A NEW METHOLOGY FOR TESTING COMPOSITE MATERIALS IN MODE III OF FRACTURE

A. López-Menéndez[a], J. Viña[a*], A. Argüelles[b], J. Bonhomme[b], V. Mollón[a], M. Lozano[b]

[a]*Department of Materials Science and Metallurgical Engineering, University of Oviedo, Campus Universitario, 33203 Gijón, Asturias, Spain*
[b]*Department of Construction and Fabrication Engineering, University of Oviedo, Campus Universitario, 33203 Gijón, Asturias, Spain*
**jaure@uniovi.es*

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Abstract

This paper presents a new device for testing composite materials in mode III of fracture, which lets to test in mode III quasi-pure, because there is not practically mode II. This does not happen with other devices used for this mode of fracture which have an important component of mode II. Another characteristic is the improvement of the quality and facility of the fitting of the specimen in the device because there are not screws and mechanical fixtures which avoids preloads before the beginning of test.

1. Introduction

Nowadays there are several methods for testing composite materials in mode III of fracture. One of them is the Split Cantilever Beam (SCB) [1-3]. In this method the specimen is loaded in one direction parallel to the delamination plane. Donaldson [1] used two aluminum blocks adhered to the specimen trying to avoid torques during the test. With this method were obtained good results but irregular overloads were induced, this was the reason of the modification of the method, named Simplified Split Cantilever Beam (SSCB) [1]. In these tests the mode II was very important, approximately a 40% of the energy release rate. In order to decrease this percentage of mode II, blocks with a very high stiffness were used in the research of Hwang and Hu [2]. Robinson and Song [4] had a new idea for decreasing the mode II. Sharif et al. [5] and Kortschot [6] designed a device for obtaining a mode III dominating, known as Modified Split Cantilever Beam (MSCB). Szekrényes [7] has carried out an interesting study about the advantages and disadvantages of this test method.

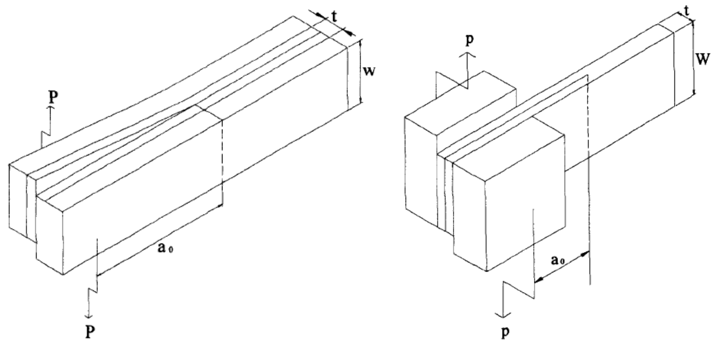

Figure 1. Schema of two test methods: Split Cantilever Beam and Simplified Split Cantilever Beam

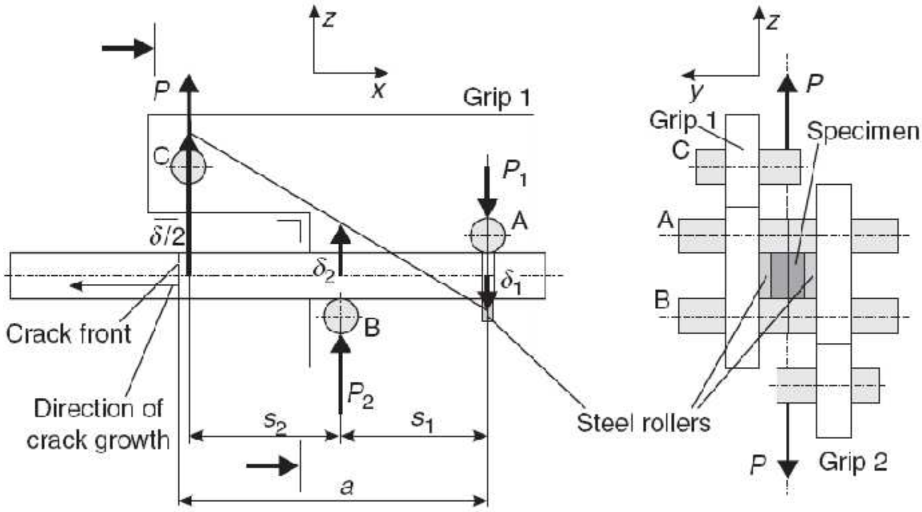

Figure 2. Schema of the Modified Split Cantilever Beam specimen and method

Anti-Clastic Plate Bending (ACPB) [8] is a method in which a rectangular specimen with chases in the middle line of it is subjected to a twist deformation. ACPB test can be carried out applying two loads perpendicular to the specimen in two opposite corners, or applying a torque load in two opposite sides. The torque load causes in the specimen an anti-clastic surface, this is, a surface with a double curvature, but with opposite sign (Gaussian curvature negative). This method is used for obtaining fracture toughness in mode III of composite materials [9].

