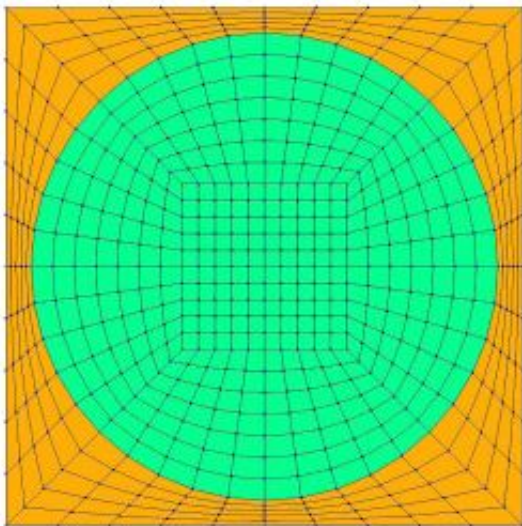


Computation of ThermoViscoelastic Beam properties of a woven composite Corrugated Boom using Abaqus SwiftComp GUI, Texgen4SC and Swift Comp 2.1

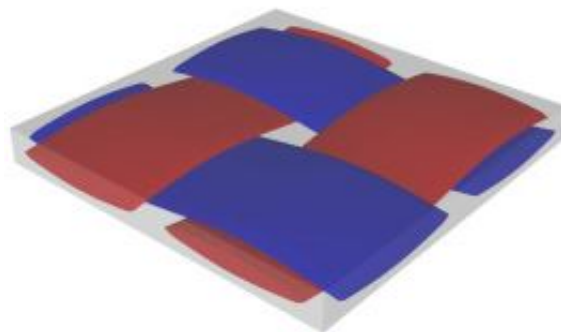
ThermoViscoelastic beam Properties of a Corrugated Boom

In this example, we want to compute the ThermoViscoelastic effective properties of a Corrugated Boom 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 ThermoViscoelastic yarn properties based on the elastic fiber and ThermoViscoelastic matrix properties at the microscale. The second part takes the effective yarn properties and matrix properties to predict the ThermoViscoelastic properties of weave composites. The third part uses the effective weave properties in the structural analysis to predict the ThermoViscoelastic properties of the Corrugated Boom.



Yarn



Weave



Corrugated boom

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)	ν_{12}	ν_{23}	α_{11} ($\mu/\text{°C}$)	α_{22} ($\mu/\text{°C}$)
233,000.0	15,000.0	8,963.0	5639	0.23	0.33	-0.54	10.08

Prony coefficients and relaxation times for the matrix. The matrix has a constant Poisson's ratio equal to 0.33 and CTE equal to $60 \mu/\text{°C}$.

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 $\nu_f = 0.64$.

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 microstructure and also for the ThermoViscoelastic homogenization of the plain weave laminate. Abaqus CAE will be used to model the boom and to run the ThermoViscoelastic 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.

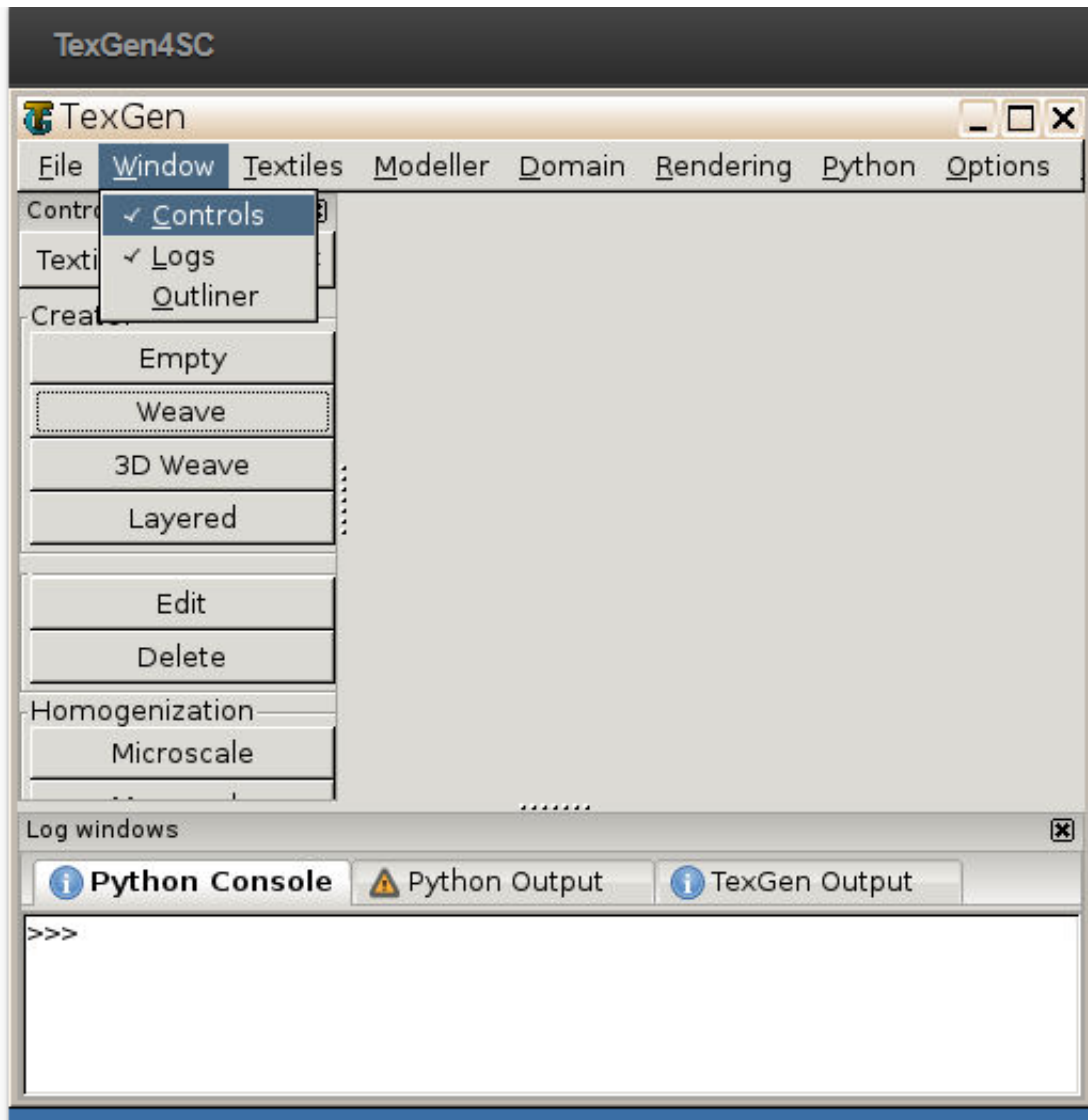
Part 2- Meso-scale analysis of the plain weave laminate using Texgen4SC2.0.

Part 3- Macro-scale analysis of the Boom 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.

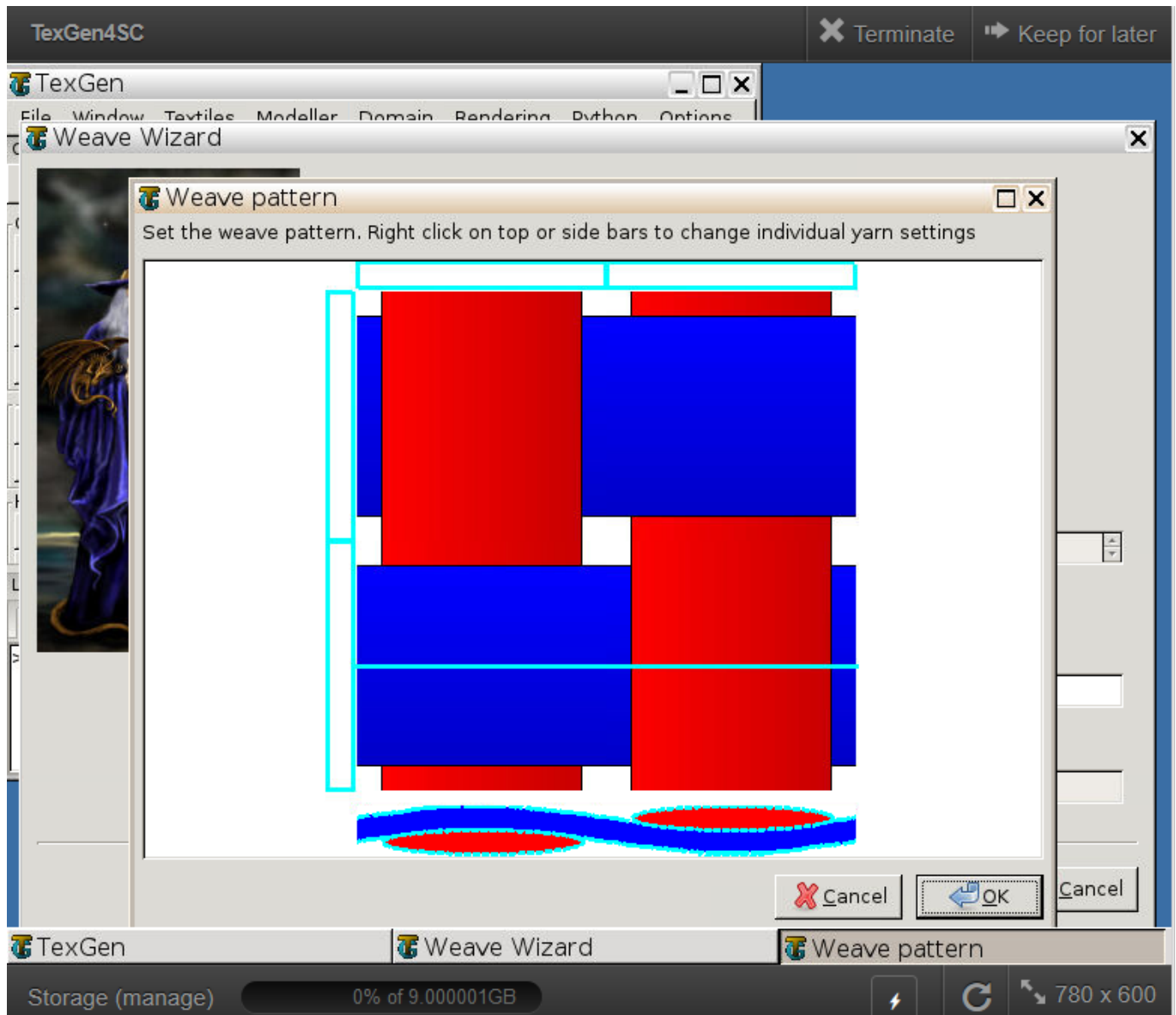
TexGen4SC 2.0 provides a function to let users import the material properties from a text file. Refer to the [Predict viscoelastic plate properties of a single-layer plain weave laminate](#) tutorials

