

Computation of effective viscoelastic properties and time-dependent constituent properties with Abaqus SwiftComp GUI

Viscoelastic Homogenization with Time-dependent Constituent Properties


In this example, we want to compute the effective properties of a composite material made of isotropic viscoelastic matrix and transversely isotropic elastic fiber. The fiber properties are defined by means of engineering constants as specified in the table below.

E_{1f} (MPa)	E_{2f} (MPa)	G_{12f} (MPa)	ν_{12f}	ν_{23f}
233,000.0	15,000.0	8,963.0	0.200	0.330

Fiber properties

defined as transversely isotropic elastic

The matrix properties are given as a time-dependent properties, which means that for each time a value of the Young's modulus is given. In addition, we will consider that the matrix has a constant Poisson's ratio equal to 0.37. We will create a text file to input the time-dependent material properties as follows.

 MaterialData - Notepad

```
File Edit Format View Help
4240          0.37    0
3995.020589  0.37    0.00199
4000.055703  0.37    0.0025
3907.769288  0.37    0.003
3915.915689  0.37    0.00323
3928.957043  0.37    0.00405
3848.963766  0.37    0.00486
3811.835591  0.37    0.00649
3790.065459  0.37    0.00811
3774.258298  0.37    0.00974
3756.704982  0.37    0.0122
3742.665689  0.37    0.0146
3728.796174  0.37    0.0179
3714.379814  0.37    0.0219
3701.781663  0.37    0.0268
3689.109482  0.37    0.0325
3677.140102  0.37    0.039
```

Time-dependent matrix properties

Please note that for different viscoelastic anisotropies, the material properties should be defined as follows in different columns.

- **Transversely isotropic.** — Young's Modulus, $E(t)$ — Poisson's ratio, $\nu(t)$ — Time, t

- **Orthotropic defined by means of engineering constants.** — $E_1(t)$ — $E_2(t)$ — $E_3(t)$ — $\nu_{12}(t)$ — $\nu_{13}(t)$ — $\nu_{23}(t)$ — $G_{12}(t)$ — $G_{13}(t)$ — $G_{23}(t)$ — Time, t

- **Orthotropic defined by means of stiffness matrix.** — $D_{1111}(t)$ — $D_{1122}(t)$ — $D_{2222}(t)$ — $D_{1133}(t)$ — $D_{2233}(t)$ — $D_{3333}(t)$ — $D_{1212}(t)$ — $D_{1313}(t)$ — $D_{2323}(t)$ — Time, t

- **Anisotropic.** — $D_{1111}(t)$ — $D_{1122}(t)$ — $D_{2222}(t)$ — $D_{1133}(t)$ — $D_{2233}(t)$ — $D_{3333}(t)$ — $D_{1112}(t)$ — $D_{2212}(t)$ — $D_{3312}(t)$ — $D_{1212}(t)$ — $D_{1113}(t)$ — $D_{2213}(t)$ — $D_{3313}(t)$ — $D_{1213}(t)$ — $D_{1313}(t)$ — $D_{1123}(t)$ — $D_{2223}(t)$ — $D_{3323}(t)$ — $D_{1223}(t)$ — $D_{1323}(t)$ — $D_{2323}(t)$ — Time, t