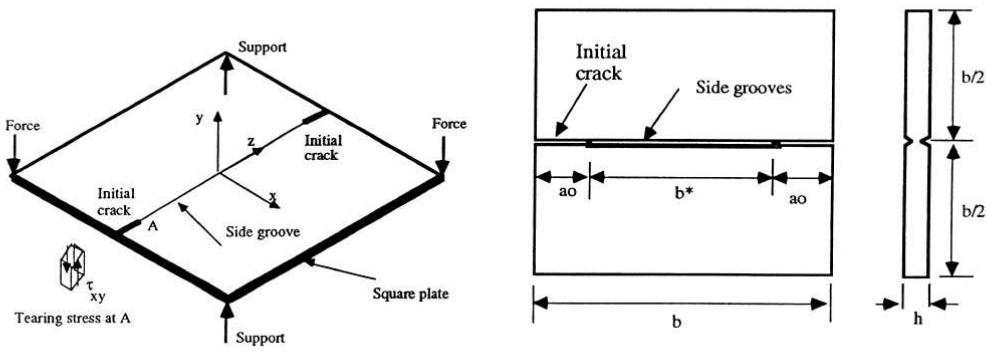

Figure 3. ACPB specimen

Another test method for mode III is known as Edge Crack Torsion (ECT) [10]. It was developed by Lee [11] and it has been considered as a great advance in the field of fracture in mode III [12-16]. An important characteristic of this test is that the Calibration Compliance Method (CC) can be applied [7], although in this test method the effect of friction is negligible [17]. Ratcliffe [18] in a recent analysis showed some drawbacks: dependence of the energy release rate from the crack length, loss of linearity in the curves load-displacement and damages in the specimen previous to the delamination failure. Pennas et al. [19] showed that the energy release rate in mode III increased with the crack growth, according with the results of Ratcliffe [16]. Recently Moura et al. [20] explained that the increment of the resistance to the crack propagation is caused because this does not advance uniformly between the load points and the damage area.

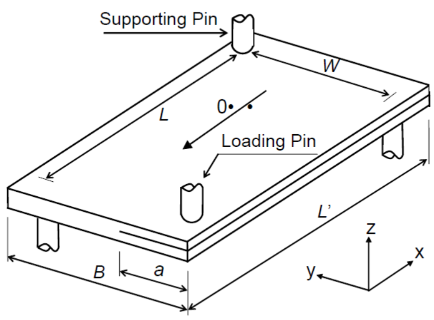

Figure 4. ECT method

More recently, de Morais and Pereira [21] published the method Four-Point Bending Plate (4PBP) in order to characterize the fracture of composite materials in mode III. This test is simpler than ECT test, but the energy release rate must be obtained using finite elements.

2. Experimental Procedure

2.1. Materiales and specimens

The material employed in this research program was manufactured by Hexcel Composites. The material is composed of a 8552 epoxy resin prepreg, modified to increase its toughness, reinforced with AS4 unidirectional carbon fibre (commercial name AS4/8552 RC34 AW196). The cured panel was obtained by cutting prepreg laminate, sequentially plied and cured in autoclave, with a volume fraction of 60%. The configuration of the laminates is symmetric $[0^o]_{16/s}$, employing a 20 mm thick Tygavac RF-260-R at the midplane as insert to form an initiation site for delamination.
The dimensions of the specimen used in the present study were: length = 200mm, width = 10 mm and thickness = 6mm.

2.2. Test procedure

A new device has been designed in order to test composite materials in mode III. Figure 5 shows two views of the device with the specimen. Also the cylinder which applies the load can be observed in the first image.

