Master Thesis

FFT-based full field damage simulation of SMC

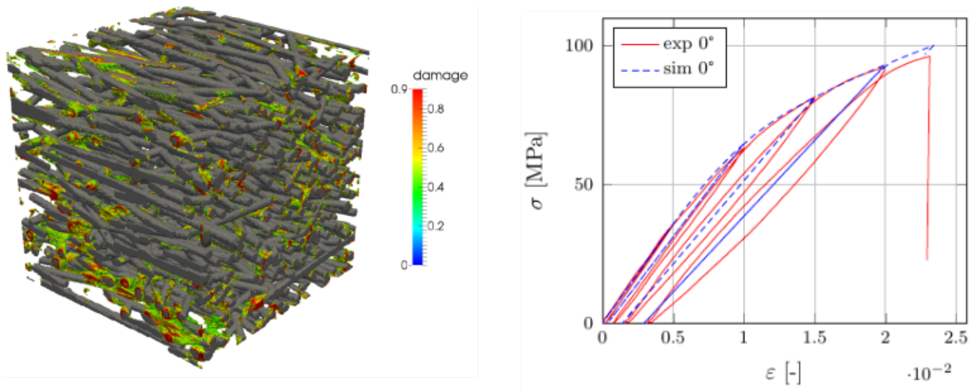

Fig. 1: Left: damaged discontinuous fiber reinforced composite, right: resulting macroscopic stress-strain relationship (from Spahn 2015)

Problem

Due to their high lightweight potential, economical mass-production and excellent formability, sheet molding compounds (SMC) are increasingly used for components in the automotive sector. So far, the lack of an understanding for robust modeling, the whole process chain as well as the process related thermo-mechanical properties do, however, not allow for an application of these classes of materials. The orientation and length distribution of the fibers in this material is highly heterogeneous and anisotropic.

The damage behavior of composites originates from three major phenomena: fiber breakage, matrix damage and fiber matrix debonding. This work aims to model the damage behavior of SMC on the Representative Volume Element (RVE) level. Such problems are challenging, especially due to their high phase contrast, large problem size and local softening behavior. Spectral Fast-Fourier Transformation (FFT) based methods proved to be suitable for such applications. At the ITM, the commercial voxel-based FFT solver GeoDict is used. GeoDict offers the possiblity to include user-defined material models as user subroutines which are identical to ABAQUS' UMATS.

Task

The goal of this thesis is to model fiber-matrix interface debonding and matrix damage in SMC by means of numerical full field simulations. In a first approach, the matrix damage will be modeled with an isotropic stiffness degradation. The interface strength is given by the probabilistic Weibull distribution. A model which reduces the effective stiffness due to the interface damage needs to be implemented. Interaction between matrix and interface damage must be considered. As RVEs, virtually generated composite structures and CT scans of real microstructures will be under consideration. A validation with uniaxial tensile tests (IAM-WK), biaxial tensile tests and acoustic emission analysis (IAM-WK) is planned. All experimental results are provided.

- Fundamentals
  - Literature: damage behavior of SMC
  - Literature: microstructural description of composites
  - Literature: fundamentals of Fast-Fourier-Transformation
  - Theory: UMAT programming in Fortran
- Tasks
  1. Gain insight into the software GeoDict
  2. Implementation of a $(1-d)$ isotropic matrix stiffness degradation model
  3. Development and implementation of an interface damage model
     (a) Identify fiber-matrix interfaces in the RVE
     (b) Find interfaces with maximal interface stress
     (c) Define damage evolution as interface degradation
  4. Perform simulations on RVEs (virtually generated and real structures from CT scans)
  5. Validation of simulations to experimental data (tensile tests and acoustic emission analysis (optional))

Literature

K. Derrien, J. Fitoussi, G. Guo, D. Baptiste. Prediction of the effective damage properties and failure properties of nonlinear anisotropic discontinuous reinforced composites. Computer Methods in Applied Mechanics and Engineering, 185(2-4), 93-107, 2000.

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J. Spahn. An efficient multiscale method for modeling progressive damage in composite materials, PhD dissertation, Technical University Kaiserslautern, 2015.

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