Are hygro-thermal environments always detrimental to the performance of off-shore composite structures?

The matrix dominated properties of composite laminates deteriorate at hot-wet environments – but wisely chosen lay-up configurations offer improved longitudinal strength, stiffness, and toughness properties.

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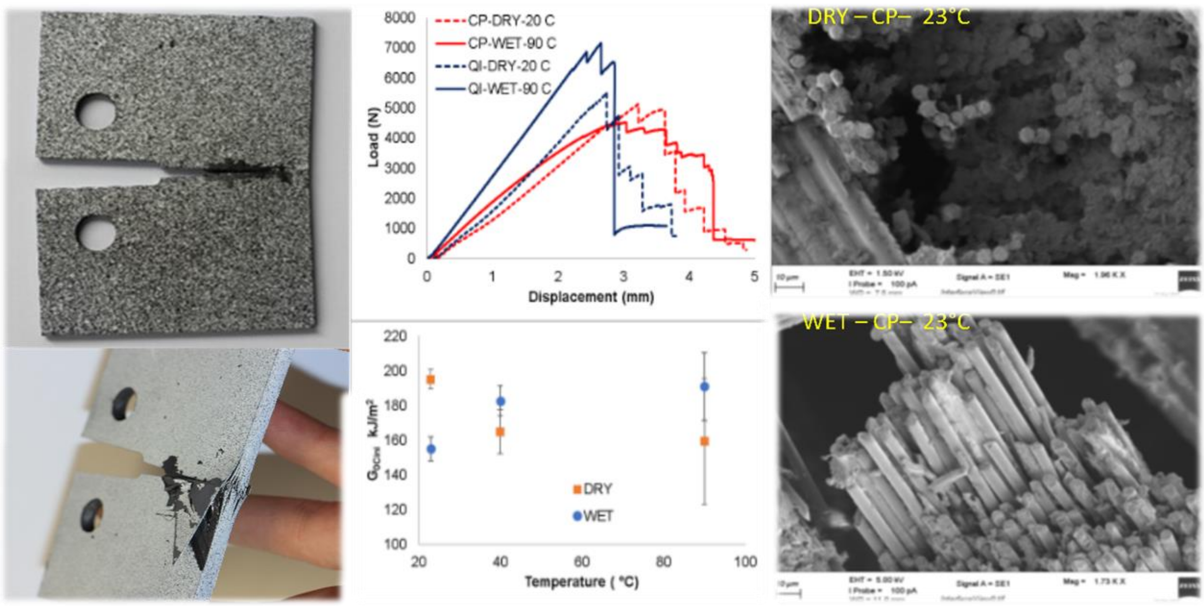
The very high loads experienced by tidal and wind turbine blades push the material selection towards high-specific-strength materials, such as Glass- or Carbon-fibre reinforced thermoset polymers. The composite blades' load-carrying capacity primarily depends on the longitudinal failure behaviour of the laminates. Even though thermoset matrices are prone to environmental degradation, the failure of the composite blades primarily depends on the fracture toughness associated with the tensile fibre failure. A better understanding of the failure mechanism of laminates made up of different material combinations and layup configurations, tested at varying in-service conditions will help to improve the life-cycle cost and performance of the offshore blades.



The longitudinal tensile failure in composite laminates is often controlled by the fracture toughness associated with tensile fibre (i.e., translaminar) failure. The overall fracture energy due to fibre-matrix debonding and fibre pull-out contributes to the translaminar fracture toughness of composites laminates. Temperature and moisture considerably affect the translaminar fracture behaviour of laminates, by degrading the bulk matrix and the matrix/fibre interface, as well as the interlaminar strength and toughness properties. Moisture ingress alters the stress transfer mechanisms at the inter-ply and intra-ply levels. The residual stress relaxation under hot-wet conditions positively influences the stress transfer mechanism for such lay-up configurations, despite the degradation of matrix-dominated properties.

Compact tension tests on IM7/8552 cross-ply ($[90/0]_{8S}$) and quasi-isotropic ($[90/45/0/-45]_{4S}$) laminates at three different temperature conditions (23 °C, 40 °C and 90 °C) revealed some intriguing insights. The fracture energy of dry specimens decreases with the increase in test temperature. Interestingly, the fracture energy of the fully saturated (wet) specimens 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 the temperature and result in higher energy dissipation. The fractographic analysis of the failure surfaces revealed that the wet specimens had more pulled out fibres than the dry specimens.

About the author:

Dr Ganapathi is a senior research associate of composite materials and structures from Bristol Composites Institute, University of Bristol. His other research interests are loading rate and temperature dependent properties of composites and Machine Learning applied to computational mechanics of composites.

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