



Seminar:

**Simulation of Composites
– Ready for Industrie 4.0?**

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Simulation driven development of composite structures: from manufacturing to sizing

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Composite materials are one of the core ingredients of advanced light weight construction in Aerospace, Automotive and Mechanical Engineering. In the framework of virtual product development, manufacturing and mechanical response of composite structures can be described numerically by finite element models. Due to the multitude of different manufacturing processes, various structural applications as well as a variety of different purposes of the simulation, a large number of specialized finite element codes and methods has been developed [1].

Especially in small and medium-sized enterprises, the full potential of virtual product development of composite structures is often not utilized, as the existing tools and methods are judged to be too complex, too time-consuming and too expensive.

Main goal of this paper is to discuss both the effort and opportunities of using the finite element code Abaqus [2] in virtual product development of composite structures.

The complete CAE-based development process is demonstrated using a storage unit cover from glass-fibre reinforced thermoplastic composite (Organo sheet). From manufacturing (draping simulation) to sizing using non-linear material models, different simulation disciplines are discussed. [3,4]. The influence of manufacturing parameters and the prediction of resulting material properties is introduced using a CFRP mountain-bike handle. [5-7].

As an outlook on future trends in manufacturing simulation, the virtual investigation of uncertainties in process parameters is discussed. Random variables are introduced to describe process parameters such as braiding angle or fibre volume. The resulting stochastic variability is investigated using Monte-Carlo simulation [8].

1 Introduction

Virtual product development can be utilized to significantly increase structural performance and reduce development lead time by cutting down the number of iteration loops between design and stress analysis. In this paper, two applications are discussed where numerical simulation tools are employed from the manufacturing stage till the final sizing of the structure.

2 Virtual Product Development of a GFRP Storage Unit Cover

In this chapter, the virtual product development process is shown for a GFRP storage unit cover for automotive applications as illustrated in Figure 1.

Starting out with a base design and corresponding 3D cad data, an initial finite element model is created which contains the nominal fibre orientations. However, during the draping process, significant deviations from the nominal fibre orientation are expected. Hence, a draping simulation is performed in order to predict the distorted local fibre orientation. The fibre orientation field is then mapped to the corresponding finite element model.

