Accepted Manuscript

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PII: S0266-3538(15)30012-9

DOI: 10.1016/j.compscitech.2015.06.006

Reference: CSTE 6126

To appear in: *Composites Science and Technology*

Received Date: 5 April 2015

Revised Date: 6 June 2015

Accepted Date: 9 June 2015

Please cite this article as: Ladani RB, Wu S, Kinloch AJ, Ghorbani K, Zhang J, Mouritz AP, Wang CH, Improving the Toughness and Electrical Conductivity of Epoxy Nanocomposites by using Aligned Carbon Nanofibres, *Composites Science and Technology* (2015), doi: 10.1016/ j.compscitech.2015.06.006.

Improving the Toughness and Electrical Conductivity of Epoxy Nanocomposites by using Aligned Carbon Nanofibres

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Abstract

There is an increasing demand for high performance composites with enhanced mechanical and electrical properties. Carbon nanofibres offer a promising solution but their effectiveness has been limited by difficulty in achieving directional alignment. Here we report the use of an alternating current (AC) electric field to align carbon nanofibres in an epoxy. During the cure process of an epoxy resin, carbon nanofibres (CNFs) are observed to rotate and align with the applied electric field, forming a chain-like structure. The fracture energies of the resultant epoxy nanocomposites containing different concentrations of CNFs (up to 1.6 wt%) are measured using double cantilever beam specimens. The results show that the addition of 1.6 wt% of aligned CNFs increases the electrical conductivity of such nanocomposites by about seven orders of magnitudes to 10^{-2} S/m and increases the fracture energy, G_{Ic}, by about 1600% from 134 to 2345 J/m^2. A modelling technique is presented to quantify this major increase in the fracture energy with aligned CNFs. The results of this research open up new opportunities to create multi-scale composites with greatly enhanced multifunctional properties.

Keywords: A. Adhesive joints; **B.** Fracture toughness; **C.** Modelling; **C.** Fibre bridging; fibre pull-out

1. Introduction

Thermosetting epoxy polymers are widely used in aerospace and automotive applications as matrices for manufacturing fibre reinforced composites and as adhesives for joining structural components. Despite offering many desirable properties, thermosetting polymers typically exhibit a low electrical conductivity and a low fracture toughness, which leads to poor resistance to crack initiation and growth [1]. In the absence of any through-thickness reinforcement, fibre composites and bonded joints are susceptible to delamination or debonding [2]. The low electrical conductivity of composites and bonded structures, especially along the thickness direction, present challenges in protecting of aircraft against lightning strikes and electromagnetic interference. Also, good electrical conductivity is needed to meet fire retardant anti-static regulations for mining equipment, and oil-gas storage and transportation. Hence, improving the through-thickness toughness and electrical conductivity of fibre composites is of great importance.

Traditional techniques to improve the through-thickness properties and damage tolerance of epoxy polymers are to form a polymeric alloy via the addition of thermoplastics [3,4] or rubber tougheners [5,6]. Although these methods provide significant improvements to the toughness, the electrical conductivity

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