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

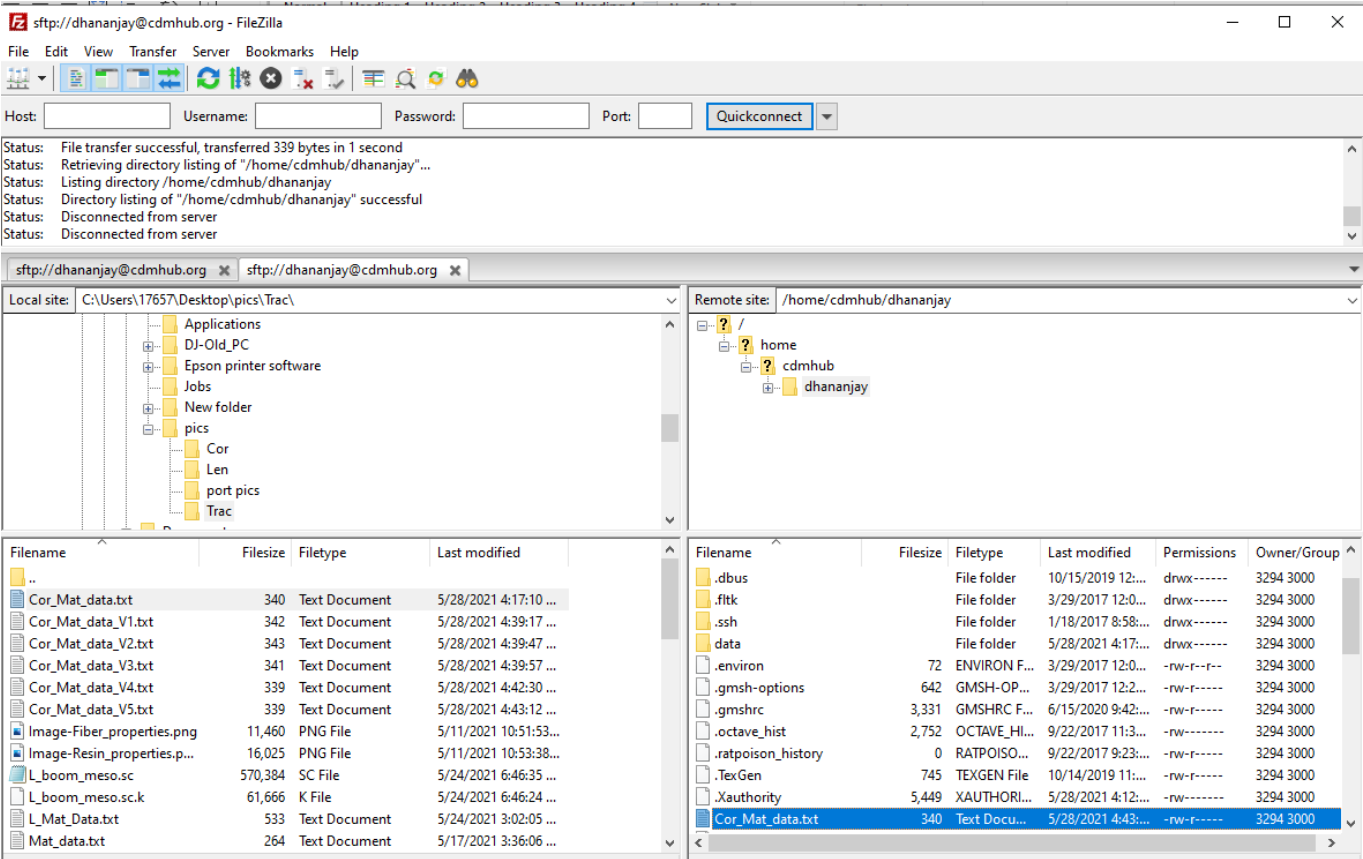
Step 1.2. Keeping the geometric properties as required, Click on the upper-right and lower-left squares to get the woven pattern.



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.

COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED



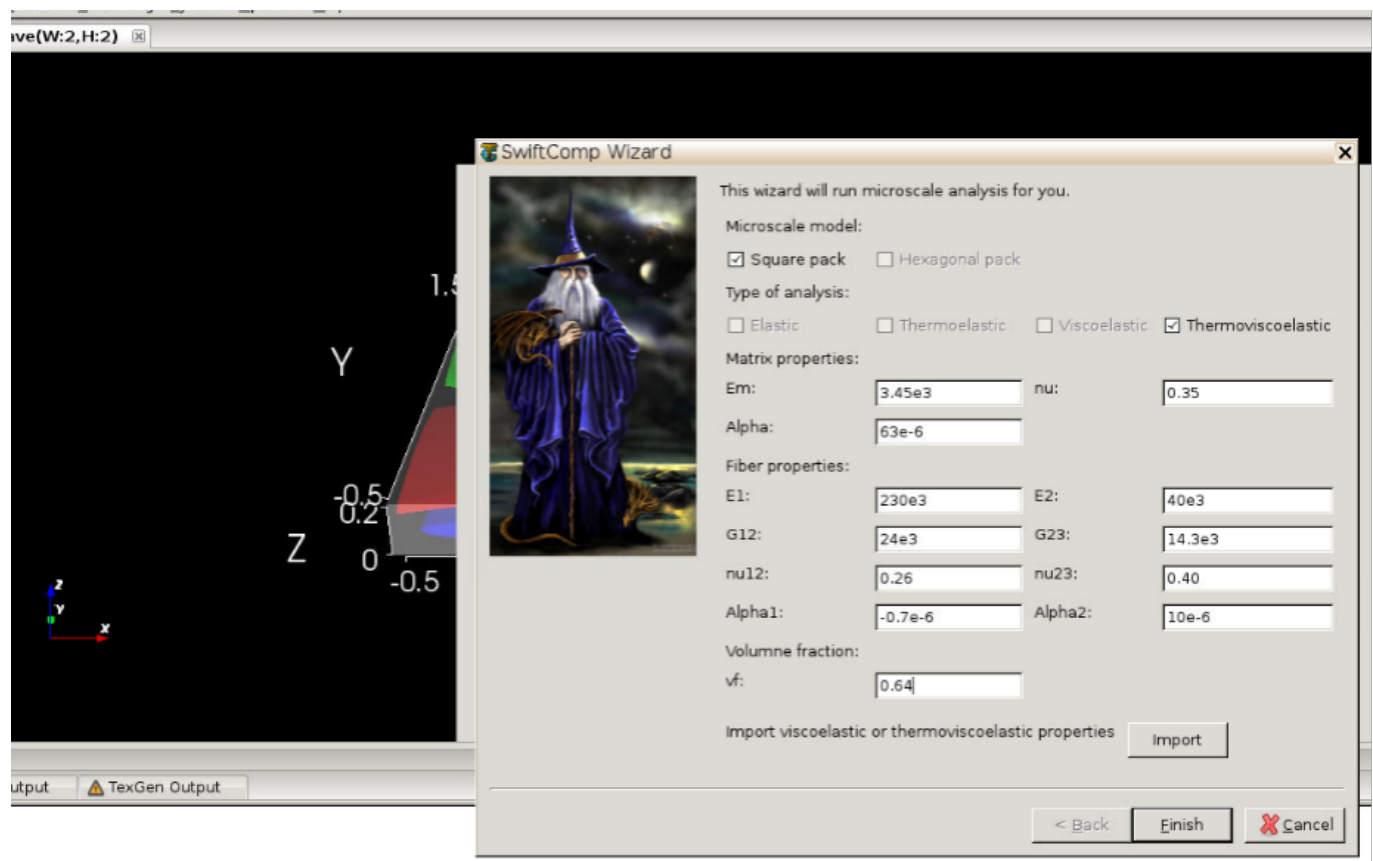
Importing Material properties text file

```
Cor_Mat_data - Notepad
File Edit Format View Help
0 10 1
***
1 0 1
0 0 P 8
1
1000 0.33
60 1
1000
224.1 0.33
60 1
100000
450.8 0.33
60 1
1000000
406.1 0.33
60 1
10000000
392.7 0.33
60 1
100000000
810.4 0.33
60 1
1000000000
203.7 0.33
60 1
10000000000
14860 0.33
60 1

2 1 1
0 0 C 1
233000 15000 15000
8963 8963 5639
0.2 0.2 0.33
-0.54 10.08 10.08 1|
```

