

## 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)	$\nu_{12f}$	$\nu_{23f}$	$\alpha_{11f}$ ( $\mu/^\circ\text{C}$ )	$\alpha_{22f}$ ( $\mu/^\circ\text{C}$ )
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  $60 \mu/^\circ\text{C}$ .

$s$	$\infty$	1	2	3	4	5	6	7
$\lambda_s$ (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

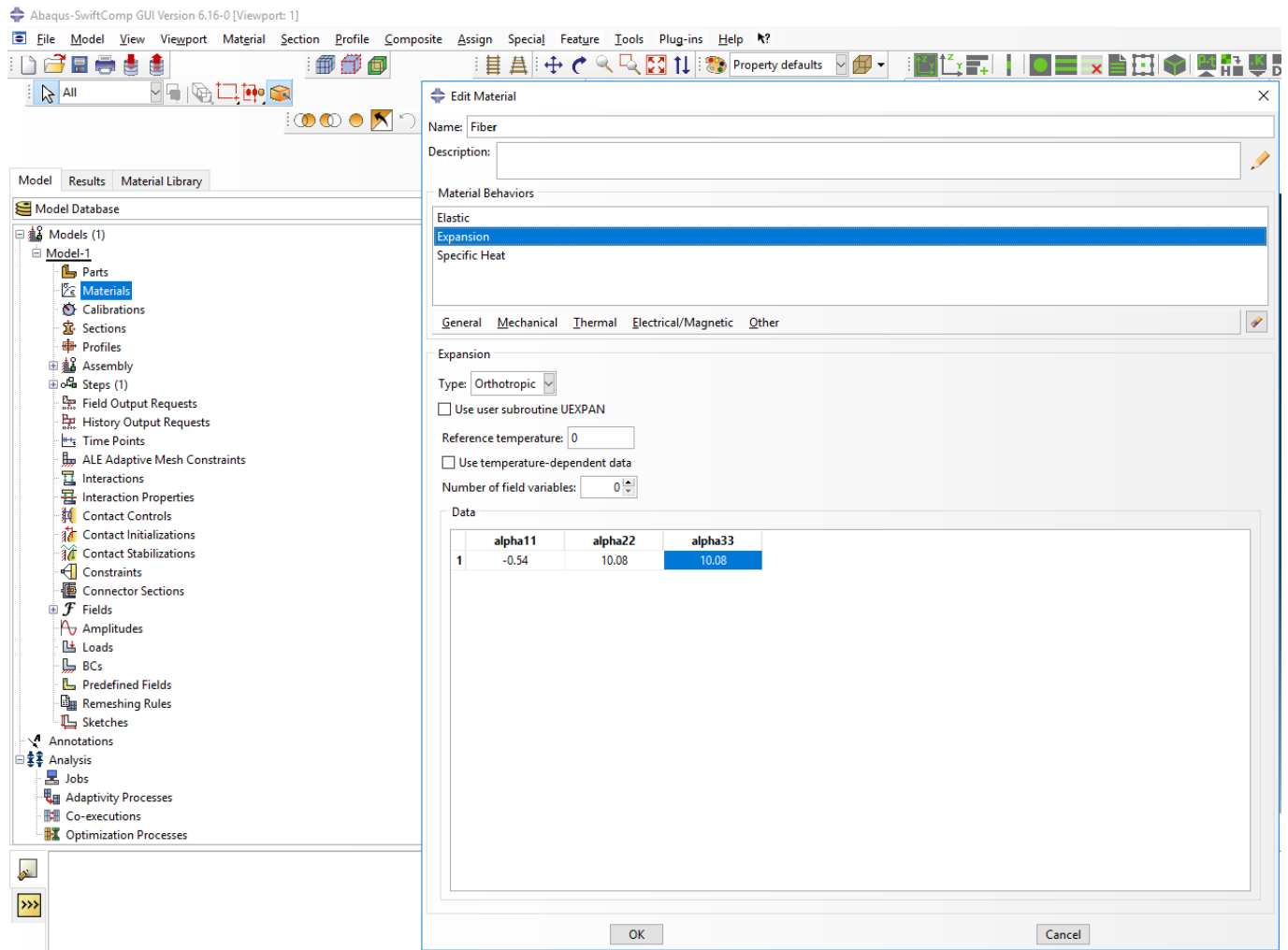
In his tutorial we will use Abaqus CAE with the Abaqus [SwiftComp](#) GUI plug-in. Abaqus CAE will be used to GUI to define the time-dependent material properties and to run the thermoviscoelastic homogenization. [SwiftComp](#) will run in the background.

