

Computation of Viscoelastic properties with Abaqus Swift Comp GUI

Viscoelastic Homogenization

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 by means of the Prony coefficients presented in the table below and following the formulation of Figure 1. In addition, we will consider that the matrix has a constant Poisson's ratio equal to 0.33.

$$E_m = E_\infty + \sum_{s=1}^n E_s \exp\left(-\frac{\xi}{\lambda_s}\right)$$

Definition of the Young modulus of the resin

s	∞	1	2	3	4	5	6	7
λ_s (s)	-	10^3	10^5	10^6	10^7	10^8	10^9	10^{10}
E_s (MPa)	1,000.0	224.1	450.8	406.1	392.7	810.4	203.7	1,486.0

Prony coefficients and relaxation times for the matrix

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

Software Used

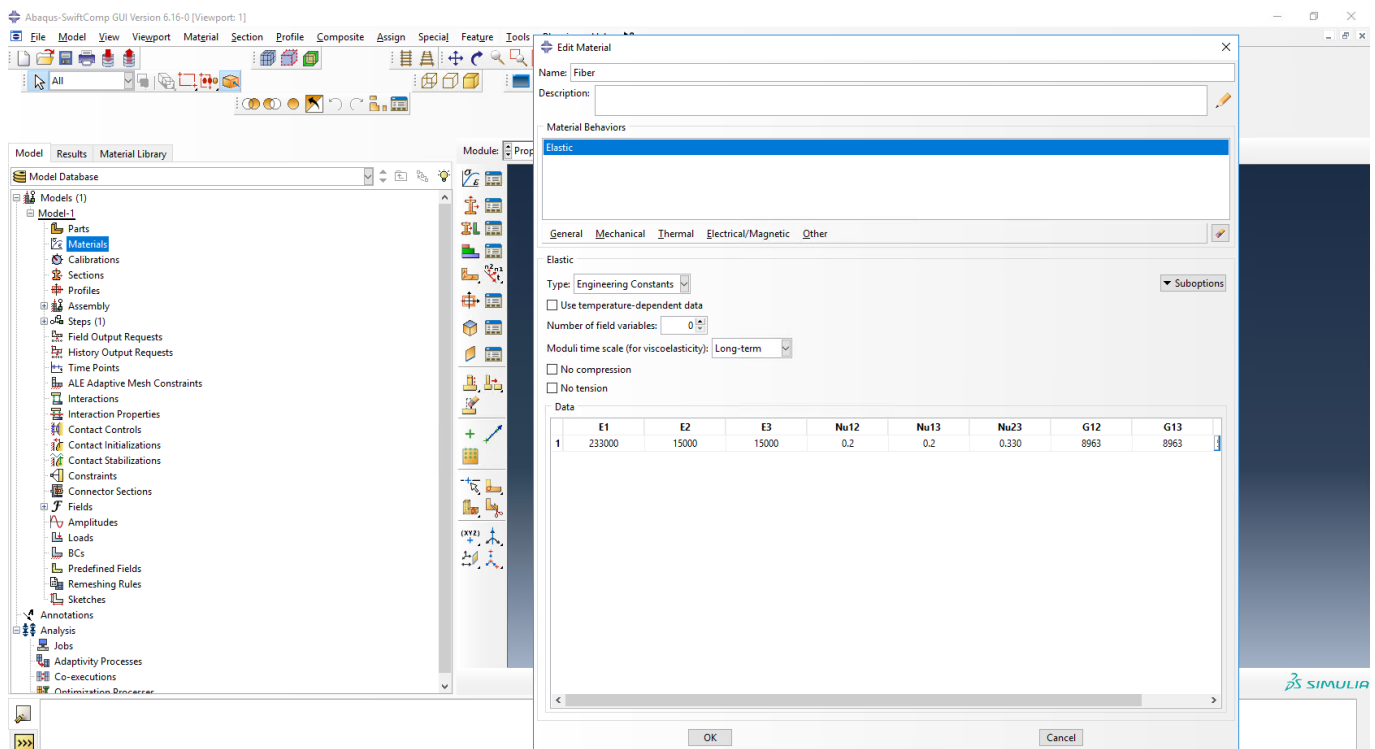
In his tutorial we will use Abaqus CAE with the Abaqus [SwiftComp](#) GUI plug-in. Abaqus CAE

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.

