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 $v_f = 0.64$.

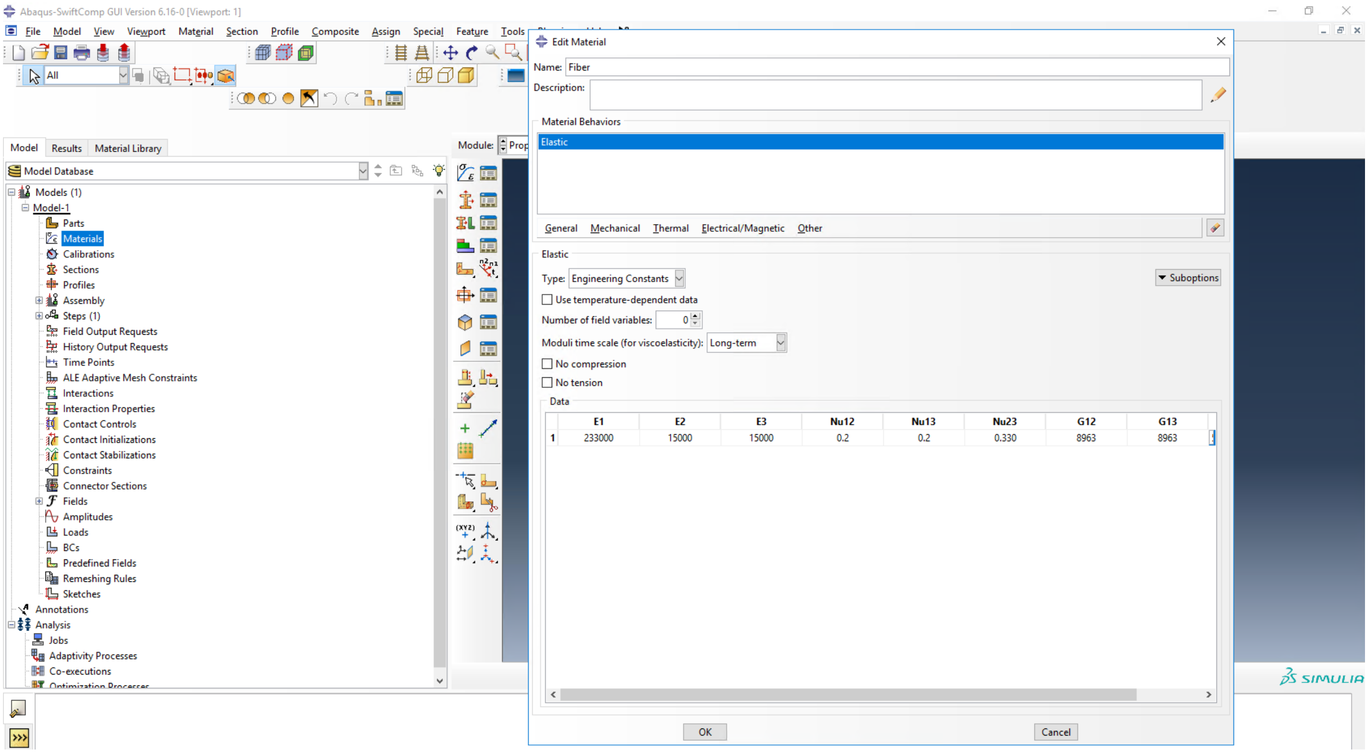
Software Used

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

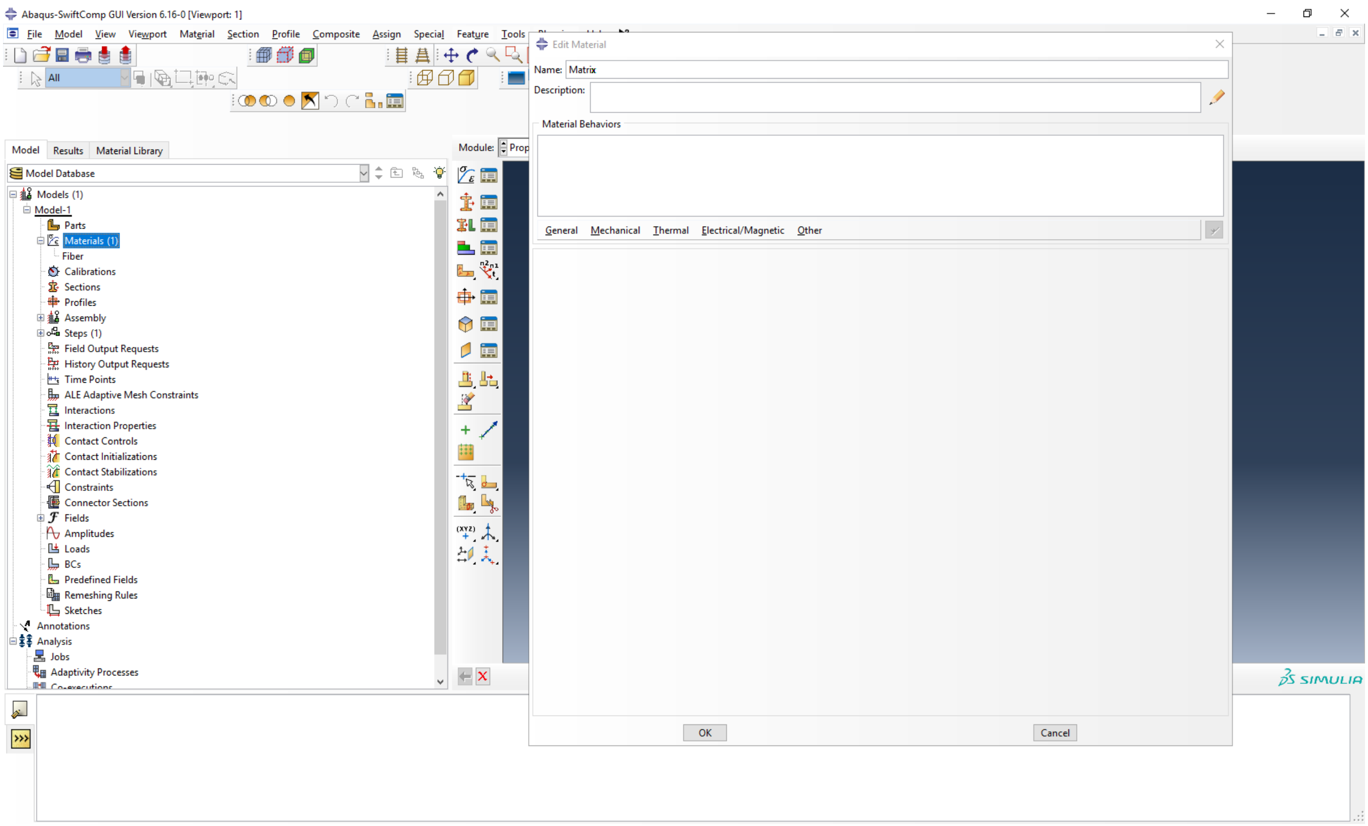
The steps required to compute the effective viscoelastic properties using Abaqus SwiftComp GUI are as follows.

