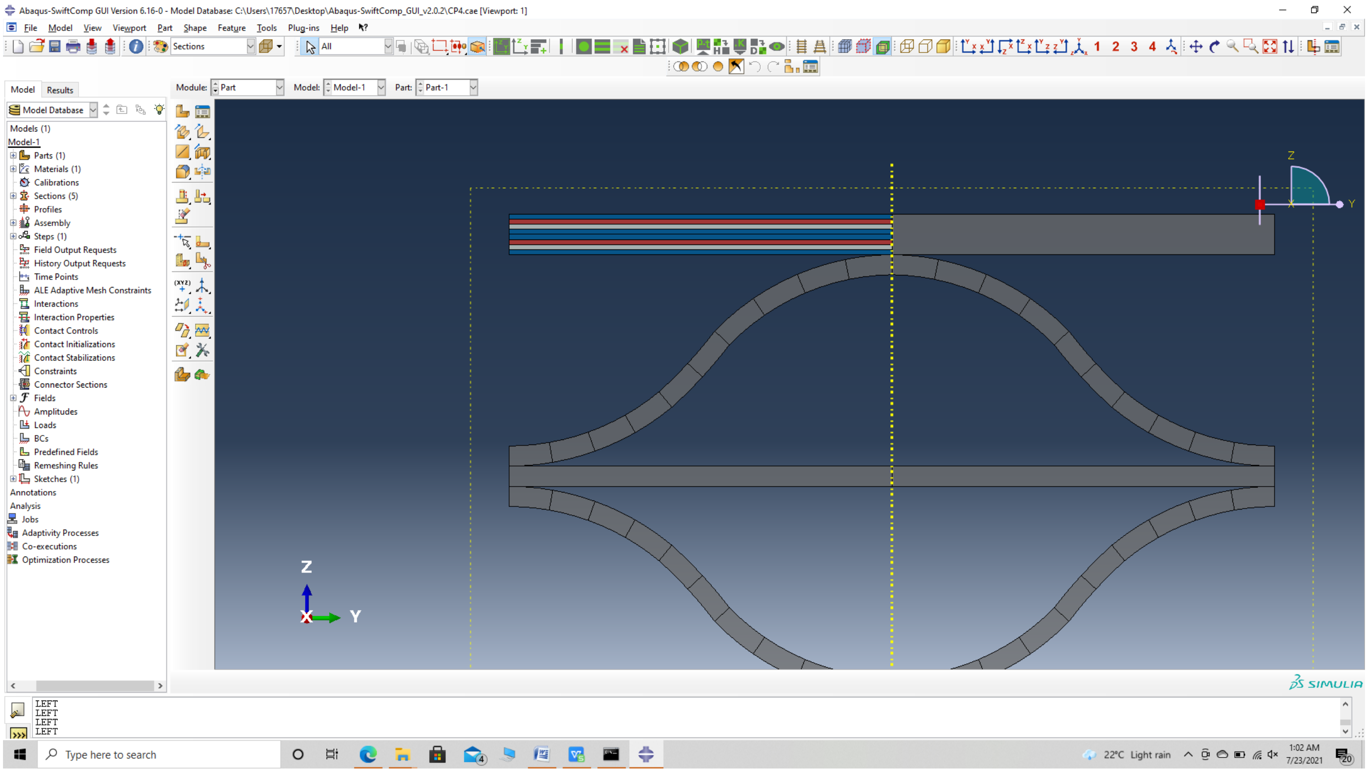
Layp area



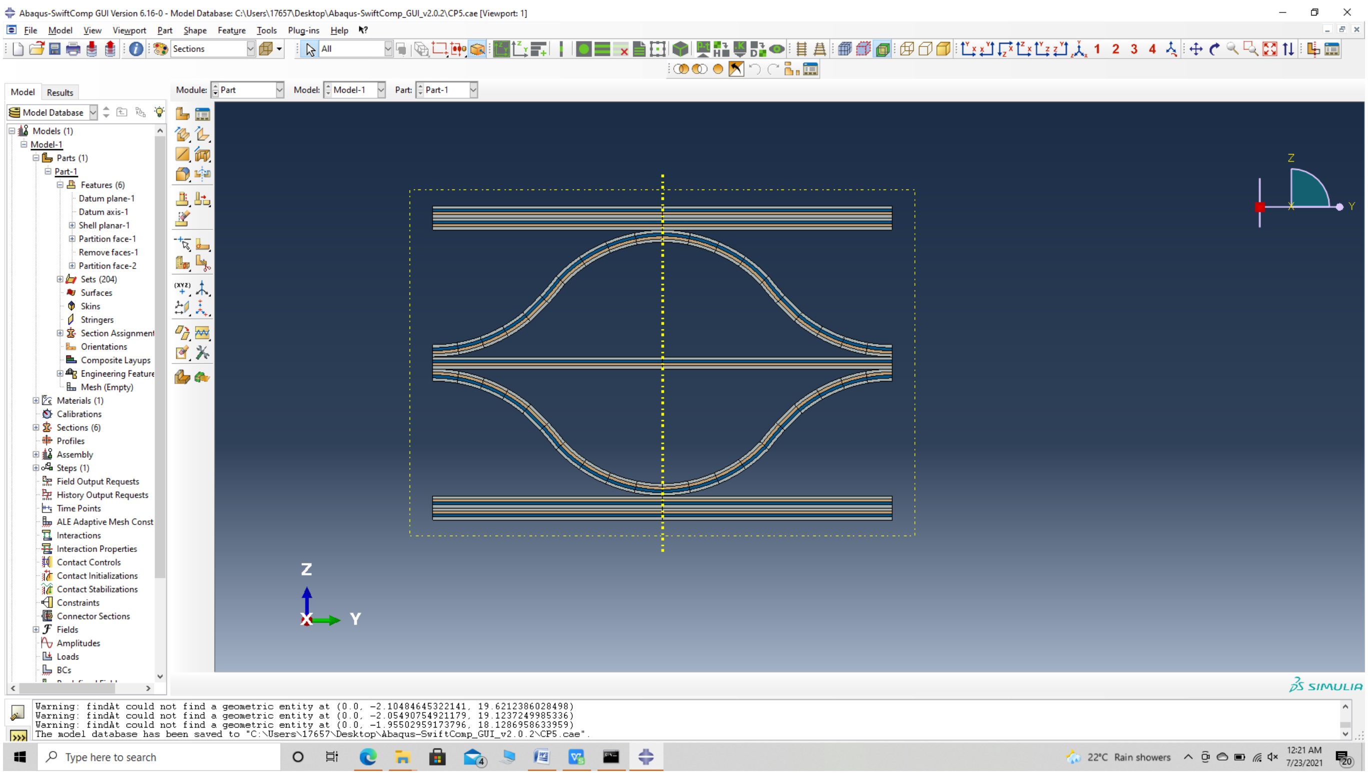
Baseline



opposite edge

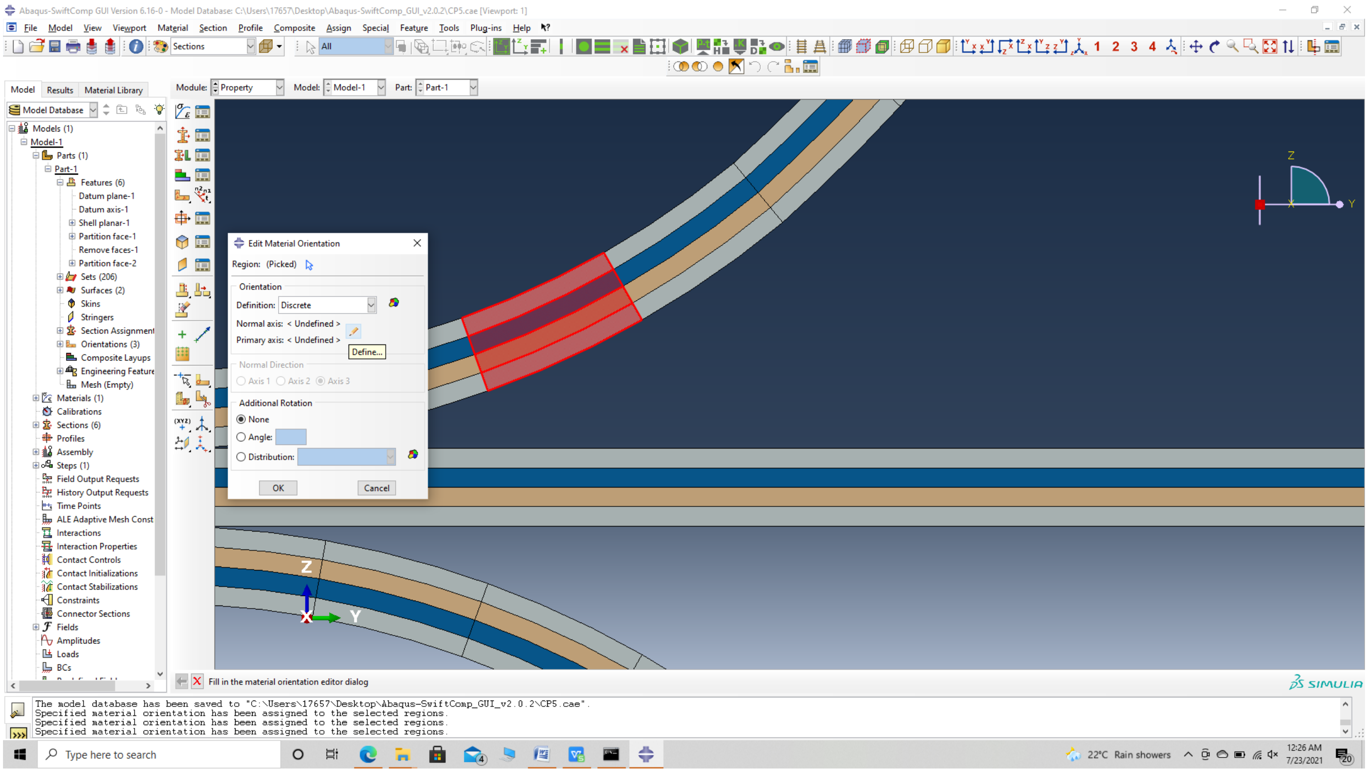


Assigned Layup

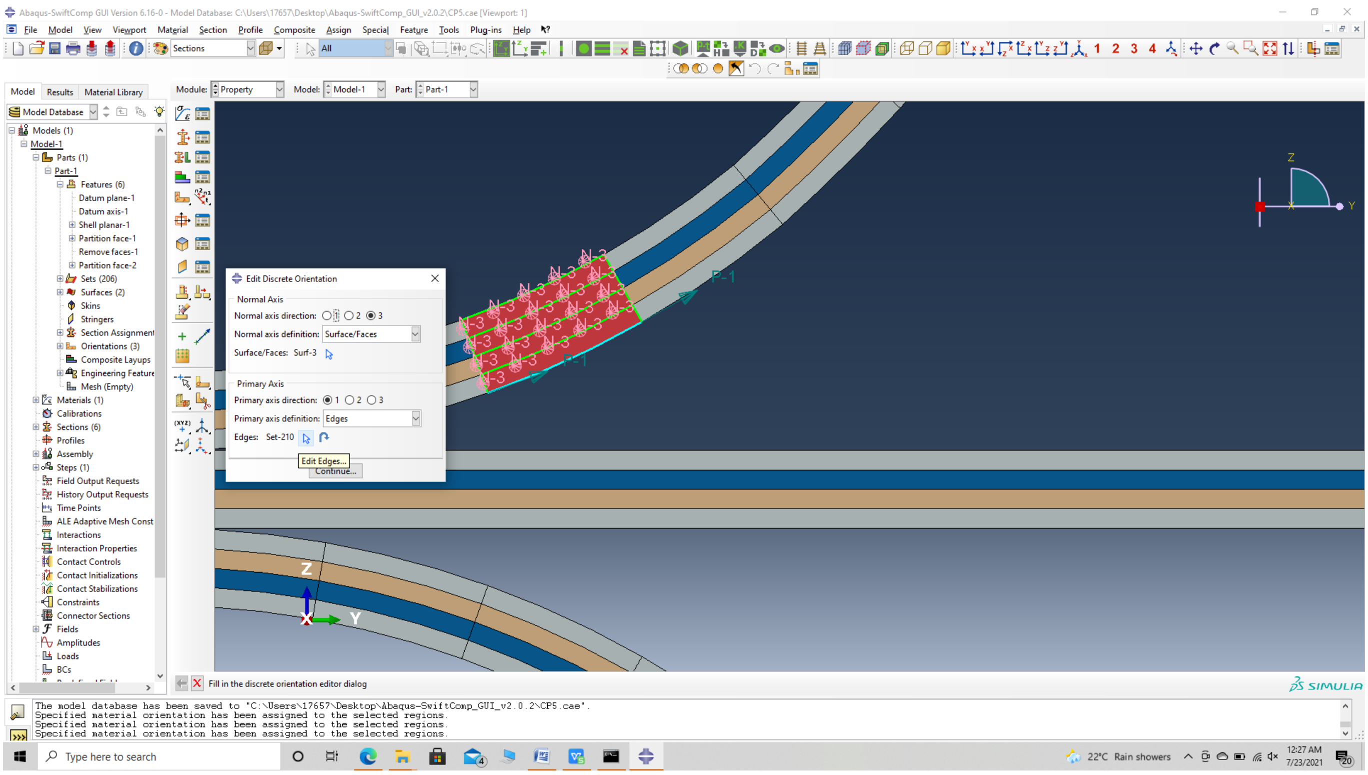


Assigned Layups