### Solution Procedure

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

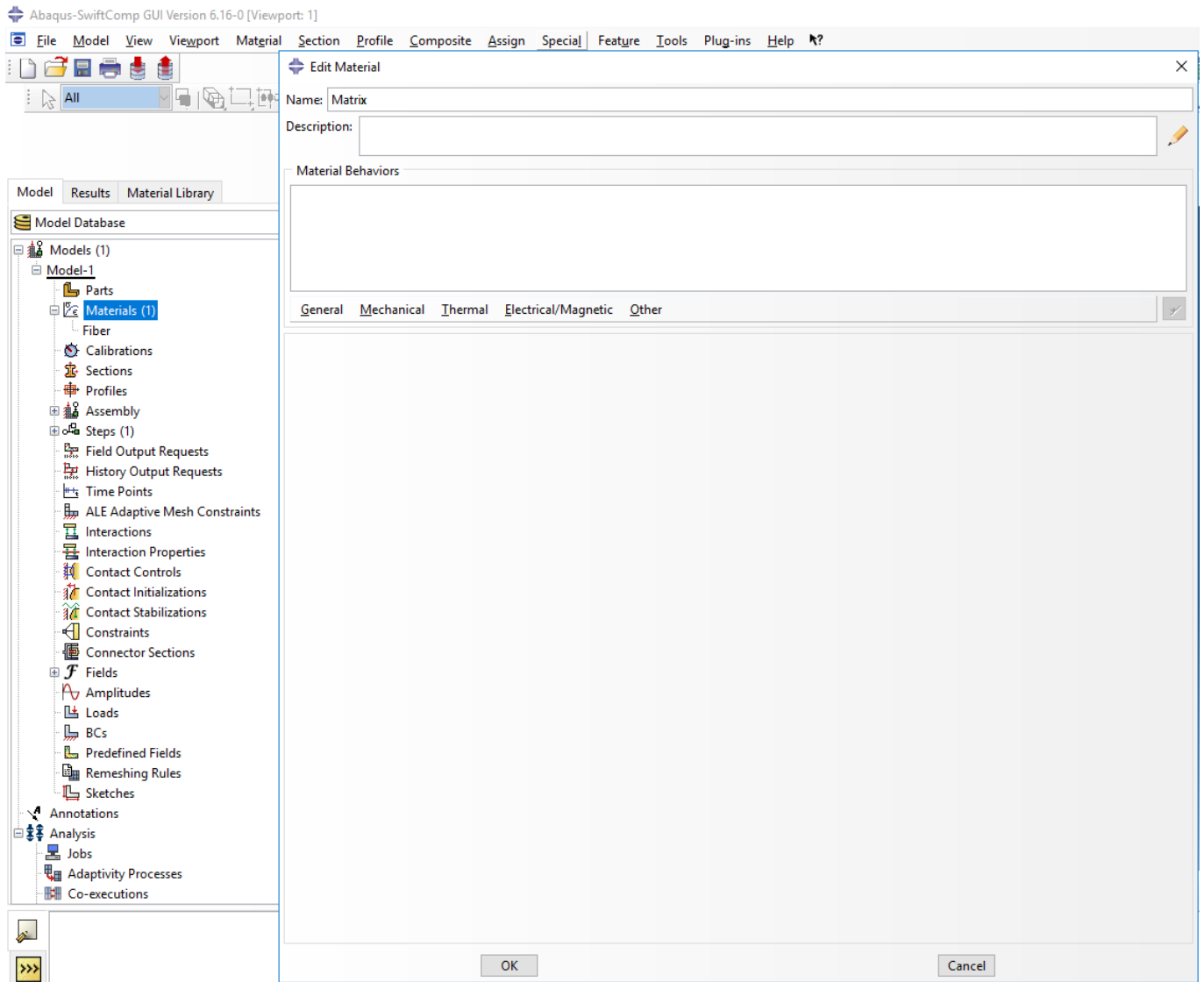
**# Step 1.** We define the material properties in global coordinate system. We click on *Materials* in Abaqus CAE and define the *Fiber* properties by means of the engineering constants. To introduce the CTEs, we select *Orthotropic* in *Type section*. We will also need to provide a

