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POLYVINYL ALCOHOL - CARBON NANOTUBE FIBERS RESPONSE UNDER PROGRESSIVE DAMAGE ACCUMULATION TENSILE TESTS

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ABSTRACT

Polyvinyl alcohol carbon nanotube (PVA-CNT) fibers were embedded in glass fiber reinforced plastic (GFRP) composites in order to be used as strain sensors of the composite. Strain sensing of the composite was made by the in-situ measurement of the embedded fiber's electrical resistance change during the mechanical tests. The types of PVA-CNT fibers produced differed in their degree of pre-stretching. The multi-functional materials were tested in monotonic tensile tests as well as in progressive damage accumulation tests. The electrical resistance readings of the PVA-CNT fibers were correlated with axial strain values, taking into account the induced damage of the composite. It has been demonstrated that increasing the fiber's pre-stretching ratio, its electrical resistance response increases due to higher degree of the CNTs alignment in the PVA matrix.

Keywords: PVA-CNT, GFRP, sensors, strain, tension, electrical resistance measurements, multi-functionability.

INTRODUCTION

The need for simple, non-sophisticated monitoring techniques led to the development of the electrical resistance change (ERC) method that was successfully applied in conductive carbon-fiber reinforced polymers (CFRPs). The electrical conductivity of the carbon fibers was first used as an index to monitor damage in CFRPs, which could be post-related to damage mechanisms in composites, such as fiber breakage, delamination, matrix cracking (Schulte, 1989). ERC monitoring concept could also work in non-conductive composites such as glass fiber reinforced polymers (GFRPs); Muto (2001) inserted a carbon fiber into GFRP during manufacturing and monitored the carbon fiber's electrical response versus the externally applied mechanical loading of the composite. Without being successful to monitor damage at low values of tensile axial strains, the idea for damage monitoring of non-conductive composites via a conductive fiber was born.

To this end, the authors have recently presented a methodology according to which innovative polyvinyl alcohol-carbon nanotube (PVA-CNT) fibers can be embedded into GFRP during manufacturing (Alexopoulos et al, 2010). The fibers were produced according to the standard process with injection of a carbon nanotubes (CNTs) suspension into a spinning coagulation agent, explicitly described by Vigolo et al. (2000). It was demonstrated that the electrical resistance of the embedded fibers changed with the applied tensile loading of the composites, and thus, this new sensor can be used for strain sensing purposes of composites. Increase in

ERC is attributed to loss and modifications of contacts of CNTs inside the PVA matrix; the key parameter in this sensor is translating this effect and transforms it into axial mechanical strain.

RESULTS AND CONCLUSIONS

Polyvinyl-alcohol carbon nanotube fibers differing on their pre-stretching ratio were embedded into the composite laminate before manufacturing. The differences of each fiber are discussed in order to be used as mechanical strain sensors. It was found that by increasing the pre-stretching ratio of the fiber, its electrical resistance response increases for the same applied axial strain, due to higher degree of the CNTs alignment in the PVA matrix.

Progressive damage accumulation tests in composites showed that hysteresis loop was formed only after exceeding approximate 40 % of fracture stress of the composite. All investigated fibers exhibited similar behaviour, while higher pre-stretched fibers presented higher electrical resistance measurements and higher hysteresis loops for the same applied mechanical load.

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