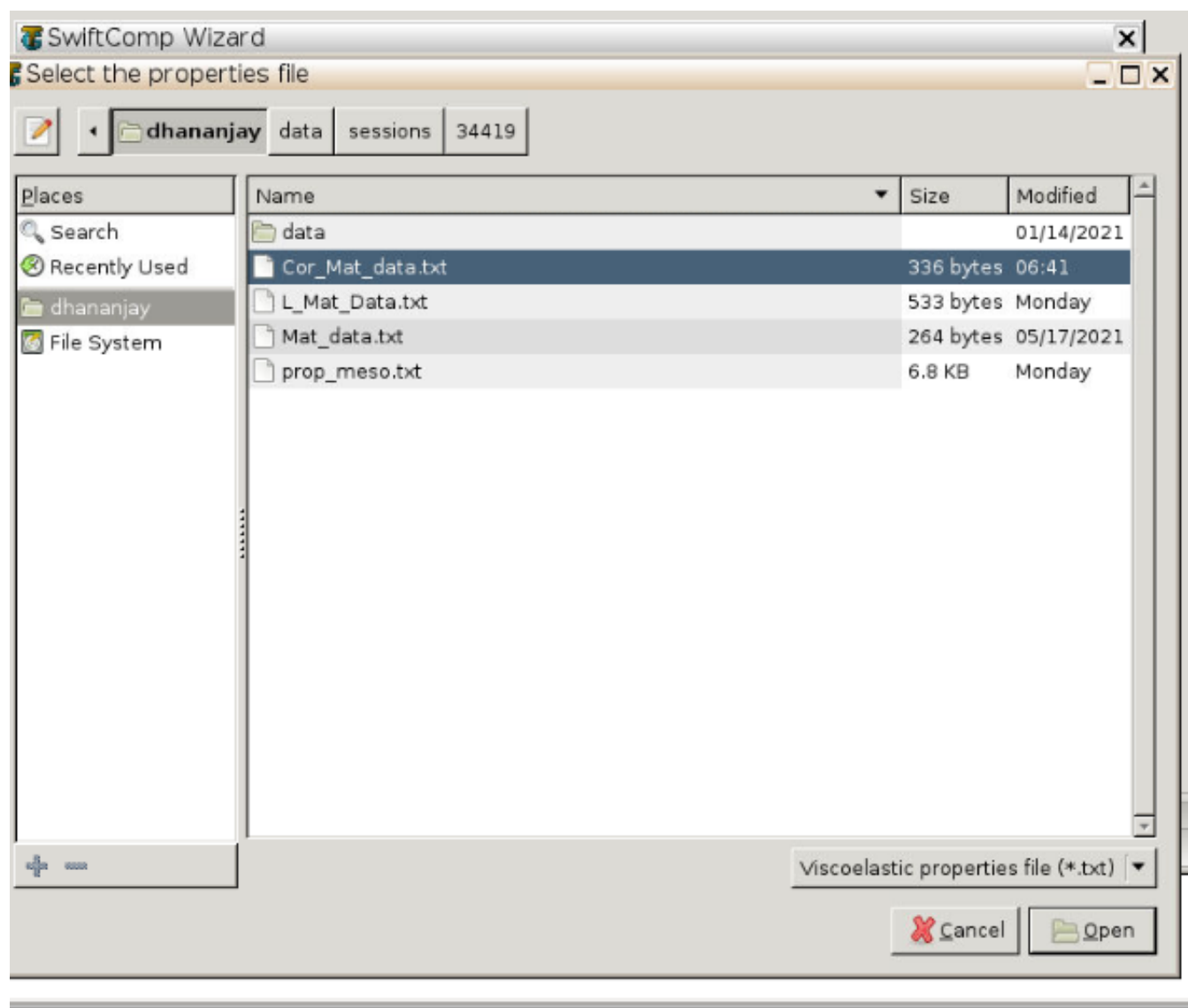
Material properties text file

Step 1.4. Once you uploaded the .txt file, click “Microscale” under “Homogenization” tab for yarn property calculation. Select “[ThermoViscoelastic](#)” as the type of analysis. Set fiber Volume fraction as 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.

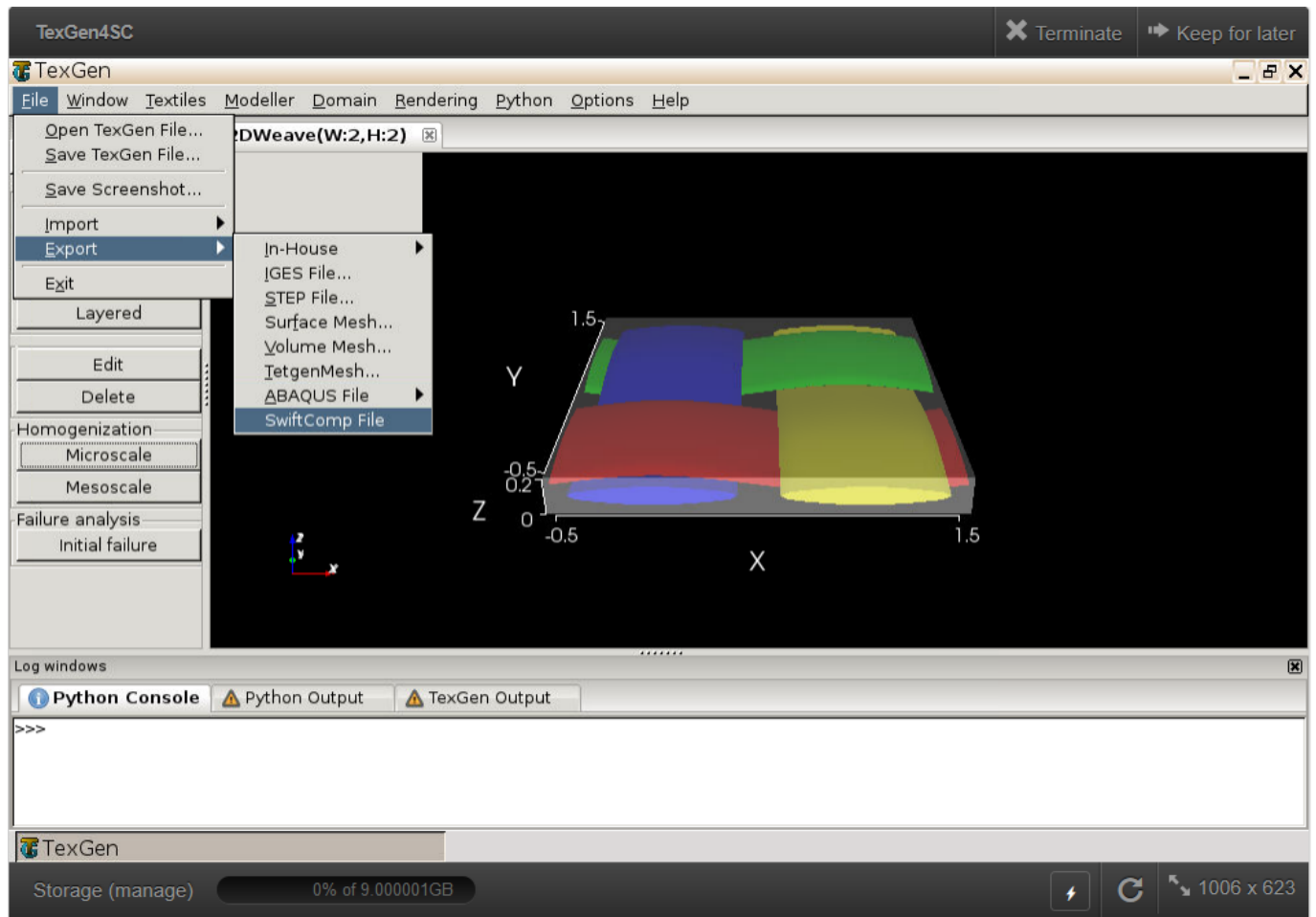
COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED

```
TexGen4SC
micro.sc.k - /home/cdmhub/dhananjay - Geany
File Edit Search View Document Project Build Tools Help
ew Open Save Save All Revert Close Back Forward Compile Build Execute Color Chooser Find Jump to
mbols Documents micro.sc.k
1 1 #-----#
2 2 Effective Viscoelastic Properties at Time: t = 1.000000E+000
3 3
4 4 The Effective Stiffness Matrix
5 5 -----
6 6 1.5905452E+005 6.9429652E+003 6.9429633E+003 -9.2747546E-004 0.0000000E+000 0.0000000E+000
7 7 6.9429652E+003 1.9819295E+004 7.6742466E+003 -1.1722393E-002 0.0000000E+000 0.0000000E+000
8 8 6.9429633E+003 7.6742466E+003 1.9819291E+004 9.8404582E-003 0.0000000E+000 0.0000000E+000
9 9 -9.2747546E-004 -1.1722393E-002 9.8404582E-003 6.0440591E+003 0.0000000E+000 0.0000000E+000
10 10 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 8.1507328E+003 -9.4817636E-005
11 11 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 -9.4817636E-005 8.1507330E+003
12 12
13 13 The Effective Compliance Matrix
14 14 -----
15 15 6.4288881E-006 -1.6234922E-006 -1.6234917E-006 4.8102178E-013 0.0000000E+000 0.0000000E+000
16 16 -1.6234922E-006 5.9765115E-005 -2.2572976E-005 1.5241626E-010 0.0000000E+000 0.0000000E+000
17 17 -1.6234917E-006 -2.2572976E-005 5.9765126E-005 -1.4133404E-010 0.0000000E+000 0.0000000E+000
18 18 4.8102178E-013 1.5241626E-010 -1.4133404E-010 1.6545173E-004 0.0000000E+000 0.0000000E+000
19 19 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 1.2268836E-004 1.4272360E-012
20 20 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 1.4272360E-012 1.2268835E-004
21 21
22 22 The Engineering Constants (Approximated as Orthotropic)
23 23 -----
24 24 E1 = 1.5554789E+005
25 25 E2 = 1.6732169E+004
26 26 E3 = 1.6732166E+004
27 27 G12 = 8.1507330E+003
28 28 G13 = 8.1507328E+003
29 29 G23 = 6.0440591E+003
30 30 nu12 = 2.5253079E-001
31 31 nu13 = 2.5253072E-001
32 32 nu23 = 3.7769485E-001
33 33
34 34 Thermal Coefficients
35 35 -----
36 36 alpha11 = 2.2939027E+000
37 37 alpha22 = 3.7609028E+001
38 38 alpha33 = 3.7608988E+001
39 39 2alpha23 = -4.0018099E-005
40 40 2alpha13 = -0.0000000E+000
```