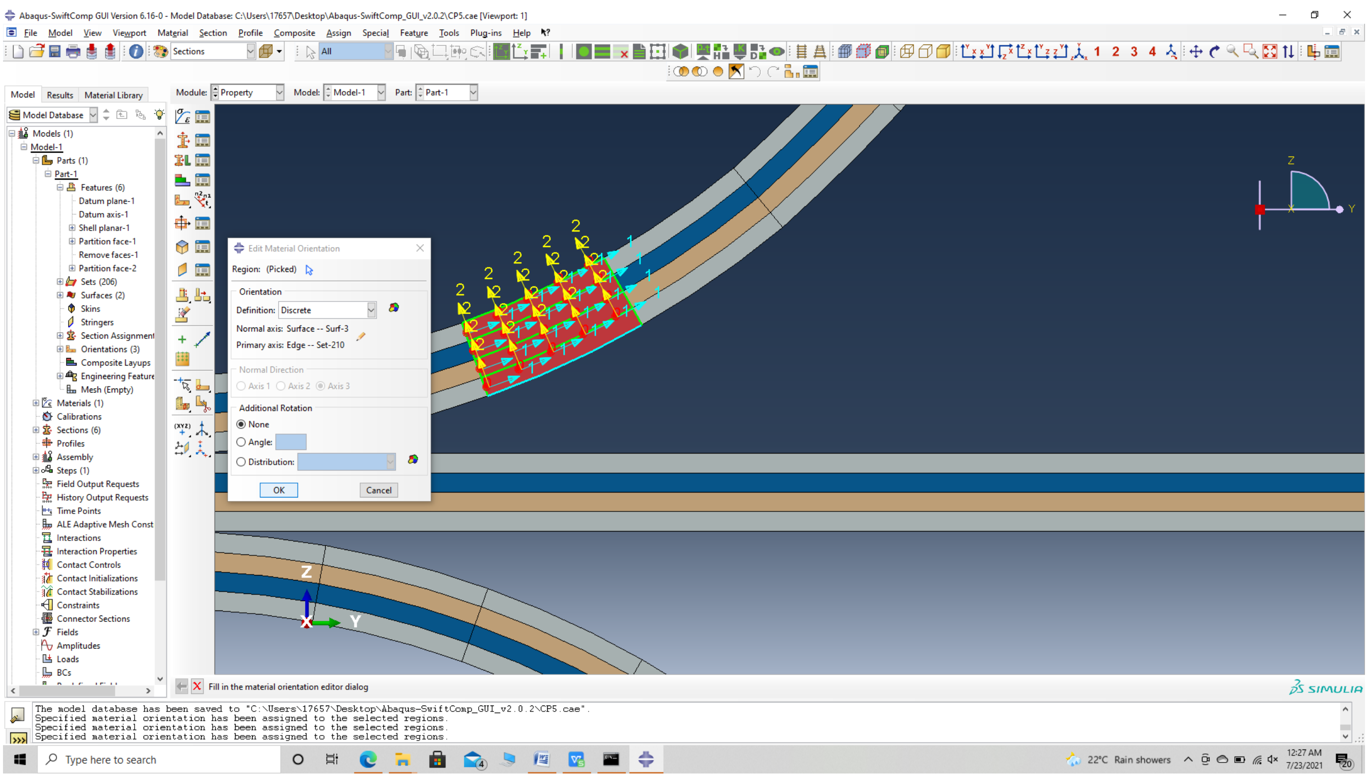
‘ # *Step 3.11.* Now we assign the material orientation for the part. Go to Assign material orientation -> select the sections of the partto be assigned orientation -> Done -> Select a CSYS (use default orientation or other method) -> Definition (Discrete) -> Define -> Primary axis orientation -> choose edge and flip direction if needed to make the axis point towards the layp direction direction -> Choose the surfaces for the normal axis definition -> Continue -> OK. Orientation Axis 1 represents the y2 axis of SwiftComp’s local orientation and orientation axis 2 represents y3 axis of SwiftComp’s local orientation. Now go to Assemble, create the part instance with dependent mesh.



