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Evolution of damage during the fatigue of 3D woven glass-fibre reinforced composites subjected to tension-tension loading observed by time-lapse X-ray tomography

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Abstract

The development of fatigue damage in a glass fibre modified layer-to-layer three dimensional (3D) woven composite has been followed by time-lapse x-ray computed tomography (CT). The damage was distributed regularly throughout the composite according to the repeating unit, even at large fractions of the total life. This suggests that the through-thickness constraint provides a high level of stress redistribution and damage tolerance. The different types of damage have been segmented, allowing a quantitative analysis of damage evolution as a function of the number of fatigue cycles. Transverse cracks were found to initiate within the weft after just 0.1% of life, followed soon after (by 1% of life) by longitudinal debonding cracks. The number and extent of these multiplied steadily over the fatigue life, whereas the spacing of transverse cracks along with weft/binder debonding saturated at 60% of life and damage in the resin pockets occurred only just before final failure.

1 Introduction

Three dimensional (3D) composites were proposed over 40 years ago in an attempt to overcome the shortcomings of 2D laminates, by incorporating fibres into the through-thickness direction. 3D weaving offer significant manufacturing benefits as well as creating versatile textiles having a range of 3D architectures. Unsurprisingly, they have emerged as promising candidates for the load-bearing applications requiring not only high in-plane (x-y) properties, but also some degree of out-of-plane (z) integrity.

In addition, z-reinforcement plays an important role in improving the energy absorption capability of 3D woven composites compared with 2D laminates. Studies [1, 2] have demonstrated that a unique energy absorption mechanism is inherent in the 3D woven composites. In the case of glass-fibre reinforced woven composites, energy is often dissipated by means of the extensive straining of z-reinforcement and