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

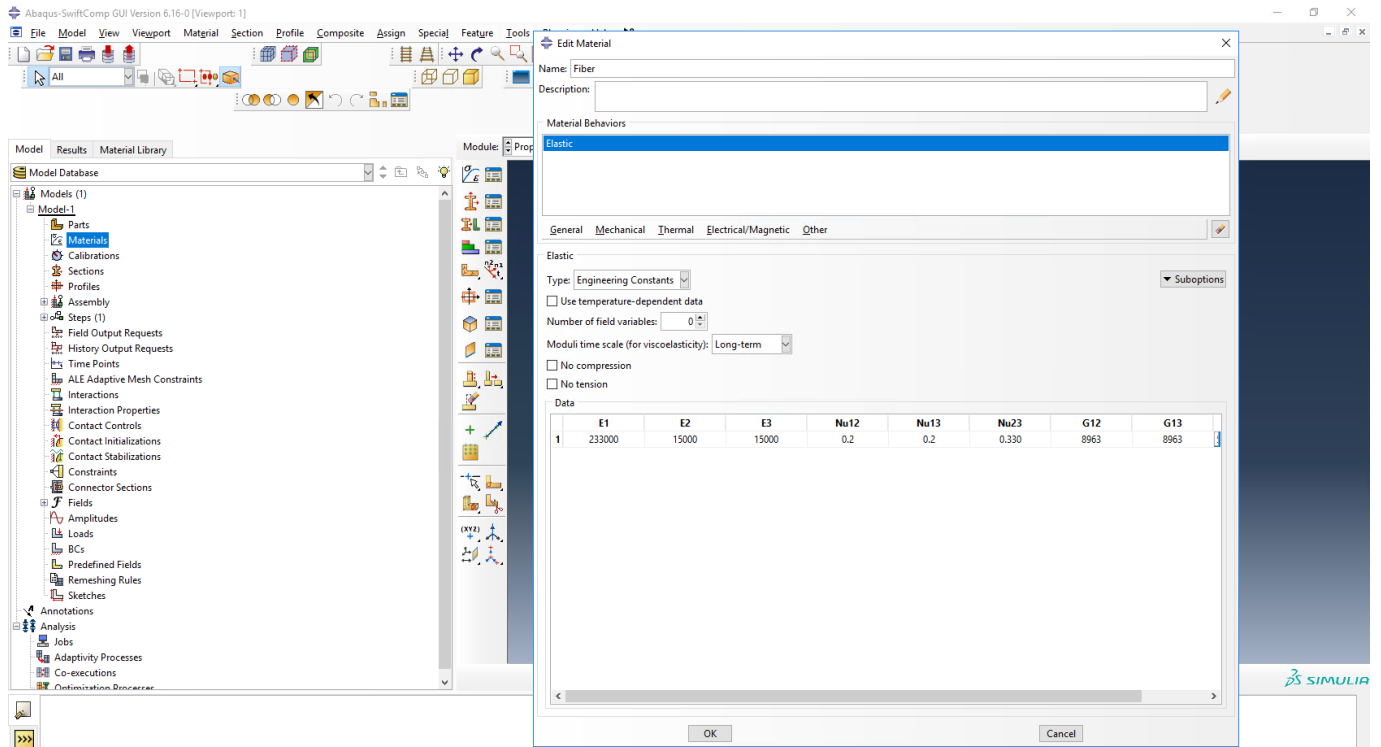
Software Used

In his tutorial we will use Abaqus CAE with the Abaqus [SwiftComp](#) GUI plug-in. Abaqus CAE will be used to GUI to define the time-dependent material properties and to run the viscoelastic homogenization. [SwiftComp](#) will run in the background.

