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ASSESSMENT OF THE QUALITIES OF CARBON NANOTUBE SENSORS FOR STRUCTURAL HEALTH MONITORING OF COMPOSITES

Moisés Zarzoso[1,2], Anastasiia Mikhalchan[1], Pablo Romero[3], Ricardo Losada[3], Juan J. Vilatela[1] and Carlos González[1,2]

[1]IMDEA Materials Institute
calle Eric Kandel 2, 28906 Getafe, Madrid, Spain
Email: moises.zarzoso@imdea.org

[2] Department of Materials Science, E.T.S. Ingenieros de Caminos, Universidad Politécnica de Madrid, P.º de Juan XXIII, 11, 28040, Madrid, Spain

[3] AIMEN
Polígono Industrial de Cataboi, 36418, O Porriño, Pontevedra, Spain

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ABSTRACT

In this work, carbon nanotube (CNT) filaments are used for monitoring the strain of carbon fibre-reinforced thermoplastic laminate plates by means of the piezoelectric properties of those filaments.

The effectiveness of a piezoelectric material can be characterized by its gauge factor, defined as the quotient of the change of electrical resistance of the material and the strain increment the material is subjected to:

$$GF = \frac{\Delta R}{\Delta \epsilon} \quad (1)$$

Where ΔR is the change of resistance and $\Delta \epsilon$ is the strain increment. While the GF of carbon fibres is close to 1.0, CNTs can achieve several times that value [1].

The structural health monitoring of a carbon composite can be achieved by means of the conductivity of the carbon fibres themselves, but this strategy presents two significant drawbacks; on the one hand, the intrinsic difficulty of accurately modelling the resulting electric circuit of the composite and its evolution under damaged conditions, on the other hand, the low GF of carbon fibres. In order to improve the GF, the addition of nanofibres of CNTs has been explored, but the difficulty of localizing the source of a change of resistivity remains.

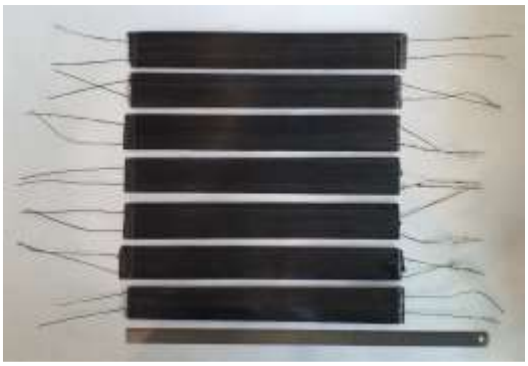

Figure 1: Coupons manufactured with embedded carbon nanotube filaments.

We propose an alternative approach in which a grid of CNT filaments is embedded in the composite and used for its structural monitoring. A high GF is achieved, while introducing a small distortion in the laminate, in opposition to alternative sensors such as fibre Bragg grating, where the sensor's glass fibre strongly influences the crack initiation in the polymer matrix.

For this purpose, a sensor filament is manufactured by extruding a coating of a polymer similar to the one of the laminate around a continuous CNT fibre; in this stage, achieving a good degree of infiltration of CNTs is key for satisfactory mechanical properties [2]. This filament is later embedded into a hot-press consolidated laminate during the laying-up stage. From this laminate, coupons with embedded sensors can be mechanized (Figure 1).

The electrical properties of these filaments are characterized prior to the embedding process, with no observed changes to these properties once embedded. After electric contacts between the CNTs and copper wires are made and checked, coupons are tensile tested. During these tests, the electrical resistance is measured simultaneously to strain by means of an external power supply connected to the filament (see the experimental setup in Figure 2).

The resulting measured resistance matches the strain experimented by the coupon, with a low noise signal, consistency between coupons and a GF greater than 3.

Figure 2: Experimental setup for simultaneous measurement of strain and electrical resistance.

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