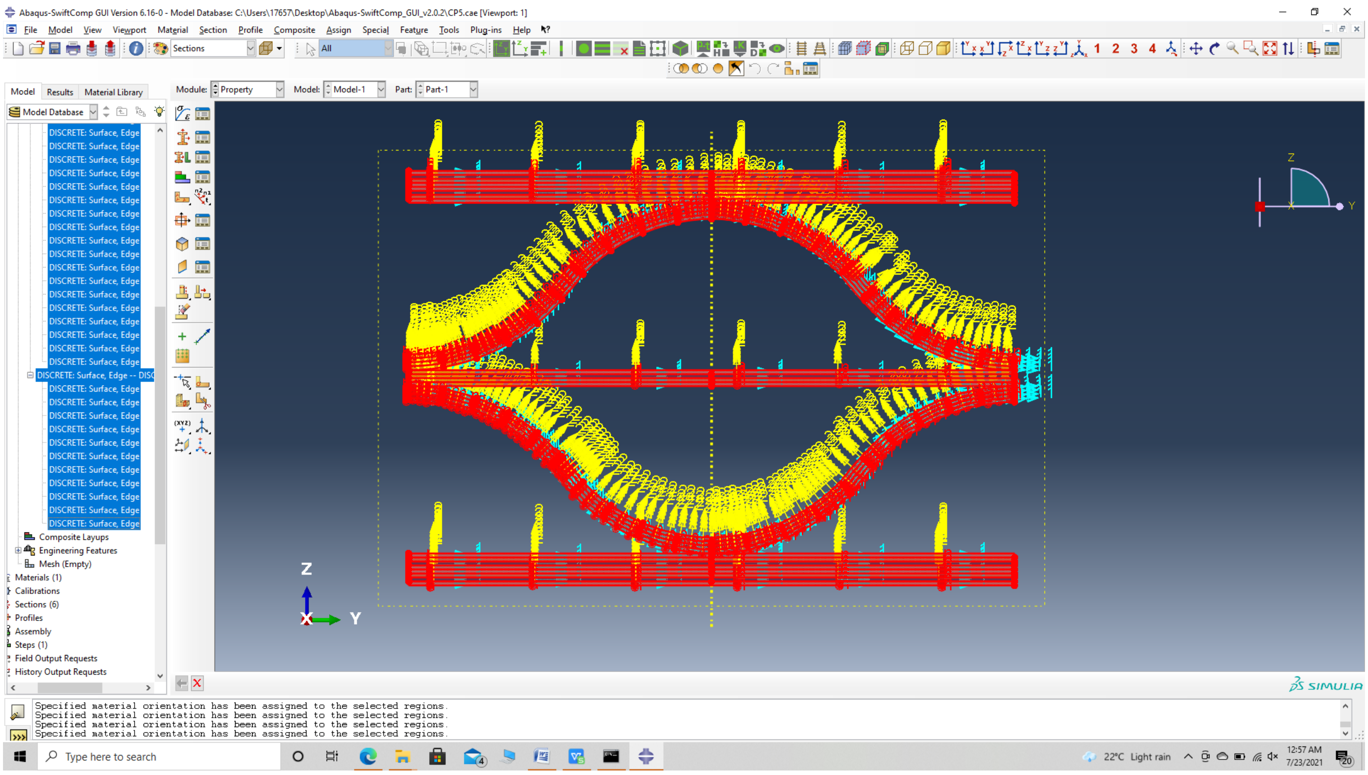
Assign material orientation



Define orientation

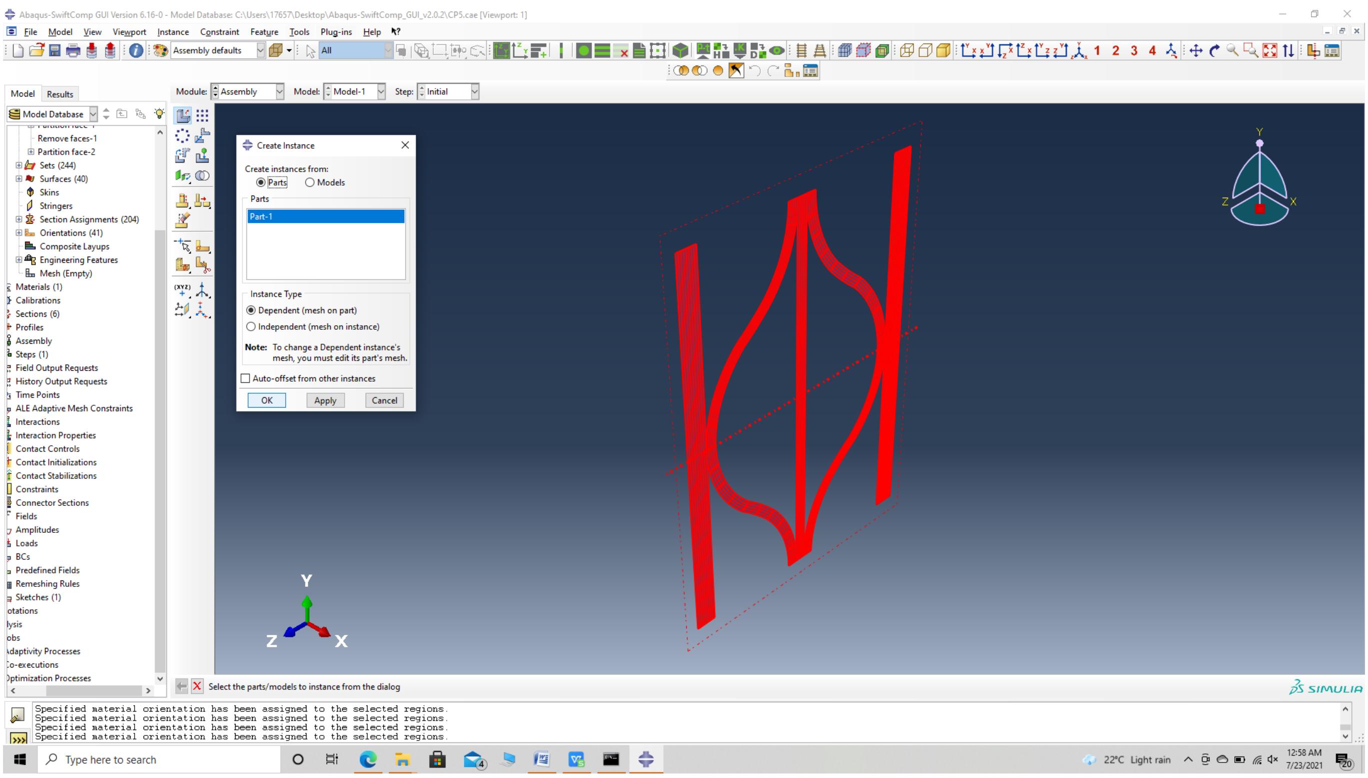


Orientation