Solution Procedure

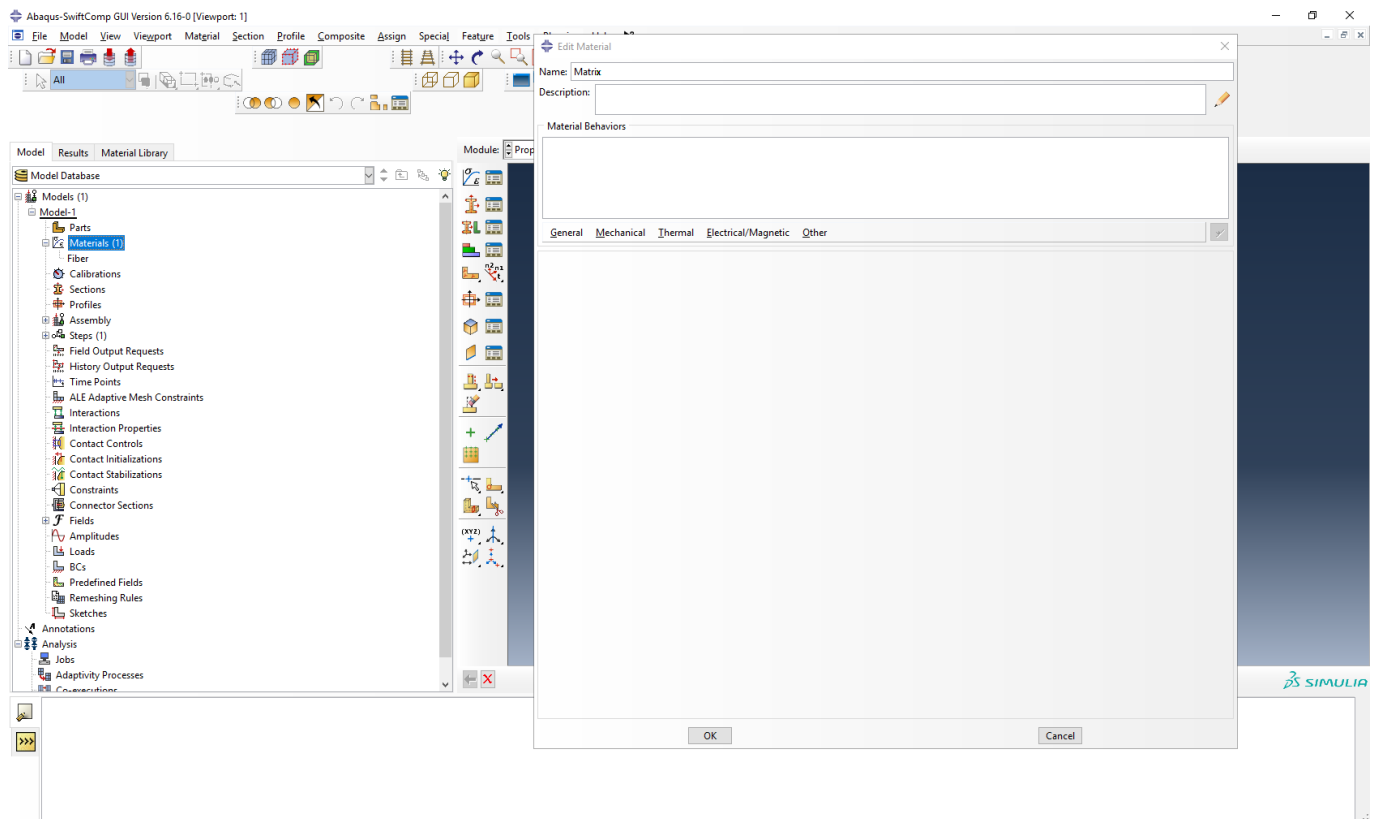
The steps required to compute the effective viscoelastic properties using Abaqus [SwiftComp](#) GUI are as follows.

Step 1. We define the material properties in global coordinate system. We click on *Materials* in Abaqus CAE and define the *Fiber* properties by means of the engineering constants and click "OK".



