12th International Conference on Sandwich Structures (ICSS-12)
DOI: 10.5075/epfl-ICSS12-2018-221-222
Lausanne - Switzerland, 19–22 August 2018

MIXED-MODE FRACTURE CHARACTERIZATION OF HONEYCOMB CORED SANDWICH COMPOSITES USING THE DCB-UBM TEST METHOD

Christian Berggreen[1] and Vishnu Saseendran[2]
[1]Department of Mechanical Engineering, Technical University of Denmark, Denmark. cbe@mek.dtu.dk
[2] Department of Mechanical Engineering, Technical University of Denmark, Denmark. vsas@mek.dtu.dk

1. INTRODUCTION

The face/core disbond or debond problem in honeycomb core sandwich composites employed in the aerospace industry has been studied widely in recent years [1, 2]. The interface fracture toughness in a sandwich must be characterized over a wide range of mode mixities. The Double Cantilever Beam loaded with Uneven or Unequal Bending Moments (DCB-UBM) specimen, which was first introduced by Sørensen et al. [3] for monolithic laminate composite specimens and later extended for sandwich composites by Lundsgaard-Larsen et al. [4] (see Fig.1), has been proven to be robust for mixed mode fracture characterization of a typical face/core interface [5, 6]. In this work, interface fracture characterization of honeycomb cored sandwich composites is studied using the DCB-UBM test method in a recently presented novel test rig. The obtained fracture toughness values will aid in creation of reliable damage assessment models for sandwich structures in aircrafts.

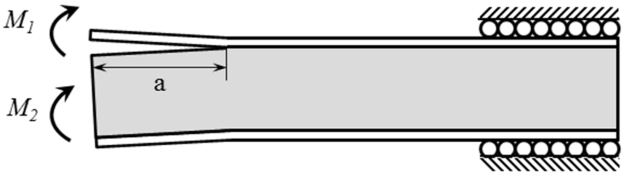
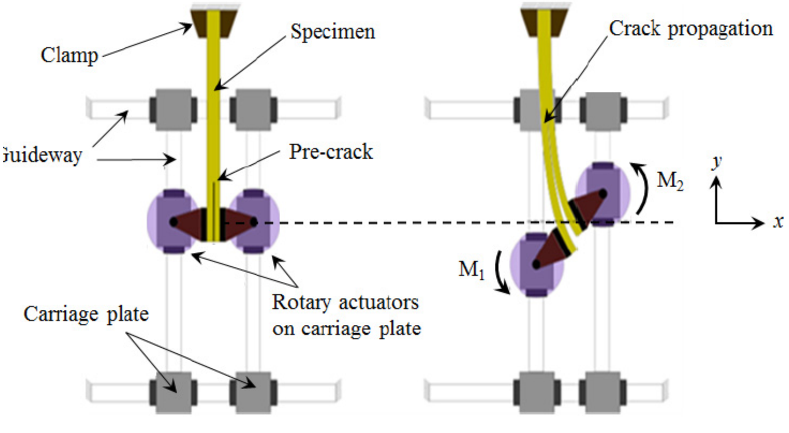


Fig. 1: Schematic illustration of DCB-UBM sandwich specimen.

The original design of the DCB-UBM test rig consisted of long wires and rollers, which made it difficult to achieve a wide range of mode-mixities. A modified novel test rig capable of applying moments to the specimen was developed and utilized for fracture characterization in this study [7]. The proposed rig consisted of two independent torsional actuators supported on rails. The actuators are able to slide independently upon crack propagation (see Fig.2). Hence, the new rig is stand-alone, compact and is able to apply high magnitudes of moment values. In addition, the current rig is able to operate in fatigue loading. It should be noted that in any DCB-UBM test rig, the mode-mixity (often expressed in terms of a phase angle, ψ) can be altered by changing the ratio of moments between the two arms, MR = M_1/M_2.



(a) (b)

Fig. 2: Principle of the modified DCB-UBM test rig with torsional actuators mounted on rails (a) prior to start of test with a pre-crack and, (b) application of moments M_1 and M_2 causing crack propagation and crack flank displacements.

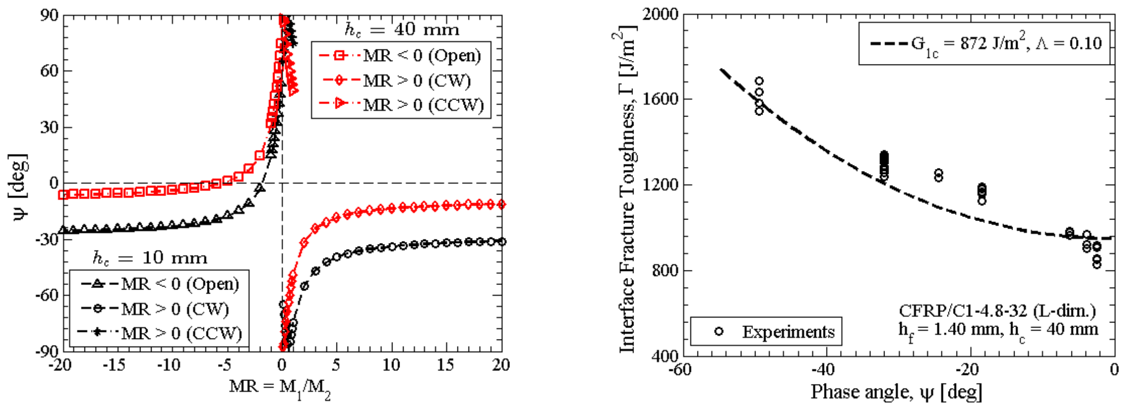
2. SPECIMEN PREPERATION AND FRACTURE CHARACTERIZATION

