

Computation of effective thermoviscoelastic properties with Abaqus Swift Comp GUI

Thermoviscoelastic Homogenization

In this example, we want to compute the effective thermoviscoelastic properties of a composite material made of isotropic thermoviscoelastic matrix and transversely isotropic thermoelastic fiber. The fiber properties are defined by means of engineering constants and coefficients of thermal expansion (CTEs) as specified in the table below.

| E_{1f} (MPa) | E_{2f} (MPa) | G_{12f} (MPa) | ν_{12f} | ν_{23f} | α_{11f} ($\mu/^\circ\text{C}$) | α_{22f} ($\mu/^\circ\text{C}$) |
|-------------------|-------------------|--------------------|-------------|-------------|--|--|
| 233,000.0 | 15,000.0 | 8,963.0 | 0.200 | 0.330 | -0.540 | 10.080 |

Fiber properties defined as transversely isotropic elastic

The matrix properties are given by means of the Prony coefficients presented in the table below. In addition, we will consider that the matrix has a constant Poisson's ratio equal to 0.33 and CTE equal to $60 \mu/^\circ\text{C}$.

| 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 $v_f = 0.64$.

Software Used

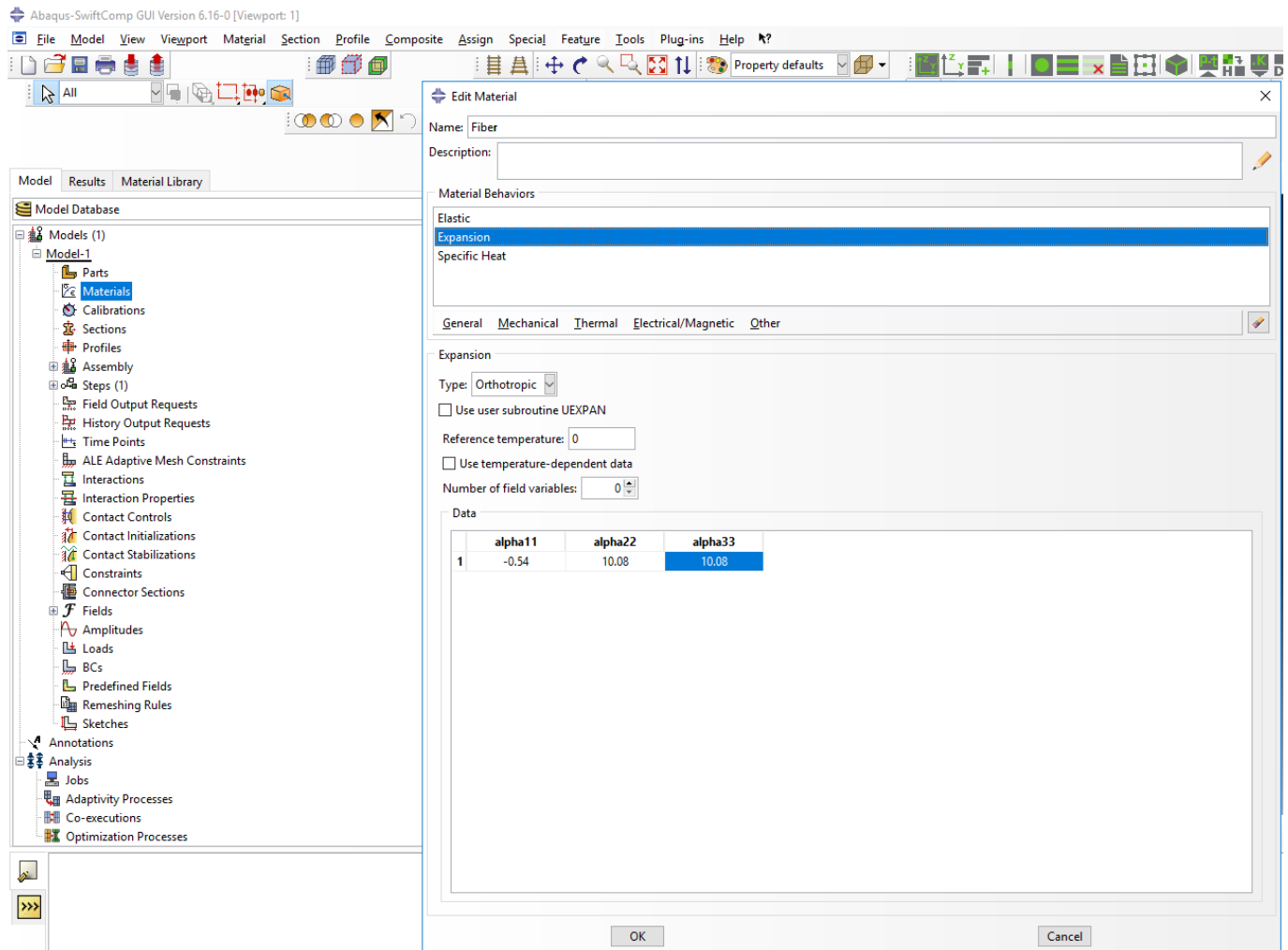
In his tutorial we will use Abaqus CAE with the Abaqus [SwiftComp](#) GUI plug-in. Abaqus CAE will be used to GUI to define the time-dependent material properties and to run the thermoviscoelastic homogenization. [SwiftComp](#) will run in the background.