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



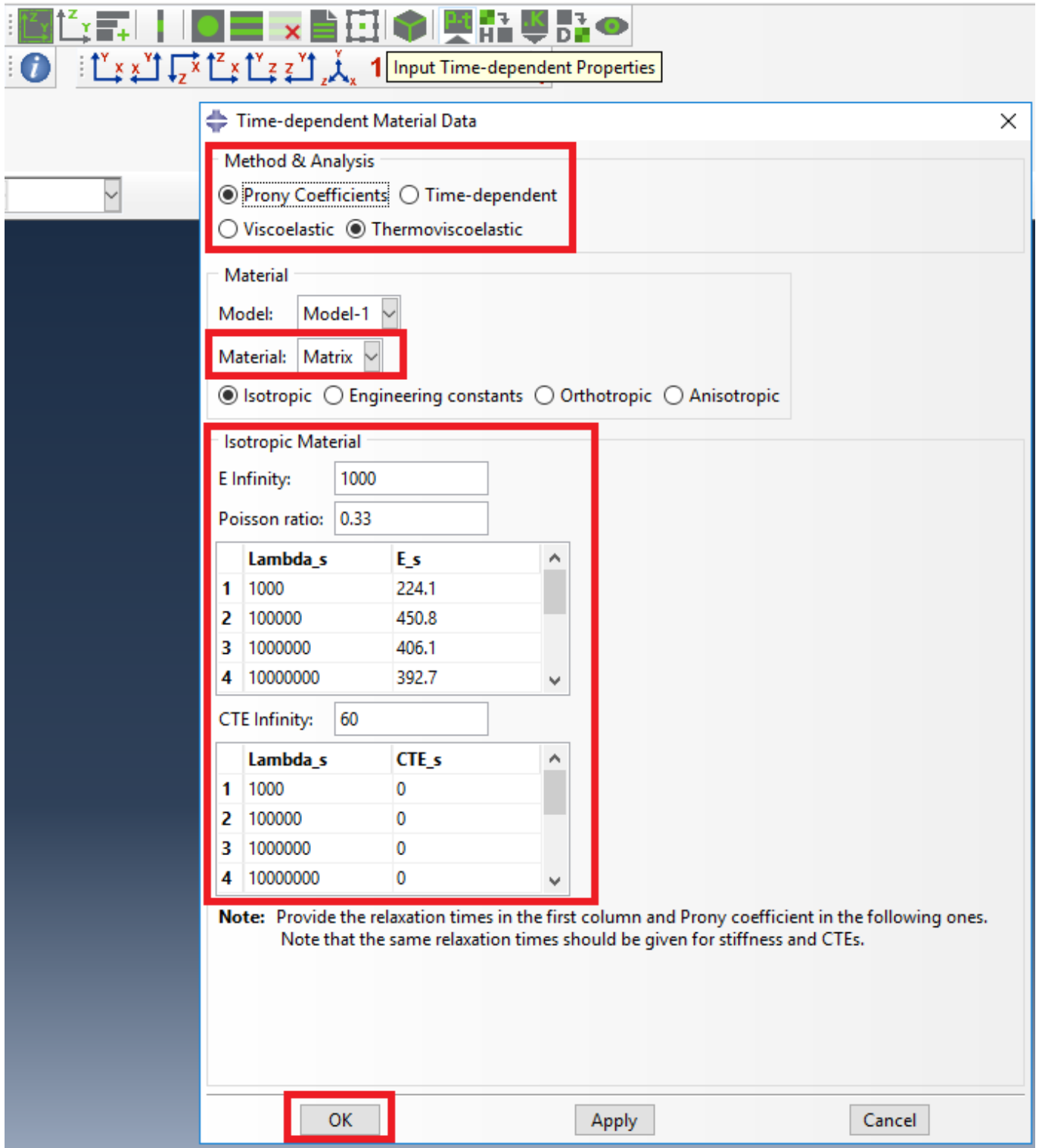
Definition of the fiber properties

