Homogenization of Fiber Composite Material Properties: an Adaptive Multiphysics Implementation

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What is the aim? Carbon composite parts contain fibers which take the main strength and a shape-giving resinous matrix. They are produced under influence of high pressures and temperatures. Calculation of heating and curing process allows prediction of resulting part geometries with shrinkage and warpage effects

What is the focus? Simulation of whole model with all fibers is not possible in most cases because of the high computational effort which is required. Therefore homogenized values for fibers and resin are calculated with FEM or analytical methods. Representative unit cells are used for calculation of resulting parameters of the compound.

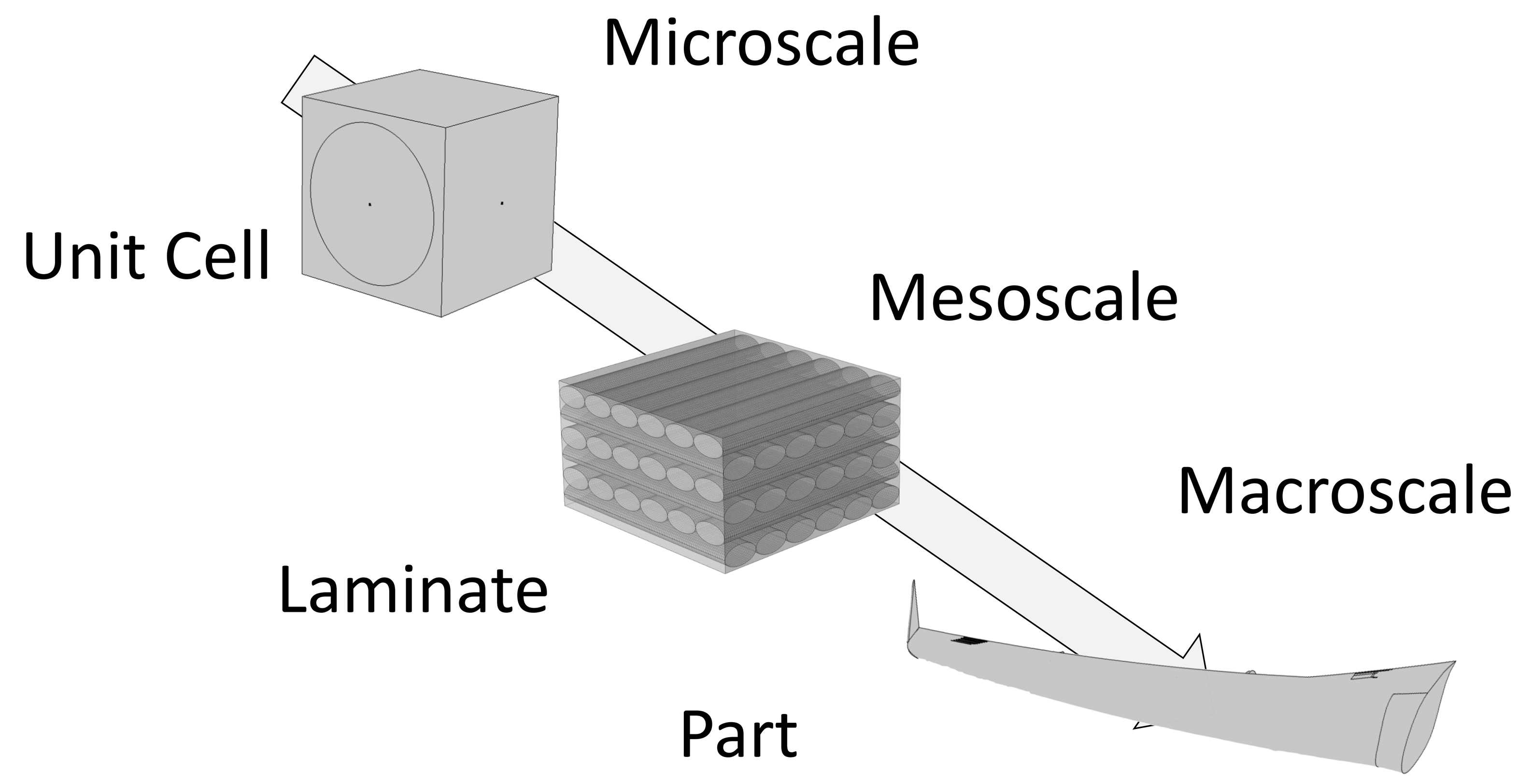

Figure 1. Approach for Simulation of curing process in different scales

Analytical approach:

- Only for simple geometries
- Good Integration in large models
- Good implementation of different parameters

FEM approach:

- RVEs with complex structure possible
- Good prediction of influence of different components
- Boundary conditions needed

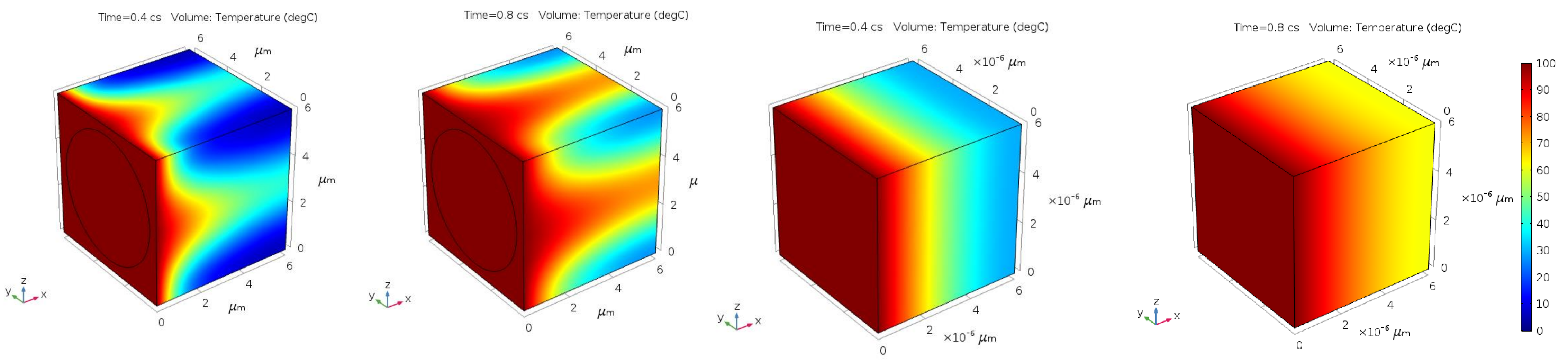

Figure 2. Temperature field of a unit cell (left) and comparison with homogenized cell (right), simulation after 0.02s and 0.08s