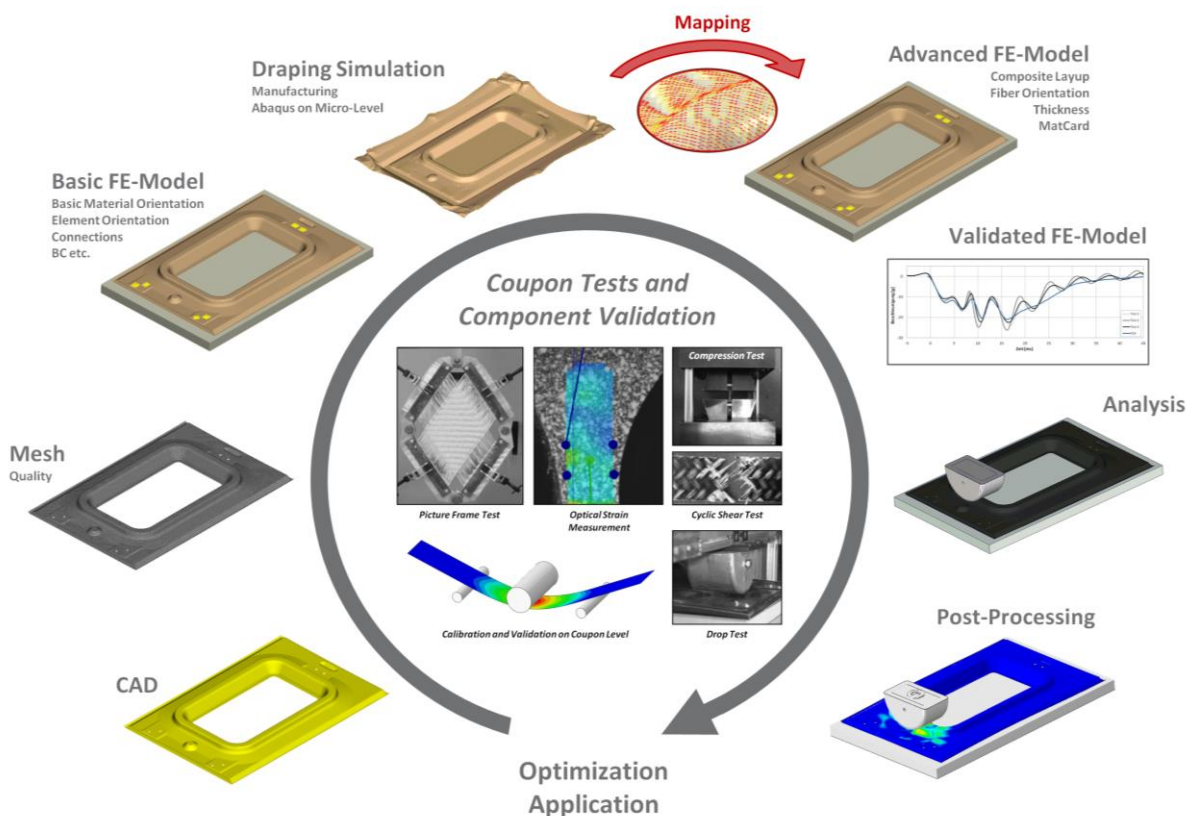


Figure 1: virtual product development process of GFRP storage unit cover

Obviously, the shearing of the GFRP fabric during draping has a significant influence on both the elastic and inelastic response of the material. In order to accurately capture this behavior, picture frame shear tests have been performed to determine the non-linear response of the fabric. As shown in Figure 2, good agreement is found between numerical prediction and shear test results.