Micro scaleResults

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

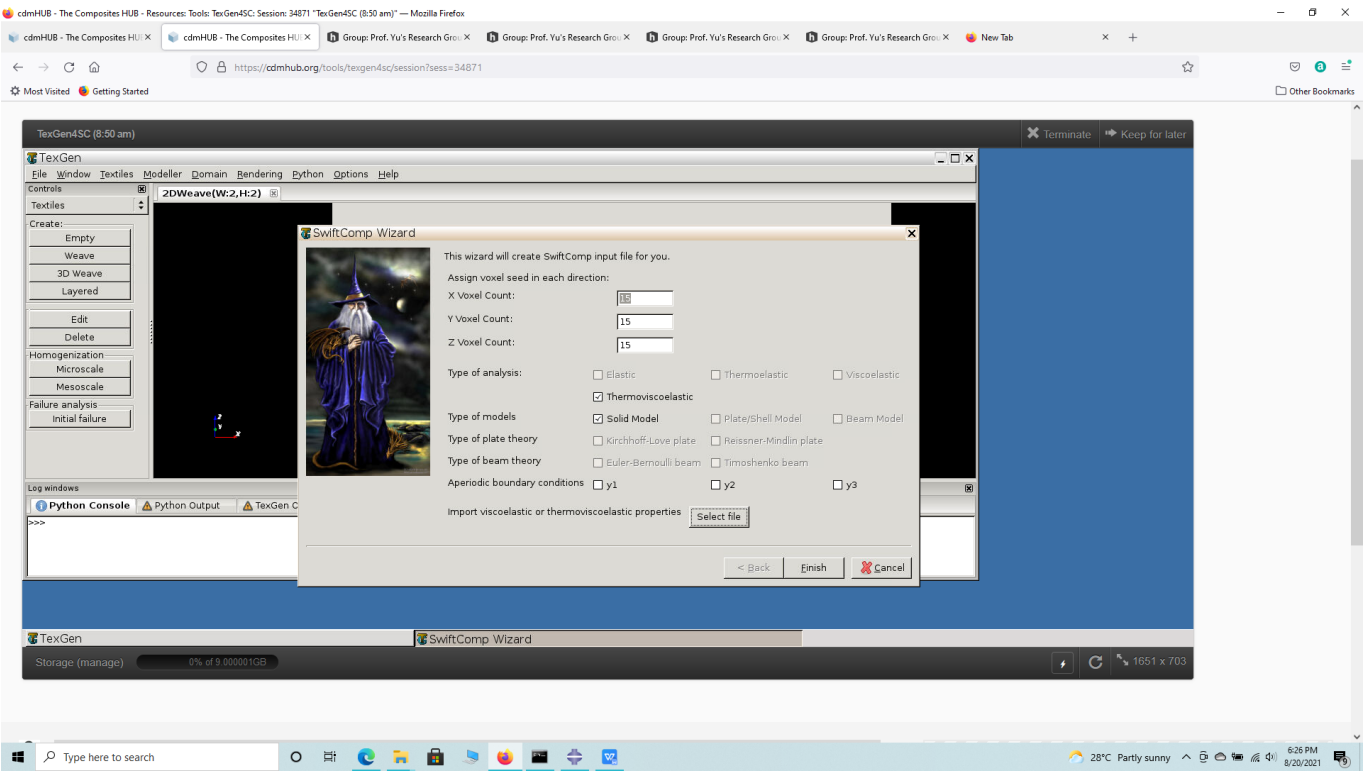
Step 2.1. Go to “File->Export->SwiftComp File” to generate the .sc file for mesoscale analysis.



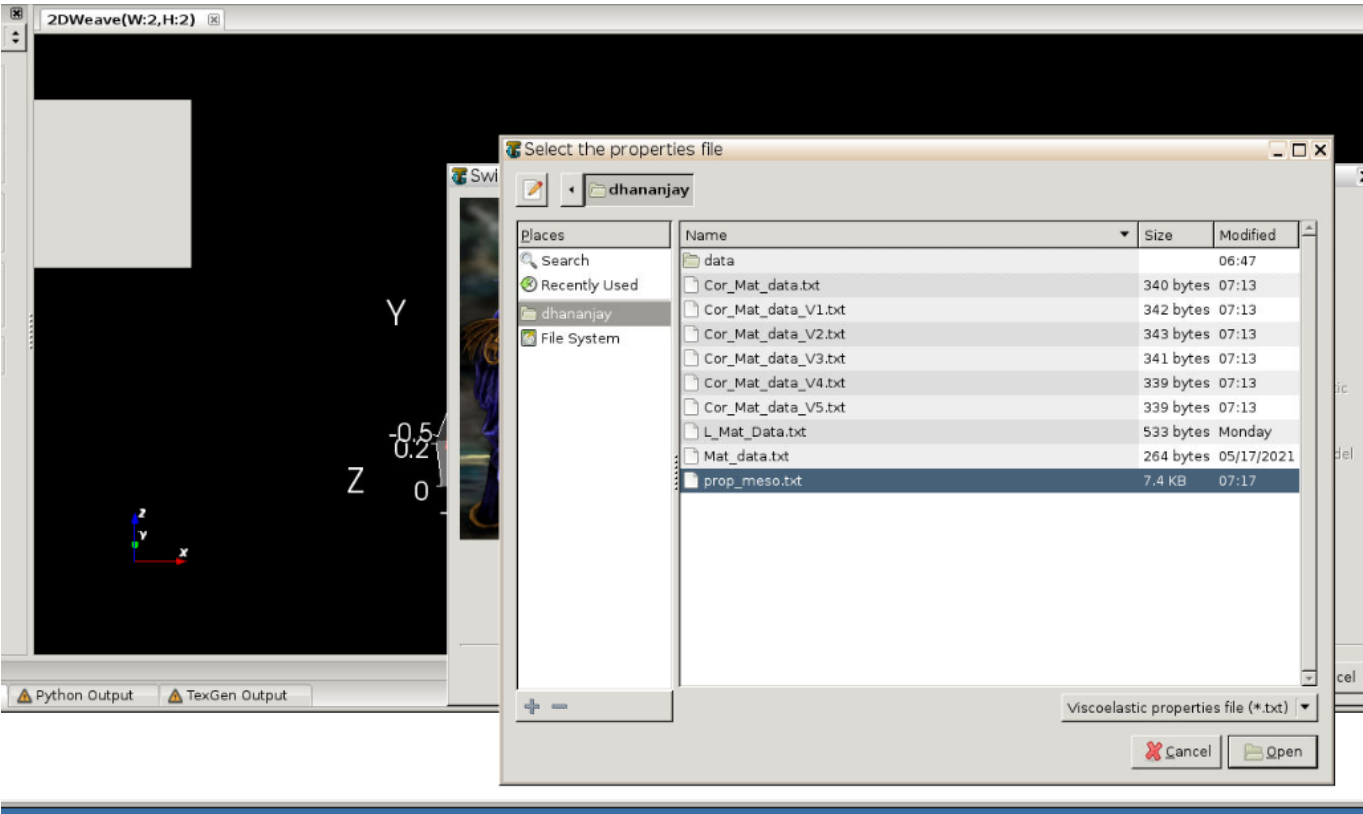
weave mesh

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.

COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED

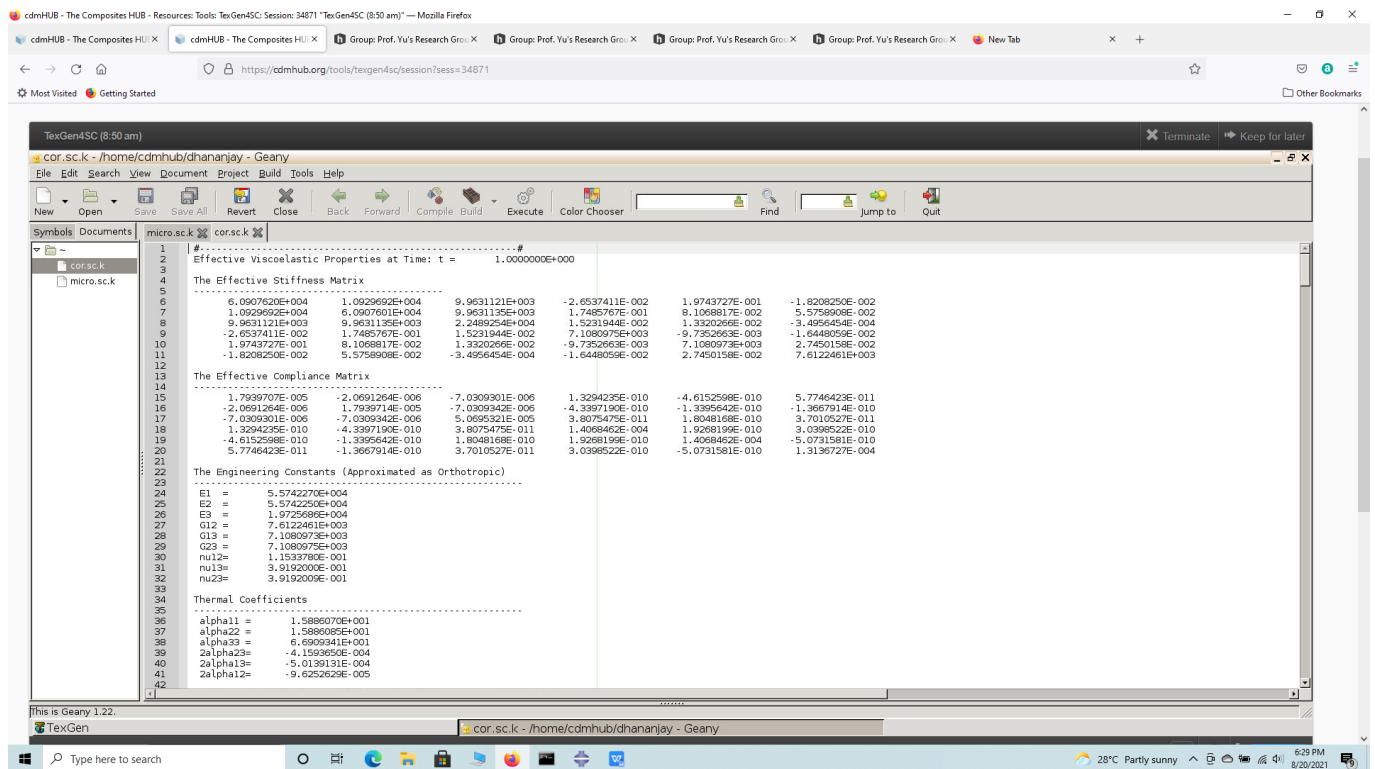


SwiftComp Wizard



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.

