High precision moulding of thermosetting composites

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Introduction

Polymer composite products are increasingly applied in demanding structures in, for example, the aerospace and the aeronautical industry. The narrow tolerances on the product geometry require the control of undesirable post-mould distortions such as warpage and spring-forward.

Figure 1. Fibre reinforced polymers comprise 80 % of the Eurofighter Typhoon

Objectives

The key to the control of the post-mould distortions is the understanding of the internal stresses that build up during the moulding cycle and residual stresses that reside afterwards. The prediction of these stresses and the resulting product distortions contributes to a 'first-time-right' design of the tooling and in a reduction of scrap material.

Methodology

A viscoelastic material model was implemented in the Finite Element package LUSAS. Figure 2 represents the highly simplified interaction between the elastic fibres and the visco-elastic matrix.

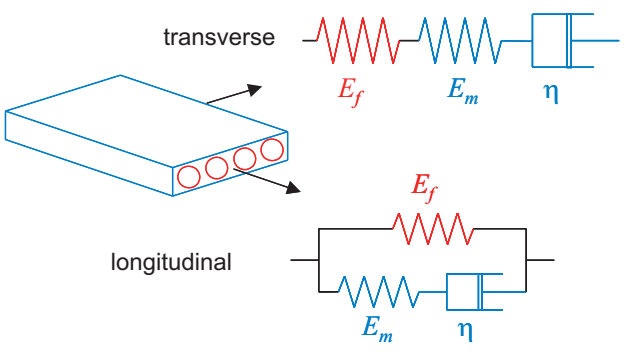


Figure 2. Schematical representation of the viscoelastic behaviour of a unidirectional composite ply

The viscosity of the matrix depends on the temperature and the cure conversion. A typical cure cycle is shown in figure 3.

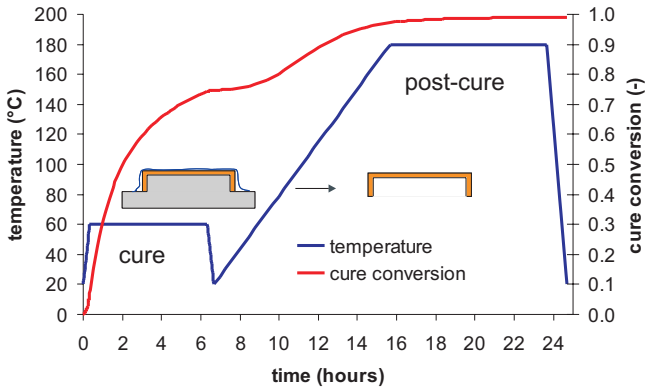
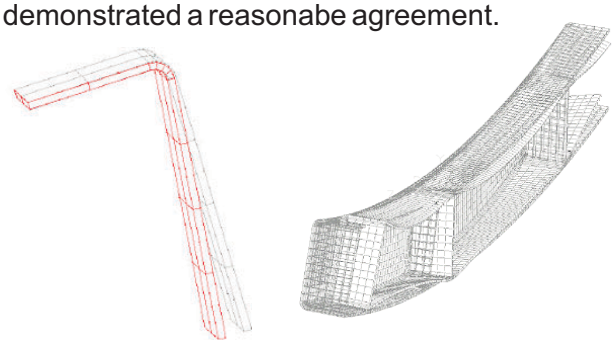


Figure 3. A typical two-step cure cycle of a carbon/epoxy composite.

Results

Two benchmarks problems were simulated using composite brick elements to represent a fibre reinforced laminate. The simulations were verified with the measured decrease of the enclosed angle (spring-forward) of an L-shape, see figure 4a. Figure 4b depicts the distortions of a C-spar. These were compared to observed deformations, which demonstrated a reasonabe agreement.



a. Spring-forward

b. Mesh and deformed mesh of a C-spar

Figure 4. Post-mould distortions of carbon/epoxy composite products

Conclusion

A viscoelastic material model was proposed to predict the buildup of stresses during and the distortions after the moulding of thermoset composite products. The modelled and measured product distortions agreed reasonably.