A Consistent Environment for the Numerical Prediction of the Properties of Composite Materials

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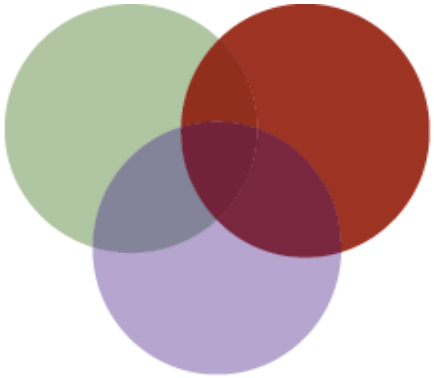
Renewable Resource Materials



Composite Technologies

Melt Processing

Our guiding theme:
From the basic material
to the final structure

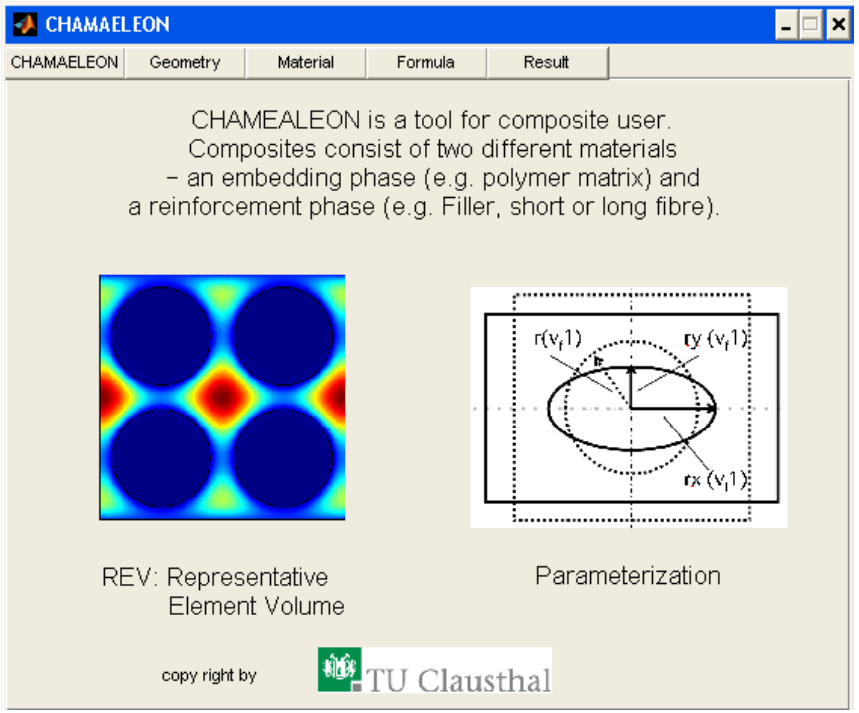
Motivation

- Composite material as an important material for the industry
- Complexity of the geometry
- Development of fast, reliable, cost optimized manufacturing
- Reduction of the research development time

Manufacturing process simulation (MPS)

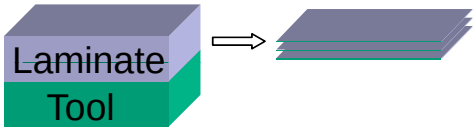
CHAMAELEON: Description

- Combination of COMSOL and Matlab features
  - GUI from Matlab
  - Solving a field problem in COMSOL
- Flexibility
  - Multiscale modeling
  - Parameterization
- Numerical homogenization

