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Discontinuous carbon fibre reinforced polymers: manufacturing and characterization

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Abstract
Carbon fibre reinforced polymers (CFRPs) present an outstanding performance in terms of mechanical performance and weight. However, when reaching their mechanical limits, they are related to delamination and catastrophic failure. This study proposes a new structure of CFRPS laminates to enhance their toughness and modify their typical failure mode. An industrial manufacturing method is used to produce the proposed new systems and tensile tests are performed to them to demonstrate a "pseudo-ductile" behaviour.

1. Introduction

Structural composite materials are made of layers, or plies, of continuous carbon fibres, held together by a resin. However, since this resin matrix is relatively brittle compared to the carbon fibre plies, carbon fiber reinforced polymers (CFRPs) present delamination failure mode and poor fracture toughness. There are several approaches to improve the interlaminar properties of CFRP such as adding nanofillers, microfibres or Z-pins to the composite material [1].

Recently, creating "discontinuities" within the composite has been proved to improve the ductile performance of the composite materials, which is known as "pseudo-ductility" [2,3]. This "pseudo-ductility" enhances the composite toughness which reduces de delamination of the composite. Among the possible forms of introducing discontinuities in composites, a bioinspired design seems to bring promising results. Particularly, in nacre, aragonite forms thin platelets linked together by a continuous protein phase, creating the so called "brick and mortar" structure. One of the main advantages of these structures is their high fracture toughness [4]. In this work, we are going to use a "brick and mortar" approach to improve the interlaminar behavior of conventional CFRP.

2. Materials and methods

2.1. Manufacturing

This study implements a biomimetic design and "brick and mortar" structure in carbon fibre composites. This is achieved by means of making discontinuities and stacking unidirectional prepreg plies (AS4/8552) with an Automated Tape Layer (ATL) machine. This method implies a high-precision and positioning of the cuts and a standard industrial process. Thus, different laminates have been manufactured with distances between cuts (brick length, *l*) and a staggered disposition of them as explained in Figure 1.

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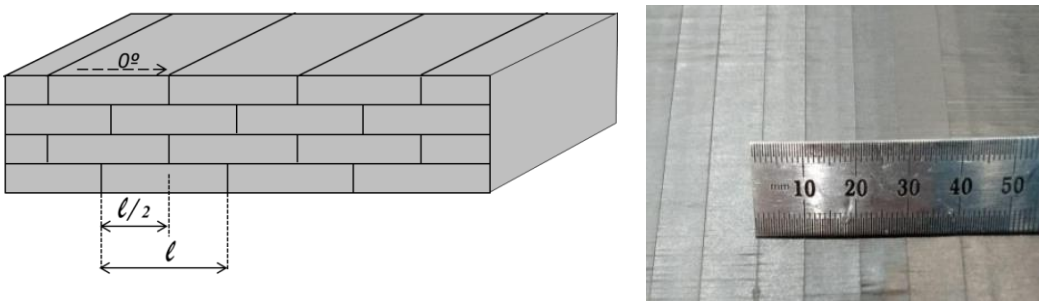

Figure 1: A) Brick and mortar structure and B) Prepreg with cuts of 10 mm (*l*) made by the ATL.

2.2. Characterization

Mechanical tests have been carried out in order to evaluate the effect of the hierarchical structure in the composite. Specifically, tensile tests were performed to continuous CFRP laminates and the three discontinuous laminates according to ASTM D3039 (Figure 2).

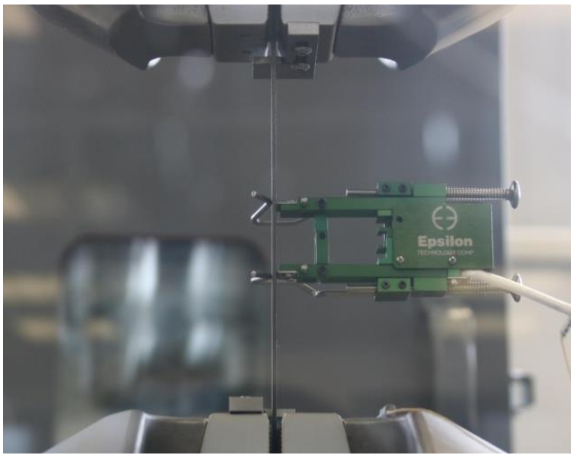

Figure 2: Tensile tests with extensometer carried out in a MTS Landmark 370.10 System (load cell 100 kN).

3. Results

A "pseudo-ductile tendency" can be observed in the stress vs strain curve obtained (Figure 3). The curvature of the stress-strain curve increases with the number of cuts present in the sample. On the other hand, ultimate strength decrease in the discontinuous samples compared to the continuous. Regarding the failure mode, for the continuous samples it is "explosive" while a different failure mode is observed in the discontinuous samples, where a crack initiates and propagates before the catastrophic failure.

A representative can be observed in Figure 3: the single line curve belong to the continuous sample and the dotted one correspond to a discontinuous sample.

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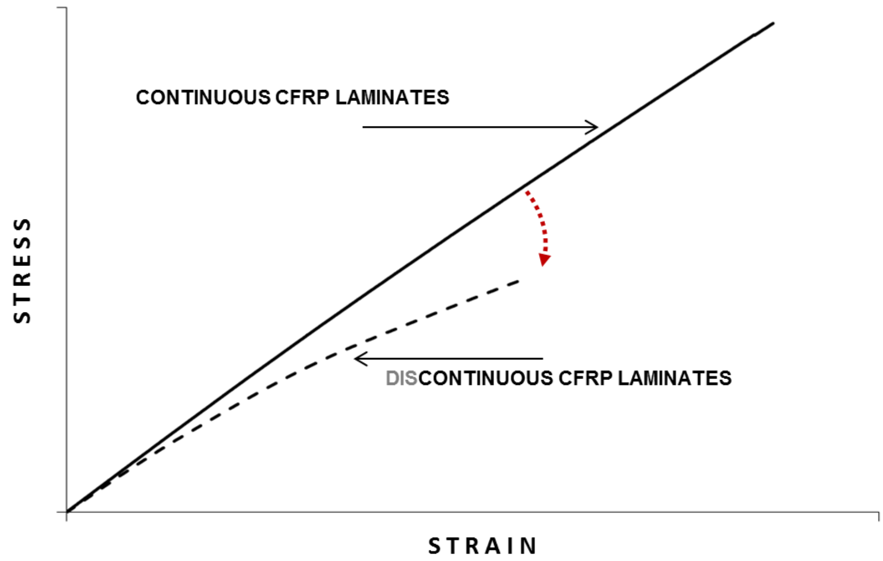

Figure 1: Representative stress-strain curves of continuous and discontinuous laminates.

4. Conclusions

Bio-inspired CFRP laminates with a "brick and mortar" structure have been manufactured successfully through and automated process. The mentioned laminates have been tested and pseudo-ductility has been proved as well as an alternative failure mode to the one related to continuous CFRP. This demonstration opens the door to a new family of composites materials that can be produced in the industry and could soften one of the main drawbacks of conventional CFRP.

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