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COMPRESSIVE CRACK RESISTANCE ANALYSIS OF UNIDIRECTIONAL THERMOPLASTIC COMPOSITES

F. Danzi[1,2], P. Campos[1,2], A. Arteiro[1,2], D. Dalli[2], C. Furtado[1,2], J. Chevalier[3], R. Tavares[3], F. Lani[3], P.P. Camanho[1,2]

[1]INEGI,
Institute of Science and Innovation in Mechanical and Industrial Engineering, Campus da FEUP, R. Dr. Roberto Frias 400, Porto,
Email: fdanzi@inegi.up.pt,

[2] DEMEC,
Department of Mechanical Engineering, Faculty of Engineering, University of Porto, R. Dr. Roberto Frias s/n, Porto.

[3] Solvay,
Material Science Application Center (MSAC), B-1120 Bruxelles, Belgium

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ABSTRACT

Thermoset composite materials are nowadays a well-consolidated reality in the aerospace industry. However, the aeronautical sector is struggling to find more sustainable and damage tolerant options to produce safer and lighter structures. Thanks to the new consolidation processes with reduced production cost, fibre-reinforced thermoplastic (FRTP) materials stand out now as an appealing alternative. Among the others, PEKK-based composites have recently attracted the interest of several companies thanks to their remarkable mechanical properties and a lower processing temperature.

This work stands out as one of the first attempts to characterize the compressive longitudinal intra-laminar fracture toughness of a carbon fibre PEKK composite (AS4/PEKK). Geometrically scaled Double Edge Notched Compression (DENC) specimens were tested in accordance with the size-effect methodology [1]. Two different specimen configurations were considered for this study: 1) edge-loaded DENC with a specimen length-to-width ratio of 1.5 [2], 2) alternative slender coupons (length-to-width ratio >4) tested with the support of a Combined Loading Compression fixture (DENCLC) [3,4].

Balanced cross-ply $[90/0]_{8S}$ laminates were consolidated by hot pressing ensuring a high level of crystallinity (>30%). Specimens were then cut using a CNC machine keeping a constant notch length-to-width ratio equal to 0.6.
All the tests showed limited sub-critical damage at the notch tip before the final abrupt failure. The absence of pronounced non-linearities during the compressive tests enabled the direct extension of the size-effect approach to this class of FRTP.

The calculated values of the steady state compressive intra-laminar fracture toughness for the 0^0 ply were R^0_{SS}=73.36 N/mm and 106.9 N/mm for the DENC and the DENCLC configuration respectively. Both values pointed toward a marked increase in the fracture toughness of high-crystallinity FRTP composites over their thermoset counterparts.
Moreover, the results showed that although well established, the DENC specimens are more sensitive to out-of-plane instabilities/premature failure arising from any minor imperfections in the two load faces. The use of the CLC rig instead allows for a more uniform load transfer that minimises the effect of any imperfection on the loaded ends of the specimens with a remarkable increase in test repeatability.

Hence, the use of the traditional DENC configuration causes an under-prediction of the compressive fracture toughness. This result is attributed to the intrinsic difficulties in obtaining a pure compressive load in the edge-loaded DENC coupons.
Furthermore, the visual inspection of the fracture surfaces in the DENC specimens shows the presence of a clear through-the-thickness inclination of the fracture plane. This phenomenon, resulted in some cases having a crack that on one side of the specimen had propagated outside the initial ligament height, indicating the possible introduction of out-of-plane bending not experienced in the DENCLC specimens.
μ-CT scans were performed on DENCLC coupons to investigate the fracture evolution along the specimen width. The tests were interrupted immediately after the peak load, so the two halves of the failed specimens were kept together to avoid any crushing progression. Fig.[1] shows the typical fracture surface of DENCLC characterised by the presence of single or multiple wedges with sharp edges caused by the micro buckling phenomena in the inner 0° layers, also confirmed by fractographic analyses.

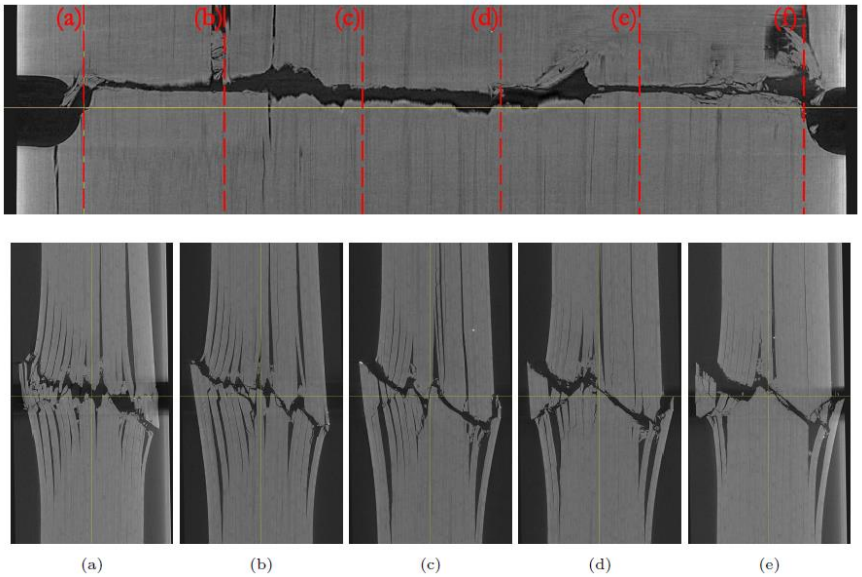

Figure 1: Fracture zone in a 35 mm wide DENCLC specimen right after the peak load.

In the light of these results the use of the combined loading rig is suggested for the estimation of the compressive longitudinal intra-laminar fracture toughness of unidirectional composites. Moreover, the good compressive crack resistance properties of this high crystallinity thermoplastic composite material is confirmed.

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