 # 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”.



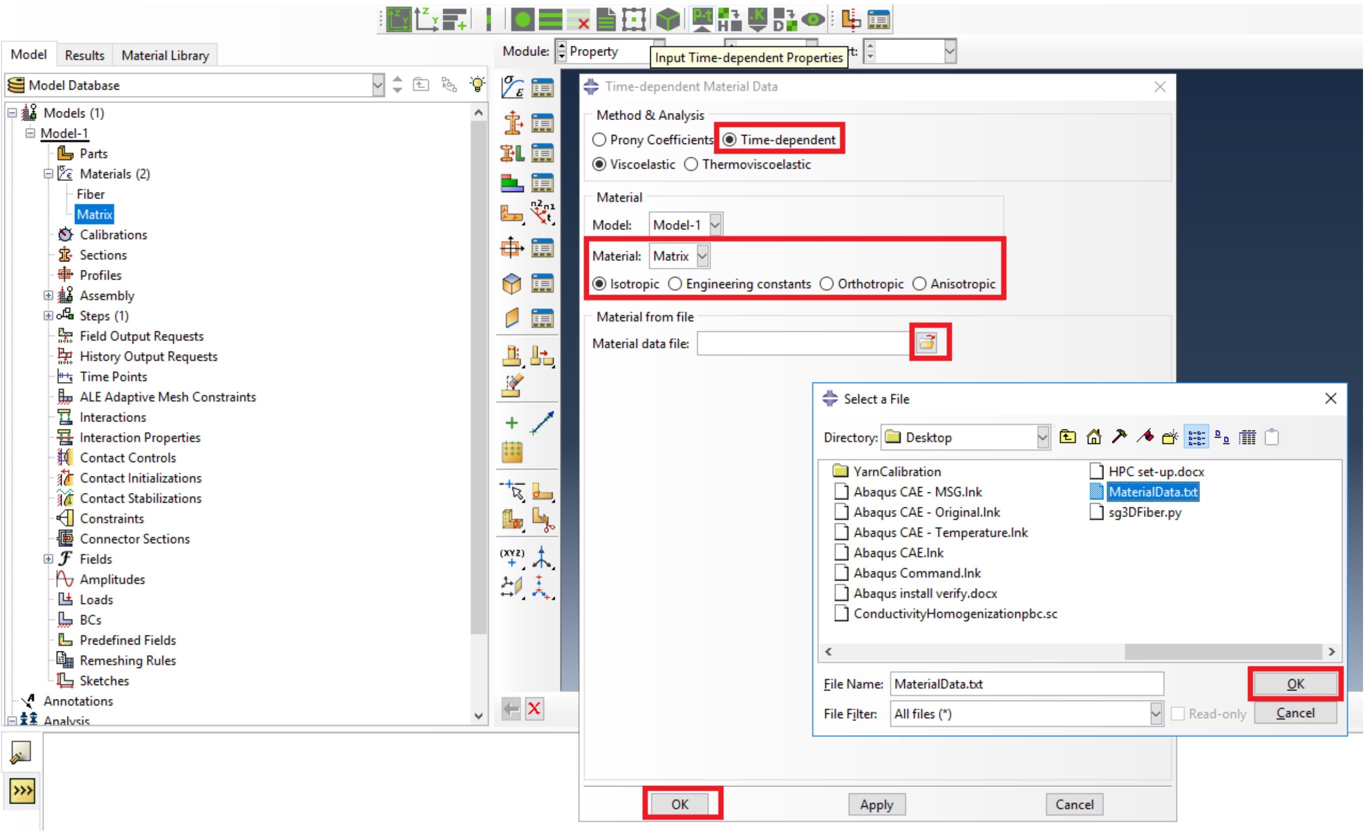
Definition of the fiber properties