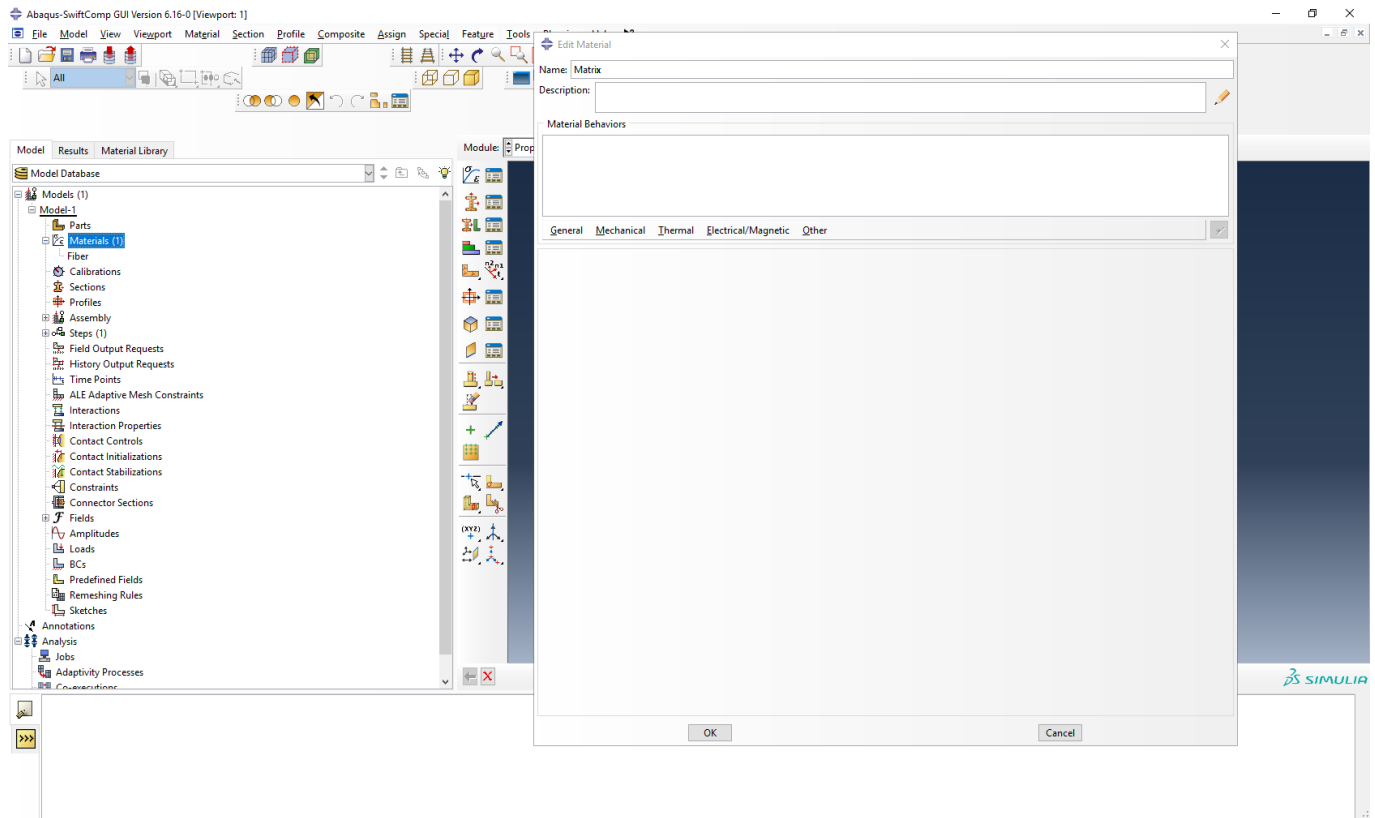
Step 1. We define the material properties in global coordinate system. We click on *Materials* in Abaqus CAE and define the *Fiber* properties by means of the engineering constants and click “OK”.