Solution Procedure

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

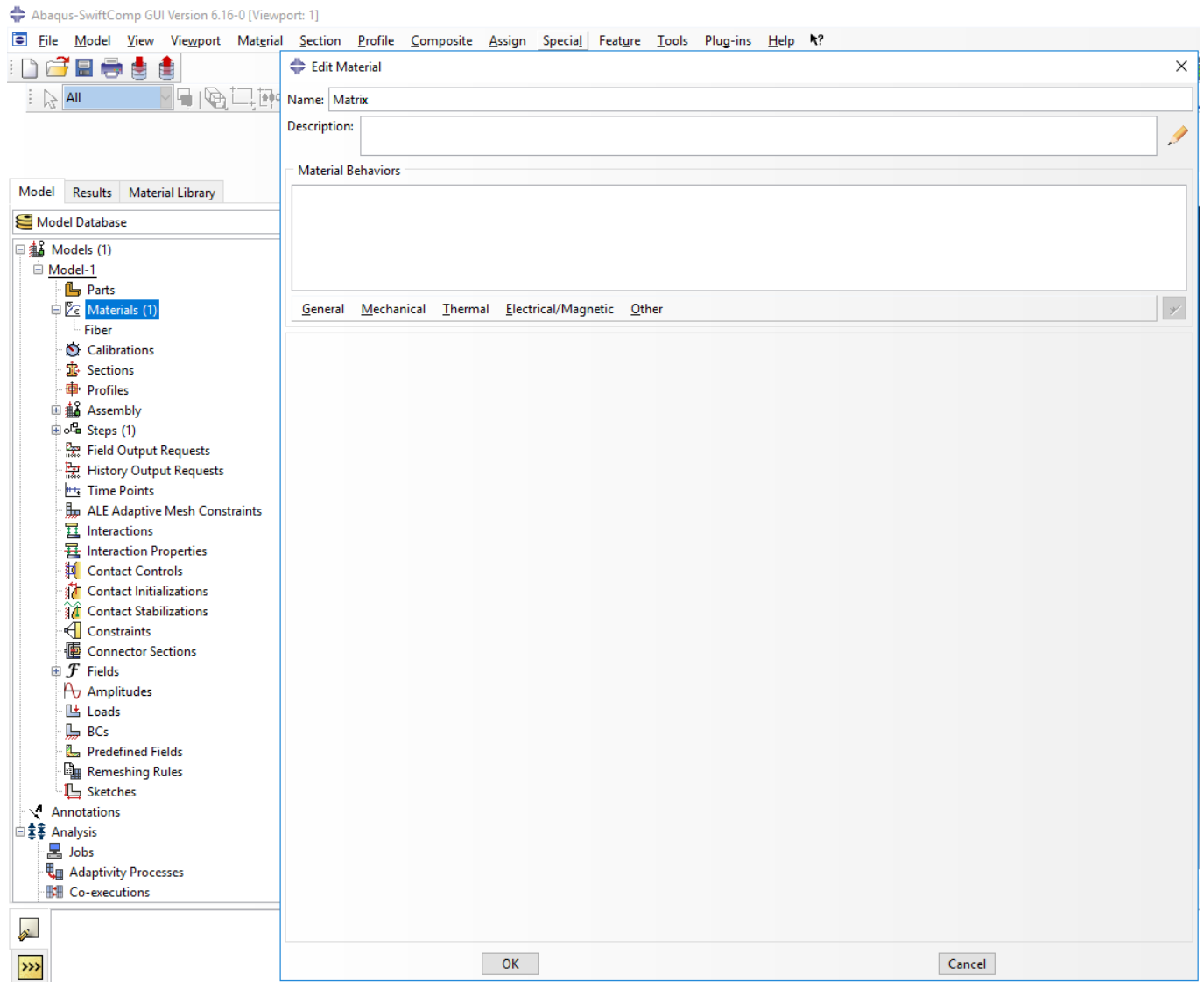
Step 1. We define the material properties in global coordinate system. We click on *Materials* in Abaqus CAE and define the *Fiber* properties by means of the engineering constants. To introduce the CTEs, we select *Orthotropic* in *Type* section. We will also need to provide a