 # 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.



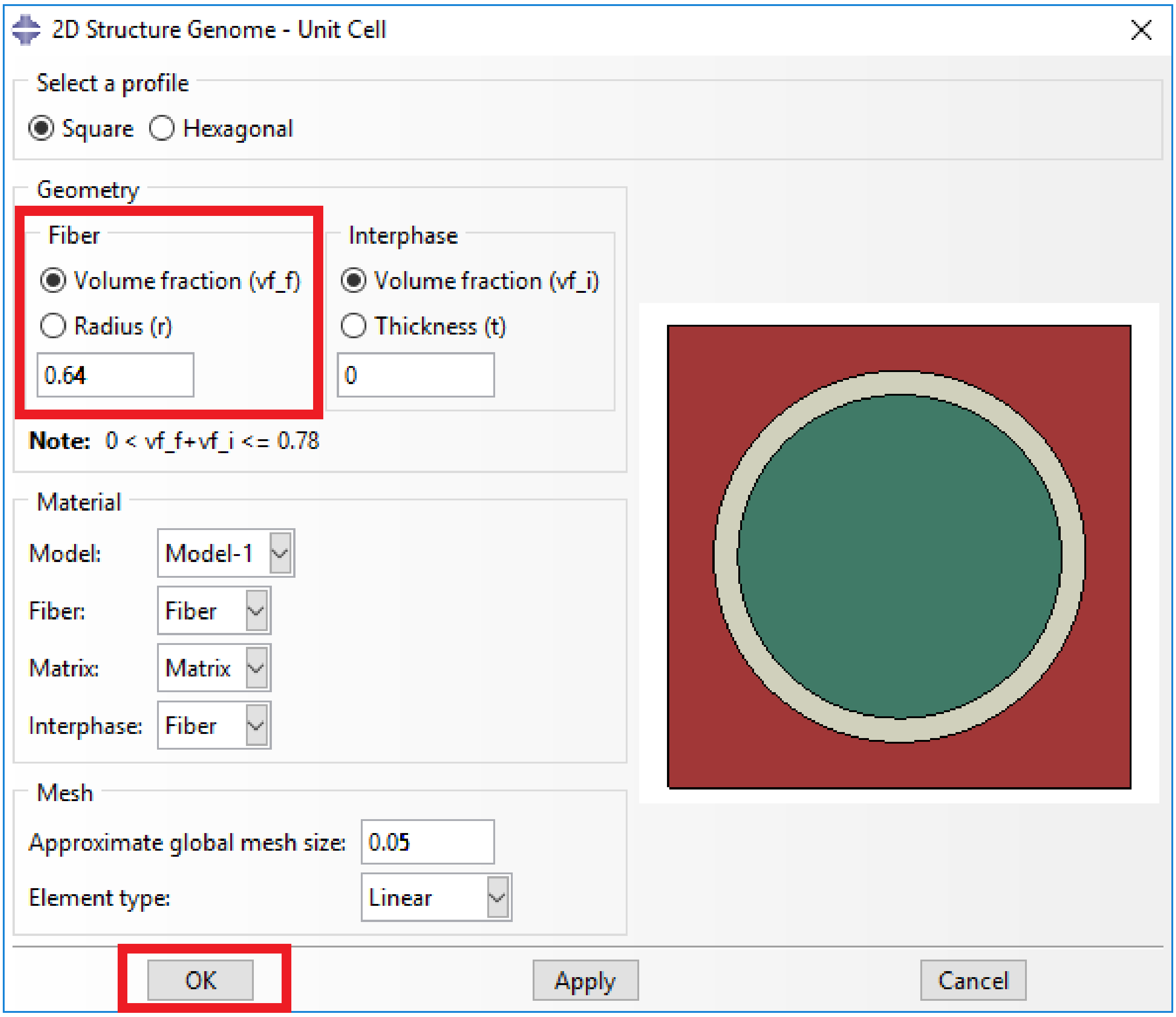
Creation of the dummy material for the matrix

