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Three-Dimensional Hygromechanical analysis of fibre polymer composites: Effect of Boundary Conditions

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Abstract

Moisture diffusion through a unidirectional fibre reinforced polymer matrix composite is studied. The stresses due to the expansion of the matrix caused by moisture diffusion are evaluated. A three-dimensional (3D) micromechanical model is developed to study diffusion both across and along the fibre. The well-known 2D plane strain condition is modelled and validated as a special case of the 3D model. The utility of 3D modelling is further demonstrated to analyse the stress along the fibre length. It is demonstrated that the variation of boundary conditions along the fibre length has a dramatic effect on the stresses. The stresses along fibre length computed through finite element analysis (FEA) are compared against an analytical solution obtained from axi-symmetric composite cylinder assemblage (CCA) model. This paper demonstrates the importance of 3D diffusion kinetics in unidirectional reinforced polymer composites.

Keywords: A. *Polymer-matrix composites (PMCs); B. Environmental degradation; C. Computational modelling; C. Micro-mechanics*

1. Introduction

Fibre reinforced polymer composites are susceptible to moist environments that can cause premature failure [1]. The difference in moisture diffusion coefficients, moisture expansion and elastic properties in the fibre and the matrix results in high interfacial stresses that often results in failure at the fibre-matrix interface [2, 3]. Finite element based micromechanical analysis is usually conducted considering different arrays of fibre matrix arrangements. The response of FRP composites subjected to elastic [4-8], thermal [7, 8] and hygral [9-12] environments is usually predicted by using 2D cross-sectional models plain stress/strain boundary conditions. As the fibre length is much higher as compared to its diameter, the 2D plane strain assumption is reasonable in assessment of responses in the interior regions [13-18]. In that paradigm, our previous work reports the importance of fibre topology in the moisture diffusion [11, 12] and stresses thereof [19]. The progression of moisture across the fibre is investigated and the importance of topological distribution of the moisture progression is demonstrated. A number of fibre-matrix architectures were created by varying topological parameters viz. inter-fibre distance, orientation and fibre density. It was concluded that by carefully designing