ABSTRACT

Deep drawing of continuous fibre reinforced thermoplastic prepregs is a promising new composite production process. Geometric models are used to simulate the draping configuration of fabrics to complex shaped tool surfaces without wrinkling or bridging. An extended model of the deep drawing process taking into consideration the forming stages, friction and fabric shearing forces, too, is presented in this paper.

INTRODUCTION

A production process for composite parts of increasing importance is the forming of continuous fibre reinforced thermoplastic prepregs. These are available in the form of semifinished lamina plates, single plies which must be stacked to lamina and several covoven and comingled materials. Various forming processes are used to produce parts, partly wellknown from corresponding forming processes of sheet metal and thermoplastic plates: deep drawing, hydro-, rubber- and diaphragm forming etc. The prepregs being used for high performance composites in most cases up to now textiles with long straight fibres, such as UD-layers and fabrics are prefered in this context. Parallely to the process technology simulation methods for the forming process have been developed, /1 bis 6/.
I - THE GEOMETRIC FABRIC MODEL

Unlike in e.g. random mats or knitted materials in fabrics in the direction of warp and weft neither flow nor strain can occur to a considerable amount. The drapability of the fabrics to double curved surfaces is merely based on the shearing of warp and weft fibres. Hence in the forming simulation fabrics are modeled as lattices, the vertices of which are posed on the tool surface in a single step keeping constant distances a and b of the warp resp. weft yarn paths. Only rhombic deformations of the lattice squares are allowed. By fixing the path of one warp and one weft fibre on the surface the position of the other yarn paths is uniquely determined. Each point is calculated from the before calculated neighbour lattice points. (fig.1)

\[ \| P_{ij} - P_{ij-1} \| = a, \quad \| P_{ij} - P_{i-1j} \| = b \]

The nonlinear equation system is solved by a Newton method. In the resultant fabric position the extent of the local shear deformation can be observed. Depending on the construction of weave and fibre density there is a limit of deformation which can not be exceeded without wrinkling. Also areas of fibre bridging can be detected. (e.g. /6/)

Different strategies are used to contrain the first warp and weft yarn paths: Often symmetry reasons call for laying them into the tool's symmetry planes, /1,2/. Geodethic paths can be presumed /4/, or the total extent of fabric deformation is minimized, /3/.

The programs based on the geometric model are an aid to define theoretically admissible fabric layups rather than a real process simulation. The various possible results are influenced by the user through more or less comfortable means of fixing the first warp and weft path.

How the process has to be performed to achieve the calculated fabric layup can not be derived directly. Contrariwise it can not be predicted how a fabric is deformed under certain process conditions.

Furthermore a pseudo simulation of the process stages by stepwise increase of the tool height shows that even in that case where the finally resulting layup does not wrinkle during the forming regions of not admissible deformation can occur. (fig.2)

An extended forming model to calculate the forming stages from a starting position of the fabric to the finished part taking into consideration the working forces, too, is presented in the following chapter.