The sandwich specimens studied in this paper consisted of aerospace grade honeycomb cores manufactured by Schütz GmbH. Cormaster C1 type core material comprising of Nomex® T412 paper was employed with three different density classes (32, 64 and 96 kg/m^3). The cell size of all chosen cores grades was 4.8 mm. The face sheets comprised of plain weave CFRP prepreg. The DCB-UBM specimens were cut from sandwich panels which were manufactured using a one shot curing process in an autoclave. The specimens comprised of a constant core thickness (h_c = 40 mm), and two face sheet thicknesses (h_f = 0.35 and 1.4 mm) were also chosen.

In order to perform fracture testing at a constant mode-mixity phase angle, the moment ratio (MR) across the two arms must remain constant throughout the test. A dedicated controller operating based on CASCADE control was utilized which ensured that the moment ratio, MR, remained constant. When rotation is applied to Arm 1 (corresponding to M1), the CASCADE algorithm ensures that a moment M_2 is applied such that the MR is held constant. The MR value was provided as input prior to start of each test, and testing was carried out in angle control mode at a fixed rate of 10 °/min. The selection of MR corresponding to a particular mode-mixity phase angle (ψ) is based on the numerical mode-mixity method, the Crack Surface Displacement Extrapolation (CSDE) [8] method. A map of MR vs. ψ for the range of tested sandwich systems was generated using the CSDE method (see example in Fig.3(a)). The energy release rate, G, was calculated from the applied moments using the *J*-integral expressions for a DCB-UBM sandwich specimen [4]. A phenomenological expression provided by Hutchinson and Suo [9] was used to fit the experimental data (by eye).

$$\Gamma(\psi) = G_{1c}\left(1+\tan^2\left[(1-\Lambda)\psi\right]\right) \tag{1}$$

where G_{1c} is the mode I fracture toughness and Λ is dimensionless parameter.



(a) (b)

Fig. 3: (a) Moment ratio (MR), vs. phase angle (ψ) map, for a 32 kg/m^3 honeycomb core specimen (h_f = 1.40 mm), (b) interface fracture toughness (Γ) vs. phase angle (ψ) for a CFRP/C1-4.8-32 honeycomb core sandwich specimen with h_f = 1.40 mm and h_c = 40 mm, for crack propagation in the L- direction.

Interface crack propagation was observed for most of the tested specimen configurations. The variation of G vs. ψ for a CFRP/C1-4.8-32 sandwich case is provided in Fig.3(b). In order to understand the influence of core density, cell size and core paper properties on the fracture toughness, results will be provided for various classes of sandwich systems.

REFERENCES

[1] E. H. Glaessgen et al., “Debonding Failure of Sandwich-Composite Cryogenic Fuel Tank with Internal Core Pressure,” J. Spacecraft and Rockets, 2005, vol. 42, no. 4, pp. 613-627.

[2] M. Rinker et al., “Characterizing Facesheet/Core Disbonding in Honeycomb Core Sandwich Structure”: NASA/CR-2013-217959 NIA Rep. No. 2013-0115, 2013.

[3] B. F. Sørensen et al., "DCB-specimen loaded with uneven bending moments." International Journal of Fracture, 2006, vol. 141, no .1, pp. 163-176.

[4] C. Lundsgaard-Larsen et al.,”A modified DCB sandwich specimen for measuring mixed-mode cohesive laws”. Engineering Fracture Mechanics, 2008, vol. 75, no. 8, pp. 2514-2530.

[5] V. Saseendran et al. "Fracture Characterization of PVC Foam Core Sandwich Specimen Using the DCB-UBM Test Method.", 21st International Conference on Composite Materials (ICCM-21). 2015.

[6] V. Saseendran et al. “Honeycomb Sandwich Face/Core Fracture Toughness Measurements using the DCB-UBM Test Method – DoSS Project”, 2017, Technical Report, Dept. of Mechanical Engineering, Technical University of Denmark.

[7] C. Berggreen et al. “A Modified DCB-UBM Test Method for Interfacial Fracture Toughness Characterization of Sandwich Composites”, 2017(manuscript under review)

[8] C. Berggreen et al. “Experimental and Numerical Study of Interface Crack Propagation in Foam-cored Sandwich Beams”. Journal Composite Materials, 2007, vol. 41, no. 4, pp. 493–520.

[9] Z. Suo et al. “Mixed Mode Cracking in Layered Materials”, Advances in Applied Mechanics, 1991, vol 29, pp: 63-191.