value to the specific heat. For this tutorial, we will consider the specific heat equal to 1. Finally, we click “Ok”.



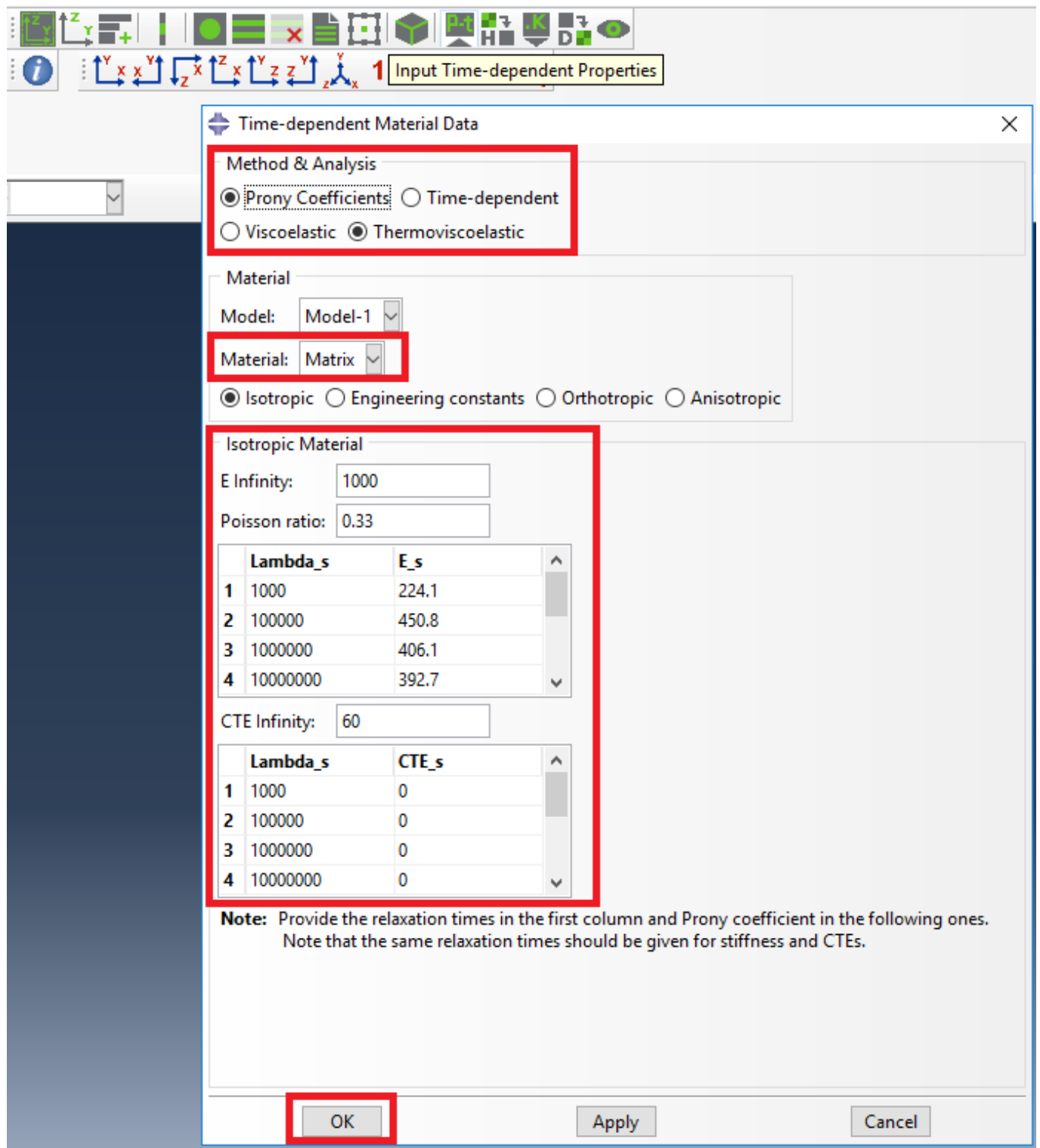