**# 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.



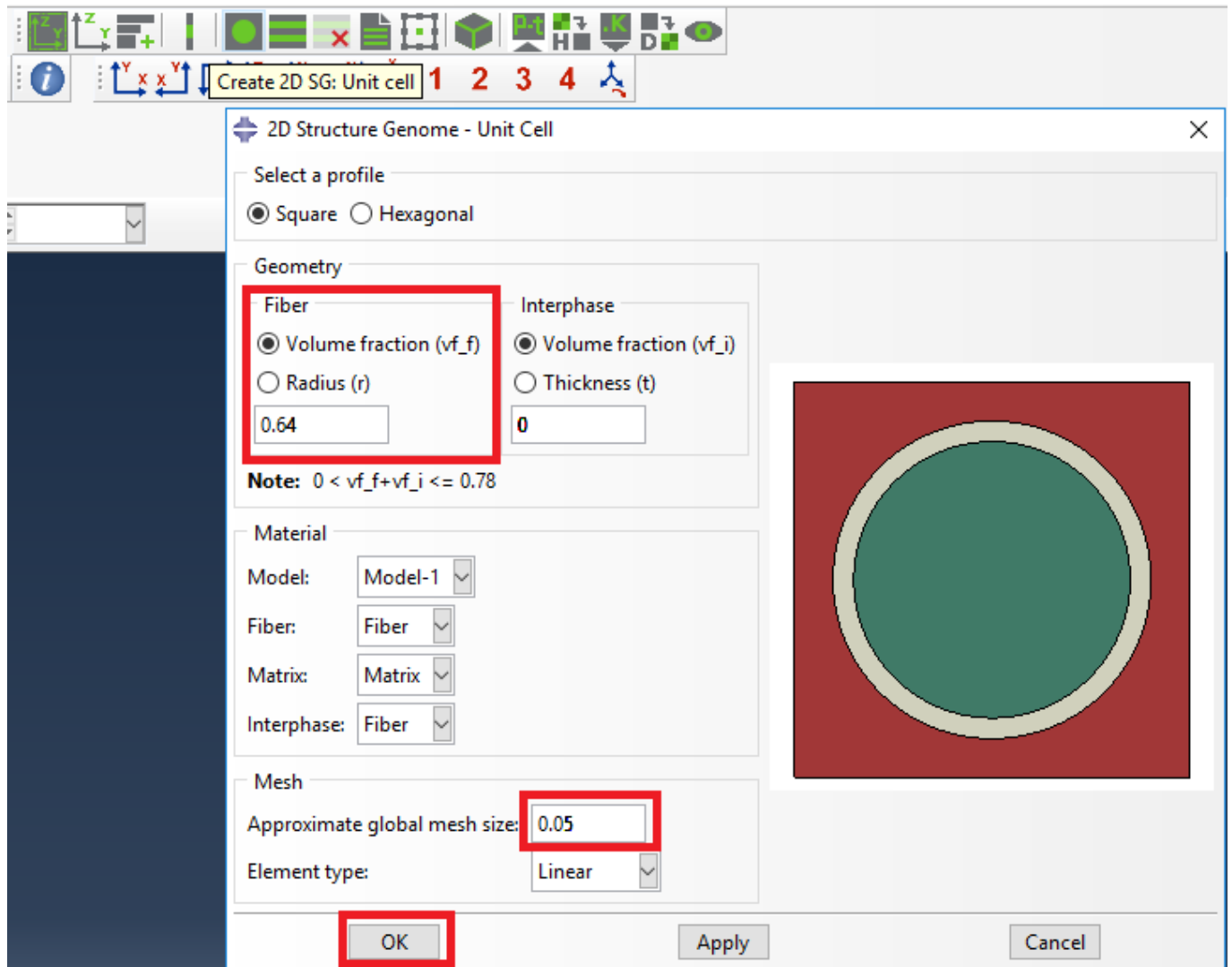
Creation of the dummy material for the matrix

