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FEASIBILITY STUDY OF STRAIN PROFILE MEASUREMENT BY A DISTRIBUTED FIBER OPTIC SENSING SYSTEM UNDER MODE I INTERLAMINAR FRACTURE TOUGHNESS OF FIBER-REINFORCED POLYMER MATRIX COMPOSITES

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1. Introduction

The measurement of the mode I interlaminar fracture toughness of composite materials is usually conducted according to the ASTM D5528-13 or the ISO 15024 standards [1,2], using a Double Cantilever Beam (DCB) specimen (Fig. 1). The propagation of this crack is obtained by imposing a relative displacement to the pins inserted into the load blocks. In order to evaluate the values of the critical energy release rate G_{IC}, the length of the crack must be measured. This is usually performed in two ways: a) by observing the position of the tip of the crack, using an optical microscope; b) by data reduction schemes, that relate the opening of the crack to the displacement of the loading pins and the applied load. In the second case, knowledge of the elastic properties of the material and a calibration that takes into account the compliance of the testing equipment is required.

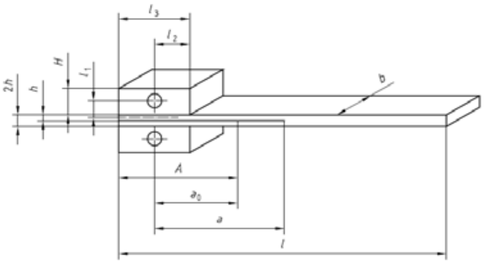

Fig. 1. The DCB specimen [2]

In this work we present a method for the determination of the crack length based on the measurement of the longitudinal strain field on the surface of the DCB specimen, using distributed sensing by Optical Backscatter Reflectometry (OBR). This techniques was successfully applied to the fatigue crack monitoring in adhesive joints [3].

2. Methods

An OBR ODiSI-B interrogator by Luna Innovations was used to measure the evolution of the strain profile. Strain measurement can be performed along the entire fibre with thousands of sensing locations interrogated simultaneously (gauge length was 1.3 mm, with a gauge separation of 0.65 mm), transforming an ordinary optical fibre into a high spatial-resolution strain sensor. One single low bending optical fibre, (type “Strain sensor 2m”, by Luna Innovations Inc.) was bonded on the top surface of a DCB specimen, as shown schematically in Fig. 2.

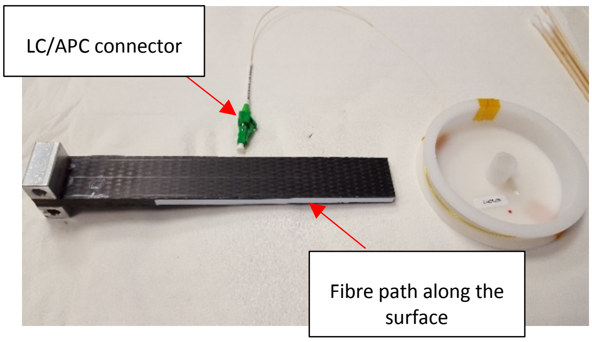

Fig. 2. OBR fibre surface bonded on a DCB specimen.

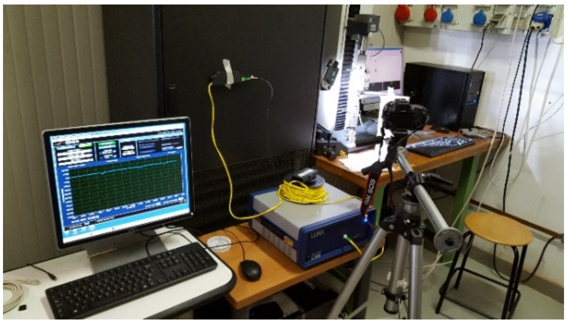

Fig. 3. Experimental setup.

Then, test was performed according to ASTM D5528-13 using an electro-mechanical tensile machine, whose maximum loads capacity is 1kN; as shown schematically in Fig. 3.

3. Results

Strain profile were recorded during the test with a sampling frequency of 23.8Hz. Fig. 4 shows the evolution of the surface strain profile: as the delamination front is advancing, the position of the minimum peak also moves in the same direction, suggesting a method to infer the position of the crack by recording and analyzing the surface strain profile. Fig. 5 shows the absolute value of the minimum peak strain, due to the presence of the delamination, during the test.

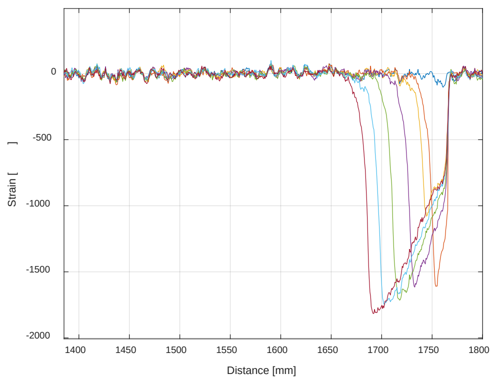

Fig. 4. Surface strain profile recorded on a DCB specimen under test.

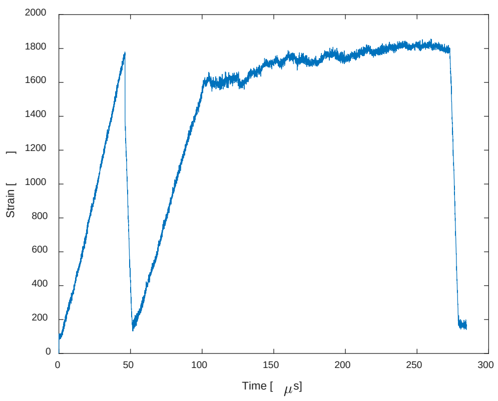

Fig. 5. Peak strain profile of a DCB specimen under Mode I interlaminar fracture toughness test.

Once the initial position of delamination (PTFE insert) is known, its growth can be determined by subtracting the actual position of the minimum peak determined by OBR to its original position. Fig. 6 shows the estimated delamination growth of a DCB specimen as a function of the test time.

4. Concluding remarks

- the distributed sensing capabilities of OBR technology allows for measuring the strain profile in DCB specimens, which is characterized by a minimum peak due to the delamination;
- by following the evolution of the minimum strain peak it is possible to monitor the position of delamination
- results are based on one single test and more tests are planned to validate the method.

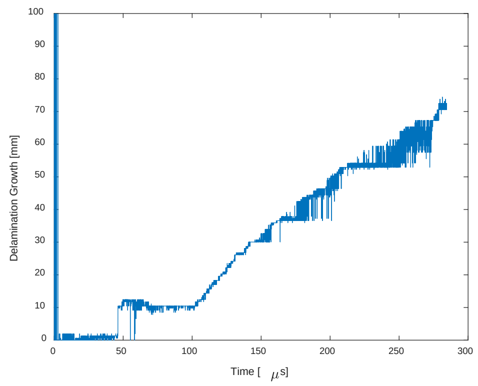

Fig. 6. Delamination growth of a DCB specimen under Mode I interlaminar fracture toughness test.

Acknowledgements

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References

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[2] ISO 15024:2001 - Fibre-reinforced plastic composites -- Determination of mode I interlaminar fracture toughness, GIC, for unidirectionally reinforced materials

[3] A. Bernasconi, M. Carboni, L. Comolli, R. Galeazzi, A. Gianneo, and M. Kharshiduzzaman, “Fatigue Crack Growth Monitoring in Composite Bonded Lap Joints by a Distributed Fibre Optic Sensing System and Comparison with Ultrasonic Testing,” J.

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