 # 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.

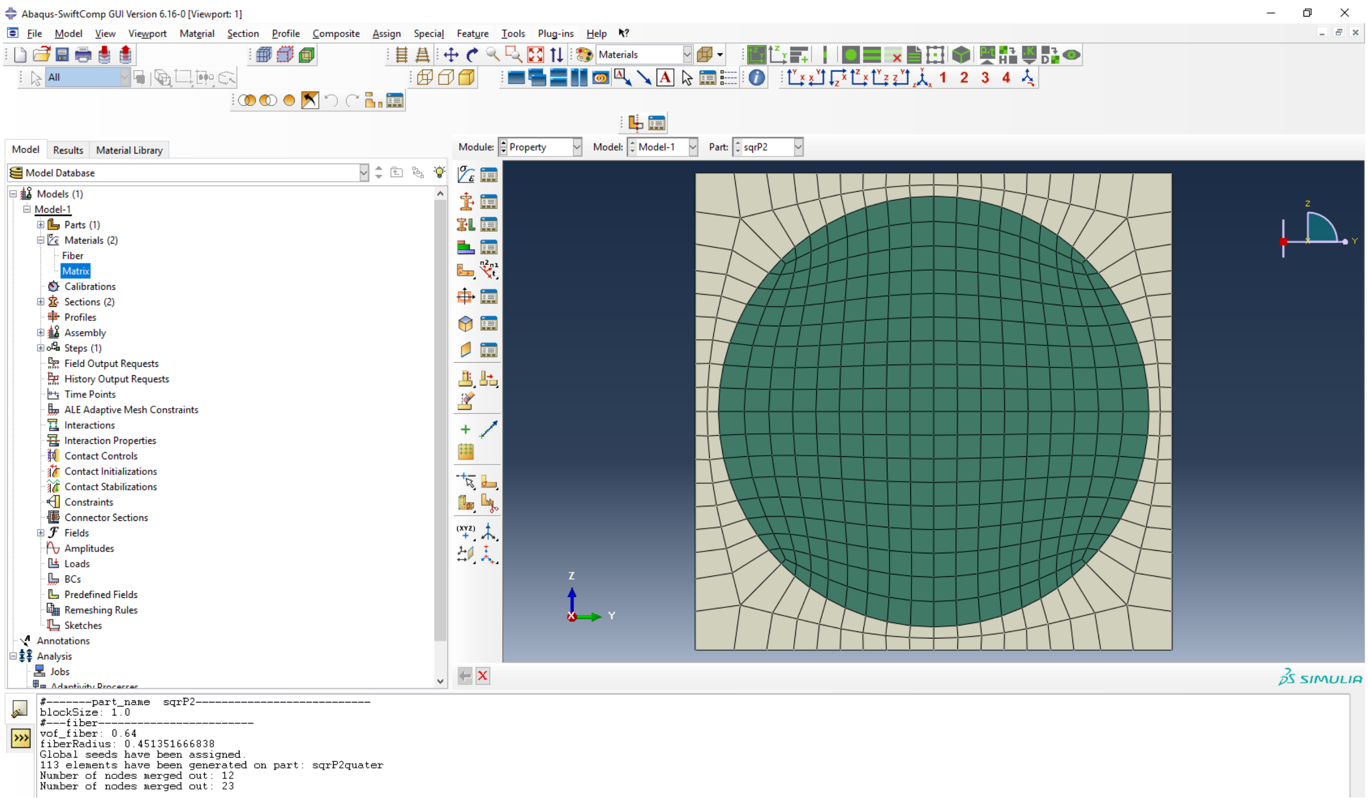


Definition of the matrix Prony coefficients