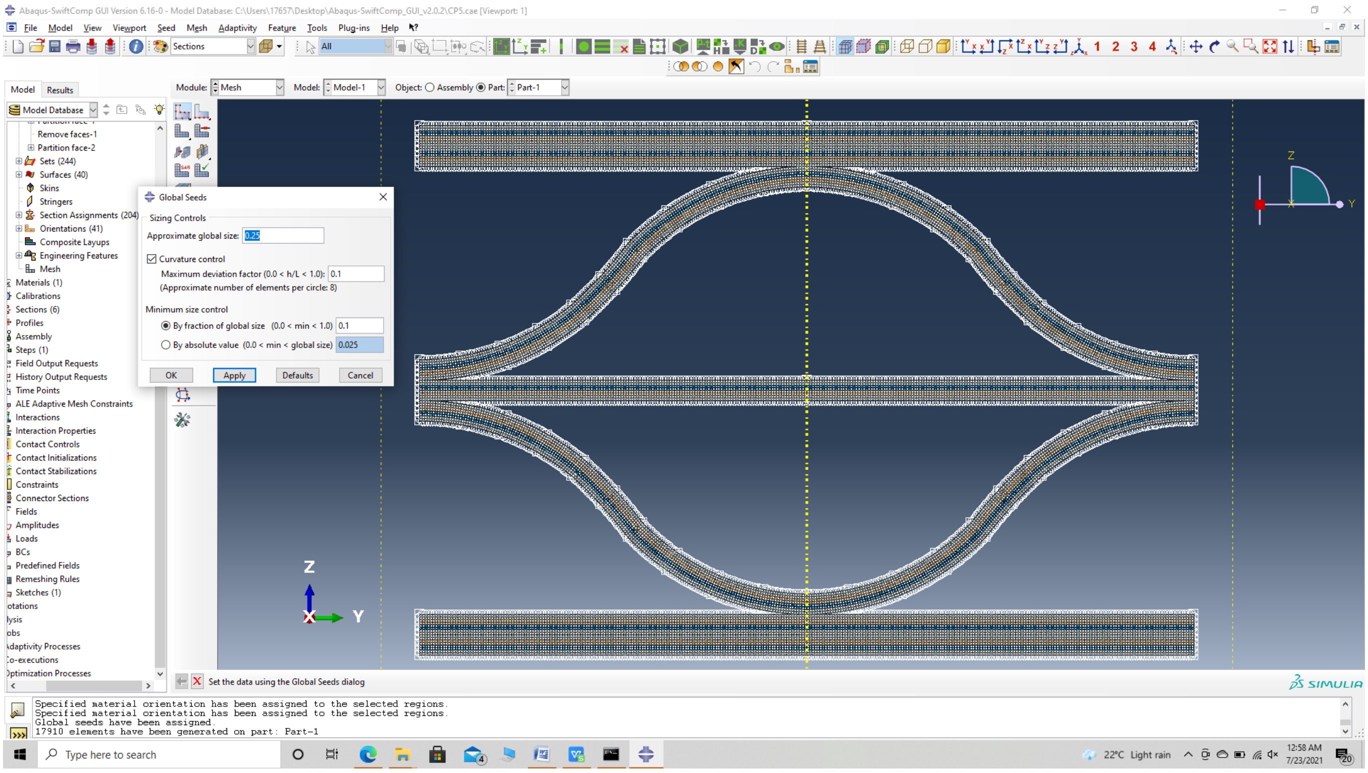
Part Orientation

‘ # *Step 3.12.* Now go to Assemble, create the part instance with dependent mesh.