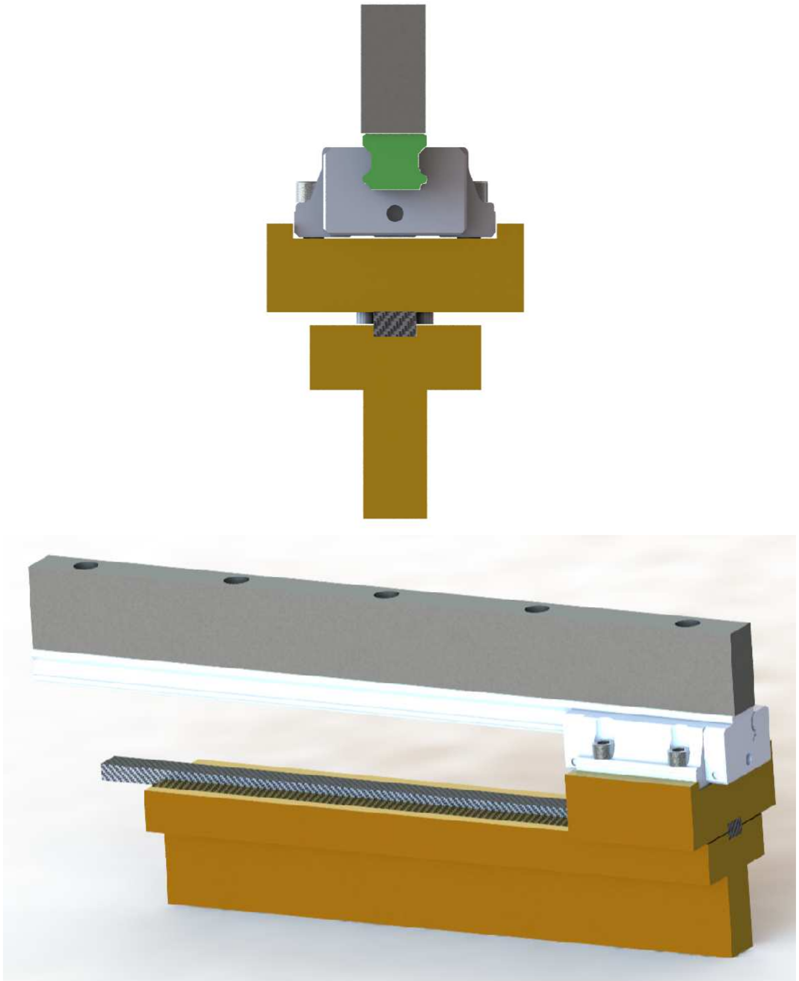

Figura 5. Test device and specimen

Figure 6 shows the axis for application of the torsional loading. The test equipment employed was a dynamic biaxial servohydraulic Walter+bai testing machine with 260 Nm and ±45º. The tests have been carried out to an angular velocity of 0.1º/s. Figure 7 shows the test equipment and the testing machine.

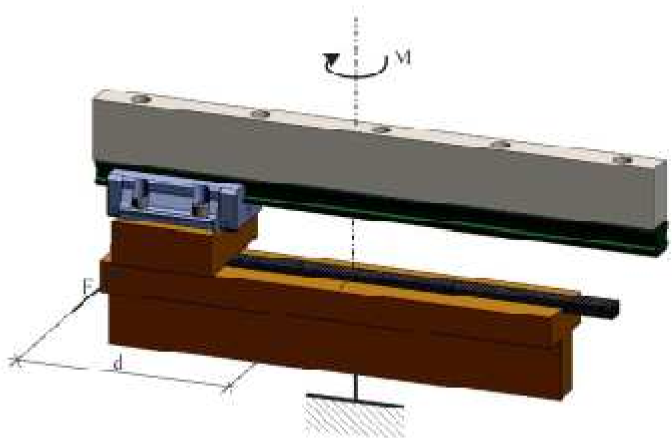

Figure 6. Device, specimen and loads.

Figure 7. Test device and testing machine.

3. Experimental results

Specimens with the point of application of load to two different distances from the insert have been tested. The selected distances were 1 and 26 mm. The aim was to obtain the quantity of modes I, II and III in each case. An Optical 3D Deformation Analysis equipment with the commercial name of ARAMIS and manufactured by GOM has been used for measuring the displacements of different selected points during the test (figure 8). Figure 9 shows the specimen with the insert to 26 mm of the loading point and the displacements in an instant close to the specimen breakage. Also three different points where the displacements were measured have been situated in the figure. The values measured can be seen in figure 10. The displacements in the directions of axes X and Y are negligible in comparison with the displacement in Z-axis. The displacements in the three points are practically the same being this a proof that there is no twist in the specimen.

