MODELLING THE DEVELOPMENT OF WARPAGE IN COMPOSITE CAR BODY PANELS DURING CURING

M. S. Kiasat[*], H. Mostofi[†], and R. Marissen[‡]

[*]*Department of Marine Technology, Amirkabir University of Technology, 424 Hafez Ave., Tehran, Iran*
[†]*Department of Automotive Engineering, Iran University of Science and Technology, Narmak, Tehran, Iran*
[‡]*Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, the Netherlands*

Abstract

In the previous parts of this comprehensive research, a new cure-dependent viscoelastic model was developed for the evolution of the mechanical behaviour of the polyester resin during curing. This model was used to simulate curing-induced residual stresses and deformations in resin specimens, taking the chemical shrinkage of the resin into account. In the present work, the viscoelastic model of the resin is used to establish the cure-dependent orthotropic viscoelastic properties of a unidirectional glass/polyester lamina by making use of micromechanical fibre/matrix models. The responses of a cross-sectional unit cell of the lamina to different modes of deformation are considered to obtain the viscoelastic properties of the lamina. Also, anisotropic curing shrinkage of the unidirectional lamina is obtained from unit cell calculations considering different fibre arrangements. The calculated curing properties of the lamina are applied in the finite element modelling of the laminates having any arbitrary combination of unidirectional layers. In order to verify the developed model, cure-induced deformations of two-layer asymmetric cross-ply [0/90] laminates are experimentally studied in the present work. It is observed that square laminates with different matrix volume fractions develop cylindrical shapes upon curing. The curvature is observed to increase with matrix volume fraction, and decrease with the increase of the laminate thickness. Due to the large deformation of the laminates, nonlinear strain-displacement equations are used in the finite element modelling, which leads to comparable results. Furthermore, two situations are considered for the laminates, one is the free curing without any constraint, and the other is the curing between aluminium plates. The smaller deformation of the laminate released from the aluminium mould is attributed to the viscoelastic relaxation of the curing stresses in the laminate, which is also obtained in the modelling. As an application of this effort, the manufacturing process of composite car body panels is simulated. Different parts of a car body like the hood and the trunk are modelled considering various symmetric and asymmetric stacking sequences for them. It is concluded that the curing stresses induce significant deformations in the composite panels which cannot be avoided even if the symmetric laminates are cured in a closed mould. The panel takes the deformed shape after releasing from the mould. The initial curvatures and bends of the panel in the mould affects the final deformed shape of the panel. Also, the curing stresses have a viscoelastic nature which may not be modelled by using the available elastic models.

Keywords: Cure-dependent viscoelastic orthotropic model, Anisotropic chemical shrinkage, Composite car panels, Curing-induced warpage, Large deformation.