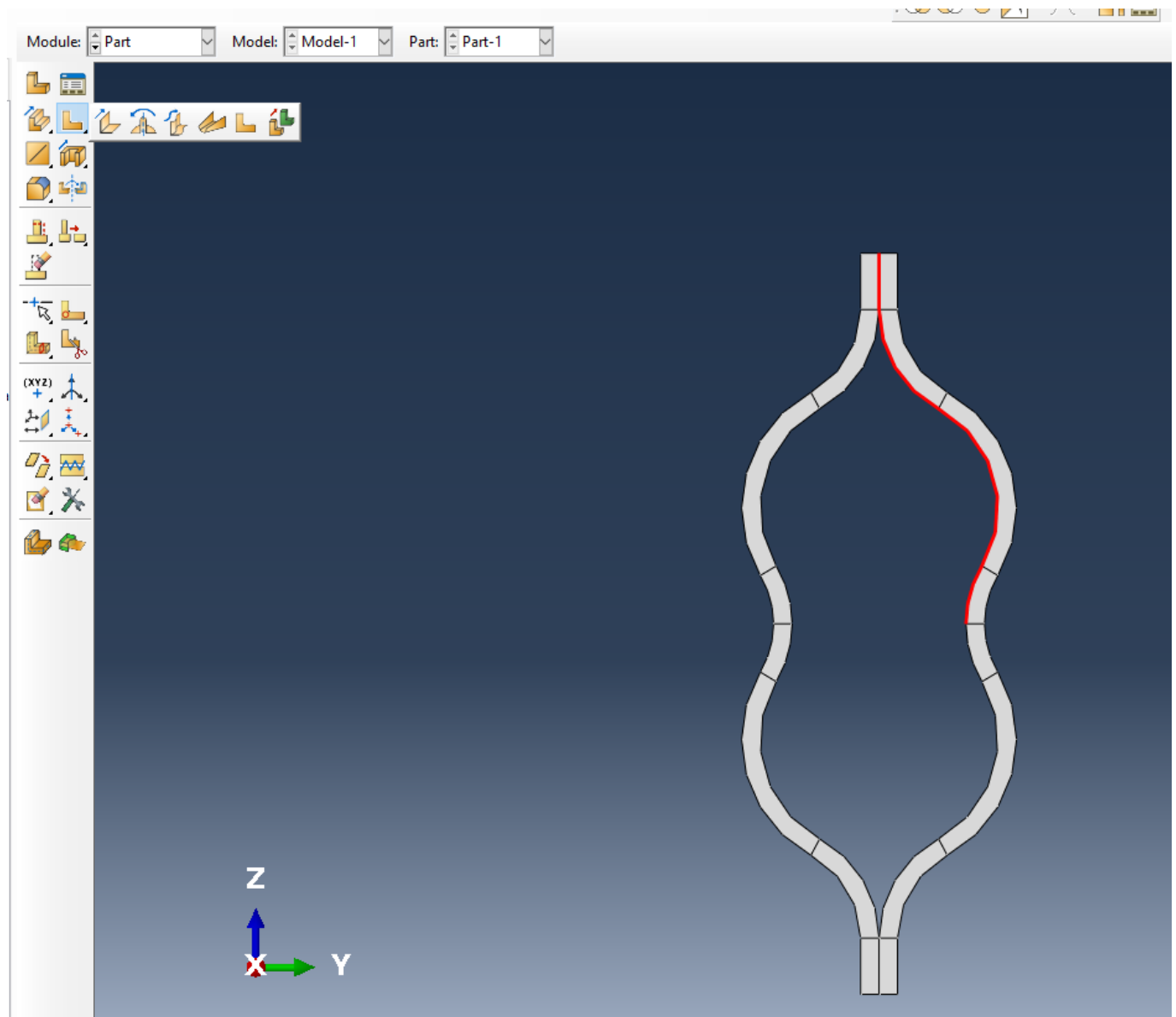


Meso Scale Results

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

Part 3- Macro-scale analysis of the Corrugated Boom 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 Boom. Use Set sketch plane for customized SG -> Create planar shell -> Select the plane and vertical axis -> Sketch a fourth of the base line (Highlighted as a red line). Its geometry is a straight line (Web height) from (0,19.78) to (0,16.78) and three curved lines (Flange) one from (0,16.78) to (3.18,11.48) centered at (6,16.78), another from (3.18,11.48) to (5.5,3.08) centered at (0.36,6.18) and another from (5.5,3.08) to (4.63,0) centered at (10.64,0). Sketch a shell of thickness to 1 mm from the right of the baseline by adding a straight line and three curved lines. Close the section at its two ends and finish the part. Mirror the part about the vertical and horizontal to get the geometry of the Boom. Partition the part to separate the web and flanges.



Part Geometry

Step 3.2. 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 and time-dependent constituent 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 3.3. Use the material properties from the previous section . We need to convert the Constitutive relations provided as SwiftComp's results into Abaqus's Constitutive relations. This can be done by switching the 4th and 6th rows for the relation and also switching the 4th and 6th column of the stiffness matrix. The relations are provided below. 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
 – D1111 (t) — D1122 (t) — D2222 (t) — D1133 (t) — D2233 (t) — D3333 (t) — D1112 (t) — D2212 (t) — D3312 (t) — D1212 (t) — D1113 (t) — D2213 (t) — D3313 (t) — D1213 (t) — D1313 (t) — D1123 (t) — D2223 (t) — D3323 (t) — D1223 (t) — D1323 (t) — D2323 (t) — a11-a22-a33-a13-a12-a23-Time, t for all time intervals.

$$\begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{23} \end{Bmatrix} = \begin{bmatrix} D_{1111} & D_{1122} & D_{1133} & D_{1112} & D_{1113} & D_{1123} \\ & D_{2222} & D_{2233} & D_{2212} & D_{2213} & D_{2223} \\ & & D_{3333} & D_{3312} & D_{3313} & D_{3323} \\ & & & D_{1212} & D_{1213} & D_{1223} \\ & sym & & D_{1313} & D_{1323} & \\ & & & & D_{2323} & \end{bmatrix} \begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{Bmatrix}$$

Abaqus's

Constitutive relations

$$\begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{23} \\ \sigma_{13} \\ \sigma_{12} \end{Bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{12} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} \\ c_{13} & c_{23} & c_{33} & c_{34} & c_{35} & c_{36} \\ c_{14} & c_{24} & c_{34} & c_{44} & c_{45} & c_{46} \\ c_{15} & c_{25} & c_{35} & c_{45} & c_{55} & c_{56} \\ c_{16} & c_{26} & c_{36} & c_{46} & c_{56} & c_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ 2\varepsilon_{23} \\ 2\varepsilon_{13} \\ 2\varepsilon_{12} \end{Bmatrix}$$

SwiftComp's

Constitutive relations

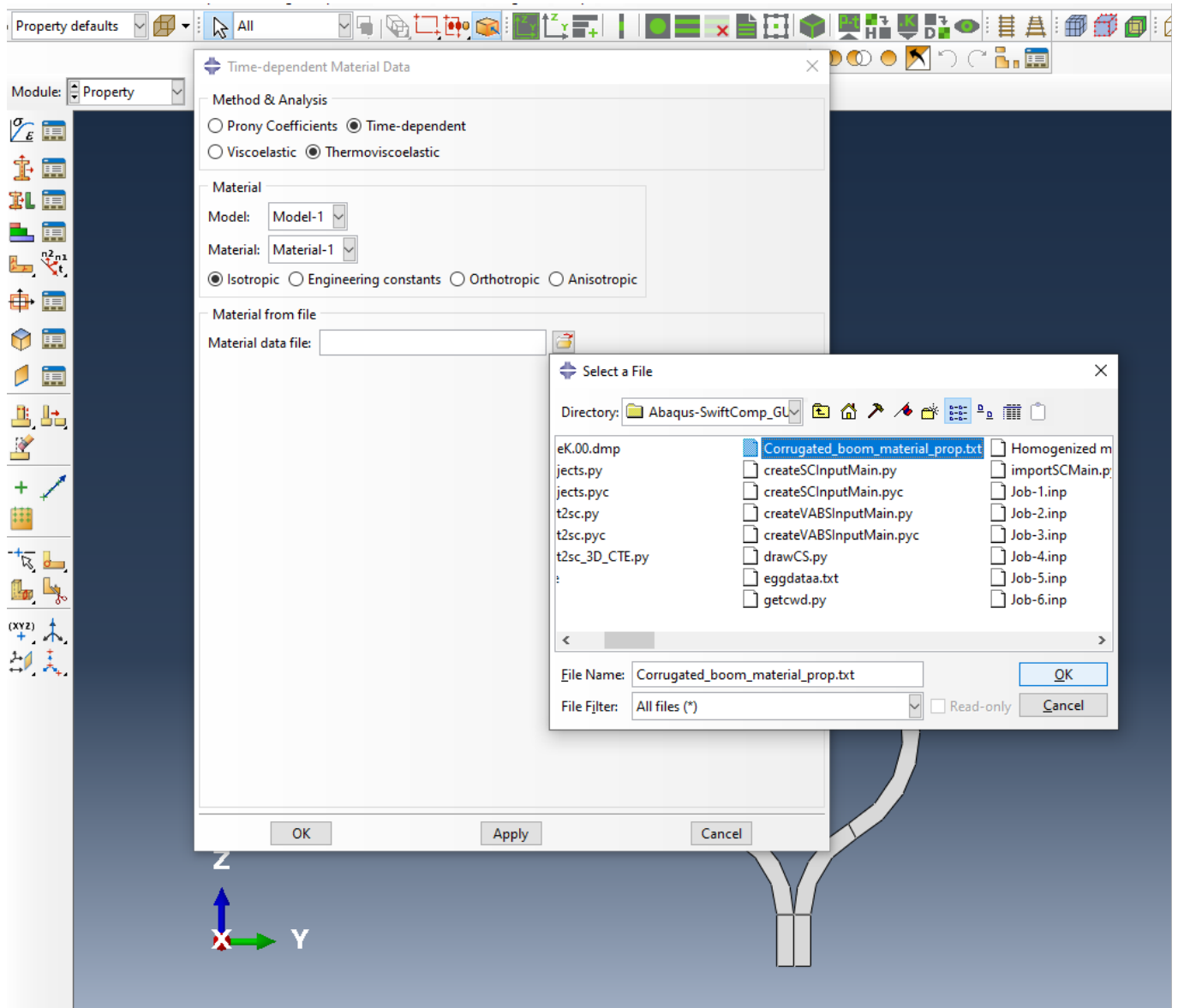
$$\begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{23} \end{Bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{16} & C_{15} & C_{14} \\ C_{12} & C_{22} & C_{23} & C_{26} & C_{25} & C_{24} \\ C_{13} & C_{23} & C_{33} & C_{36} & C_{35} & C_{34} \\ C_{16} & C_{26} & C_{36} & C_{66} & C_{56} & C_{46} \\ C_{15} & C_{25} & C_{35} & C_{56} & C_{55} & C_{45} \\ C_{14} & C_{24} & C_{34} & C_{46} & C_{45} & C_{44} \end{bmatrix} \begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ 2\varepsilon_{12} \\ 2\varepsilon_{13} \\ 2\varepsilon_{23} \end{Bmatrix}$$

