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Fiber Orientation Effects on Mode I Fatigue Delamination: Proposed Model for Saturation and Zero-Bridging Prediction

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Abstract

Characterisation of the effect of lay-up on the delamination growth revealed a complex set of damage characteristics. Tortuous propagation resulted in higher fibre bridge densification in the off-axis laminates, requiring an increased number of experimental tests to validate the characterisation of fibre bridge saturation effects. The main objective of this research is to apply a modified Sørensen model [1] to measure the fibre bridge (FB) stress curve. In addition, the research aims to estimate the full saturation curve. These objectives will contribute to a more efficient and accurate characterisation of fatigue delamination behaviour in composite materials. The procedure was carried out using a model proposed in the literature [2] for unidirectional composites, to estimate positions of the sull-saturated and fibre bridge Paris curves. The proposed model, based on physical considerations of FB stress formation, was applied to a quasi-static curve and a fatigue curve for each lay-up: 0//0, 0//45 and 0//90. Based on the resulting R-curve, the FB stress curve is derived for each case. This approach accurately models the fatigue behaviour and bridging effects in composites by providing the zero bridging curve (Fig. 1). Following a similar procedure, but now adding the full saturation stress integrated along the end opening delamination, provides the additional strain energy in the steady state region (Fig. 1). This approach allows a more efficient and cost-effective characterisation of fatigue delamination behaviour with a reduced number of experiments, and evaluates the feasibility of applying the proposed model to a single quasi-static and fatigue curve. In addition, the proposed method addresses a comprehensive understanding of fatigue behaviour considering the effect of fibre orientation, thereby contributing to a more comprehensive understanding of fatigue behaviour.

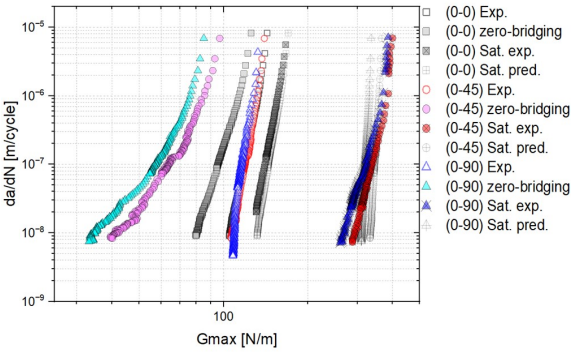

Figure 1. Zero-bridging and bridging saturation effect on Paris curve

[1] Sørensen BF eta. Large-scale bridging in composites: R-curves and bridging laws. Compos Part A 1998;29:1443–51.
[2] Monticeli, FM et al. A Novel Analytical Model to Characterise the Monotonic and Cyclic Contribution of Fibre Bridging During Mode I Fatigue Delamination in (C)FRPs. *Composites Part B: Engineering* (2025): 112319.

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