 # 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.

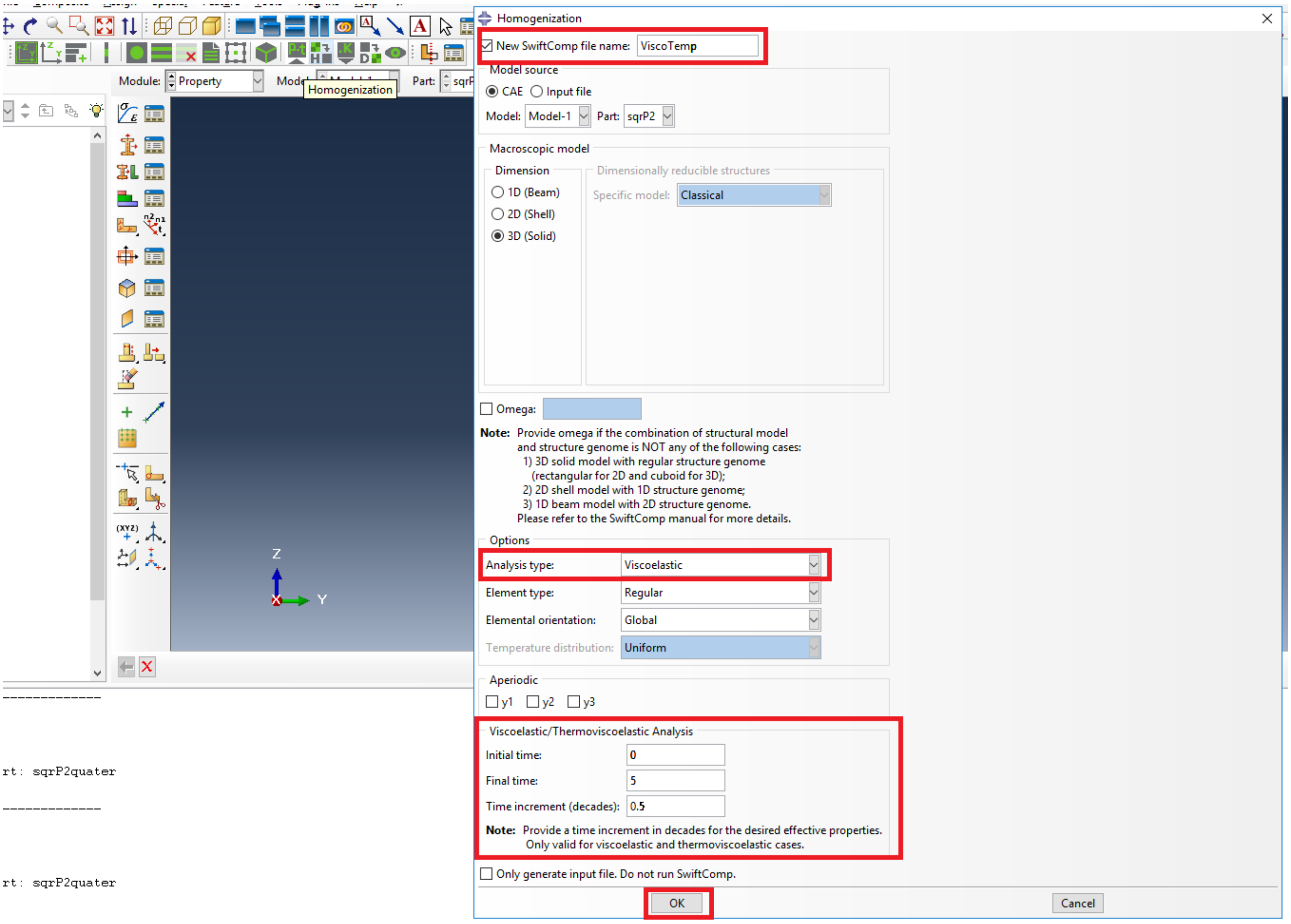


