Health Monitoring in Composite Materials Using Carbon Nanoreinforcement Networks

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Summary: Multiscale composites have been fabricated using matrix doped with carbon nanotubes or fibres coated with a sizing agent that contained the nanoreinforcements. Mechanical tests were made, and the electrical resistance was measured simultaneously. Both methods demonstrated that these systems worked as stress/strain and damage sensors.

1 INTRODUCTION

The adequate combination of carbon nanotubes (CNTs) doped matrix with traditional fibres may allow the development of composites that have improved mechanical properties, especially in the thickness direction [1], while providing new functionalities associated to the increase of the electrical conductivity. Values in the order of 10^{-2} S/m should be sufficient for stress/strain and damage sensing via electrical conductivity methods.

In this work, carbon nanoreinforced composites have been fabricated using: 1) doped matrix and 2) coating the fibres with a sizing agent that contained carbon nanotubes. Combined mechanical/electrical tests were performed in order to evaluate the sensibility of both types of composites manufacturing. Tensile and interlaminar shear strength tests were made and the electrical resistance was measured in-situ. Although the use of doped matrix made difficult the fabrication of the composites, both methods demonstrated the feasibility of stress/strain and damage sensing.

2 MATERIALS AND TESTING METHODS

To obtain CNT/epoxy mixtures, CNTs were dispersed in the epoxy resin using a laboratory scale three-roll calendering mill following a previous optimized calendering process [2]. To deposit the sizing agent over the carbon or glass fibre (CF and GF, respectively) fabrics, it was first diluted with distilled water at a ratio of 1:2 (sizing agent: distilled water) and then infused into a ten-layer plain woven fabric using the vacuum-assisted resin transfer moulding (VARTM) technique. Multiscale composites were fabricated by hand lay up in the case of using doped matrix and by VARTM when fibres were coated with the sizing agent.

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The different specimens were then tested in tensile tests (MTS Alliance RF-100) following the ASTM D638 procedure and interlaminar shear strength following the ASTM D2344. During the tests, the electrical resistance of the samples was measured using a four-wire ohmmeter (Agilent 34410A).

3 RESULTS

Fig. 1 shows the result of the test made to a multifunctional GF composite containing 0.3 % of CNTs. The composite was tested in direction perpendicular to GFs. During the first part of the test, i.e. at the elastic deformation zone, the resistance increased linearly with the load applied. In the plastic deformation zone, the slope of the curve strongly increased, showing that changes in the conductivity mechanisms were taking place. Several cracks were observed in the composite after the testing, suggesting that the formation of cracks, their growth and evolution were the main reasons for the conductivity decrease of the samples. The increase of viscosity due to the incorporation of CNTs gave rise to composites with porosity because the vacuum applied during the manufacturing of the composite was not enough for the extraction of the bubbles accumulated in the CNT/epoxy mixture. The alternative was the use of fiber sizing agent which contains a uniform distribution of CNTs. Fig. 2 shows CNT agglomeration on the surface of sized carbon and glass fibers. In these multiscale composites a conductive CNT network was formed that allowed the monitoring of strain and damage during testing.

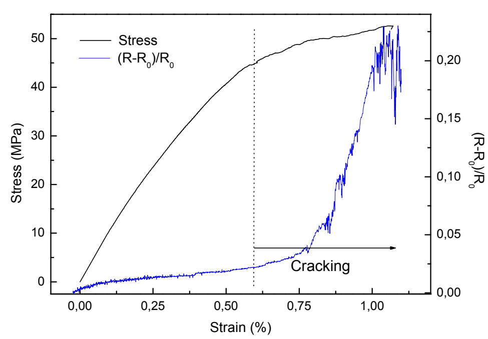

Fig. 1 Stress-strain and resistance change curves for the GF composite with a matrix doped with 0.3 % CNT.

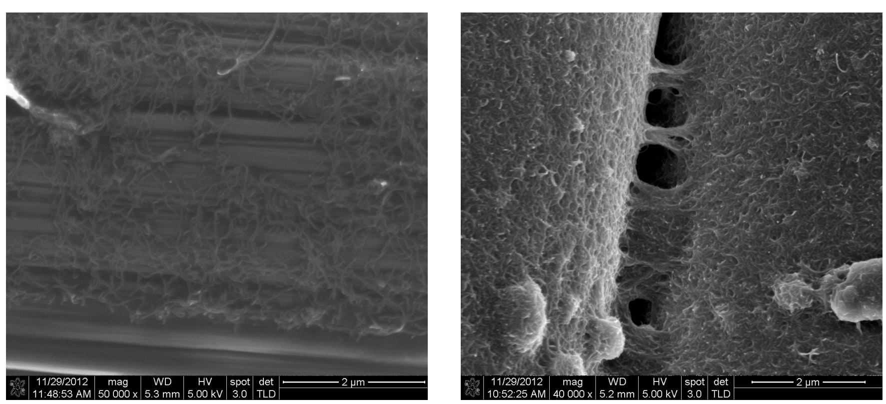

Fig. 2 CNTs on a) carbon and b) glass fibre after sizing treatment of the fibre fabric.

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