**# 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”.



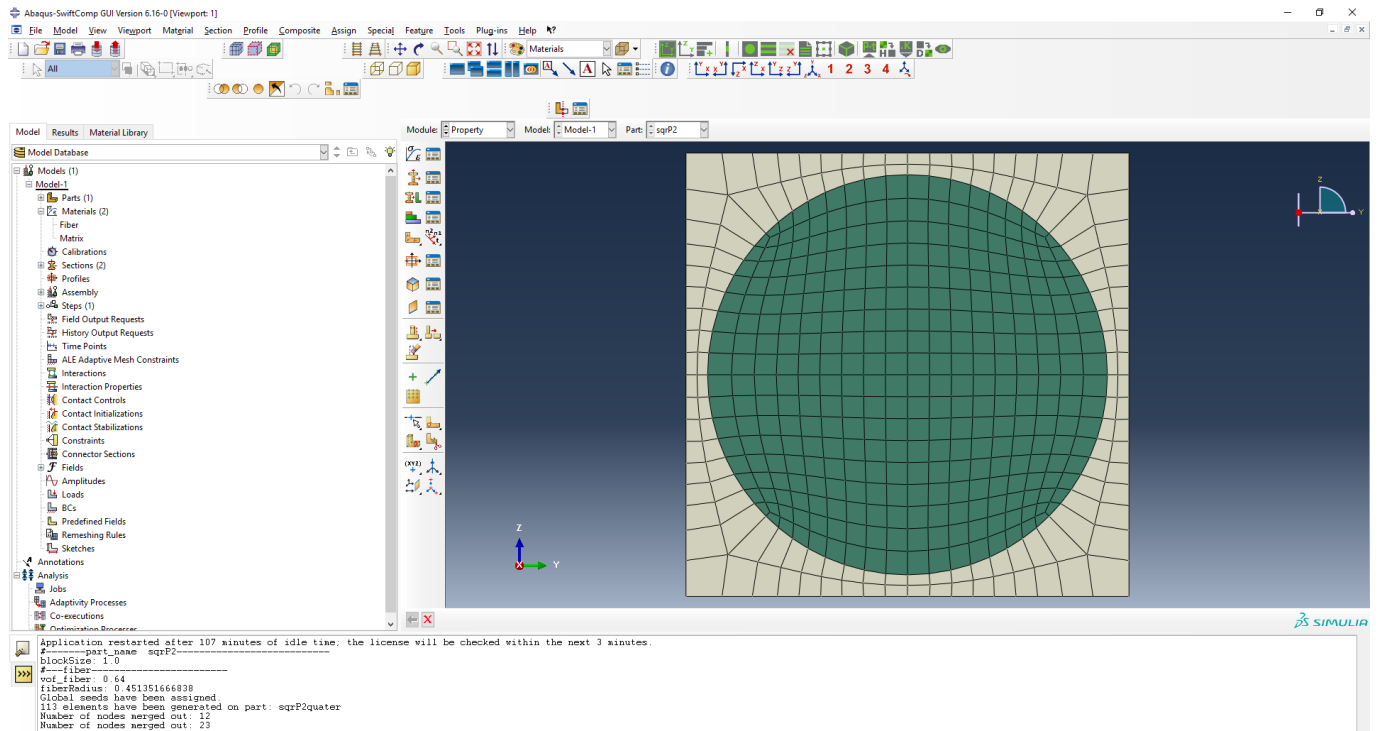
Definition of the matrix Prony coefficients

**# 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).

# COMPUTATION OF EFFECTIVE THERMOVISCOELASTIC PROPERTIES WITH ABAQUS SWIFT COMP GUI

**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   *
*                               *
*   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 103640.787
Inputs echoed in file Thermoviscoelasticpsc.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 Thermoviscoelasticpsc.sc.k!

Finished homogenization!

SwiftComp ends at 103641.285
SwiftComp finished successfully!
    
