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Procedia Structural Integrity 2 (2016) 245–252

Structural Integrity Procedia

www.elsevier.com/locate/procedia

21st European Conference on Fracture, ECF21, 20-24 June 2016, Catania, Italy

Woven fabric composites: Can we peel it?

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Abstract

The present work focuses on the applicability of the mandrel peel test to quantify the fracture toughness of woven fabric Carbon/PEEK composites. For this purpose, the mandrel peel test was compared to the standardized DCB test. Unstable crack propagation (stick-slip) was observed in both testing techniques. Nevertheless, each time unstable crack propagation occurs it is arrested by the mandrel. As a result more crack re-initiations were observed per unit crack length. This effect is expected to increase the statistical relevance of a single test and thereby increases the reliability of the test. As an additional advantage the mandrel peel test is very easy to perform compared to the DCB test. The crosshead speed and the peel arm width were varied in this study to obtain the influence of these variables on the test results. Fractographic investigations were performed to study the nature of the crack propagation for the two different testing techniques.

Peer-review under responsibility of the Scientific Committee of ECF21.

Keywords: Fracture mechanics, thermoplastic composite materials, mandrel peel test.

1. Introduction

Well-accepted test methods are available to characterize the static interlaminar fracture toughness of Uni-Directional (UD) composite materials. The most frequently applied methods are the double cantilever beam (DCB)

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Peer-review under responsibility of the Scientific Committee of ECF21.
10.1016/j.prostr.2016.06.032

test for mode I, and the end-loaded split (ELS) beam test for mode II crack propagation. Both tests are illustrated in Figure 1. The existence of ISO (ISO 15024, and ISO 15114) and ASTM (ASTM D 5528, ASTM D 7905) standards for both methods illustrates their maturity. The reliability of these test methods is partially due to the stable crack propagation that most UD reinforced materials show during testing. When these methods are applied to woven fabric reinforced composites the crack propagation observed is however unstable [De Baere et al. (2012), Alif et al. , (1998), Gill et al. (2009)]. This is particularly true for highly tough thermoplastic composites. The unstable crack propagation (stick-slip) that is frequently observed in DCB tests for the woven material yields few GIC values. Therefore, GIC-propagation values for UD specimens are statistically more reliable than GIC-unstable propagation value for woven specimens [Compston et al. (1998)]. Moreover, the unstable crack propagation makes the interpretation of the test results rather difficult and the comparison with unidirectional questionable.

A lot of effort has been spent in understanding the mechanism behind the stick-slip phenomenon [Webb e al. (1997), Webb et al. (1998), Maugis et al. (1988), Ciccottia et al. (1998), Kinloch et al. (1998)]. The resistance to crack growth is assumed to be a function of the crack tip velocity. Stick-slip fracture has been associated with unstable and non-monotonic crack growth resistance, especially in the regions of negative slope in the crack growth resistance vs. curvature or crack speed curve. This leads to a condition where steady continuous crack growth cannot be realized. When the unstable crack starts to propagate (crack tip velocity increases), it reduces the resistance thus increases the crack speed [Webb e al. (1997), Webb et al. (1998), Maugis et al. (1988)].

The stick-slip behaviour has been treated in different researches such as in Webb e al. (1997), Webb et al. (1998), Maugis et al. (1988), Ciccottia et al. (1998), Kinloch et al. (1998). The determination of the mode-I adhesive fracture energy of structural adhesive joints using double cantilever beam and tapered double cantilever beam specimens is discussed in the ISO 25217 standard. The standard proposes that the G_{IC} values of initiation, propagation and arrest has to be averaged separately.

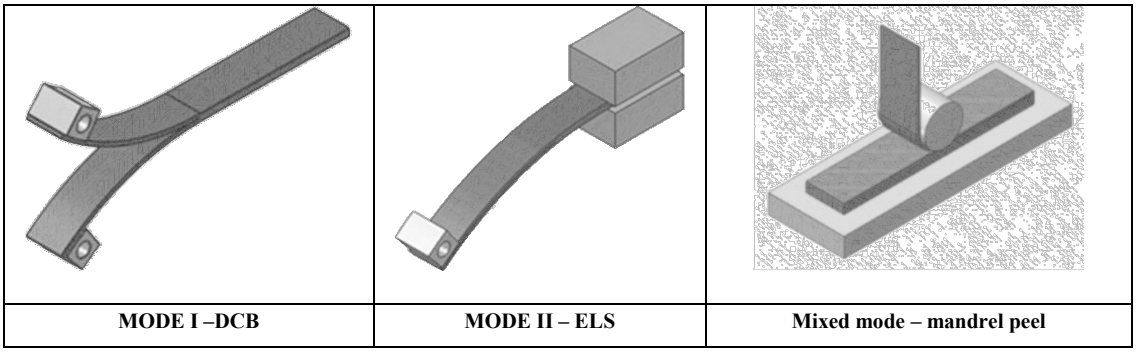

Figure 1: DCB, ELS, and mandrel peel test scheme

The mandrel peel test, as shown in the right illustration in Figure 1, may be a suitable alternative to DCB test for woven fabric reinforced composites. The test is an adaptation of the 90° peel test and was first proposed by Kawashita et al. (2004) to measure the fracture toughness of a metal-epoxy-metal peel specimen. It involves the use of a mandrel to control the bending stresses in the peel arm. The previous works in [Kok et al. (2015), Su et al. (2016), Grouve et al. (2013)] showed that this test was able to characterize the fracture toughness of UD-UD, UD-woven and UD-metal combinations.

The observed stick-slip behavior and the tedious test procedure make the DCB test unattractive for woven fabric reinforced composites. As an alternative, the present work focuses on the applicability of the mandrel peel test to quantify the fracture toughness of woven fabric Carbon/PEEK composites. For this purpose, the mandrel peel test was compared to the DCB test. The crosshead speed and the tape width were varied in this study to study the influence of these variables on the test results. Fractographic investigations were performed to study the nature of the crack propagation with the different testing techniques.