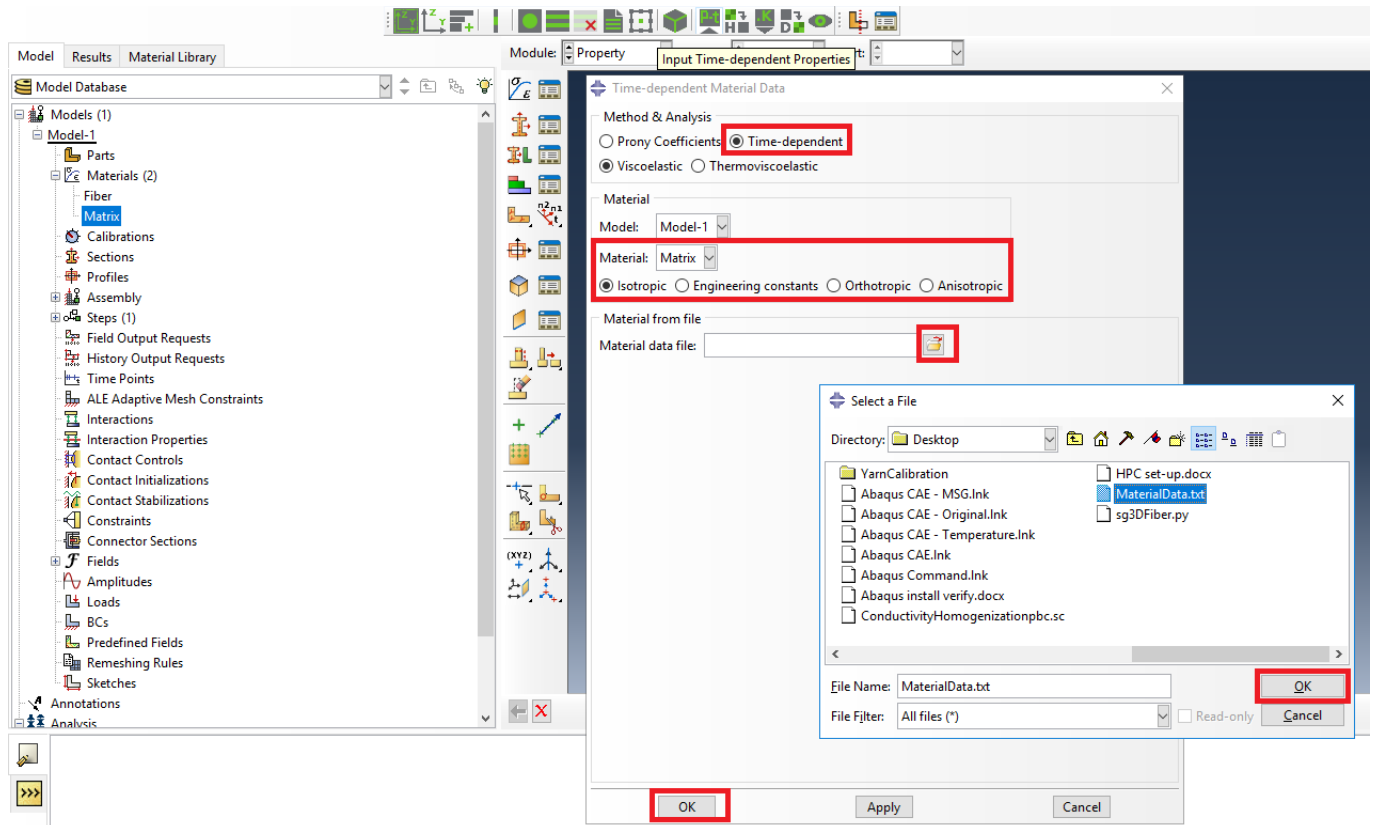
Definition of the fiber properties

Step 2. Within the *Materials* of Abaqus CAE, we create a dummy material called “Matrix”. Please note that we will not define the Prony coefficients of the resin using the Abaqus [SwiftComp](#) GUI in the next step.



Creation of the dummy material for the matrix

Step 3. In the Abaqus [SwiftComp](#) GUI menu, we click on Input Time-Dependent Properties. We select “Time-dependent” and “Viscoelastic” in the Method & Analysis section. We pick “Matrix” as the Material to be modified in the drop down menu. Then, we look for the text file used to input the material properties. This text file can be located in any folder of the computer. Finally, we click the two “Ok”s as shown in the picture.



Definition of the matrix Prony coefficients

Step 4. From the default the Abaqus [SwiftComp](#) GUI SGs, we pick the 2D Structure Genome with Square pack. We input the fiber volume fraction, define the approximate global mesh size, and click “Ok”. A square pack microstructure will be automatically generated.

2D Structure Genome - Unit Cell

Select a profile
 Square Hexagonal

Geometry

Fiber
 Volume fraction (vf_f)
 Radius (r)
0.64

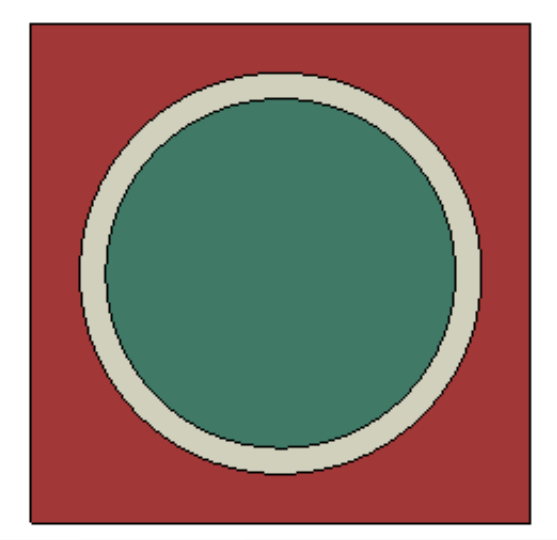
Interphase
 Volume fraction (vf_i)
 Thickness (t)
0