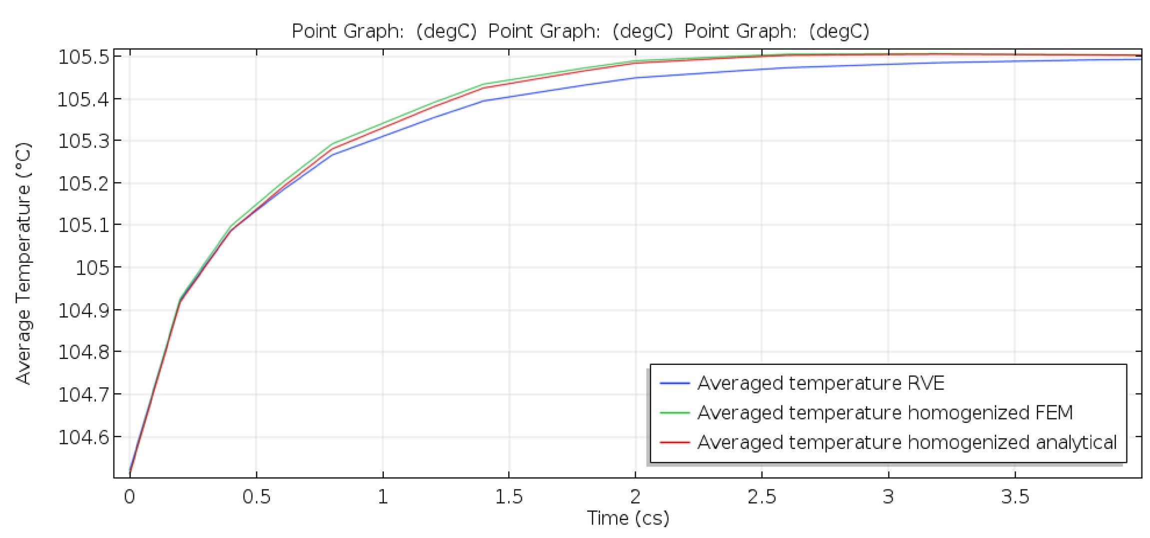

Figure 3. Comparison of average temperature over time while heating

Thermal analysis: Calculation of homogenized specific heat capacity and thermal conductivities was made using heat transfer module of COMSOL Multiphysics®. Comparison with an analytical approach shows good results.