Figure 8. Test using optical displacement analysis

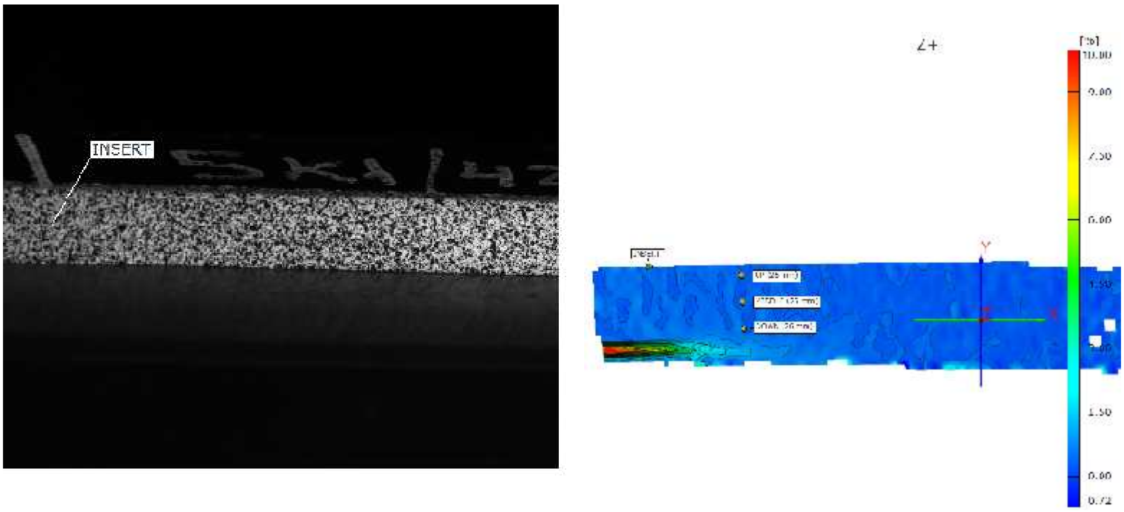

Figure 9. Specimen with insert and load applied to 26 mm from it. Displacements previous to the failure of the specimen

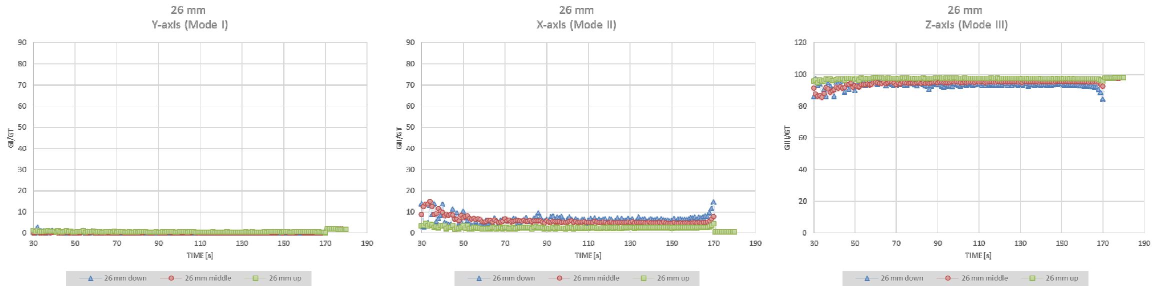

Figure 10. Displacements in the directions of three axes

Figure 11 shows the specimen with the insert to 1 mm of the loading point and the displacements in an instant close to the specimen breakage. Also three different points where the displacements were measured have been situated in the figure. The values measured can be seen in figure 12. The displacements in the directions of axes X and Y are negligible in comparison with the displacement in Z-axes. The displacements in the three points are practically the same being this a proof that there is no twist in the specimen.