Definition of the fiber properties

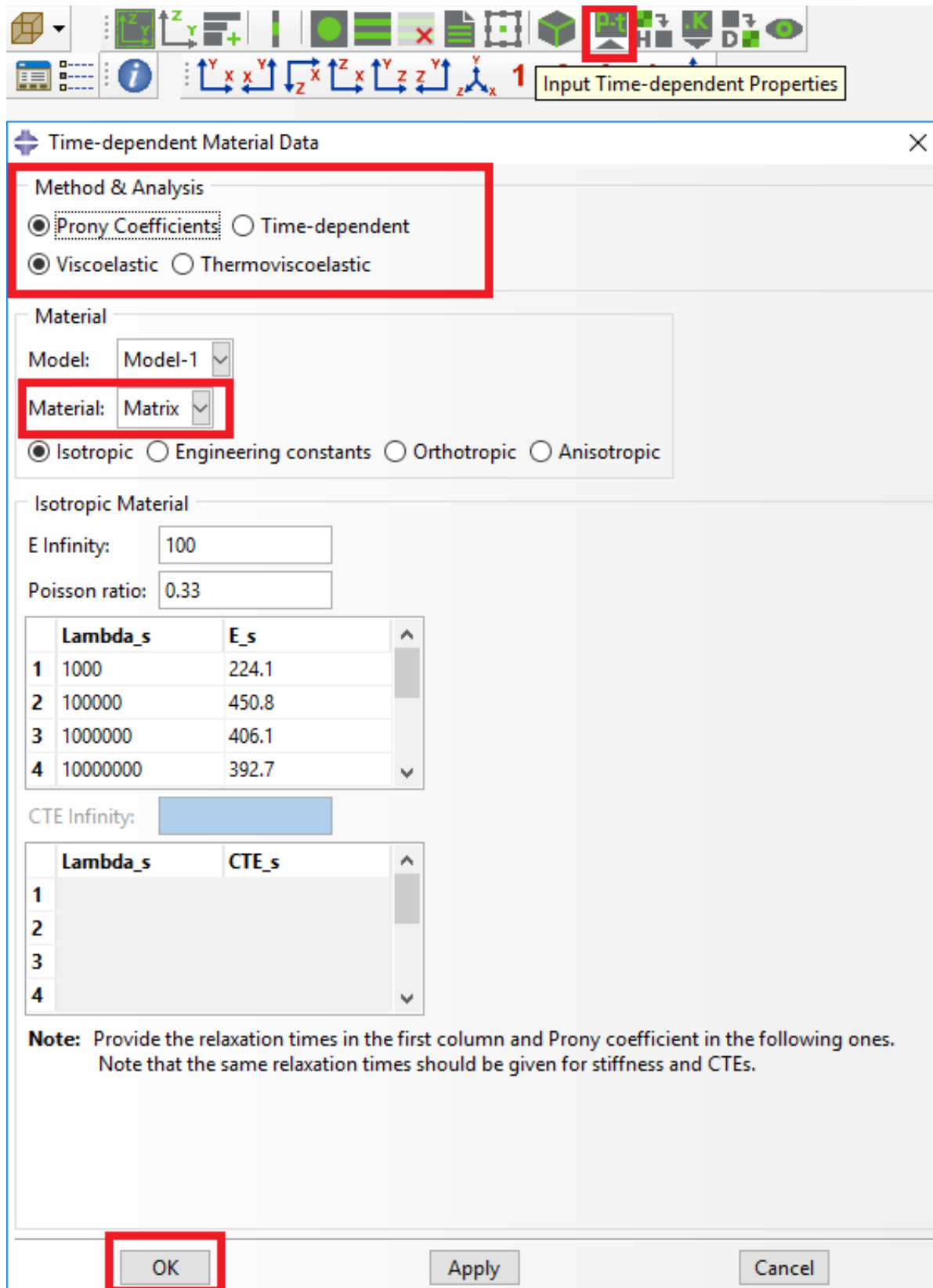
Step 2. Within the *Materials* of Abaqus CAE, we create a dummy material called “Matrix”. Please note that we will not define the Prony coefficients of the resin using the Abaqus [SwiftComp](#) GUI in the next step.

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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 “Prony Coefficients” and “Viscoelastic” in the Method & Analysis section. We pick “Matrix” as the Material to be modified in the drop down menu. Then, we input the relaxed Young modulus, Poisson’s ratio and the Prony coefficients following the equation presented above. Finally, we click “Ok”.