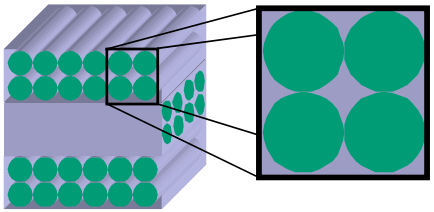


Geometry: Multiscale Modeling

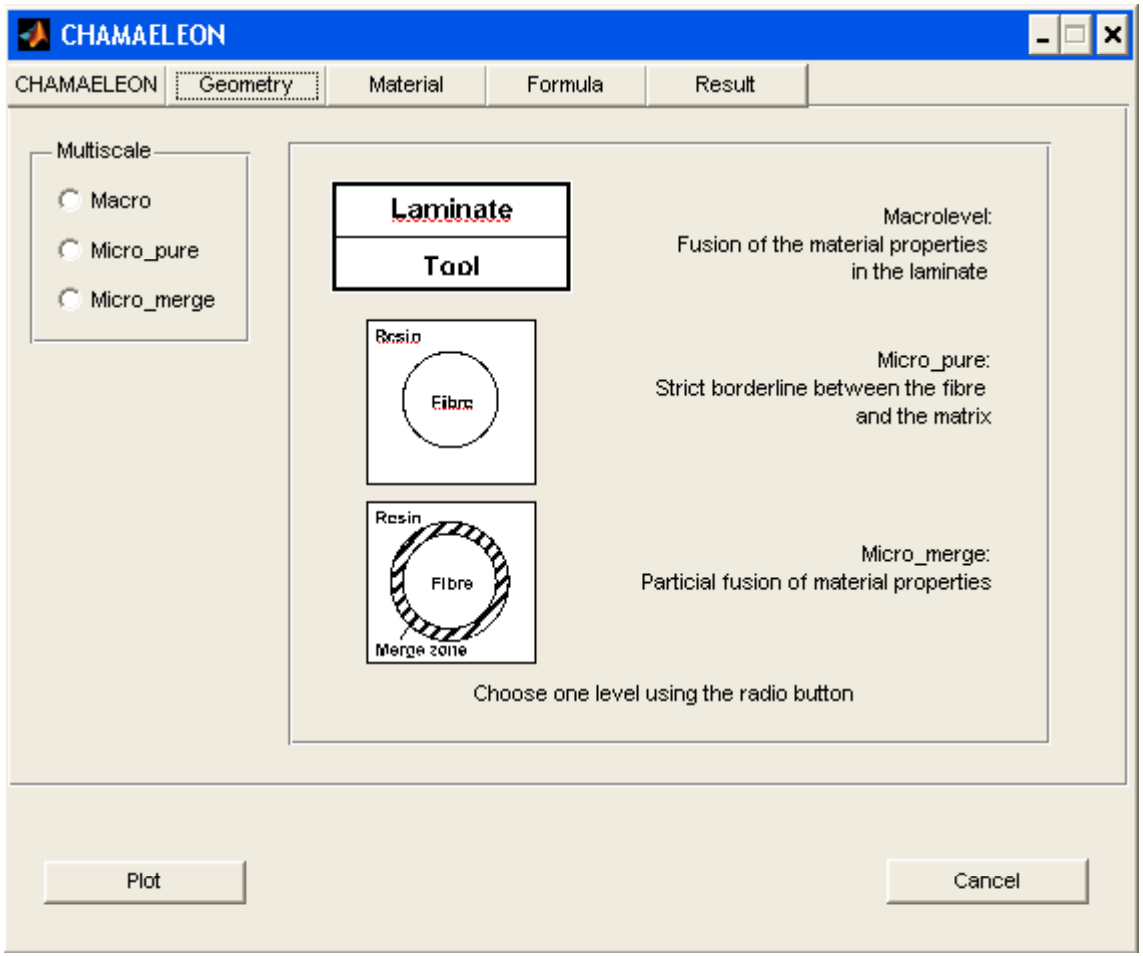
- Macro Level



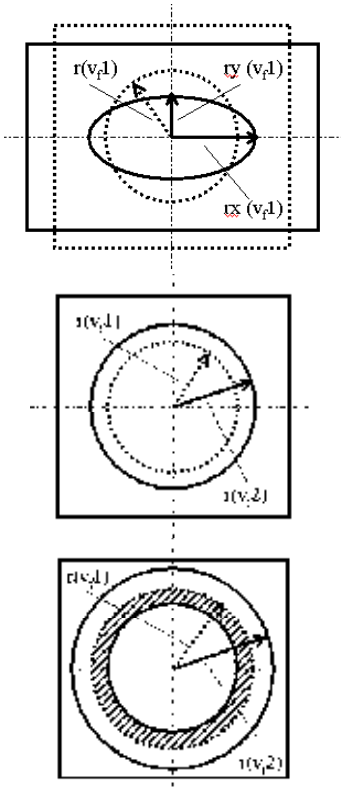
- Micro/meso Level

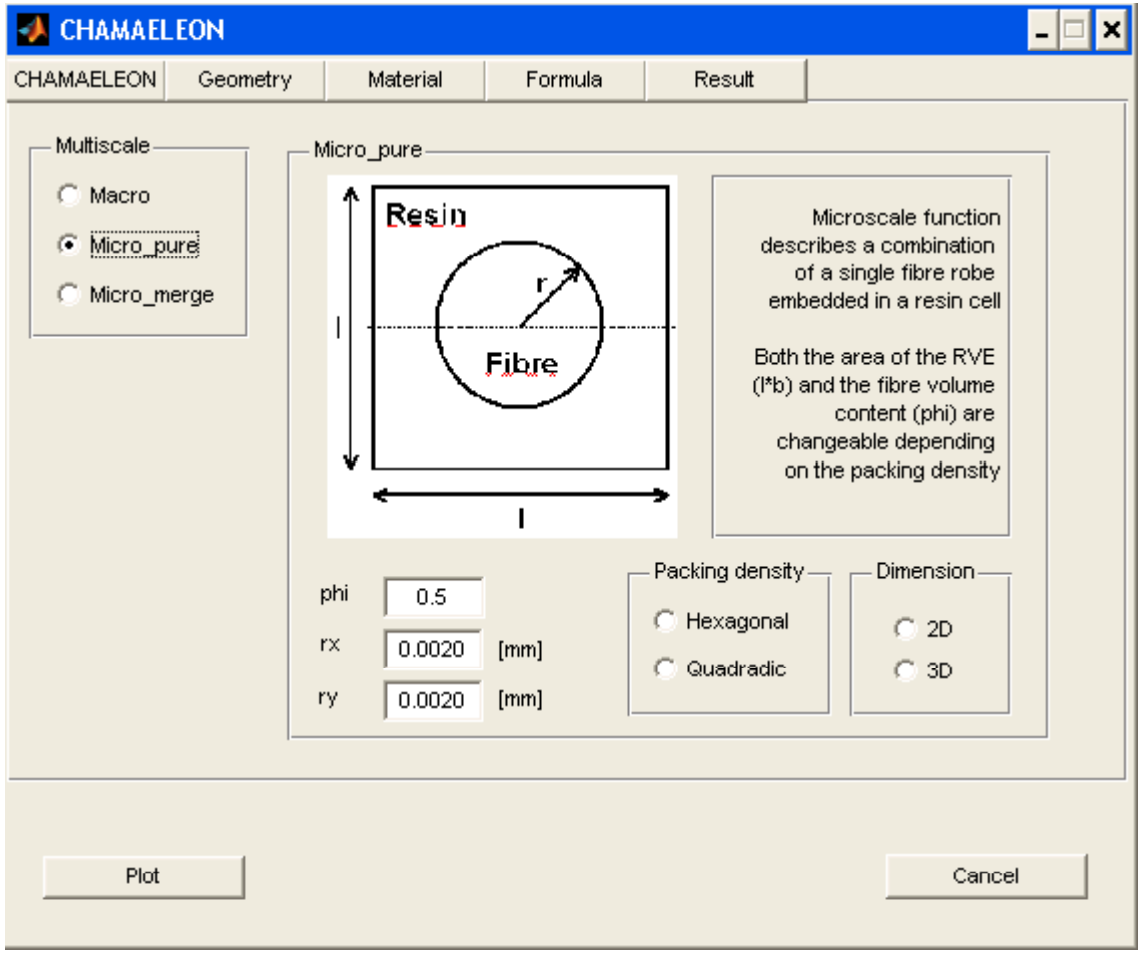


REV: Representative Elementary Volume



Geometry: Parameterization

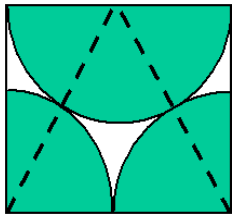




Material properties