Definition of the fiber properties

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.



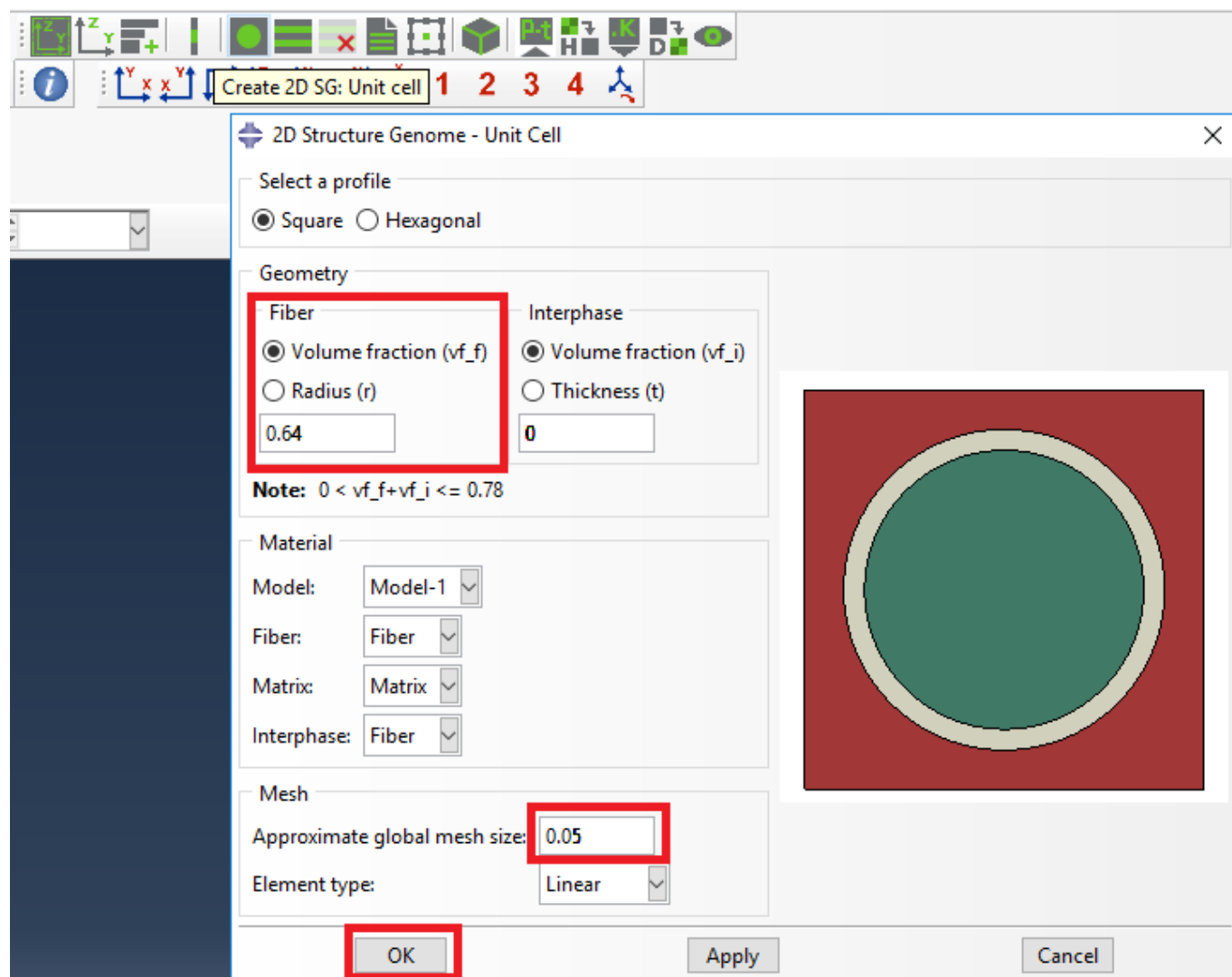
Creation of the dummy material for the matrix