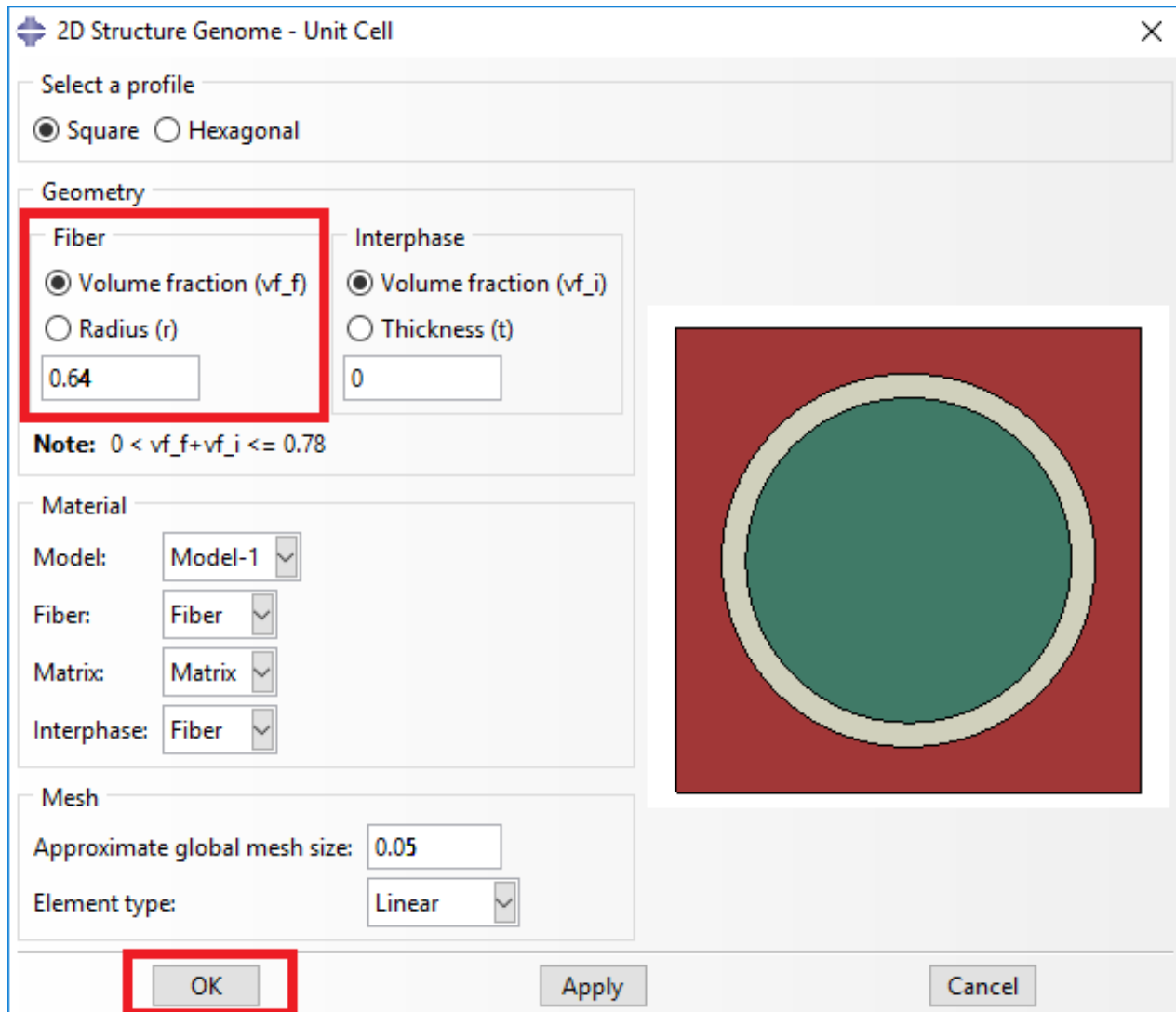


Definition

of the matrix Prony coefficients

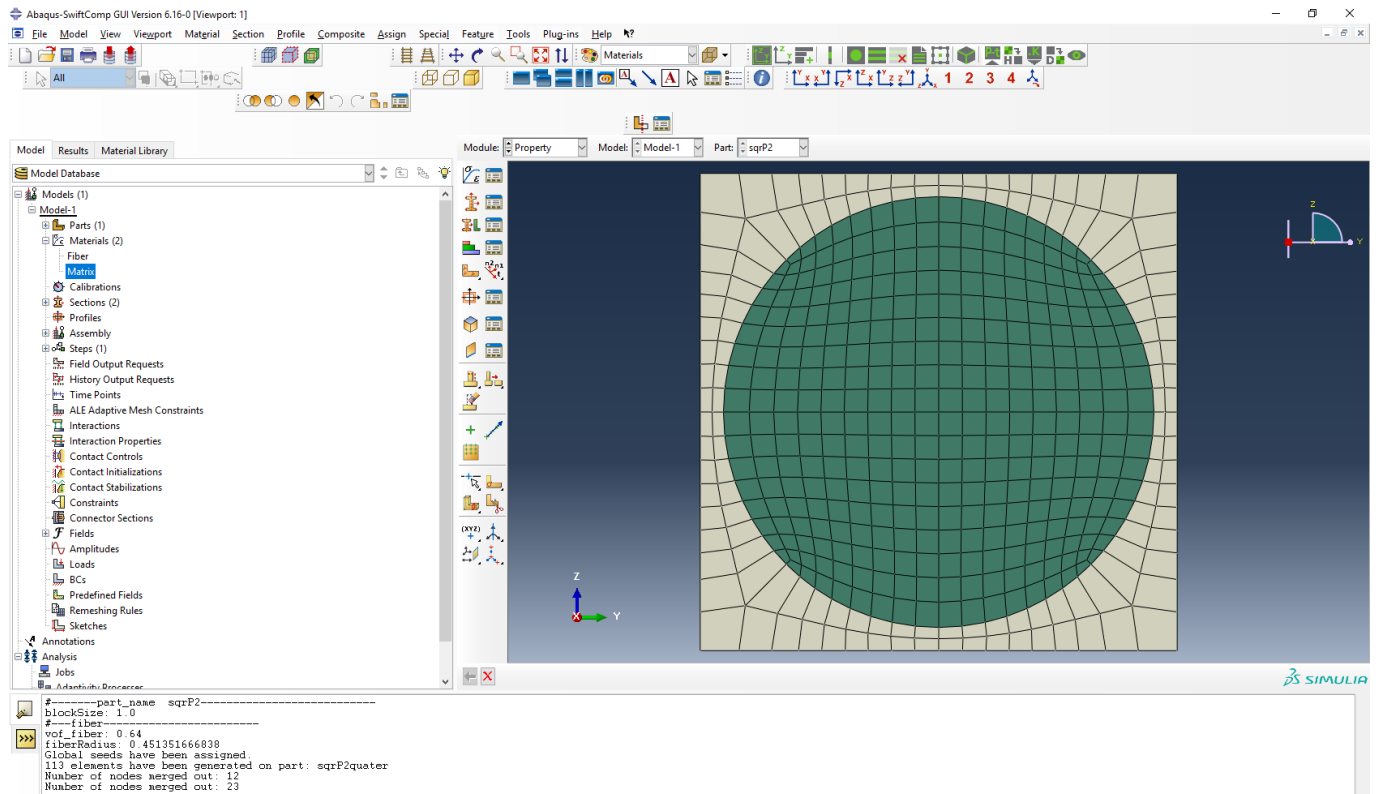
Step 4. From the default the Abaqus [SwiftComp](#) GUI SGs, we pick the 2D Structure Genome