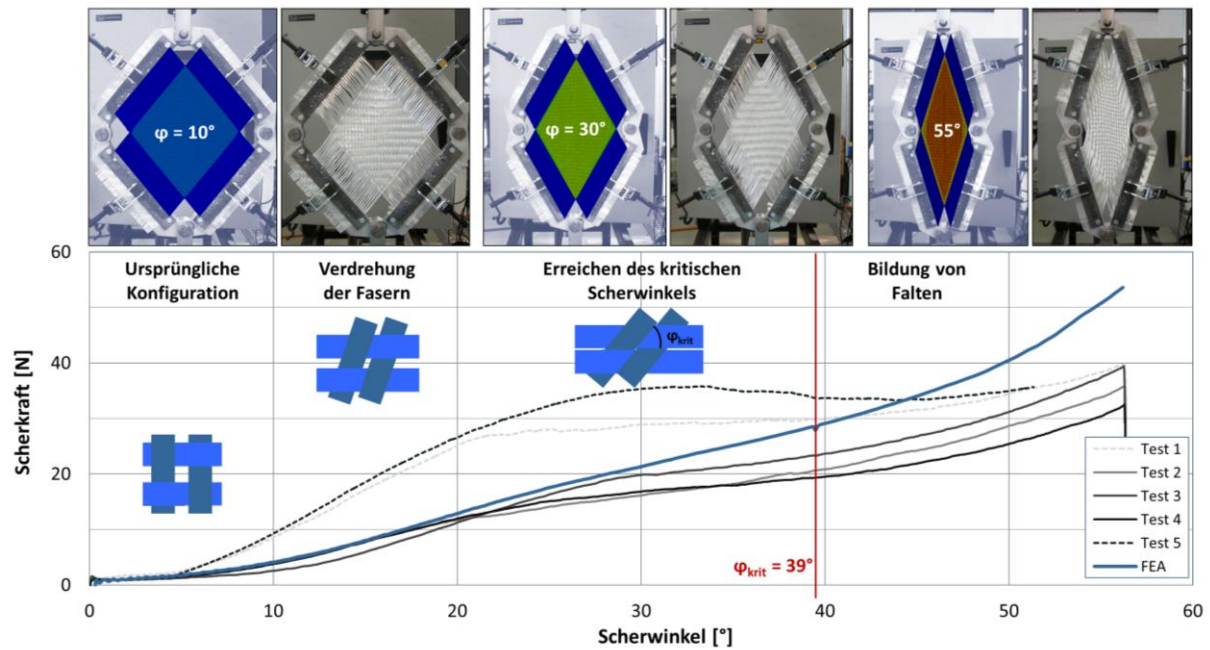


Figure 2: picture frame shear test

Combining the local fibre orientation obtained by the draping simulation with the validated non-linear material model, a highly accurate prediction model is created. Validation tests on macro scale are performed and indicate a good agreement between prediction of global response through FEA and the test results on macros scale.

The final validated model is used to investigate the influence of various design changes on the resulting structural properties in order to significantly speed up the development process.

3 Virtual Product Development of Braided Composite Materials

Braided composite structures offer a reliable and robust manufacturing process at relatively low costs which is very suitable for medium to large scale production. Depending on various process parameters, such as braiding speed (both rotational and translational), yarn thickness, number of yarns, curvature of the structures core, the resulting final fibre architecture will vary significantly.

Various tools for braiding simulation, based on analytical and finite element approaches have been developed which can be utilized to predict the resulting fibre architecture.

Based on a known geometry of the fibres, a mesomechanical finite element model can be created in order to predict the mechanical properties on macroscale, as shown in Figure 3. The meso model is created using the open source software TexGen. Periodic boundary conditions are applied on the faces of the unit cell. Both elastic and inelastic parameters can be predicted, using non-linear anisotropic material models for the yarns.

