Methodology for Evaluating Theproperties of Carbon Nano Tubes for Engineering Applications

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Abstract

Owing to the superior mechanical properties of Carbon Nanotubes (CNTs), research has been initiated to use this nanomaterial in construction industry. The elastic modulus of CNT is of great importance in order to use CNTs in construction industry. For judicious and effective application of CNT in construction industry where mass scale utilization is inevitable, it is important to accurately assess the properties of CNTs since these nano fiber materials are extremely cost sensitive. There is no well established tool or method available for the engineers to determine the properties of CNT, other than to accept the manufacturer’s data. Nanoscale continuum theory uses a representative volume to determine the elastic modulus which does not include the effect of radius and aspect ratio. In the present study, numerical model is developed and the validated one is used to study the effects of geometrical variability’s on the properties of CNT. Further, a methodology has been proposed to determine the mechanical properties, such as tensile stiffness, of the Carbon nanotube with a given structural arrangement (chirality and radius) if the same for the basic configuration, graphene, is known. The procedure discussed in this study will be helpful to the engineers to easily estimate the properties such as elastic modulus or tensile stiffness of CNTs before incorporating into conventional materials for developing new materials with enhanced properties.

Keywords: Carbon nanotube; Elastic modulu; Nanoscale continuum theory; Finite element analysis

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Introduction

Carbon nanotube (CNT) is a cylindrical nanostructure which is envisioned as a roll of graphene sheet. The radius of the nanotube ranges from 0.3nm - 100nm and it has a very high aspect ratio. CNT may be single walled (SWNT) or multi-walled (MWNT). Iijima[1] discovered the CNT while studying the carbon produced by arc evaporation of graphite in the helium atmosphere using High Resolution Transmission Electron Microscopy (HRTEM). Since then, various experimental and theoretical studies have been carried out by researchers around the world to determine its mechanical, chemical and electrical properties.

Ruoff and Lorrents[2] reported that CNTs possess superior mechanical properties and can be used as a potential reinforcing material to develop composites of desirable mechanical properties. Konsta-Gdoutos et al.[3] found that the macro and nano-properties of cement got enhanced by dispersion of MWNT using ultrasonic energy and use of surfactant. Experiments conducted by Tyson et al.[4] on cement reinforced by 0.1 and 0.2 weight percentage of CNTs showed that the flexural strength, ductility, strain to failure, elastic modulus and fracture toughness of the material also got increased.

The elastic modulus of CNT is of great importance for developing a composite material by adding CNTs. Various researchers carried out experimental studies based on techniques using HRTEM, Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) to determine the elastic modulus of SWNTs and MWNTs. The elastic modulus of CNT reported by each researcher is scattered and found to fall in a range of 1TPa to 6TPa. Treacy et al.[5] observed the thermal vibrations of MWNT in TEM and reported its elastic modulus to be in the range of 0.4 - 4.15TPa with an average of 1.8TPa. Characteristics of SWNT in room temperature were observed by Krishnan et al.[6] using Transmission Electron Microscopy and its elastic’s modulus was found to vary in the range of 0.9 - 1.7TPa with an average of 1.25TPa. The elastic modulus of an individual MWNT was reported as 1TPa based on its cross sectional analysis in SFM (Scanning Force Microscopy)[7]. The cooling-induced compressive deformation of CNT was monitored by micro-Raman Spectroscopy by Lourie and Wagner[8] and the elastic modulus of SWNT and MWNT was derived to be in the range of 2.8 – 3.6 TPa and 1.7 – 2.4 TPa respectively. Tensile tests were conducted by pulling MWNT using AFM tips and its behavior was observed under Scanning Electron Microscope (SEM). The tensile strength and the stiffness of MWNT obtained by this method was 11-63 GPa and 0.27 – 0.95 TPa respectively [9].