

# MODE I AND MODE II INTERLAMINAR FRACTURE ENERGIES OF PULTRUDED COMPOSITE MATERIAL

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## Abstract

There are two distinct aims when carrying out material tests in case of composites for establishing interlaminar fracture energies. The first is to establish 'single ply data' that can be obtained from the aligned unidirectional fibres bonded by a matrix loaded in a variety of directions and other is investigation of laminated composite behaviour. Research for second phase is more challenging but relatively more practical and can provided factual analysis of material behaviour. It also attracts industrial interest for gathering knowledge of behaviour of their products. Hence research is done with focus on establishing useful data for pultruded section of C channel from *FIBREFORCE COMPOSITES (UK) LTD.*

An effort has been made in this research to establish fracture energies in Mode I and Mode II type fracture conditions. Established linear elastic-fracture mechanics techniques are used to ascertain interlaminar fracture energies [1, 3]. Testing is conducted by following established standards and research literature available [4, 5]. Data is analysed by different methods to check the agreement between them [2]. Testing of the material is also conducted with crack growth in 45° and 90° relative to unidirectional layers to collect and analyse data to examine the behaviour of material. Similar data analysis methods are used to achieve results in order to compare them with those of fracture energies obtained with crack growth in direction of unidirectional fibres.

Crack growth and surface of all the specimens are closely examined and analyzed to find the physical reason of difference of crack front relative to the change in unidirectional fibre direction.

For the pultruded section of C channel from *FIBREFORCE COMPOSITES (UK) LTD.* It is established that the value of interlaminar fracture energy  $G_{Ic}$  with crack growth at 0°, 45° and 90° are 0.6, 0.8 and 1 kJ/m<sup>2</sup> respectively. Values of  $G_{Ic}$  with

crack growth at 0°, 45° and 90° are 1.2, 1.7 and 2.3 kJ/m<sup>2</sup> respectively. Value for axial stiffness is 250.583 N/mm<sup>2</sup>. Content volume percentage of reinforcement and matrix are 36.0% and 61.4% respectively

## References

- [1] Edited by J M Hodgkinson 'Mechanical Testing of Advanced fibre composites' First Edition, CRC Press, Cambridge England, 2000.
- [2] Hashemi S, Kinloch AJ, Willams JG, ' The analysis of interlaminar fracture in uniaxial fibre-polymer composites', Proc Royal Soc A, 1990 427 173-99
- [3] Hashemi S, Kinloch AJ, Willams JG. Corrections needed in double cantilever beam tests for assessing the interlaminar failure of fibre composites. J Mater Sci Lett 1989;8:125.
- [4] Standard test method for mode I interlaminar fracture toughness of unidirectional fibre-reinforced polymer matrix composite, ASTM Designation: D 5528-94a, 1994.
- [5] Fibre-reinforced plastic composites Determination of mode I interlaminar fracture toughness,  $G_{Ic}$ , for unidirectionally reinforced materials BS ISO 15024:2001