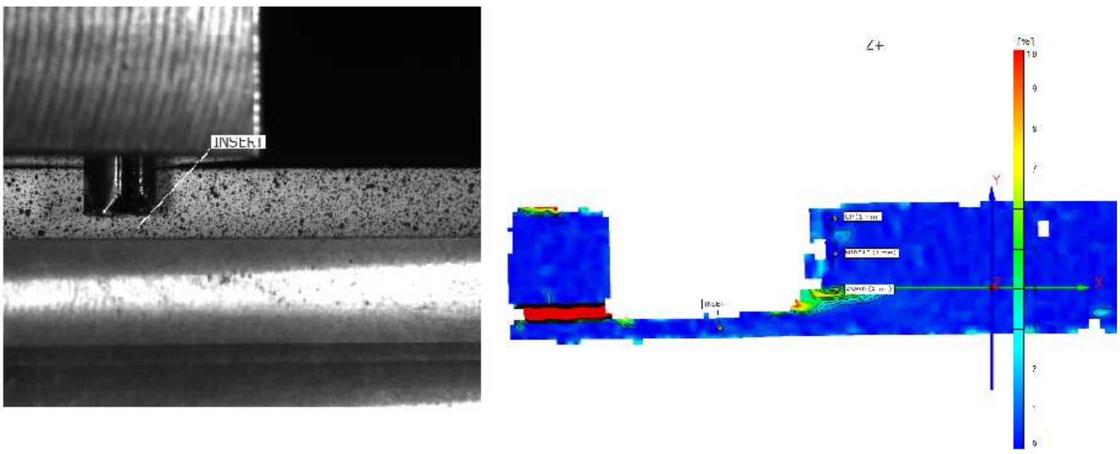

Figure 11. Specimen with insert and load applied to 26 mm from it. Displacements previous to the failure of the specimen

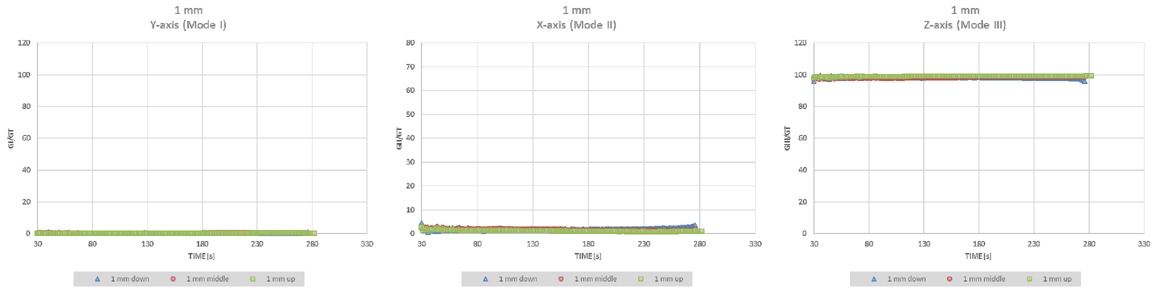

Figure 12. Displacements in the directions of three axes

Figure 13 show the comparison between the displacements in the direction of the X-axis (mode II) y of the Z-axis (mode III) in both cases, this is, applying the load to 26 mm and to 1 mm of the insert. In this last case the mode III is practically pure.

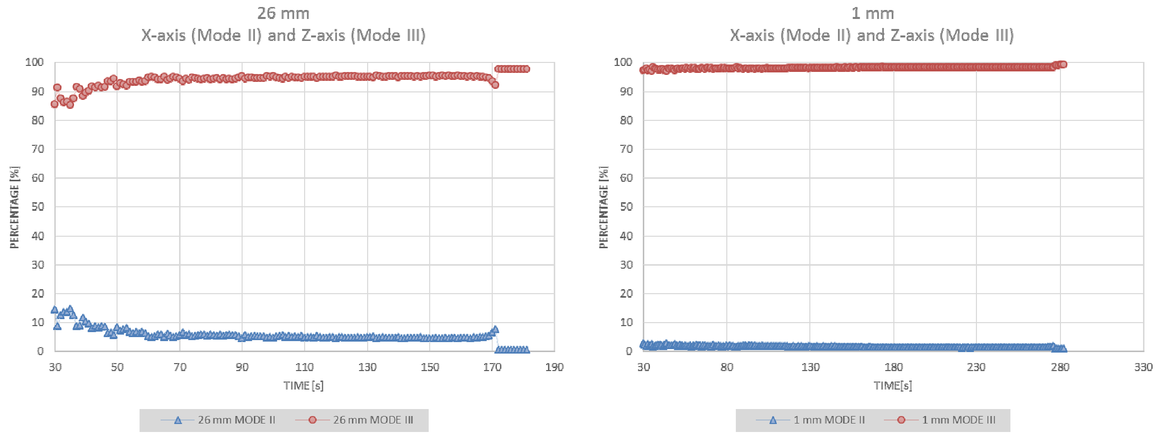

Figure 13. Displacements in X-axis and Z-axis when the load was applied to 26 and 1 mm of the insert.

4. Conclusions

The new device designed allows obtaining practically a mode III pure in the point of the crack. Also if the load is applied close to the crack the mode III obtained is more pure. The percentages of mode III with this device are higher than those obtained with previous methods.

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