Definition of the 2D SG square pack microstructure



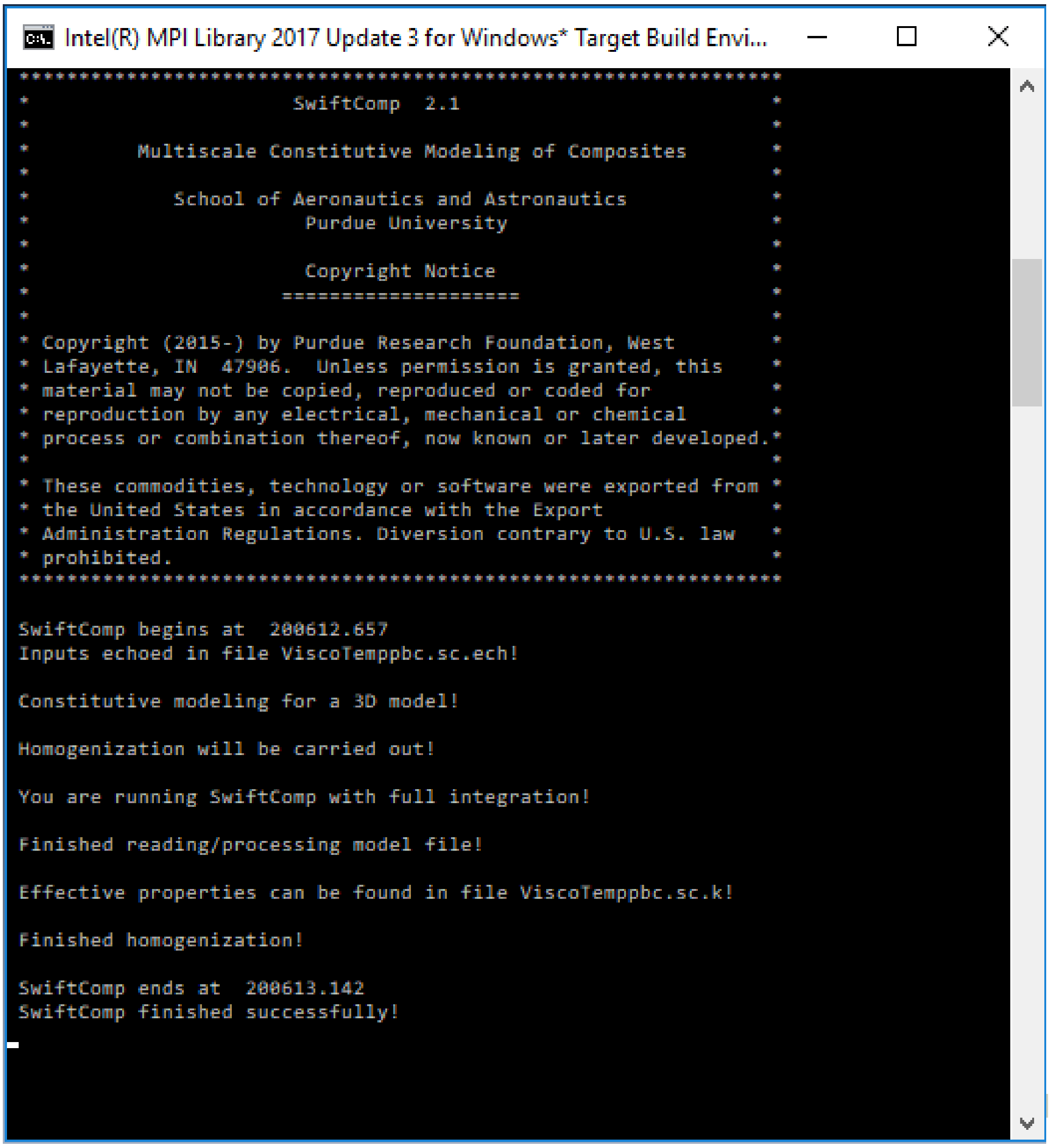
2D SG square pack microstructure

 # 