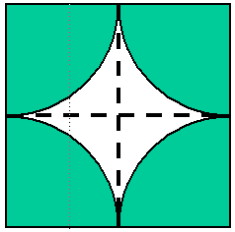
- Packing density

Hexagonal

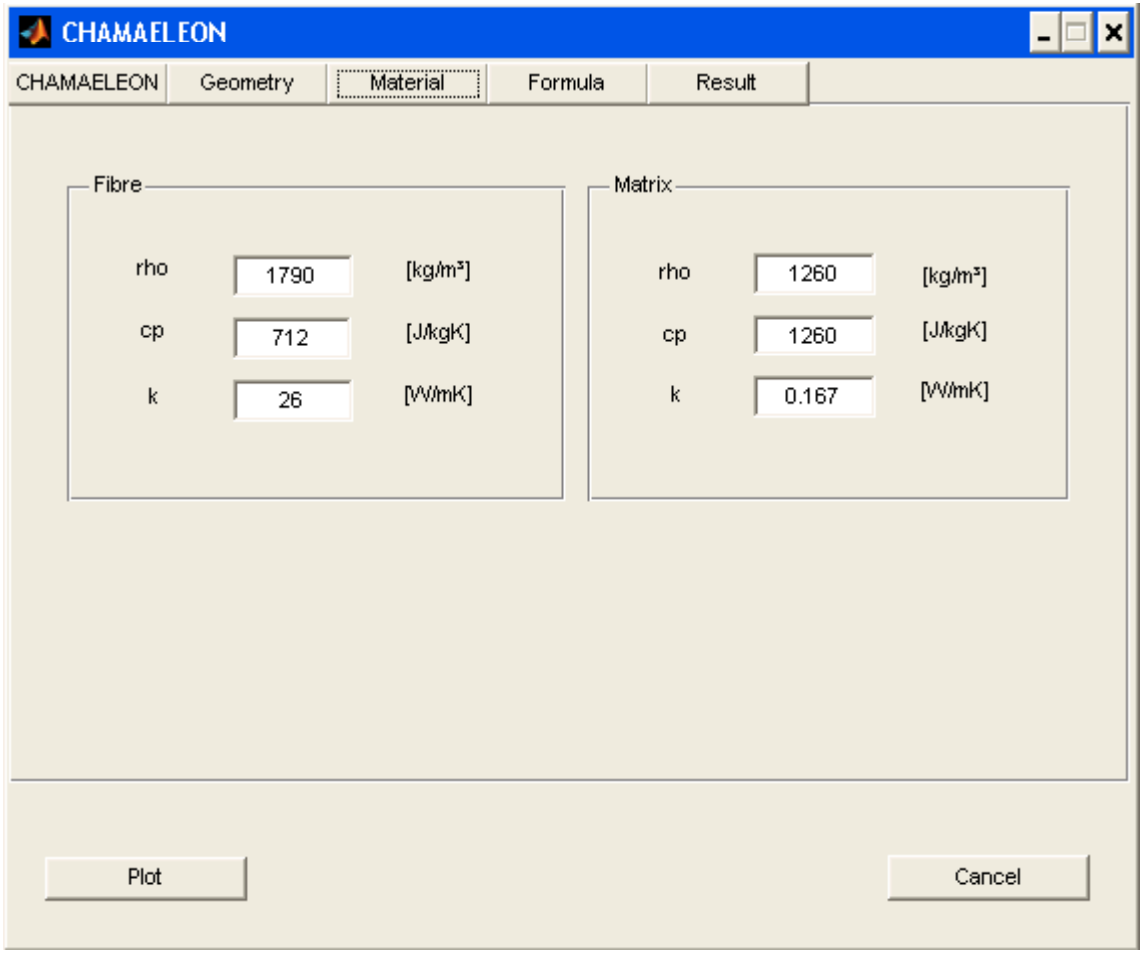


φ max = 0.91

Quadradic

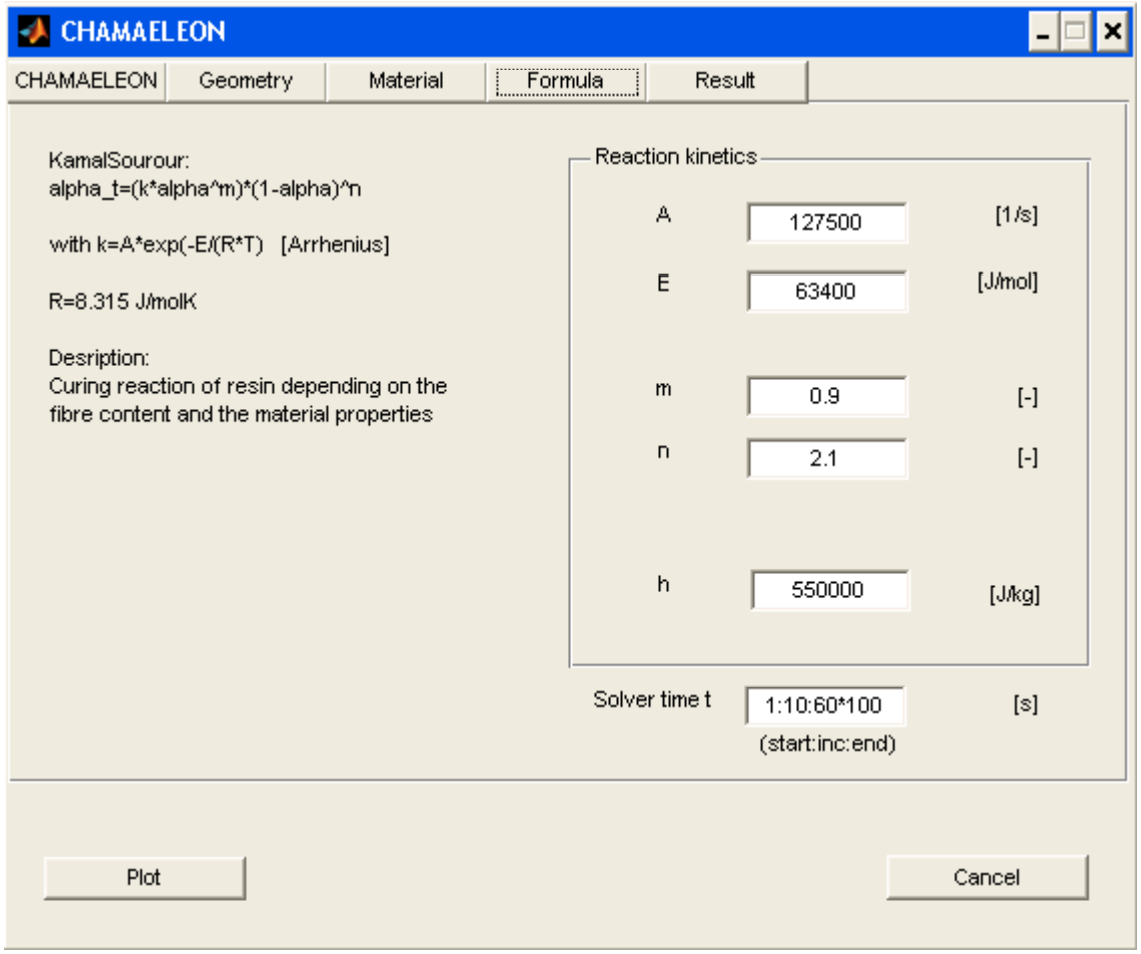


φ_max = 0.79



Formula

- Environment for physical problems
- Interface between COMSOL and Matlab



Formula for thermal properties

- Rule of Mixture
  - Density: $\rho_l = v_f * \rho_f + (1 - v_f) * \rho_m$