Step 3. In the Abaqus [SwiftComp](#) GUI menu, we click on Input Time-Dependent Properties. We select “Prony Coefficients” and “Thermoviscoelastic” 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, Prony coefficients, and the constant CTE value. It is noted that we also introduce 0 in the Prony coefficients of the table. Finally, we click “Ok”.



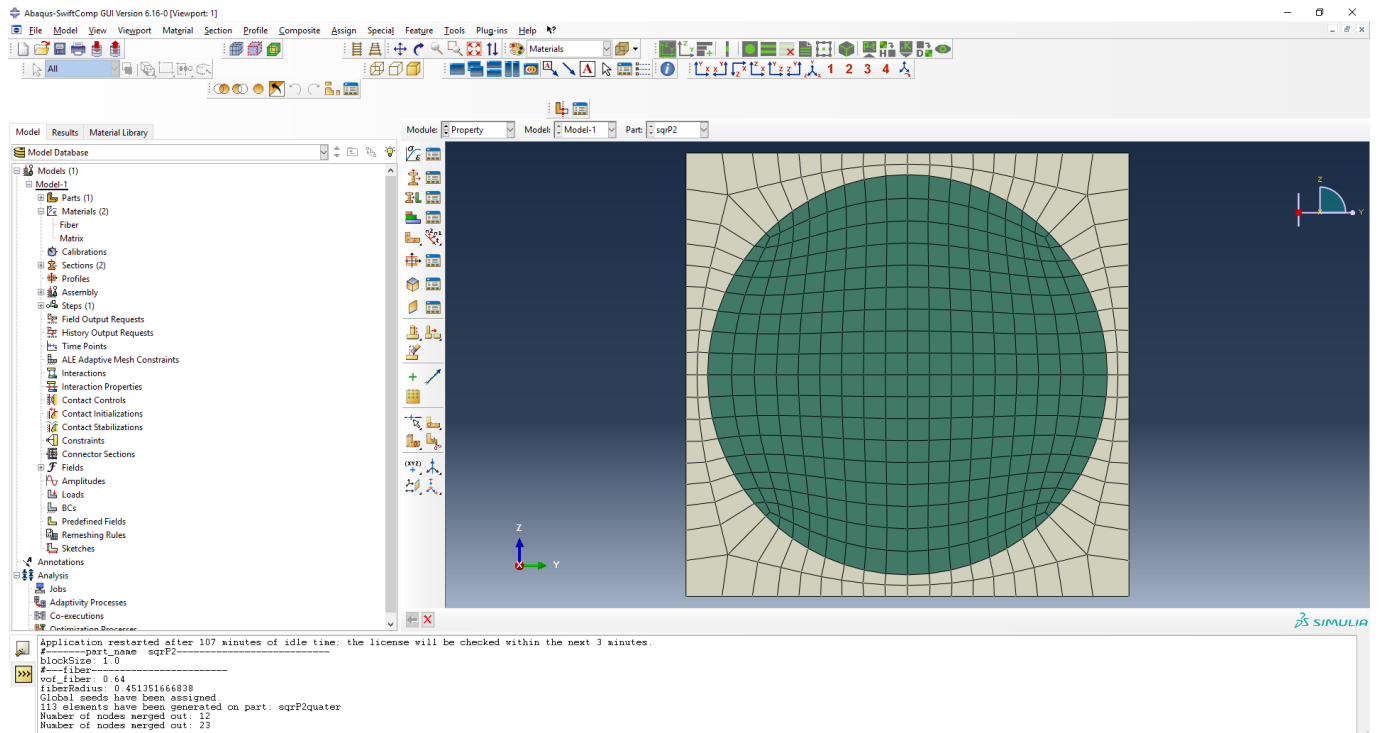
Definition of the matrix Prony coefficients