Note: $0 < vf_f + vf_i \leq 0.78$

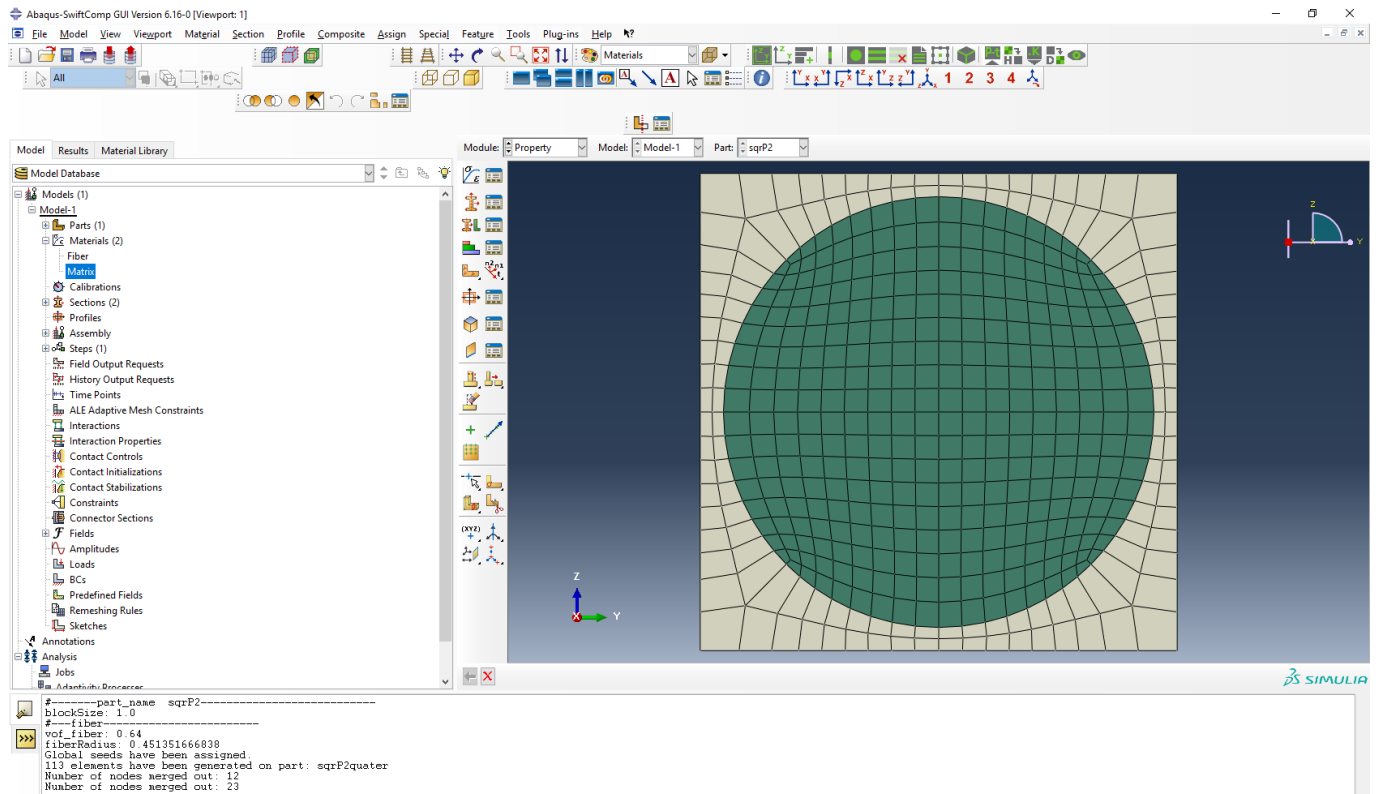
Material
Model: Model-1
Fiber: Fiber
Matrix: Matrix
Interphase: Fiber

