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Background

The breakthrough of advanced composite materials in various applications has occurred to a smaller extent than might have been expected previously, mainly due to the high integral costs of composite products: a high cost of manufacturing added to the already expensive raw material. There is a clear need for improved cost-effectiveness. The key issues are considered to be: cheaper production processes, higher production rates and predictable component accuracy.
Thermoplastic composites have a good potential, but the current knowledge of the material behaviour under full-scale production conditions is still inadequate. Academic research can produce the numerical tools to assist in building up the required know-how. Composite forming simulations will be a useful tool to predict e.g. process distortions and the occurrence of wrinkling, thus reducing cost of rework and lead time.

Previous Work

In the BriteEuram programme PRECIMOULD (BE97-4351), a prototype software package was developed to predict tooling geometry corrections and processing conditions to achieve accurate 3D shapes of composite products. To this end, the material behaviour and the processing factors affecting composite part accuracy had to be understood and quantified. Appropriate models were developed for autoclave and RTM processing of various Woven Fabric (WF) reinforced thermoset materials and verified by experiments. Full scale demonstrators were designed and produced based using the PRECIMOULD solver, implemented in the LUSAS finite element package.

Current Work

A national research project on high precision rubber press forming of thermoplastic composites started in 2001, with Ten Cate Advanced Composites and Fokker Special Products as partners. Using previous results on the thermoelastic properties of WF reinforced thermoplastics, more sophisticated models are developed for the stress evolution during rapid cooling in WF composites with a semi-crystalline matrix such as PPS. The constitutive models are to be implemented for thermal shells in the in-house developed DIEKA finite element program.
Of course, the fibre orientations will have a dominant effect on the distribution of stiffness and thermal expansion. Hence, the fabric distortion during rubber press forming has to be known prior to any further component deformation analysis. Geometric models are an obvious option, with certain limitations in describing the material behaviour and the interaction of the deformation in different areas of the laminate. It was chosen to include the drape forming process in the FE simulation.

A single layer Fabric Reinforced Fluid model was implemented and presented at Esaform 2001 [1]. A double hemisphere geometry was used to compare the FE results with a geometrically based method. The results indicate the effects of the interaction between different areas of a laminate on the local deformations.

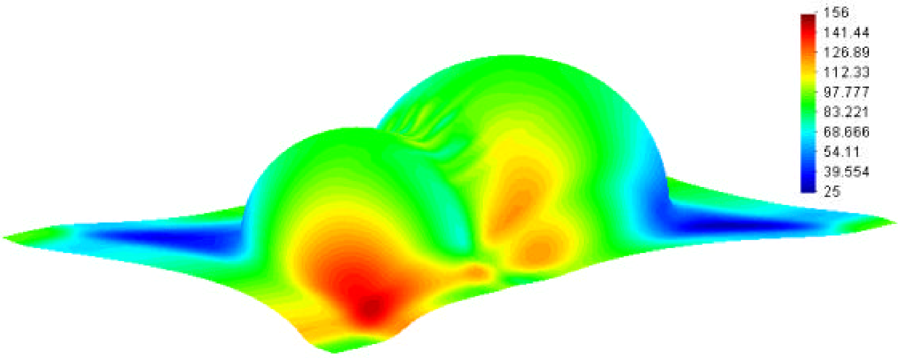

Fig. 1 Enclosed fibre angle for the FEM drape simulation of a double hemisphere geometry (from [1]).

Recently, rubber press experiments were performed at Fokker Special Products, on a similar geometry, using different laminate lay-ups (0°/90°, 45°/-45° and a quasi-isotropic 0°/90°/45°/-45° lay-up) and different materials. Results for glass/PPS and carbon/PPS are shown in figs 2 and 3.

Fig. 2 Rubber pressed 4-layered glass/PPS (Ten Cate Cetex SS303) laminates, with 0°/90°, 45°/-45° and a quasi-isotropic 0°/90°/45°/-45° lay-up.

Fig. 3 Rubber pressed 4-layered carbon/PPS (Ten Cate Cetex CD286) laminates, with 0°/90°, 45°/-45° and a quasi-isotropic 0°/90°/45°/-45° lay-up.

The multilayer quasi-isotropic results are distinctly different from the single-layer 0°/90° and 45°/-45° deformation patterns. A certain amount of interply shear can be observed, but the restricted freedom of deformation easily leads to wrinkling in the laminate. A multi-layer finite element model is currently under development.

Benchmark problem?

The geometric simplicity and the number of effects playing a role in the laminate deformations makes this experiment a challenging benchmark for composite forming simulations, focussing on the physics of the problem rather than issues in the geometric representation of CAD and FE systems.

References

1. E.A.D. Lamers, S. Wijskamp & R. Akkerman, Modelling of fabric draping: Finite elements versus a geometrical method, Esaform 2001.