FINITE ELEMENTS MODELLING OF FABRIC DRAPING

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Introduction

Over the last years, the demand for fabric-reinforced composites, is growing in the aeronautical industry. Due to better production processes such as the Rubber Press Forming (RPF) process for thermoplastic composites, production costs could be reduced. Therefore, fabric-reinforced thermoplastics are getting increasingly better economical competitors to other construction materials.
However, when manufacturing doubly curved high precision parts, dimensional accuracy problems of the product can occur. This is partly caused by the process of draping. Due to draping the angle between the warp and weft yarns vary over the product with its double curvature. As a result the thermomechanical properties in the product show a corresponding distribution, leading to inhomogeneous shrinkage and warpage. Obviously, the resulting fibre orientations must be known accurately to predict these dimensional instabilities so they can be accounted for on beforehand.

Objective

The objective is to develop a Finite Element (FE) model to predict the drapability and fibre re-orientation of fabric-reinforced composites in doubly curved products in the RPF-process for thermoplastics.

Experiments

Experiments were performed with 4-layered laminates of Ten-Cate's Cetex® material. The Satin 8H fabric glass fibre reinforced Poly Phenylene Sulfide (PPS) composites were formed in the RPF-process into a double dome shape (see Figure 1).

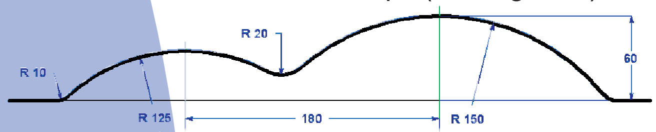

Figure 1: Cross-section of the double dome shape

Using a different laminate build-up (cross-ply and Quasi-Isotropic (QI)) drape characteristics of the composite as a function of its lay-up are found.

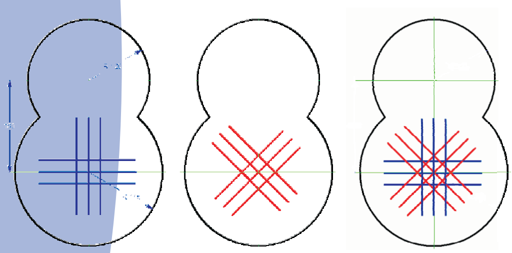

Figure 2: Fibre orientations for $[0/90]_{2s}$ cross-ply, $[45/-45]_{2s}$ cross-ply and QI $[0/90 \mid 45/-45]_S$ laminates

Modelling

To predict the drapability of a product and the fibre re-orientation a simulation model was developed in the FE package *DiekA*. In *DiekA* a fabric-reinforced fluid model was implemented (1) and the RPF-process for composite materials was modelled using its process-specific boundary conditions.

Results

In Figures 3 and 4 the modelled and the experimental drape results are shown. The resulting fibre re-orientation can be related to the outer shape of the products. The resulting outer shapes agree quite well for the cross-ply laminates but not for the QI laminate where wrinkling occurs. The inaccurate prediction is most likely caused by interlaminar shear that is not accounted for in the model.

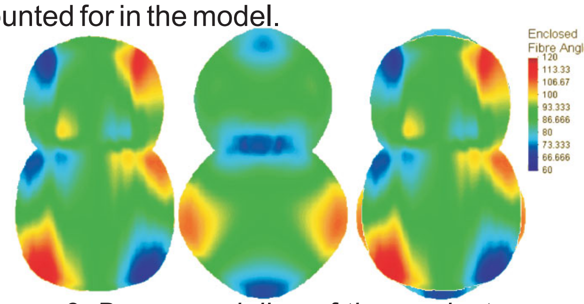

Figure 3: Drape modeling of the product, $[0/90]_{2s}$ cross-ply, $[45/-45]_{2s}$ cross-ply and QI $[0/90 \mid 45/-45]_S$ laminates

Figure 4. Experimental drape results for $[0/90]_{2s}$ cross-ply, $[45/-45]_{2s}$ cross-ply and QI $[0/90 \mid 45/-45]_S$ laminates

Conclusion

A FE-model was developed to predict the drapability and the fibre re-orientation of woven fabric thermoplastic composites in the Rubber Press Forming process. The model gives quite good predictions for the cross-ply laminates but not for the QI laminate. To predict the re-orientation of QI laminates more accurately, interlaminar shear behaviour must be taken into account in the model.

References

1. A.J.M. Spencer, "Theory of fabric-reinforced viscous fluids", *Composites*: Part A, Volume 31, p.1311-1321, 2000