Mesh
Approximate global mesh size: 0.05
Element type: Linear

OK Apply Cancel

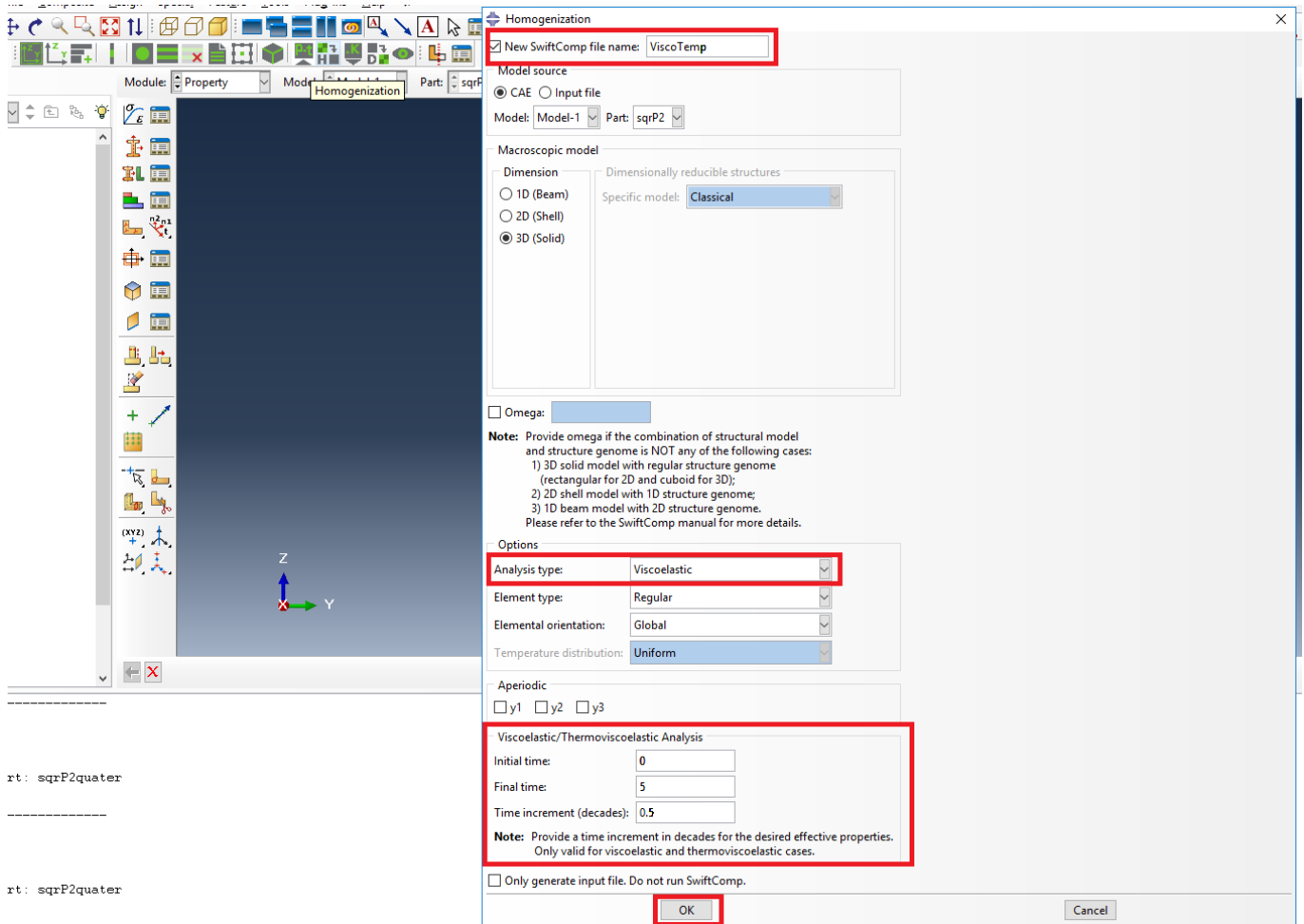


Definition of the 2D SG square pack microstructure



2D SG square pack microstructure

Step 5. Now, we will compute the effective viscoelastic properties. To do so, we click on *Homogenization* and select *Viscoelastic* 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).



