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Micromechanics modeling of the uniaxial strain-sensing property of carbon nanotube cement-matrix composites for SHM applications

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Highlights

- Strain sensitivity of cement-based nanocomposites is analytically modeled
- Strain-induced reorientation of CNTs is modeled by orientation distribution function
- Change in the percolation threshold is modeled by Komoro and Makishima's approach
- Wavy state of nanotubes is modeled by means of a helical approach
- Two-parameter agglomeration model of non-uniform fibers distribution is proposed

Abstract

Recent advances in the field of Nanotechnology have made possible the development of new smart materials, among which Carbon NanoTube (CNT) cement-based composites are attracting an increasing attention. These composites exhibit strain-sensing capabilities providing measurable variations of their electrical properties under applied mechanical deformations. This unique property, together with the similarity between these composites and structural concrete, suggests the possibility of developing distributed strain-sensing systems with substantial improvements in the cost-effectiveness of large-scale concrete structures. In order to design and optimize self-sensing CNT-based composites, it is therefore essential to develop theoretical models capable of simulating the relationship between external mechanical strains and the effective electrical conductivity. This paper presents a micromechanics model to predict the piezoresistive properties of CNT cement-based nanocomposites, with the consideration of waviness and non-uniform distributions of nanoinclusions. The origin of the piezoresistive response is attributed to (i) strain-induced changes in the volume fraction, (ii) filler reorientation and, (iii) changes in the tunneling resistance. In order to count on an experimental basis to use as benchmark for validation, several nanocomposite cement-based specimens are manufactured and tested under uniaxial compression.

Keywords:
Carbon nanotube, Cement-matrix composites, Piezoresistive modeling, Percolation, Smart concrete, Structural Health Monitoring

1. Introduction

The great economic, social and environmental impacts of civil infrastructures make preventive maintenance vital for structural engineering. The field of SHM encompasses a wide range of techniques which enable timely inspection and maintenance, resulting in enhanced serviceability and longer life-cycle of structures [1, 2]. Nonetheless, the inherent size of civil structures makes existing monitoring systems hardly applicable to the large scale, which is often termed the "scalability issue" of SHM. Recent advances in the field of Nanotechnology have led to the development of new multifunctional and smart materials. In particular, electrically conductive Carbon NanoTube (CNT) cement-based composites open a vast

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