Orthotropic Hyperelastic Energy Formulations for the Geometrically Nonlinear Simulation of Textile Surface Structures

M. Motevalli, J. Uhlemann[a], N. Stranghöner[a], D. Balzani[*]

[*] Chair of Mechanics-Continuums Mechanics
Ruhr-University Bochum
44801 Bochum, Germany
daniel.balzani@rub.de

[a] Institute for Metal and Lightweight Structures
University of Duisburg-Essen
45117 Essen, Germany
iml@uni-due.de

Abstract

New hyperelastic orthotropic material formulations are proposed for the simulation of textile membranes. They are obtained as extensions of the model in [1] by orthotropic functions describing the interaction behavior. A part of the models is polyconvex [2, 3] and thus, a physically meaningful and mathematically robust formulation is obtained. The models are adjusted to the stress-strain paths of a coated textile fabric under cyclic uniaxial and biaxial tension tests in warp and fill direction. From the experiments it is shown that a saturated elastic state can not yet be reached within only 3 to 5 load cycles, which however is standard procedure in practical engineering. In contrast to this, here the number of cyclic loads is increased until a newly defined saturation criterion is reached. An improved parameter adjustment procedure is proposed for the identification of model parameters such that the remaining material parameters can be uniquely identified. The lateral contraction of the uniaxial tension tests is included during parameter adjustment and thereby, the analysis of the strong crosswise interaction between the warp and fill yarns described by orthotropic models is enabled. It is shown that a linear elastic model can not sufficiently represent the complex material behavior and even a nonlinear (hyperelastic) model with a simple superposition of purely transversely isotropic energies for the warp and fill directions fails to qualitatively describe the mechanical response. The adjusted material model is implemented to compare the robustness of the different models in real-world applications. Moreover, a new large scale experimental setup is presented which serves as basis for the validation of the models in a structural problem.

References

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