FRACTURE TOUGHNESS AND CRACK RESISTANCE CURVES IN THE LONGITUDINAL COMPRESSION FAILURE OF POLYMER COMPOSITES

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ABSTRACT

This paper presents a new methodology to measure the compressive crack resistance curve of the longitudinal plies of carbon-epoxy laminates. The methodology is based on three main steps: the first one corresponds to the determination of the energy release rate of cross-ply laminates with two edge cracks using a parametric finite element model. The energy release rate is used in the definition of a relation between the crack resistance curve and the size effect. Finally, experimental tests are performed in scaled double-edge notched specimens to quantify the size effect law, thus proving the last piece of information required to define the crack resistance curve. The full crack resistance curve is obtained for the IM7-8552 carbon epoxy composite material. The methodology proposed in this paper overcomes the inherent limitations of the existing test methods, and it serves as the basis for the identification of cohesive laws used in some analysis models.

Keywords: Polymer-matrix composites (PMCs), Fracture toughness, Analytical modeling, Mechanical testing.

INTRODUCTION

The development of a new generation of tougher composite materials presents several challenges to the existing methods for the measurement of the fracture toughness associated with cracks that propagate perpendicularly to the fiber direction. The intra-laminar fracture toughness is relevant not only for material screening and qualification, but also to define the softening laws used in recent analysis models that predict the ultimate strength of composite structures (Camanho, 2013).

The Compact Tension (CT) test specimen is normally used to measure the fracture toughness and the crack resistance curve (R-curve) of composite materials reinforced by unidirectional fibres. While reliable results can be obtained for brittle material systems using appropriate data reduction methods, the introduction of tougher resins leads to higher loads for crack propagation, which may cause buckling of the unnotched end of the CT test specimen.

There is also the need to measure the fracture toughness and the corresponding R-curve associated to the propagation of a kink-band, which shows a crack-like behaviour (Bažant, 199) with an R-curve that results from the broadening of the damage height (Moran, 1995).

It is considered here that the compact compression test specimen is inadequate to measure the compressive crack resistance curves of polymer composite materials. In fact, the correction
factor used in the data reduction method of the compact compression test method to calculate the energy release rate is the same as that used in the compact tension method. However, the contact tractions that occur on the crack faces during a compact compression test render the data reduction method inaccurate. This was demonstrated in a previous investigation where the J-integral around the crack tip was computed using digital image correlation. It was shown that the R-curve of the compact test specimens using the J-Integral and the data reduction method proposed by Pinho et al. (Pinho, 2006) are virtually the same for tension but not for compression.

It should also be noted that the compact compression specimen triggers diffused damage during the propagation of the kink-band, artificially increasing the value of the measured fracture toughness, and that it is not possible to identify the location of the tip of the kink band (Catalanotti, 2010). Therefore, it is considered that while the compact compression test method may be used to measure the initial value of the fracture toughness it does not provide reliable information for the generation of the R-curve.

This means that the analysts have no reliable test methods to measure some of the required material properties, namely the fracture toughness related with the propagation of a kink-band and the corresponding R-curve.

This fact provides the motivation for this paper, whose objective is to propose a new methodology to obtain the R-curve of composite materials that fail by the propagation of a kink-band.

REFERENCES