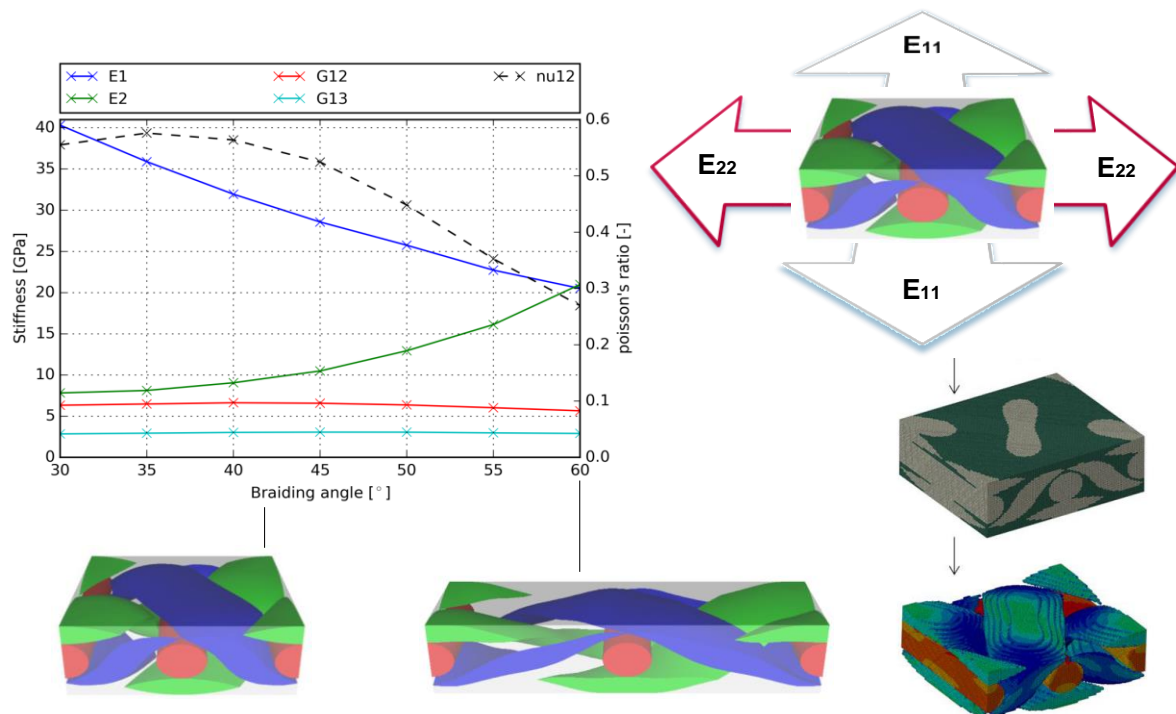


Figure 3: mesomechanical model of braided cfrp

The resulting material properties as a function of the fibre geometry are mapped to the macro scale finite element model as shown in Figure 4. Experimental validation is performed using a bending test. Using the validated reference model, a numerical optimization of the fibre layout is performed.

Targets of the optimization are a minimized stiffness in order to minimize strain on the cyclists hands while not decreasing the failure load.

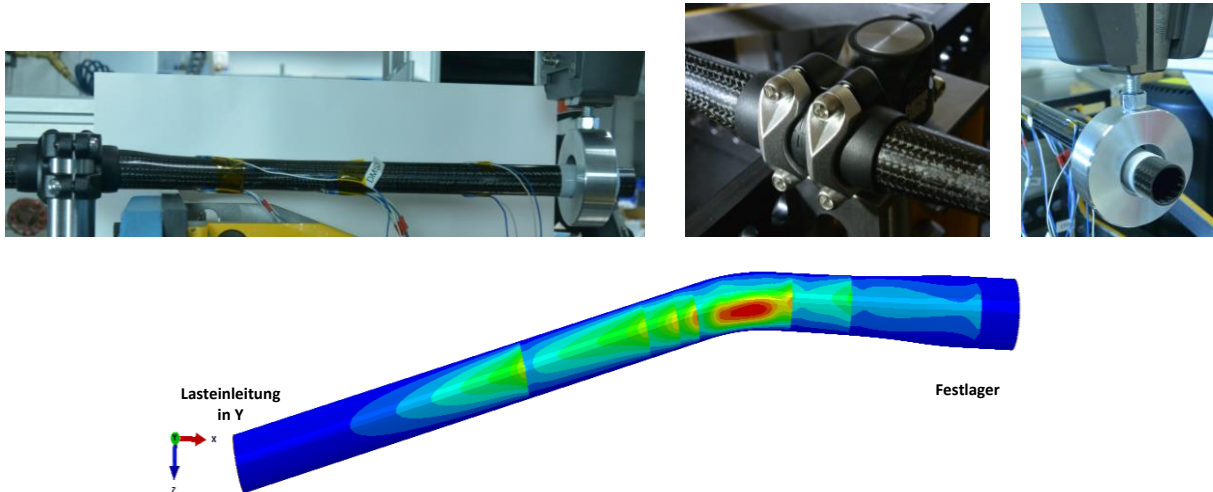


Figure 4: macro scale model and test set up

4 Outlook

In both previous chapters, deterministic models and input data are used to describe the structural response. However, with increasing computational power, it is possible to go a step beyond deterministic models and also include stochastic uncertainties in the manufacturing process.

For the case of braided composites, the effect of possible uncertainties at unit cell level, resulting in macroscopic mechanical properties is studied. A FEM-based approach is used for the probabilistic homogenization, established on the stress method (periodic boundary conditions on the outer edges of the unit cell and under specific interface stresses). Random variables for the description of the inherited randomness are used, while the elastic parameters variability is calculated through Monte Carlo simulations. The first three statistical moments and the probability distribution of the effective elastic parameters are computed for various cases of uncertainty (braiding angle, undulation angle, volume fraction, fiber/matrix modulus etc.) and various input statistics (distributions, variance etc.).

Results offer a perspective on the variability influence of the random parameters, an estimation of the statistical characteristics of the homogenized tensor and also highlight the importance of realistic uncertainty quantification.

5 Acknowledgement

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6 References

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