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

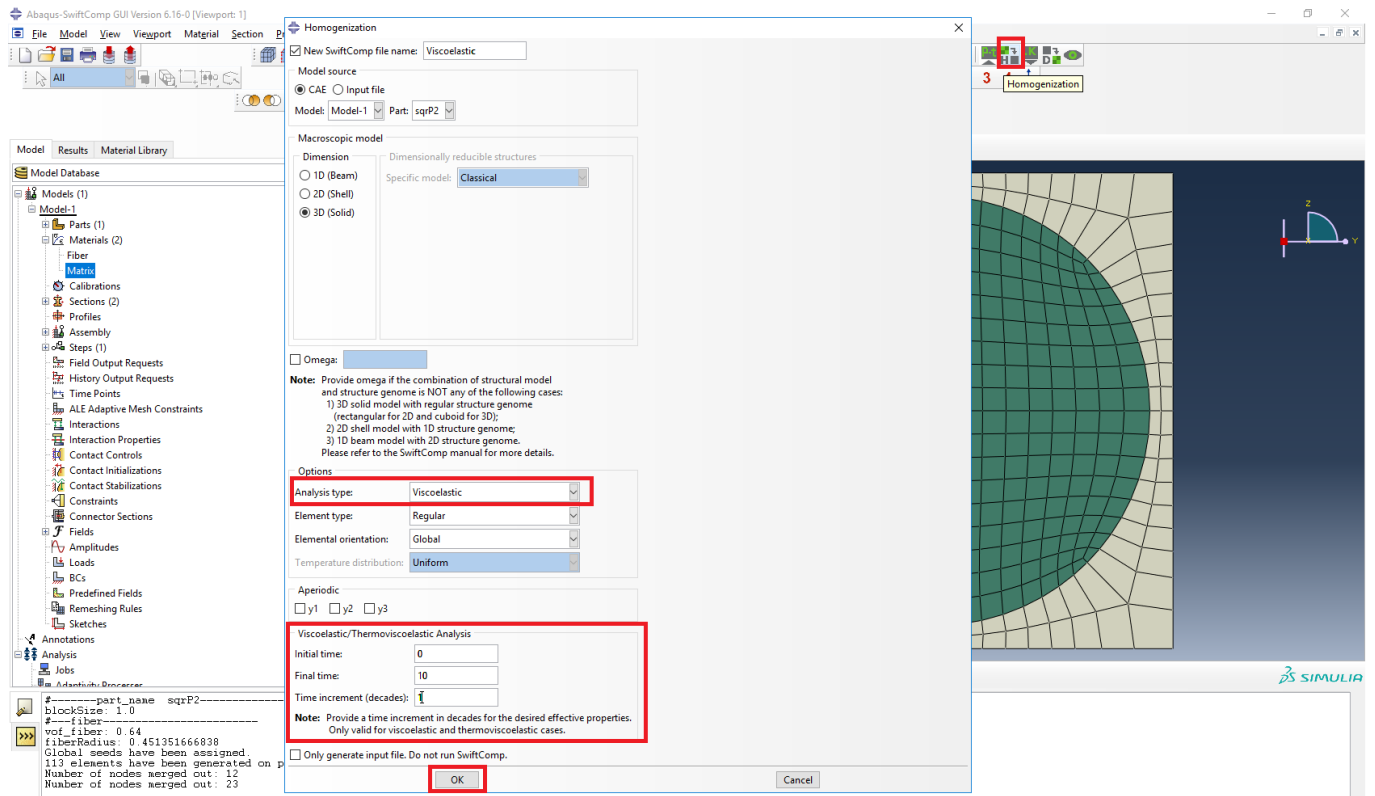
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2D SG square pack microstructure

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).

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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...
*****
*                               *
*           SwiftComp 2.1       *
*                               *
* Multiscale Constitutive Modeling of Composites *
*                               *
* School of Aeronautics and Astronautics *
*           Purdue University   *
*                               *
*           Copyright Notice   *
*           =====          *
*                               *
* Copyright (2015-) by Purdue Research Foundation, West *
* Lafayette, IN 47906. Unless permission is granted, this *
* material may not be copied, reproduced or coded for *
* reproduction by any electrical, mechanical or chemical *
* 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 084915.999
Inputs echoed in file Viscoelasticpbc.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 Viscoelasticpbc.sc.k!

Finished homogenization!