```

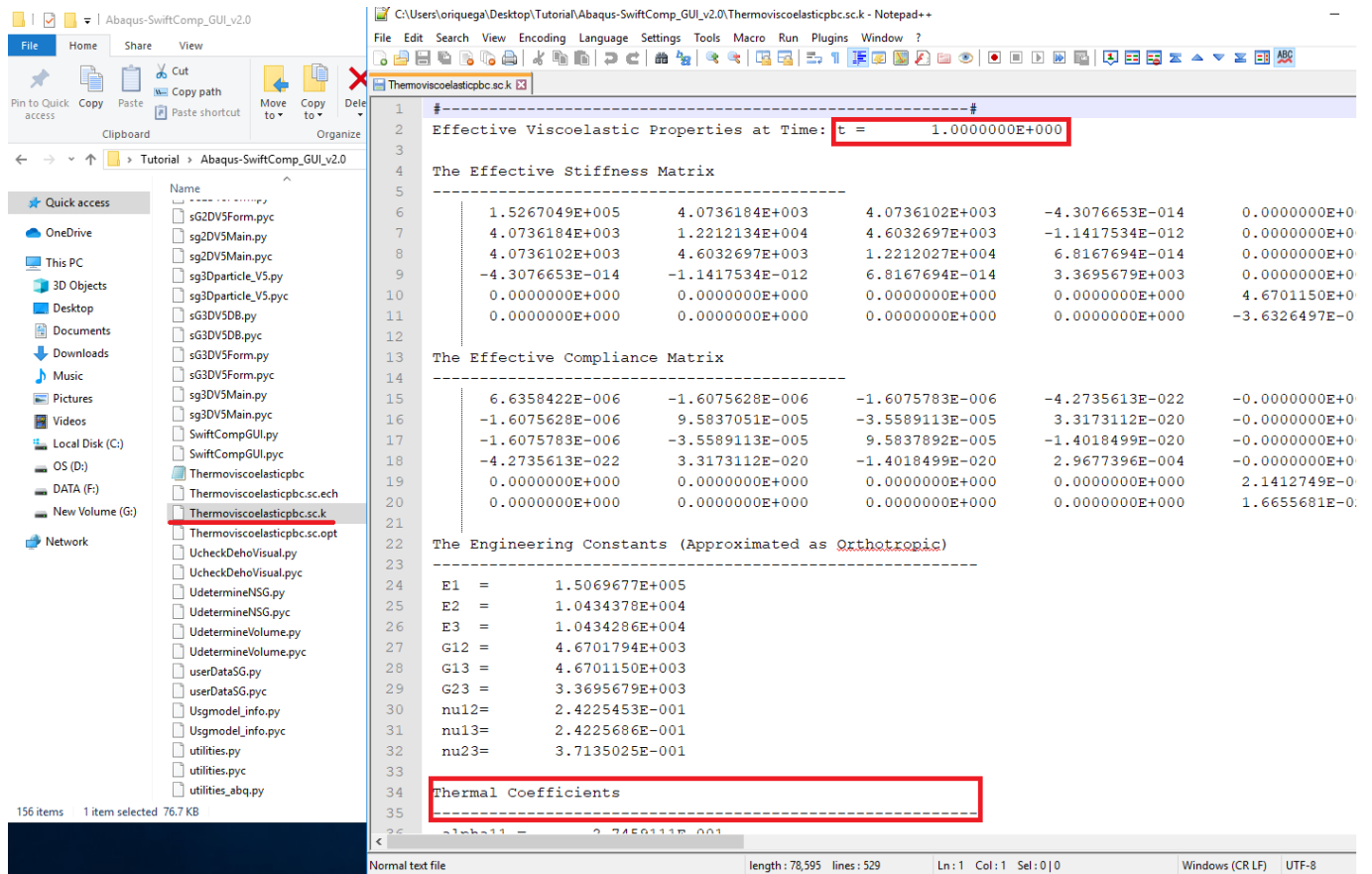
SwiftComp running

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+000
7      4.0736184E+003    1.2212134E+004    4.6032697E+003    -1.1417534E-012    0.0000000E+000
8      4.0736102E+003    4.6032697E+003    1.2212027E+004    6.8167694E-014    0.0000000E+000
9      -4.3076653E-014    -1.1417534E-012    6.8167694E-014    3.3695679E+003    0.0000000E+000
10     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    4.6701150E+000
11     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    -3.6326497E-012
12
13 The Effective Compliance Matrix
14 -----
15     6.6358422E-006    -1.6075628E-006    -1.6075783E-006    -4.2735613E-022    -0.0000000E+000
16    -1.6075628E-006    9.5837051E-005    -3.5589113E-005    3.3173112E-020    -0.0000000E+000
17    -1.6075783E-006    -3.5589113E-005    9.5837892E-005    -1.4018499E-020    -0.0000000E+000
18    -4.2735613E-022    3.3173112E-020    -1.4018499E-020    2.9677396E-004    -0.0000000E+000
19     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    2.1412749E-001
20     0.0000000E+000    0.0000000E+000    0.0000000E+000    0.0000000E+000    1.6655681E-001
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.