

Introduction

The Rubber Press Forming process (RPF) is a relatively fast method for manufacturing fabric-reinforced thermoplastic products. Typically, the production cycle time is in the order of a few minutes, thereby reducing production costs significantly compared to the production with, for example, thermosetting materials.

However, dimensional accuracy problems of the product can occur when manufacturing doubly curved high precision parts. This is partly caused by the process of draping. Due to draping the angle between the warp and weft yarns varies over the product. As a result the thermomechanical properties in the product show a corresponding distribution, leading to inhomogeneous shrinkage and warpage. The resulting fibre orientations must be known accurately to predict these dimensional distortions so they can be accounted for on beforehand.

From previous studies it is known that draping of thermoplastics is influenced by the buildup of the laminates. Due to interlaminar effects, quasi-isotropic (QI) lay-ups drape significantly worse than cross-ply laminates.

Objective

The objective is to develop a Finite Element (FE) model to predict the drapeability and fibre reorientation of multi layered fabric-reinforced composites.

Experiments

4-layered satin 8H fabric glass fibre-reinforced poly (phenylenesulphide) composites were formed in the RPF-process into a double dome shape (Figure 1).

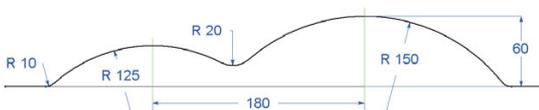


Figure 1: Cross-section of the double dome shape

The drape characteristics of the composites as a function of their lay-up are found by using two cross-ply buildups ($[0^\circ/90^\circ]_{2s}$ and $[45^\circ/-45^\circ]_{2s}$), and a QI ($[0^\circ/90^\circ/45^\circ/-45^\circ]_s$) lay-up.

Modelling

A multi layer drape material model, based on the single layer fabric-reinforced fluid model (1), was implemented in the FE-package *DiekA*. In the model, the plies in the laminate are allowed to deform individually (see Figure 2), using a constant traction between the plies. A *virtual power* method is applied to solve the individual ply deformations. Weighted

averaging of the individual ply stresses results in the stress response of the laminate. The RPF-process is then modelled using its process-specific boundary conditions in an Arbitrary Lagrangian Eulerian formulation.

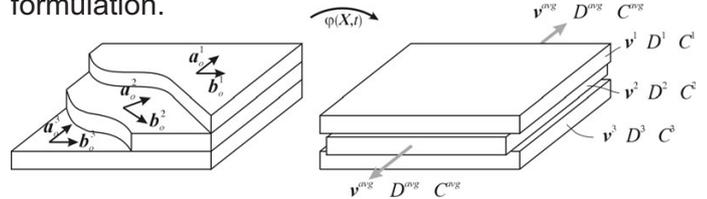


Figure 2: Three layers deforming individually

Results

The experimental and modelled drape results are shown in Figures 3 and 4, respectively. The resulting fibre reorientation can be related to the outer shape of the products. The resulting outer shapes agree quite well for all laminates. The areas denoted with an S show large shear deformation. Wrinkling occurs for the QI laminate due to interlaminar shear effects and is indicated with an arrow. This phenomenon is confirmed by the model.

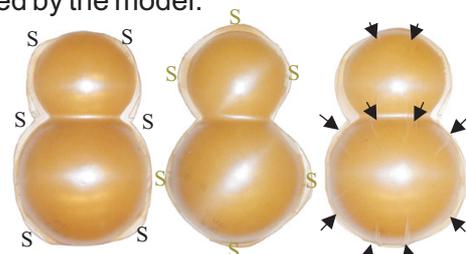


Figure 3: Experimental drape results for $[0^\circ/90^\circ]_{2s}$, $[45^\circ/-45^\circ]_{2s}$ and QI lay-up

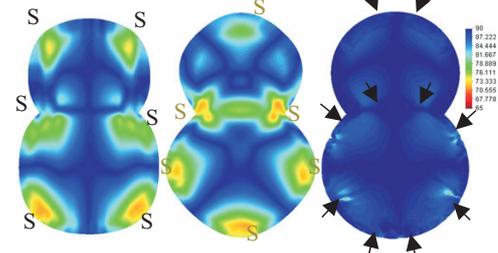


Figure 4: Drape modelling results for $[0^\circ/90^\circ]_{2s}$, $[45^\circ/-45^\circ]_{2s}$ and QI lay-up

Conclusion

A finite element model was developed to predict the drapeability and the fibre reorientation of multi layered fabric-reinforced thermoplastic composites in the Rubber Press Forming process. The model incorporates interlaminar shear and predicts the drape behaviour satisfactorily.

References

1. E.A.D. Lamers, S. Wijskamp & R. Akkerman, Fibre Orientation Modelling for Rubber Press Forming of Thermoplastic Laminates, *Esaform* 2002, p. 323-326.