Definition of the viscoelastic homogenization step

Step 6. We click on *Ok* to run the homogenization step. [SwiftComp](#) on the background will run the homogenization.



```
Intel(R) MPI Library 2017 Update 3 for Windows* Target Build Envi...
SwiftComp 2.1
Multiscale Constitutive Modeling of Composites
School of Aeronautics and Astronautics
Purdue University
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*****
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process or combination thereof, now known or later developed.
These commodities, technology or software were exported from
the United States in accordance with the Export
Administration Regulations. Diversion contrary to U.S. law
prohibited.
*****
SwiftComp begins at 200612.657
Inputs echoed in file ViscoTempabc.sc.ech!
Constitutive modeling for a 3D model!
Homogenization will be carried out!
You are running SwiftComp with full integration!
Finished reading/processing model file!
Effective properties can be found in file ViscoTempabc.sc.k!
Finished homogenization!
SwiftComp ends at 200613.142
SwiftComp finished successfully!
```

SwiftComp

running on the background

Step 7. The results can be found in the `.sc.k` file as shown next. Note that the effective properties will be outputted for each specified time.


```

C:\Users\orivega\Desktop\Abaqus-SwiftComp_GUI_v2.0\ViscoTempppbc.sc.k - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
ViscoTempppbc.sc.k
1 #-----#
2 Effective Viscoelastic Properties at Time: t = 1.0000000E+000
3
4 The Effective Stiffness Matrix
5 -----
6 1.5022356E+005 1.9005934E+003 1.9005317E+003 1.9539925E-014 0.0000000E+000 0.0000000E+000
7 1.9005934E+003 5.6630274E+003 1.9065375E+003 -1.4424018E-012 0.0000000E+000 0.0000000E+000
8 1.9005317E+003 1.9065375E+003 5.6626731E+003 1.0365042E-012 0.0000000E+000 0.0000000E+000
9 1.9539925E-014 -1.4424018E-012 1.0365042E-012 1.0788270E+003 0.0000000E+000 0.0000000E+000
10 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 1.6152414E+003 -1.8509638E-012
11 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 -1.8509638E-012 1.6152694E+003
12
13 The Effective Compliance Matrix
14 -----
15 6.6993079E-006 -1.6820740E-006 -1.6821225E-006 -7.5415551E-022 -0.0000000E+000 -0.0000000E+000
16 -1.6820740E-006 1.9958091E-004 -6.6631366E-005 3.3088940E-019 -0.0000000E+000 -0.0000000E+000
17 -1.6821225E-006 -6.6631366E-005 1.9959339E-004 -2.8081957E-019 -0.0000000E+000 -0.0000000E+000
18 -7.5415551E-022 3.3088940E-019 -2.8081957E-019 9.2693271E-004 -0.0000000E+000 -0.0000000E+000
19 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 6.1910249E-004 7.0943976E-019
20 0.0000000E+000 0.0000000E+000 0.0000000E+000 0.0000000E+000 7.0943976E-019 6.1909179E-004
21
22 The Engineering Constants (Approximated as Orthotropic)
23 -----
24 E1 = 1.4926915E+005
25 E2 = 5.0104994E+003
26 E3 = 5.0101859E+003
27 G12 = 1.6152694E+003
28 G13 = 1.6152414E+003
29 G23 = 1.0788270E+003
30 nu12= 2.5108175E-001
31 nu13= 2.5108900E-001
32 nu23= 3.3385642E-001
33
34
35 Effective Density = 0.0000000E+000
36 #-----#
37 Effective Viscoelastic Properties at Time: t = 3.1622777E+000
38
Normal text file length: 52,745 lines: 386 Ln: 28 Col: 80 Sel: 0|0 Windows (CR LF) UTF-8 INS

```

Results corresponding to the effective viscoelastic properties

References

1. Liu, X.; Tang, T.; Yu, W., Pipes, R. B.: "Multiscale modeling of viscoelastic behavior of textile composites," International Journal of Engineering Science, Vol 130, September 2018, pp. 175-186, DOI: 10.1016/j.ijengsci.2018.06.003.
1. 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.