$$C_{p\ homogenized} = \frac{\int_\Omega C_p \, d\Omega}{\int_\Omega d\Omega}$$

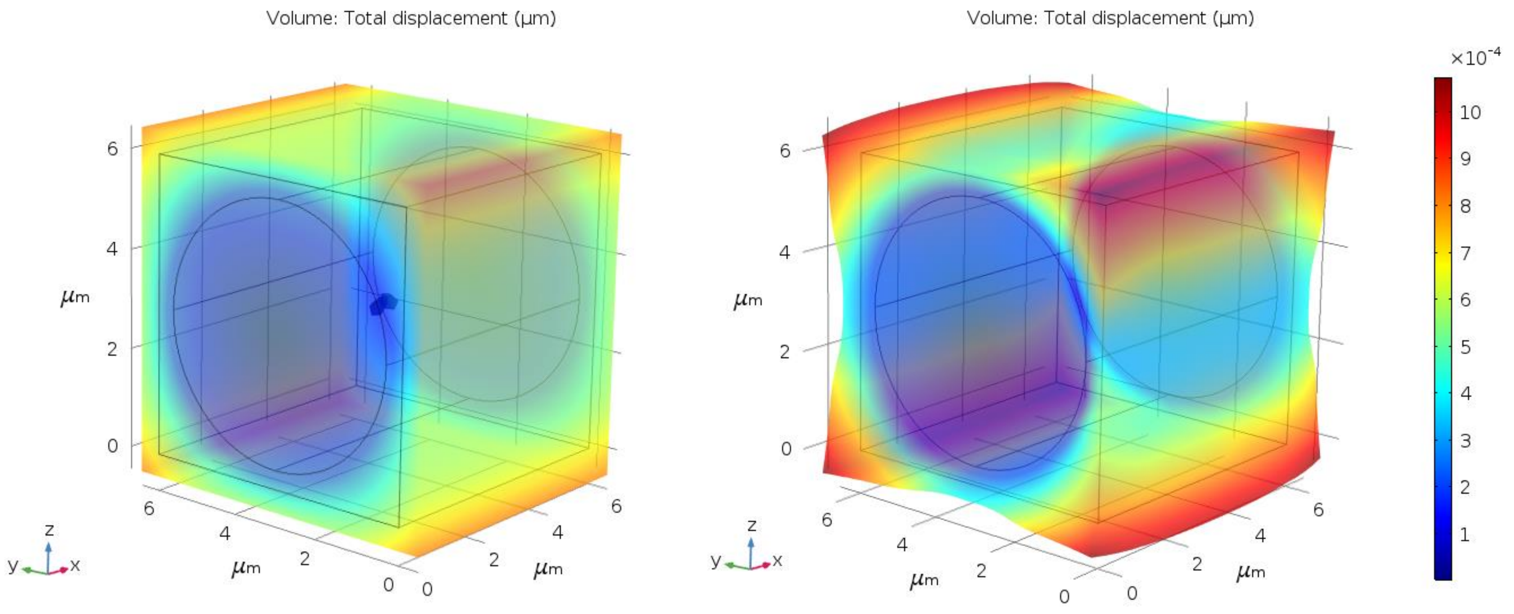

Figure 4. Displacement field of RVE at thermal expansion with displacement constraint (top) ans without (bottom)

Thermal expansion: FEM approach is used for calculation of effective coefficient of thermal expansion longitudinal and transversal to fiber orientation. Integration coupling variables are used for constraining deformation of the boundaries.

$$\alpha_{\ homogenized} = \frac{\int_\Omega \varepsilon_{th} \, d\Omega}{T - T_{ref}}$$

Thermal expansion of laminate: Structure of representative volume elements is used for calculation of properties of a laminate. Comparison of the properties with results from calculation using classical laminate theory shows variances of 50%.

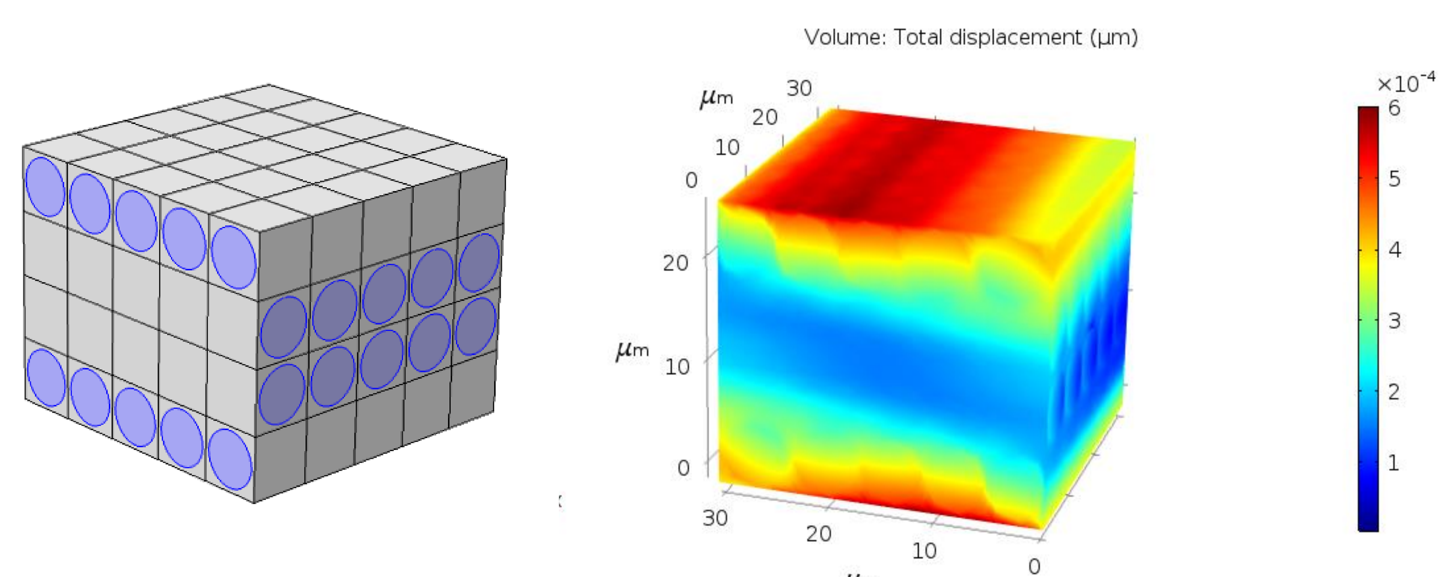

Figure 5. Laminate model for calculation or resulting thermal expansions