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).*



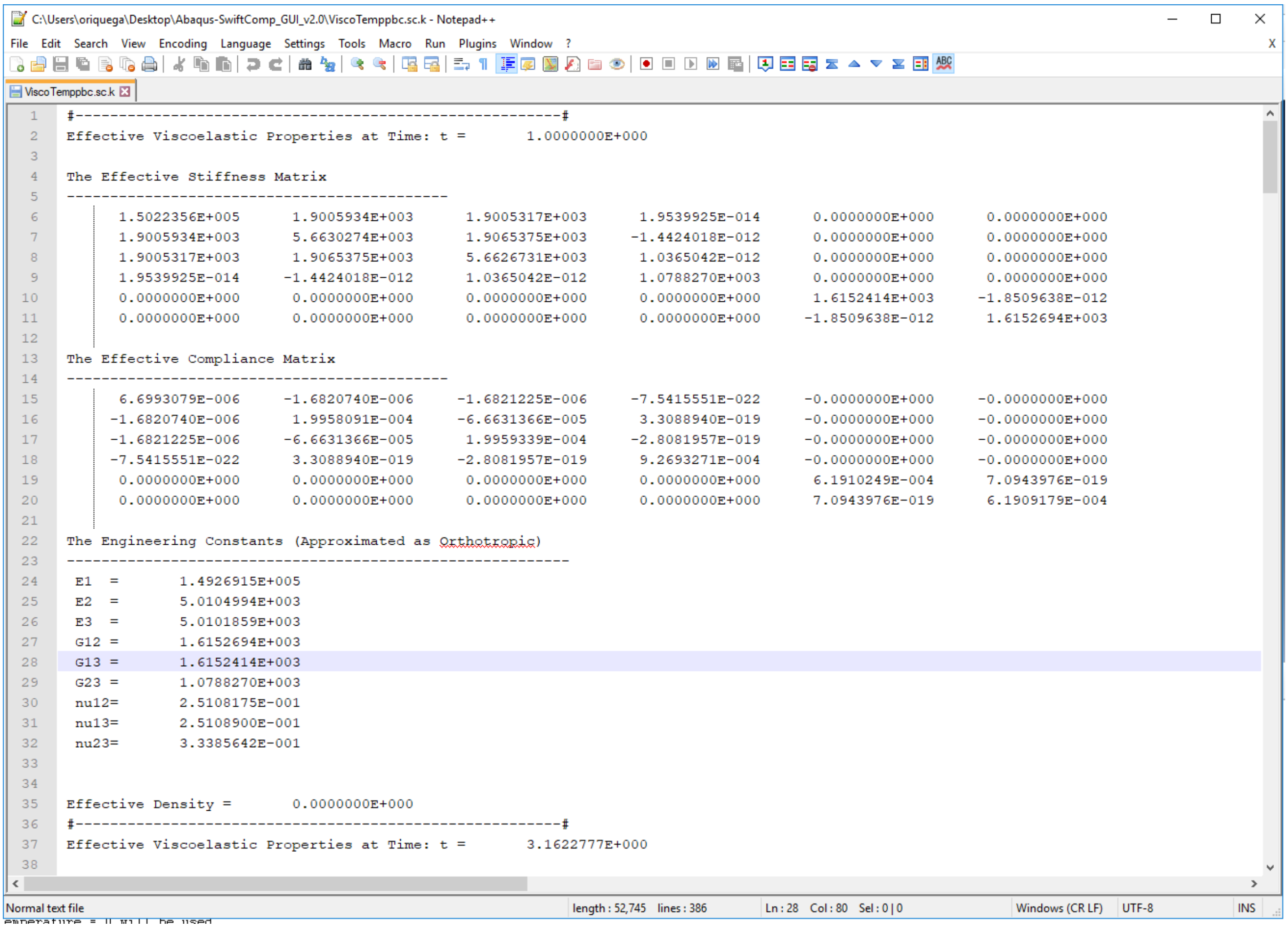
Definition of the viscoelastic homogenization step