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

COMPUTATION OF EFFECTIVE THERMOVISCOELASTIC PROPERTIES WITH ABAQUS SWIFT COMP GUI



2D SG square pack microstructure

Step 5. Now, we will compute the effective thermoviscoelastic properties. To do so, 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).

Homogenization

☒ New SwiftComp file name: Thermoviscoelastic

Model source
☒ CAE ☐ Input file
Model: Model-1 Part: sqrP2

Macroscopic model
Dimension
☐ 1D (Beam)
☐ 2D (Shell)
☒ 3D (Solid)
Dimensionally reducible structures
Specific model: Classical

☐ 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: Thermoviscoelastic
Element type: Regular
Elemental orientation: Global
Temperature distribution: Uniform

Aperiodic
☐ y1 ☐ y2 ☐ y3

Viscoelastic/Thermoviscoelastic Analysis
Initial time: 0
Final time: 10
Time increment (decades): 1
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

Definition of the thermoviscoelastic 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          *
*                               *
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*      Purdue University                                         *
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*                               *
*****

SwiftComp begins at  103640.787
Inputs echoed in file Thermoviscoelasticpb.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 Thermoviscoelasticpb.sc.k!

Finished homogenization!

SwiftComp ends at  103641.285
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, which includes the effective CTEs, will be outputted for each specified time.

COMPUTATION OF EFFECTIVE THERMOVISCOELASTIC 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      1.5267049E+005      4.0736184E+003      4.0736102E+003      -4.3076653E-014      0.0000000E+0
7      4.0736184E+003      1.2212134E+004      4.6032697E+003      -1.1417534E-012      0.0000000E+0
8      4.0736102E+003      4.6032697E+003      1.2212027E+004      6.8167694E-014      0.0000000E+0
9      -4.3076653E-014      -1.1417534E-012      6.8167694E-014      3.3695679E+003      0.0000000E+0
10     0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      4.6701150E+0
11     0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      -3.6326497E-0
12
13 The Effective Compliance Matrix
14 -----
15      6.6358422E-006      -1.6075628E-006      -1.6075783E-006      -4.2735613E-022      -0.0000000E+0
16     -1.6075628E-006      9.5837051E-005      -3.5589113E-005      3.3173112E-020      -0.0000000E+0
17     -1.6075783E-006      -3.5589113E-005      9.5837892E-005      -1.4018499E-020      -0.0000000E+0
18     -4.2735613E-022      3.3173112E-020      -1.4018499E-020      2.9677396E-004      -0.0000000E+0
19     0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      2.1412749E-0
20     0.0000000E+000      0.0000000E+000      0.0000000E+000      0.0000000E+000      1.6655681E-0
21
22 The Engineering Constants (Approximated as Orthotropic)
23 -----
24 E1 =      1.5069677E+005
25 E2 =      1.0434378E+004
26 E3 =      1.0434286E+004
27 G12 =      4.6701794E+003
28 G13 =      4.6701150E+003
29 G23 =      3.3695679E+003
30 nu12=      2.4225453E-001
31 nu13=      2.4225686E-001
32 nu23=      3.7135025E-001
33
34 Thermal Coefficients
35 -----
36 alpha11 =      2.7458111E-001
```

Results corresponding to the effective thermoviscoelastic properties

References

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.