HYPERELASTIC MEMBRANE APPROACH FOR MACROSCOPIC FORMING SIMULATIONS OF UNIDIRECTIONAL NON-CRIMP FABRICS (UD-NCF)

Bastian Schäfer[1]*, Dominik Dörr[2], Ruochen Zheng[3], Naim Naouar[3], Luise Kärger[1]
[1]*Lightweight Engineering, Institute of Vehicle System Technology (FAST), Karlsruhe Institute of Technology (KIT), Karlsruhe, 76131, Germany*
[2]*Simutence GmbH, Karlsruhe, 76131, Germany*
[3]*INSA Lyon, CNRS, LaMCoS, UMR5259, 69621 Villeurbanne, France*
*presenting author: *bastian.schaefer@kit.edu*

A hyperelastic membrane model is proposed for unidirectional non-crimp fabrics based on superimposed shear, transverse tension and compression perpendicular to the rovings. The model accurately predicts the forming behavior for different geometries.

Abstract

Unidirectional non-crimp fabrics (UD-NCFs) provide an excellent lightweight potential for high-performance components due to their straight fibers. However, during forming they are prone to wrinkling and gapping compared to woven or biaxial textiles. The unidirectional reinforcement direction requires the consideration of different deformation modes during modeling besides shear, which is the main deformation mode of most models for woven or biaxial textiles [1]. A hyperelastic model is proposed to describe the membrane behavior of UD-NCFs based on superimposed shear, transverse tension and compression perpendicular to the fiber rovings [2]. The membrane deformation modes are related to suitable invariants based on principle material directions of the UD-NCF, cf. Fig. 1a.

Experimental off-axis tension tests with bias angles of 30°, 45° and 60° are used to impose different ratios of superimposed strains [3] and subsequently parameterize the model, cf. Figure 1b. The resulting approach is validated by forming simulations of a hemisphere and tetrahedron geometry, cf. Figure 1c. Good qualitative and quantitative agreement with experimental tests is achieved for the outer contour after forming as well as the strains measured by digital image correlation.

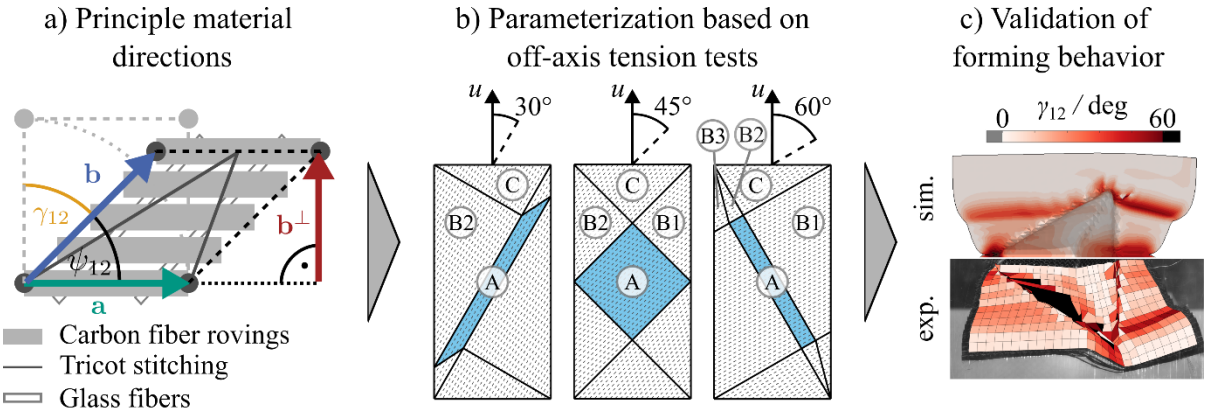

Figure 1: *a) Principle material directions of the hyperelastic membrane modeling approach [2]; b) Schematic illustration of the off-axis tension tests used for the parameterization [3]; c) Validation of the forming behavior based on tetrahedron forming test*

[1] F. J. Schirmaier, D. Dörr, F. Henning, and L. Kärger, *A macroscopic approach to simulate the forming behaviour of stitched unidirectional non-crimp fabrics (UD-NCF)*, Comp. Part A, 102, 2017, p. 322–335.

[2] B. Schäfer, D. Dörr, R. Zheng, N. Naouar, and L. Kärger. *A hyperelastic approach for modeling the membrane behavior in finite element forming simulation of unidirectional non-crimp fabrics (UD-NCF)*. Comp. Part A, 185, 2024, Art. 108359.

[3] B. Schäfer, R. Zheng, N. Naouar, L. Kärger, *Membrane behavior of uni- and bidirectional non-crimp fabrics in off-axis-tension tests*, Int. J. of Mat. Form., 16, 2023, 68.