

Accepted Manuscript

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PII: S1359-8368(16)30227-X

DOI: [10.1016/j.compositesb.2016.04.010](https://doi.org/10.1016/j.compositesb.2016.04.010)

Reference: JCOMB 4208

To appear in: *Composites Part B*

Received Date: 30 June 2015

Revised Date: 1 January 2016

Accepted Date: 3 April 2016

Please cite this article as: Liu R-g, Xu Z-h, Yin J, Huang J-j, Liu D, Xie G-h, A coupled mechanical and electrical model concerning piezoresistive effect of CFRP materials, *Composites Part B* (2016), doi: 10.1016/j.compositesb.2016.04.010.

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A coupled mechanical and electrical model concerning piezoresistive effect of CFRP materials

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Abstract

Structural health monitoring (SHM) including the real-time cure monitoring and non-destructive evaluation (NDE) in-service has been highly demanded with respect to smart composite material for the safe working of civil structures. Carbon fiber–reinforced polymer (CFRP) material is extremely strong and light fiber-reinforced polymer which can be used as electrical resistors due to its obvious piezoresistivity. This study presents an experimental investigation into the piezoresistive effect of CFRP tendon prepared by PAN-based carbon fiber and resin matrix modified with different carbon powder contents (i.e. 0%, 2%, 4%, 6%, and 8% by weight). Tests results showed that the mean value of initial electric resistance exhibited a decrease trend with increasing carbon powder content until it becomes stable when the powder content is greater than 6%. Electric resistance rate (dR/R) versus strain (ϵ) for different CFRP tendon specimens shows similar three stages regardless the carbon powder contents. An approximate liner relationship between dR/R and ϵ can be observed in the first stage for all tested specimens. Tests results also indicated that the sensitivity (K) increased with the increasing carbon fiber content at the beginning and followed by a decrease. The change law of K and its mechanism were evaluated and discussed from the microscopic point of view. Based on the analysis and low-energy theory, a coupled mechanical and electrical model combined resistivity scalar field response and structural strain vector field was established. The model provided herein was thereafter assessed and verified by comparing with existing tensile testing results. The consistence of the growth trend between the model and test results indicates the feasibility and reliability of the coupled model.

Keywords

A. Carbon fiber; B. Electrical properties; B. Mechanical properties; C: Analytical modeling; Piezoresistivity.

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