Hygro-thermal effects on the translaminar fracture toughness of composite laminates

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Summary

Longitudinal tensile failure of the composite laminates is often controlled by the fracture toughness associated with the tensile fibre (i.e., translaminar) failure. Different failure mechanisms such as fibre breakage, fibre-matrix debonding, and fibre pull-out may contribute to the total dissipated energy of the laminates. Temperature and moisture considerably affect the translaminar fracture behaviour of the composite laminates by degrading the bulk matrix, the matrix/fibre interface, and the inter-laminar properties. Moisture uptake and swelling alter the inter-ply and intra-ply stress transfer mechanisms and there exists considerable experimental evidence to prove that the hygro-thermal conditions are detrimental to the performance of composites structures [1]. There are selected material combinations and lay-up configurations that result in improved longitudinal strength properties at hot-wet conditions [2]. It is presumed that the residual stress relaxation under hot-wet conditions positively impacts the stress transfer mechanism for such lay-up configurations, despite the degradation of matrix-dominated properties. Therefore, it is vital to investigate the translaminar fracture mechanism and the associated energy dissipation of the hygro-thermal conditioned laminates.

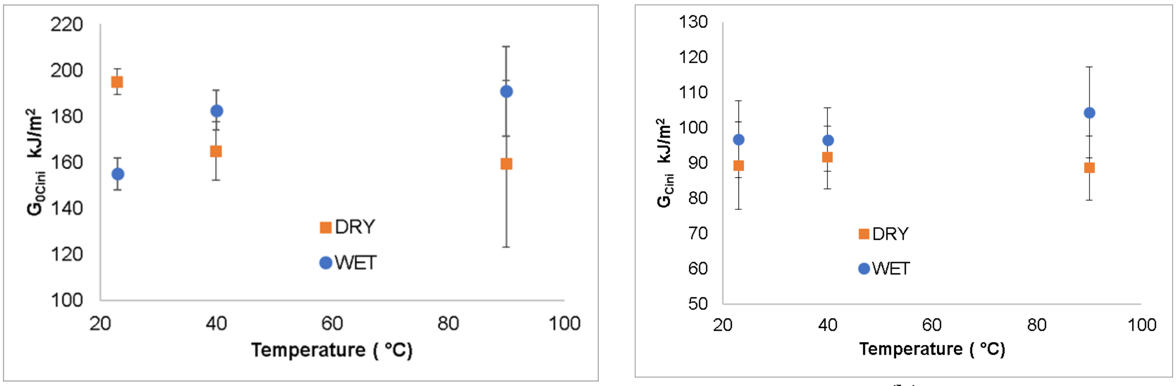
Experimental details

In this work, compact tension tests on IM7/8552 cross-ply ($[90/0]_{8S}$) and quasi-isotropic ($[90/45/0/-45]_{4S}$) laminates were conducted at three different temperature conditions (23 °C, 40 °C and 90 °C). The laminates were fabricated from the autoclave curing of IM7/8552 prepregs and then cut into required sizes using a suitable end mill cutter. Carbide coated drills are used to make 9.6 mm diameter loading pin holes. A pre-crack of 16 mm was made by using a 4 mm end mill cutter and then extended to further 10 mm using a saw machine with ~0.4 mm cutting disc. The crack extension was captured by using a video gauge set up as shown inf Figure 1. The "wet" specimens were hygro-thermally conditioned in a humidity chamber at 70 °C and ~85% relative humidity until full saturation.

Figure 1. The compact tension test specimen captured by the video gauge set up.

Results & discussions

Figure 2(a). shows the initiation fracture energy of 0° plies obtained from the translaminar failure of cross-ply (CP) laminates. As expected, the fracture energy of dry specimens decreases with the increase in test temperature. Interestingly, the fracture energy of fully saturated (wet) coupons increases with the temperature. The fibre/matrix interface of the wet specimens becomes weaker and promotes the fibre pull-out failure of the laminates. The fibre pull-out length and the fracture process zone of the wet laminates increase with temperature and result in higher energy dissipation.



(a) (b)

Figure 2. Initiation fracture energy of the (a) 0° plies obtained from the translaminar failure of $[90/0]_{8S}$ cross-ply laminates and (b) $[90/45/0/-45]_{4S}$ Quasi-Isotropic laminates.

Figure 2(b) compares the initiation energy of dry and wet quasi-isotropic (QI) laminates. The initiation energy of the dry coupons slightly increases (~2%) as the temperature increase from 23 °C to 40 °C and decreases at 90 °C (~1%). It can be concluded that the initiation facture energy of the dry QI laminates is not significantly affected by the increase in temperature. The fracture energy of the wet QI specimens is higher than the dry specimens due to the weak fibre/matrix interface and increased fibre pull-outs. The initiation fracture toughness of the elevated temperature (90 °C) wet QI specimens is ~17% higher than the room temperature (23 °C) dry specimens.

Impact

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Acknowledgments

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References

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