  - Thermal conductivity: $\lambda_l = v_f * \lambda_f + (1 - v_f) * \lambda_m, \quad \lambda_t = \frac{\lambda_{fl}\lambda_m}{v_f\lambda_m + v_m\lambda_{ft}}$
  - Heat Capacity: $c_{p_l} = \frac{v_f * \rho_f * c_{pf} + (1 - v_f) * \rho_m * c_{pm}}{v_f * \rho_f + (1 - v_f) * \rho_m}$
- Curing kinetics

$$\frac{d\alpha}{dt} = (k \cdot \alpha^m)(1 - \alpha)^n$$ KamalSourour

with

$$k = A \cdot \exp(\frac{-E}{RT})$$ Arrhenius

Use of COMSOL

- Equation
  - Heat transfer by Conduction:

$$\rho C_p \frac{dT}{dt} - \nabla \cdot (k \nabla T) = Q$$

  - PDE general mode for implementation of the KamalSourour equation

$$e \frac{\partial^2 u}{\partial t^2} + d \frac{\partial u}{\partial t} + \nabla \cdot \Gamma = F$$

with

$$e = 0, \quad d = 1, \quad \Gamma = 0 \quad \text{and} \quad F = (k \cdot \alpha^m)(1-\alpha)^n$$

Results

- Numerical homogenization
  - Analytical

$$\lambda_l = v_f * \lambda_f + (1 - v_f) * \lambda_m,$$

  - Numerical:

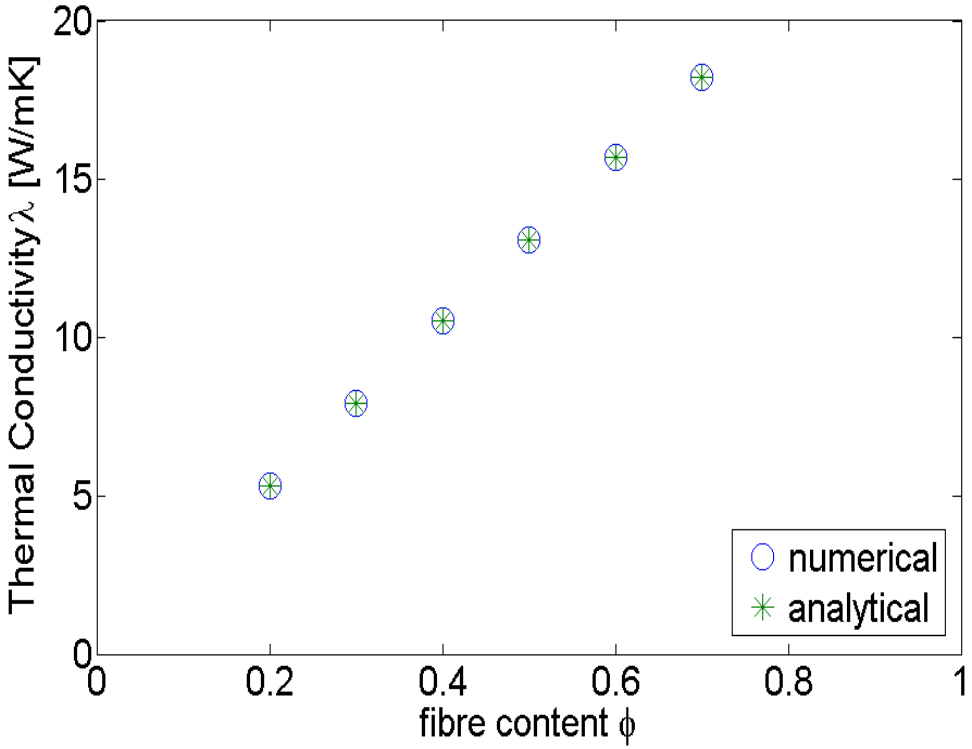
Thermal conductivity from the heat flux equation:

$$\dot{\vec{q}} = -\lambda \cdot gradT$$

Implementation in COMSOL:

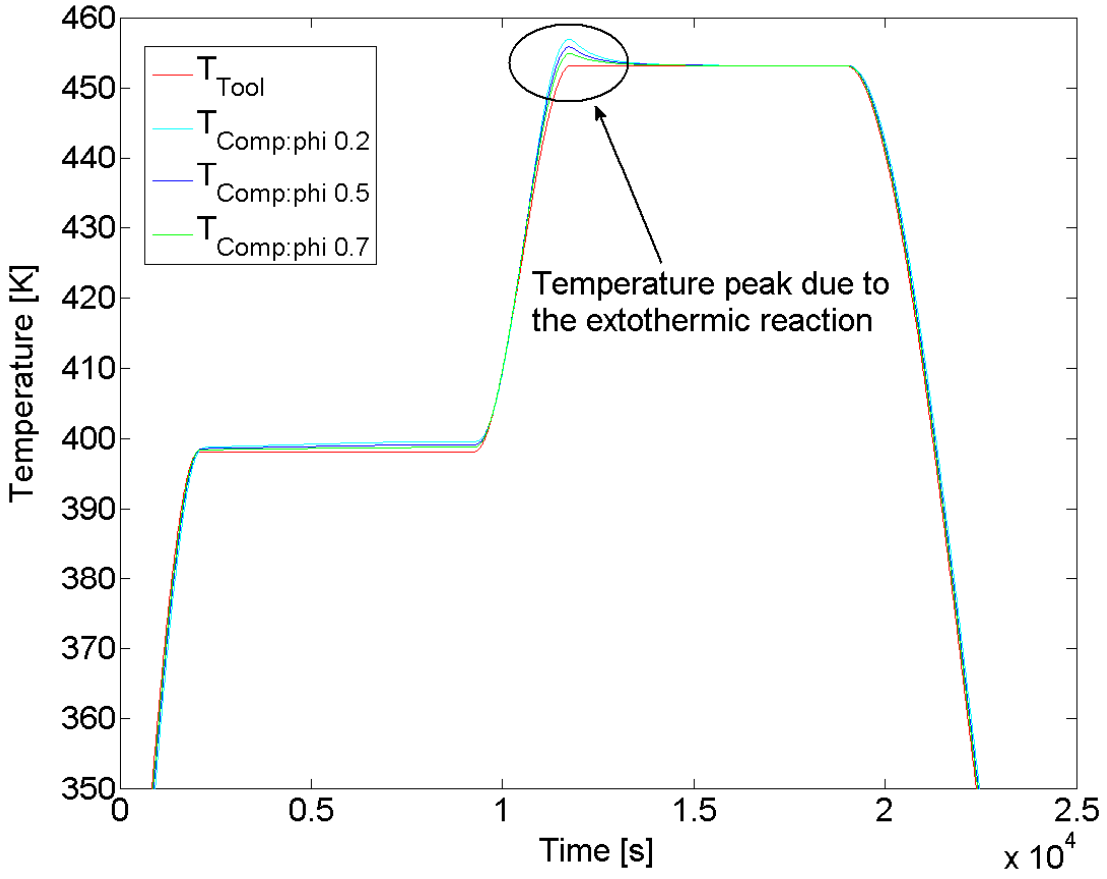
Subdomain Integration:

$$\lambda \approx -flux / gradT$$



Results

- Influence of exothermic reaction



Conclusion and outlook

- CHAMAELEON especially designed for user with interest in:
  - Fast investigation of the influence on global laminate properties
  - Optimization of the process parameter
- Principle of CHAMAELEON extensible to other physical area such as:
  - moisture behaviour,
  - electrical or
  - mechanical properties
- Intention of 3D illustrations considering the growing complexity of the geometry

Thank you for your attention!

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