MATERIAL MODELS FOR DRAPING SIMULATION OF CARBON FIBRE FABRIC WITH PROCESS-INDUCED VARIANCES OF SHEAR RIGIDITY AND CONTACT PARAMETERS

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Abstract

The manufacturing of fibre-reinforced composites with woven or non-crimp reinforcements requires the forming of the fabric to the desired shape of the structural part. The very important feature for the designer of the fibre-reinforced composites is their anisotropy, i. e. the directional dependence of their mechanical properties. A slight deviation of the fibres from the optimal load-bearing direction decreases the mechanical properties considerably. Defects such as wrinkles, gaps and fibre pull-out further influence the properties and the performance of the final composite product. Thus, it is desirable to have a tool that is able to predict the fibre orientation and to anticipate possible defects in the textile structure. A previously developed material model for the simulation of textile draping in LS-Dyna® is further improved by incorporating coupled shear and tension material behaviour. The aspects of contact between plies are investigated in order to examine multilayer forming behaviour of textile reinforcements reported elsewhere.

The material model is based on a nonlinear anisotropic laminate formulation. It takes into account the typically low bending and shear stiffness of fabrics compared to their large in-plane tensile stiffness in the fibre directions. The macroscopic approach allows fast and ro-bust forming simulations. The shear-tension coupling is realised with the implementation of response surfaces of mechanical behaviour of dry fabrics under combined tensile and shear loads. This is especially necessary for the simulation of forming processes where blank holders induce membrane stresses. Results of shear tests with a novel picture frame are used as input data. The test apparatus uses pneumatic cylinders with low friction characteristics and load cells on both axes to control the initiated tensile forces while shearing the fabric.

Fabric plies interact with each other during the forming of multilayer preforms. The local stacking sequence affects the forming results. Thus, friction between fabrics is analysed. Fabrics are previously sheared to investigate the influence of the fibre orientation on the con-tact behaviour. The measured friction behaviour is implemented into the model with respect to relative fibre orientation.

The validation procedure includes forming tests with hemisphere and L-shape geometries with different relative orientations of the two reinforcement fabrics and with different blank

holder forces. Results show very good agreement of the simulations with the experimental tests in terms of fibre orientation and wrinkling.

It is concluded that the incorporation of the shear-tension coupling and the contact behaviour between fabric plies gives improved results for forming simulations with the occurrence of membrane stresses. With the availability of a comprehensive model the interactions between process parameters during textile forming can be studied.