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Nonlinear hyperviscoelastic modelling of intra-ply deformation behaviour in finite element forming simulation of continuously fibre-reinforced thermoplastics

Dominik Dörr[a], Frank Henning[a,b], Luise Kärger[a]

[a] *Karlsruhe Institute of Technology, Rintheimer Querallee 2, 76137 Karlsruhe, Germany*
[b] *Fraunhofer - Institute for Chemical Technology, Joseph-von-Fraunhofer-Strae 7, 76327 Pfinztal*

Abstract

A nonlinear hyperviscoelastic approach for modelling rate-dependent intra-ply deformation behaviour in FE forming simulation of continuously fibre-reinforced polymers is presented. This approach follows either a Voigt-Kelvin approach or a generalized Maxwell approach based on a multiplicative decomposition of the deformation gradient. The constitutive equations are implemented in a "Discrete Kirchhoff Triangle" shell-formulation within an Abaqus user-element, including a physical decoupling of membrane and bending behaviour. The approach is parameterized for a thermoplastic UD-tape (PA6-CF) at different strain-rates and temperatures above the crystallization temperature and applied to iso-thermal forming simulation. Parametrization results reveal that only the generalized Maxwell approach represents the whole material characteristic. Moreover, a difference in forming behaviour is observed for the investigated temperatures and constitutive equations. The difference, however, is small, which reveals that iso-thermal forming simulation following a Voigt-Kelvin approach is suitable for prediction of forming behaviour within a suitable process window, where isothermal conditions are assumable.

Keywords: Forming, Process Simulation, Finite element analysis (FEA), Tape