SwiftComp's

output stiffness matrix converted into Abaqus's input stiffness matrix

(Image(L3.34.png, desc="Rearranged Material properties ") failed - File not found)

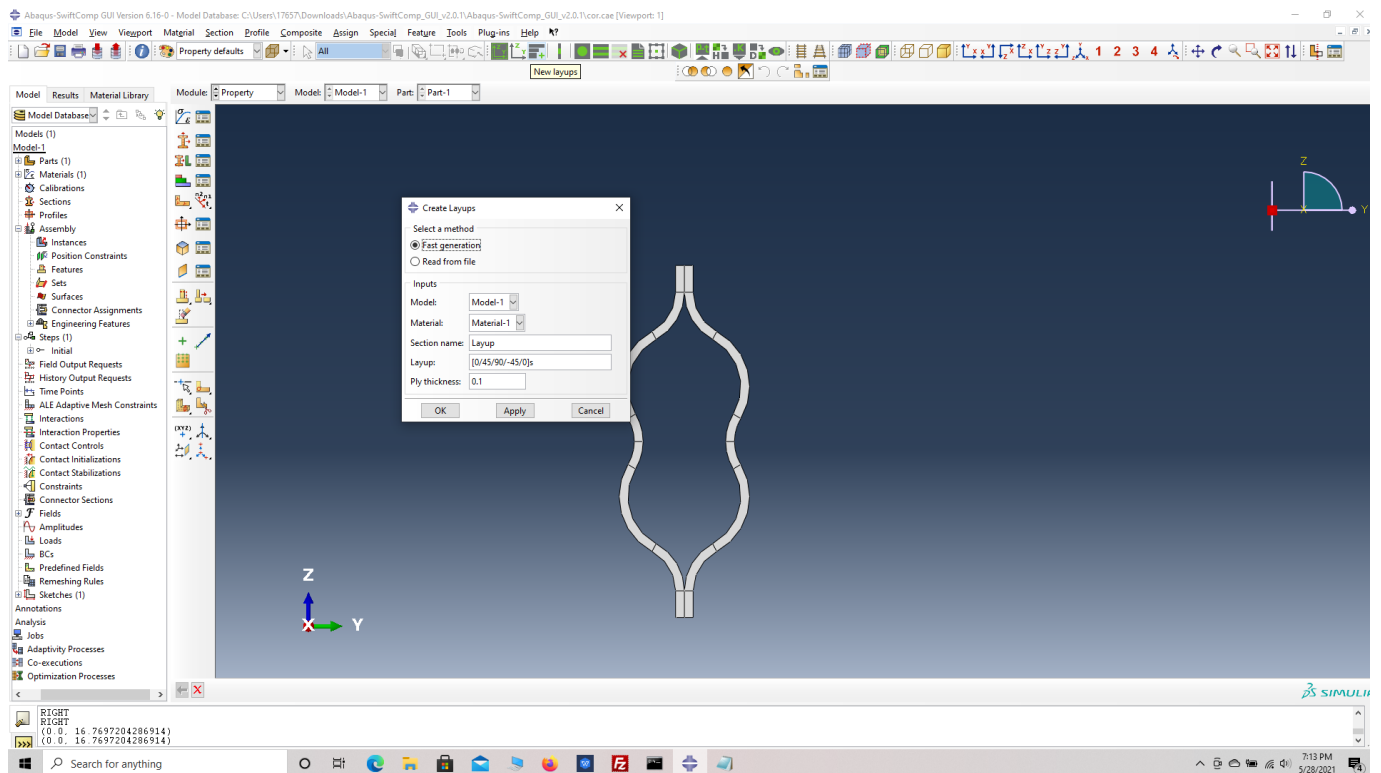
(Image(L3.3.png, desc="Material properties file") failed - File not found)



Material properties file

Step 3.4. 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 (0/45/90/-45/0)s as the laminate for the corrugated Boom.

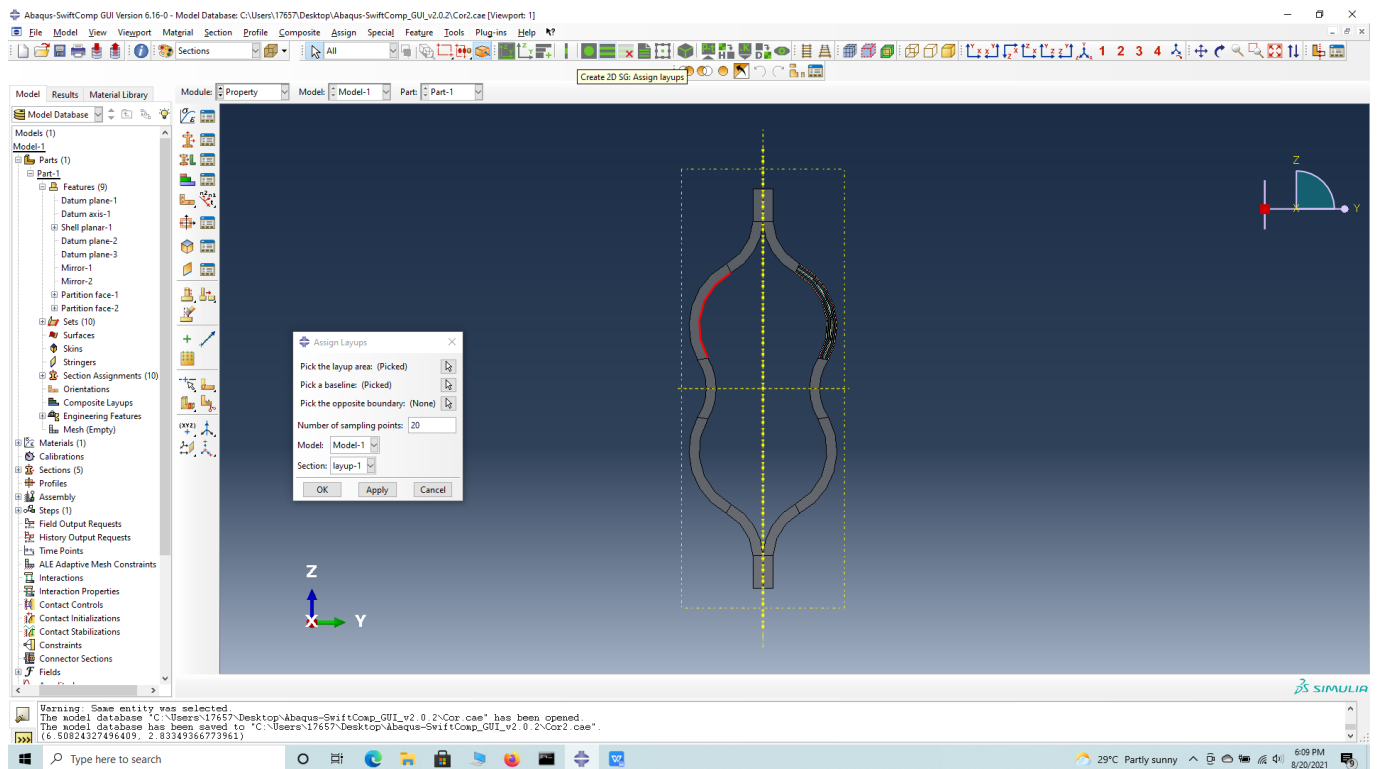
COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED



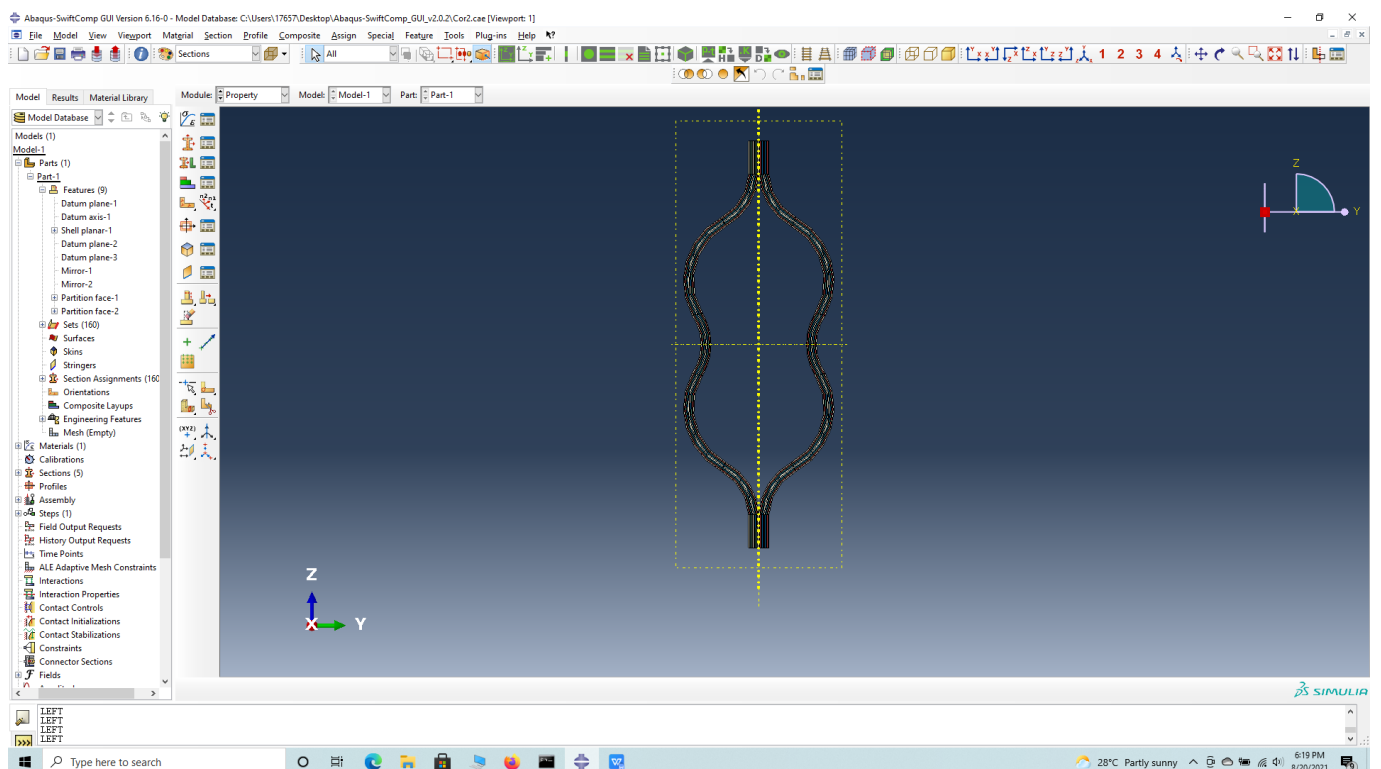
Layups

' # Step 3.5. 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 twelve sections

COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED



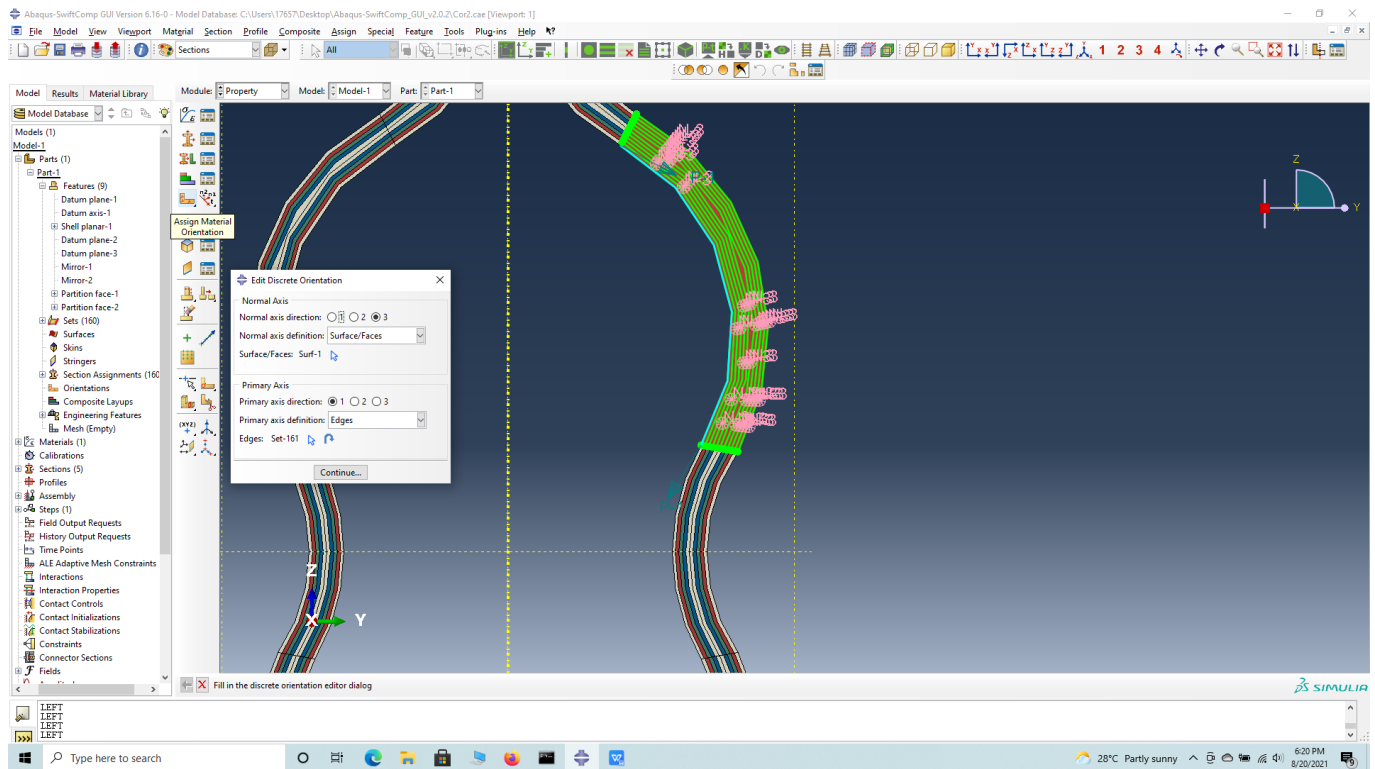
Assign Layouts



Assign Layups

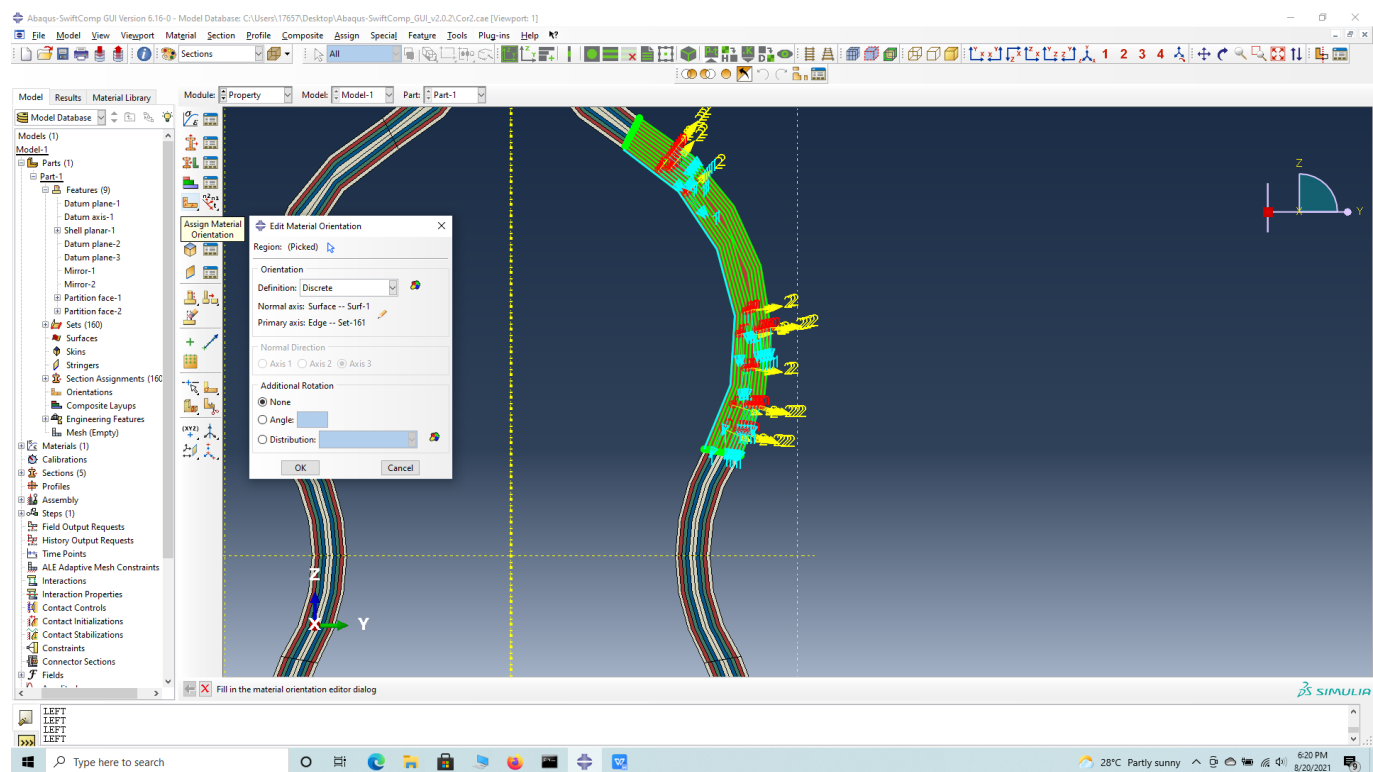
' # Step 3.6. Now we assign the material orientation for the part. Go to Assign material orientation -> select the sections of the part with the same orientation -> Done -> Select a CSYS

(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 a layup 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.