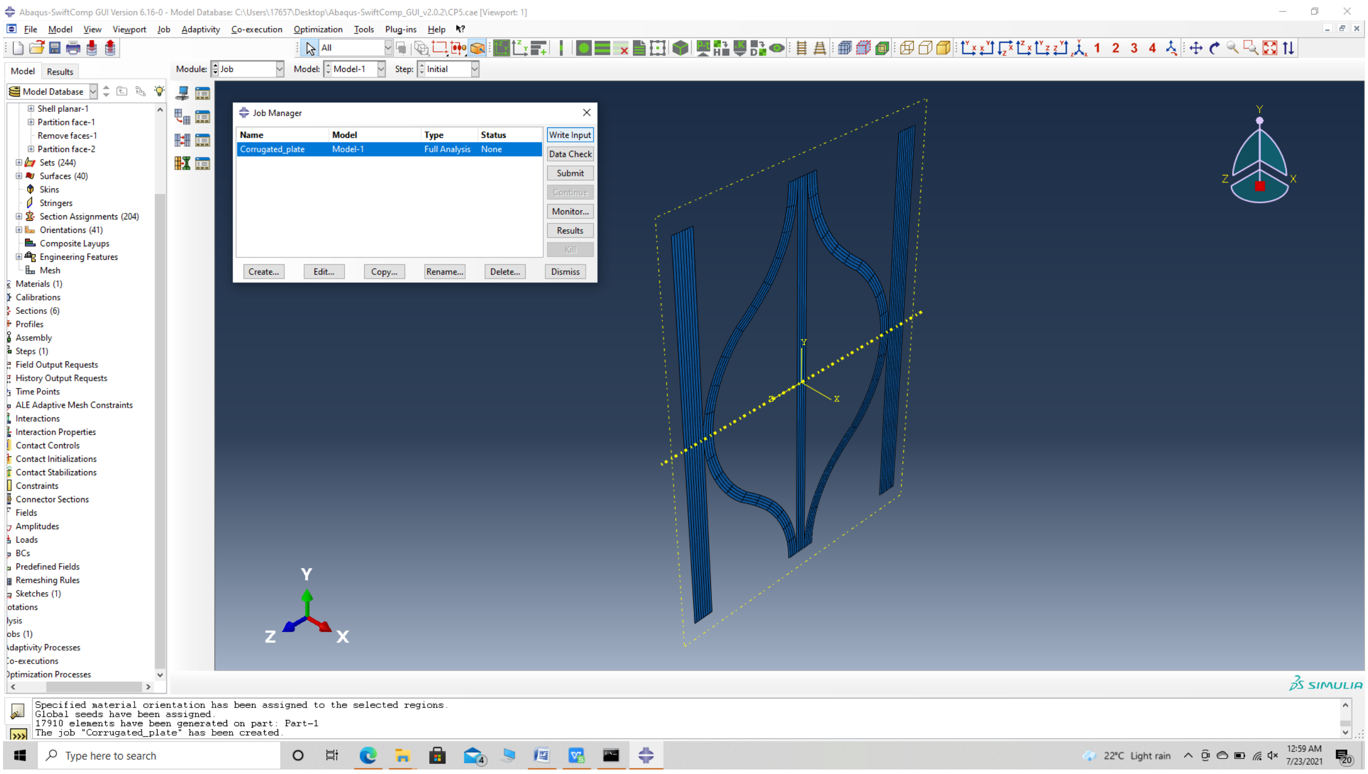
assembly

 # Step 3.13. In the Mesh section, Seed the Part and set approximate global mesh size, then Click ‘Mesh Part’



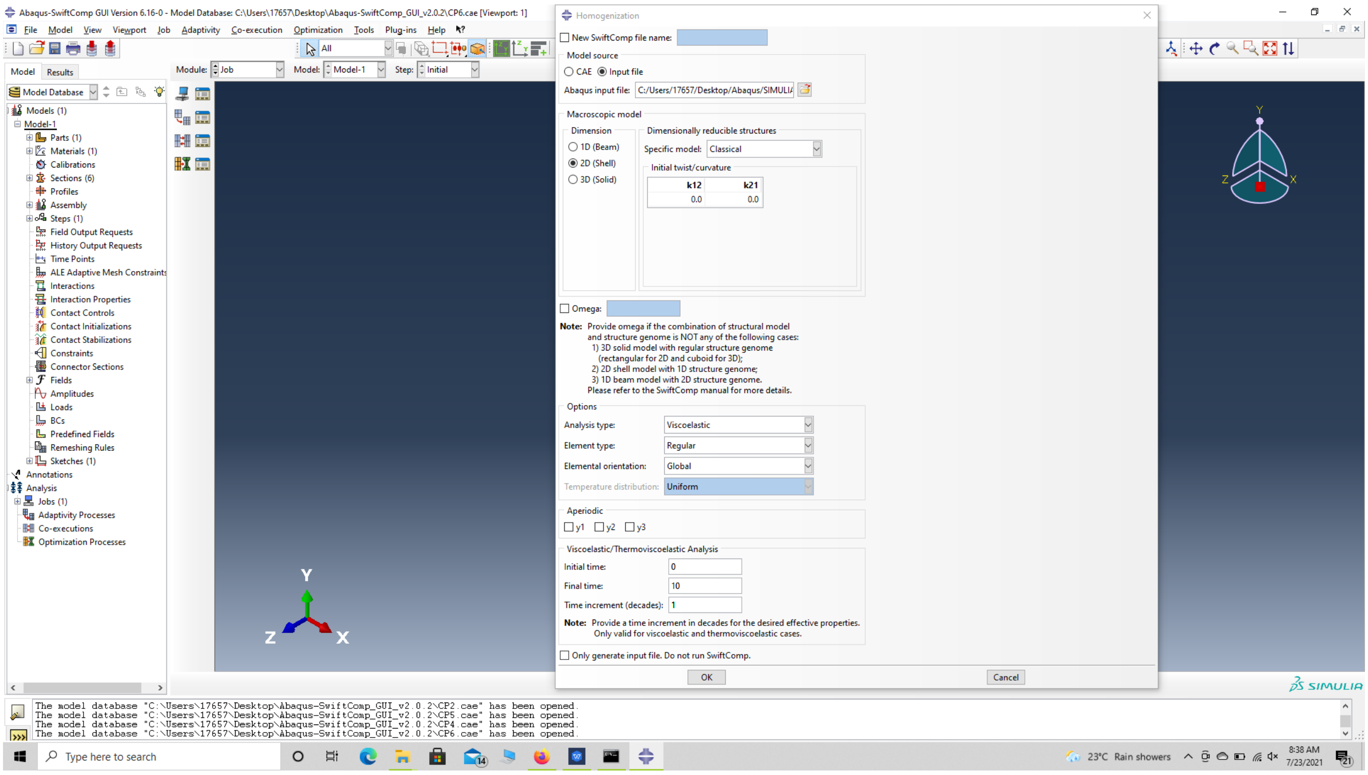
Mesh

 # Step 3.14. Create a job and write its input file.



ip file

 # Step 3.15. Homogenize the part preferably as a plate using the Homogenization via input file option to get the final results. In the Viscoelastic/Thermoviscoelastic Analysis section, we define the range of the time (i.e. Initial time" and Final time") in which we want to output the effective properties as well as the frequency (i.e. Time increment" defined in decades).



Homogenization

References

Rique, O.; Liu, X.; Yu, W., Pipes, R. B.: "Constitutive modeling for time- and temperature-dependent behavior of composites," Composites Part B: Engineering, Vol 184, March 2020, DOI: 10.1016/j.compositesb.2019.107726.