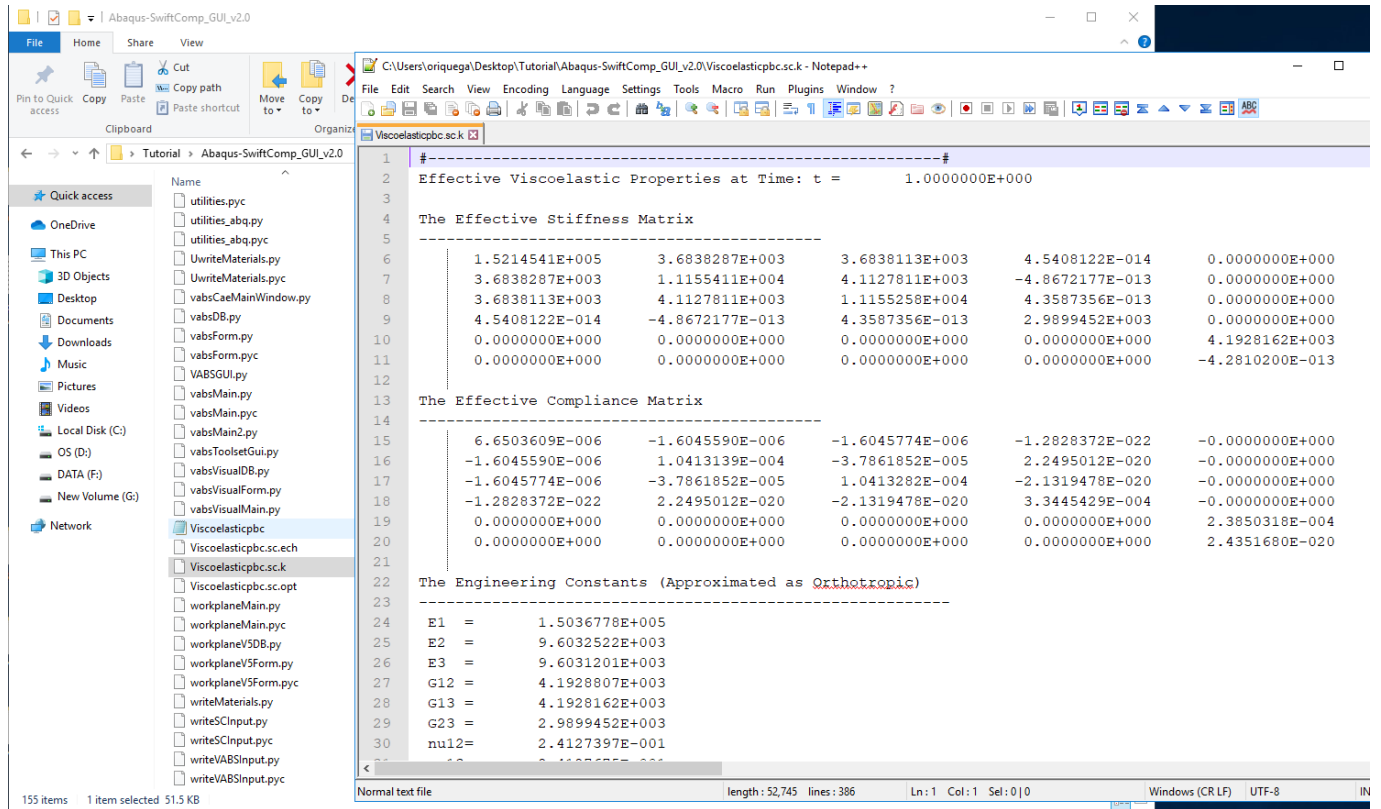
SwiftComp ends at 084916.491
SwiftComp finished successfully!
_
```

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.

COMPUTATION OF VISCOELASTIC PROPERTIES WITH ABAQUS SWIFT COMP GUI



```

1  #-----#
2  Effective Viscoelastic Properties at Time: t = 1.0000000E+000
3
4  The Effective Stiffness Matrix
5  -----
6      1.5214541E+005    3.6838287E+003    3.6838113E+003    4.5408122E-014    0.0000000E+000
7      3.6838287E+003    1.1155411E+004    4.1127811E+003    -4.8672177E-013    0.0000000E+000
8      3.6838113E+003    4.1127811E+003    1.1155258E+004    4.3587356E-013    0.0000000E+000
9      4.5408122E-014    -4.8672177E-013    4.3587356E-013    2.9899452E+003    0.0000000E+000
10     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    4.1928162E+003
11     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    -4.2810200E-013
12
13  The Effective Compliance Matrix
14  -----
15     6.6503609E-006    -1.6045590E-006    -1.6045774E-006    -1.2828372E-022    -0.0000000E+000
16    -1.6045590E-006    1.0413139E-004    -3.7861852E-005    2.2495012E-020    -0.0000000E+000
17    -1.6045774E-006    -3.7861852E-005    1.0413282E-004    -2.1319478E-020    -0.0000000E+000
18    -1.2828372E-022    2.2495012E-020    -2.1319478E-020    3.3445429E-004    -0.0000000E+000
19     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    2.3850318E-004
20     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    2.4351680E-020
21
22  The Engineering Constants (Approximated as Orthotropic)
23  -----
24  E1 = 1.5036778E+005
25  E2 = 9.6032522E+003
26  E3 = 9.6031201E+003
27  G12 = 4.1928807E+003
28  G13 = 4.1928162E+003
29  G23 = 2.9899452E+003
30  nu12 = 2.4127397E-001

```

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.