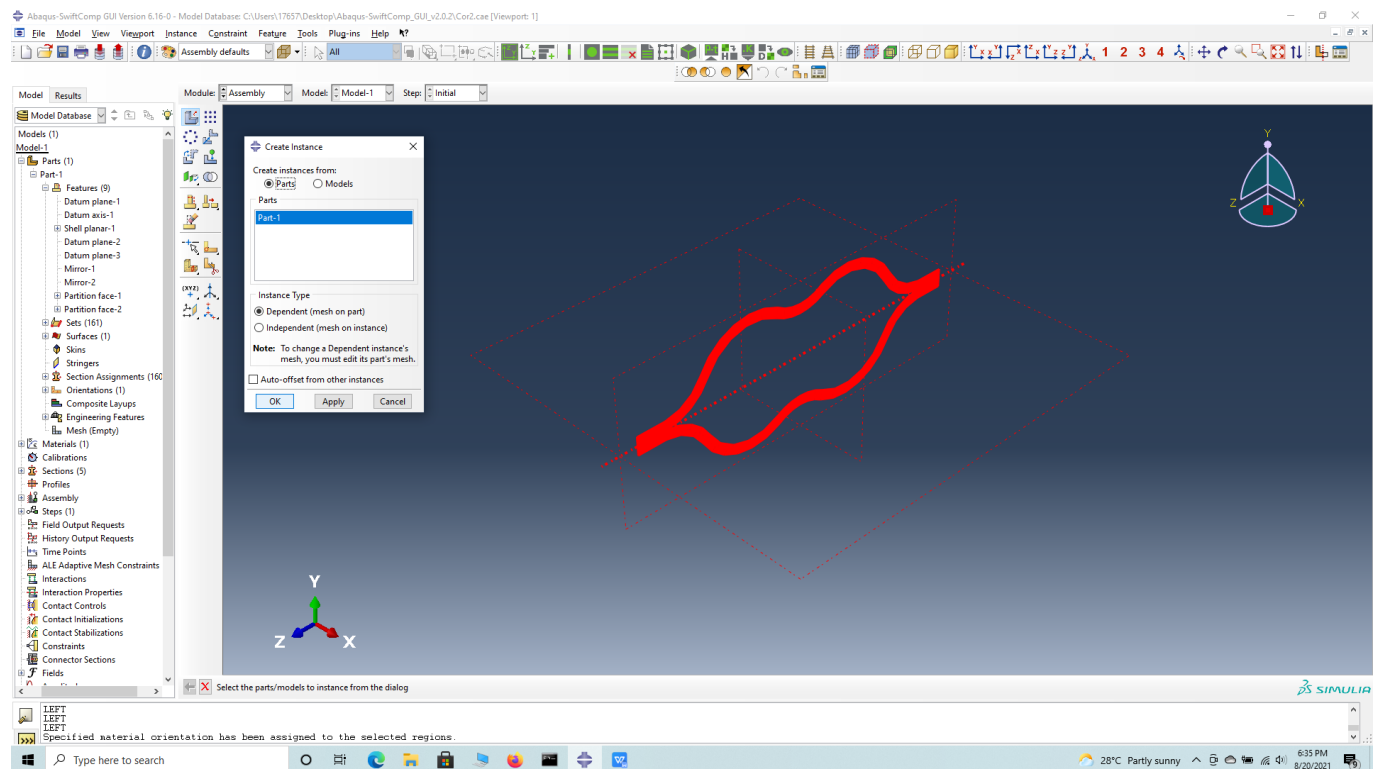
Edit edges

COMPUTATION OF THERMOVISCOELASTIC BEAM PROPERTIES OF A WOVEN COMPOSITE CORRUGATED



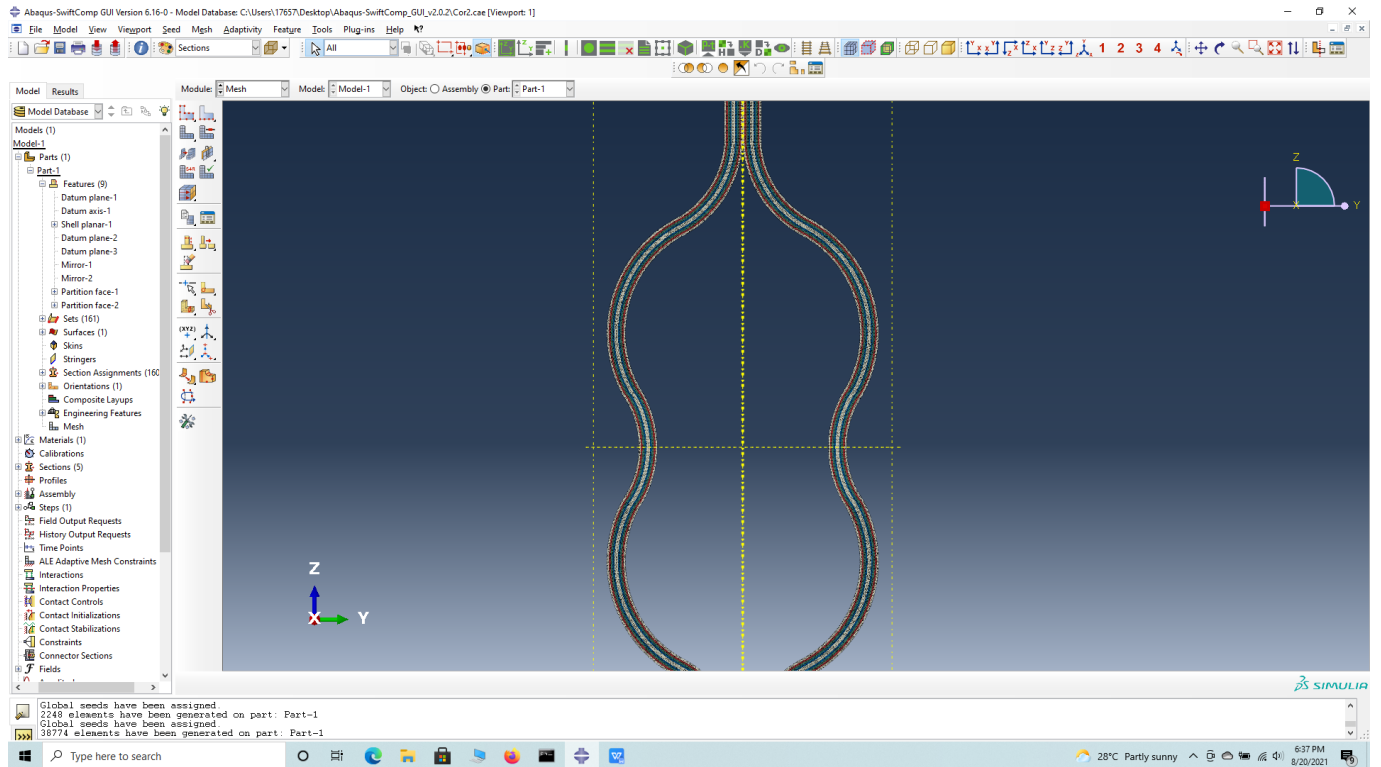
Define material orientation

' # Step 3.7. Now go to Assemble, create the part instance with dependent mesh.



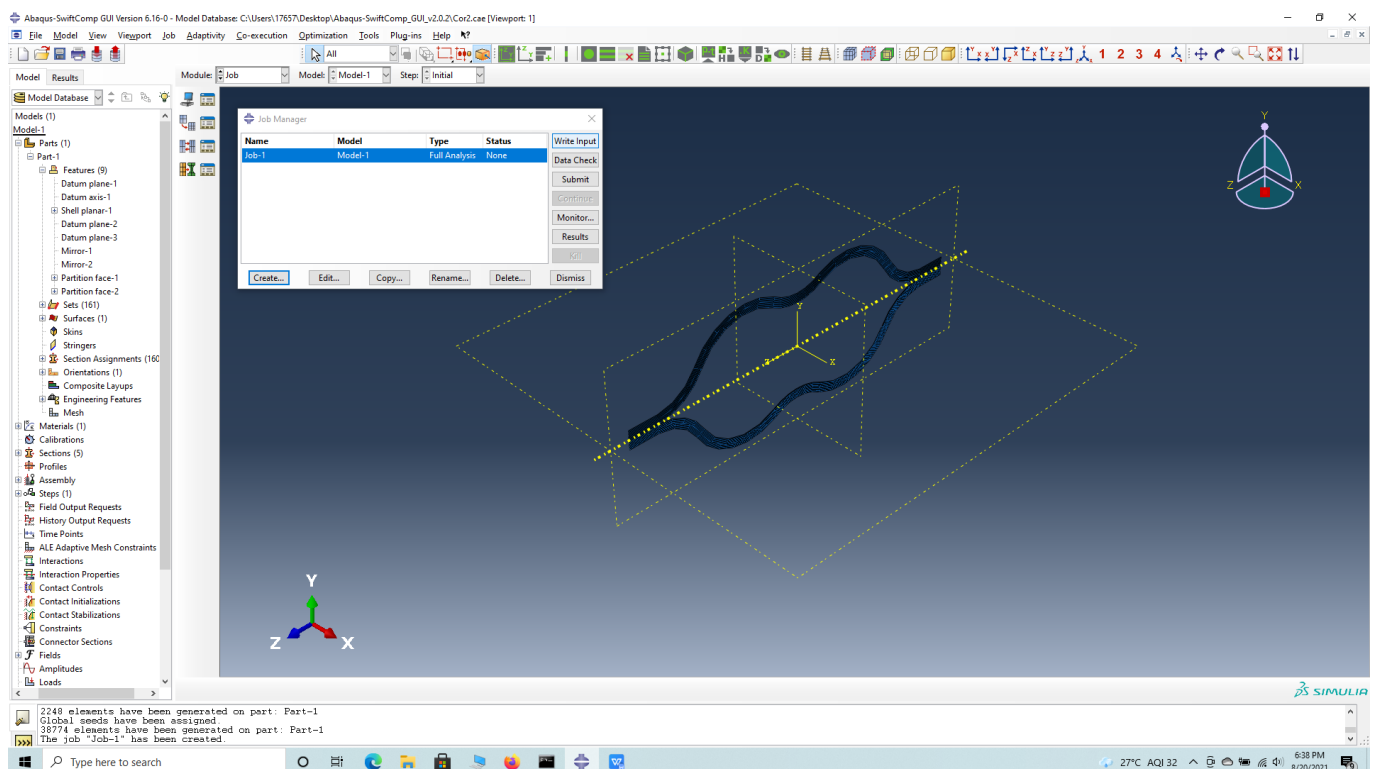
assembly

Step 3.8. In the Mesh section, Seed the Part and set approximate global mesh size, then Click 'Mesh Part'




Mesh

Step 3.9. Create a job and write its input file.



ip file


Step 3.10. To the effective viscoelastic properties. we click on Homogenization and select [ThermoViscoelastic](#) in Analysis Type. 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). Homogenize the part preferably as a beam using the Homogenization via input file option to get the final results.

 Homogenization

☐ New SwiftComp file name:

Model source

☐ CAE ☒ Input file

Abaqus input file: 

Macroscopic model

Dimension

☐ 1D (Beam)
☐ 2D (Shell)
☒ 3D (Solid)

Dimensionally reducible structures

Specific model:

☐ Omega:

Note: Provide omega if the combination of structural model and structure genome is NOT any of the following cases:

- 1) 3D solid model with regular structure genome (rectangular for 2D and cuboid for 3D);
- 2) 2D shell model with 1D structure genome;
- 3) 1D beam model with 2D structure genome.

Please refer to the SwiftComp manual for more details.

Options

Analysis type:

Element type:

Elemental orientation:

Temperature distribution:

Aperiodic

☐ y1 ☐ y2 ☐ y3

Viscoelastic/Thermoviscoelastic Analysis

Initial time:

Final time:

Time increment (decades):

Note: Provide a time increment in decades for the desired effective properties.
Only valid for viscoelastic and thermoviscoelastic cases.

☐ Only generate input file. Do not run SwiftComp.

OK

Cancel

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.