Modelling of Residual Stresses in Rubber Pressed Composite Products

S. Wijskamp, E.A.D. Lamers & R. Akkerman

University of Twente, Twente Institute of Mechanics
PO Box 217, 7500 AE Enschede, The Netherlands
phone +31-(0)53-4892426, e-mail s.wijskamp@wb.utwente.nl

Continuous-fibre-reinforced thermoplastic composites are increasingly used in demanding applications in, for example, the aerospace industry. The use of specialty thermoplastics such as polyetherimide (PEI), polyphenylenesulfide (PPS) and polyether-etherketone (PEEK) reinforced with glass, carbon or aramid fibres results in solvent and corrosion resistant products with high specific stiffness and high melting temperature. These composites can be moulded into complicated shapes with the rubber pressing process where a relatively hot laminate is shortly pressed between a cold rubber mould and a cold steel tool. The process is fast compared to the forming of thermosetting polymer matrix composites where extensive curing times are involved.

During the moulding, residual stresses build up that cause unwanted distortions of the final product. These stresses are caused by anisotropic shrinkage and non-symmetric process conditions. The anisotropic shrinkage can be thermally induced or it can be a result of crystallization. The upper and lower mould induce non-symmetrical process conditions: the former is a highly deformable elastomeric with a very low thermal conductivity, whereas the latter is made from high stiffness steel with a high thermal conductivity. As a result, the laminate exhibits a non-uniform temperature profile through the thickness during moulding, and has different mechanical boundary conditions on the top and bottom side.

The objective is to model the build-up of residual stresses in carbon fabric reinforced PPS (a semi-crystalline polymer) during moulding and the shape distortions they cause in the final product. The geometry of the moulding tool can then be compensated for the distortions, resulting in a “first time right”-design of the tool.

Previous studies [1] showed that the largest part (75%) of the residual stresses is induced by anisotropic shrinkage. Now, the attention is focused on the stresses due to the temperature profile during pressing and the resulting morphology. This profile is computed by solving the one-dimensional heat transfer problem with the crystallization kinetics using an explicit finite difference method. Subsequently, the evolution in time of the internal stress profile is solved, resulting in the final residual stress profile when the product is released from the mould.

The results from both the heat transfer simulation and the stress computations need to be verified by an experimental program, involving the measurement of the temperature profile and residual stress measurements on simple geometries. In the future, FE will be applied to include thermal contact and the non-symmetric mechanical boundary conditions.

Reference

[1] S. Wijskamp, E.A.D. Lamers & R. Akkerman, Effects of out-of-plane properties on distortions of composite panels, in: A.G. Gibson (editor), *International Conference on Fibre Reinforced Composites FRC2000*, Woodhead Publishing Ltd., 2000