\# **Step 6.** We click on *Ok* to run the homogenization step. SwiftComp on the background will run the homogenization.



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.

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

The Effective Stiffness Matrix
--------------------------------------------
      1.5022356E+005      1.9005934E+003      1.9005317E+003      1.9539925E-014      0.0000000E+000      0.0000000E+000
      1.9005934E+003      5.6630274E+003      1.9065375E+003     -1.4424018E-012      0.0000000E+000      0.0000000E+000
      1.9005317E+003      1.9065375E+003      5.6626731E+003      1.0365042E-012      0.0000000E+000      0.0000000E+000
      1.9539925E-014     -1.4424018E-012      1.0365042E-012      1.0788270E+003      0.0000000E+000      0.0000000E+000
      0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      1.6152414E+003     -1.8509638E-012
      0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000     -1.8509638E-012      1.6152694E+003

The Effective Compliance Matrix
--------------------------------------------
      6.6993079E-006     -1.6820740E-006     -1.6821225E-006     -7.5415551E-022     -0.0000000E+000     -0.0000000E+000
     -1.6820740E-006      1.9958091E-004     -6.6631366E-005      3.3088940E-019     -0.0000000E+000     -0.0000000E+000
     -1.6821225E-006     -6.6631366E-005      1.9959339E-004     -2.8081957E-019     -0.0000000E+000     -0.0000000E+000
     -7.5415551E-022      3.3088940E-019     -2.8081957E-019      9.2693271E-004     -0.0000000E+000     -0.0000000E+000
      0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      6.1910249E-004      7.0943976E-019
      0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      7.0943976E-019      6.1909179E-004

The Engineering Constants (Approximated as Orthotropic)
----------------------------------------------------------
 E1  =       1.4926915E+005
 E2  =       5.0104994E+003
 E3  =       5.0101859E+003
 G12 =       1.6152694E+003
 G13 =       1.6152414E+003
 G23 =       1.0788270E+003
 nu12=       2.5108175E-001
 nu13=       2.5108900E-001
 nu23=       3.3385642E-001


Effective Density =       0.0000000E+000
#-------------------------------------------------------#
Effective Viscoelastic Properties at Time: t =       3.1622777E+000
```

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.