Effects of Carbon Nanotube on Mechanical Properties of Composite plates - A Review Paper

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ABSTRACT

This review paper presents the findings of the researchers about the mechanical properties of composite materials by more detailed discussion of theoretical and mechanichal properties for the entire range of the deformation amplitudes. Carbon nanotubes (CNTs), due to their superlative mechanical and physical properties, have shown a high potential to improve properties of composite materials. Adding CNTs into conventional composite materials at very low weight fractions can improve mechanical properties of the resulting nanocomposites. Among these properties are an extremely high tensile strength and stiffness. Scientists have estimated these values using force fields to model the atomic interactions and by using tools such as the atomic force microscope to actually measure the elasticity and tensile strength. Estimates of the stiffness of single walled carbon nanotubes generally fall in the range of 0.9 – 1.5 TPa with a tensile strength of approximately 100-150 GPa.

Keywords: Carbon Nanotube; Mechanical Propertie; Elasticity and Tensile StrengthIntroduction

Carbon nanotubes (CNTs) are tiny tubes with diameters of a few nanometers and lengths of several microns made of carbon atoms. Carbon nanotubes have been used in various fields of applications in recent years due to their high physical, chemical, and mechanical properties [1-22]. One of these fields is composite materials in which CNTs are added to a matrix not only as reinforcement but also to obtain other physical and chemical properties such as electrical conductivity and corrosion resistance. Carbon nanotubes are specially introduced into polymer matrices like epoxy to fabricate polymer matrix nanocomposites which presents a new generation of composite materials [20-31 & 68]. Gojny et al. [32] fabricated double-walled carbon nanotubes/epoxy nanocomposites and reported increases in strength and Young's modulus of the resulting nanocomposites at nanotube content of 0.1 wt.%. Martone et al. [33] investigated the effect of dispersed multi-walled carbon nanotube (MWCNT) on the enhancement of elastic modulus in an epoxy system. Tai et al. [34] reported the enhancement of strength and Young's modulus of phenolic composites reinforced with single-walled carbon nanotubes. Dispersion of nanofillers plays a very important role in the use of filler properties in polymeric composites. Nanoparticles due to large surface area and mostly high aspect ratio tend to agglomerate greatly which reduces the ability to show their expected properties [35]. A technique to achieve good dispersion of nanoparticles is ultra-sonication which can be used also for CNTs. Applying this method to disperse CNTs in a low-price polymer-like polyester which has good properties such as versatileness, quick curing, and low viscosity leads to fabrication of CNT/polyester composite with enhanced properties. Despite many investigations in CNT/polymer composites as were reviewed by Thostenson et al. [36], only a few works on CNT/polyester composites in the literature are present. Seyhan et al. [37] used amine functionalized and untreated carbon nanotubes to fabricate polyesterbased nanocomposites by a three-roll mill dispersion technique.

Since the discovery of this form of carbon atoms by Iijima in 1991, many attentions have been drawn to use the outstanding, many scientists and engineers have extensively devoted their effort to promoting their development and applications. Before full realization of the potential of the nanotechnologies in engineering applications, there is much work remaining to be done, such as good command of their physical properties and behaviors and well-controlled manipulation of the nano-structures to achieve desired material responses. In literature, extensive experimental studies using various advanced measurement tools with various nano-manipulation techniques have been carried out to identify the mechanical properties and behaviors of CNTs, including Young's modulus, shear modulus, buckling behavior, and vibrational response [35-42].

One of the main problems in characterizing the radial elasticity of CNTs is the knowledge about the internal radius of the CNT; carbon nanotubes with identical outer diameter may have different internal diameter (or the number of walls). In 2008, a method using an atomic force microscope was introduced to determine the exact number of layers and hence the internal diameter of the CNT. In this way, mechanical characterization is more accurate.[43]

1. Materials and Methods

Conventional aerospace composites have been composed of high-stiffness carbon fibres to maintain dimensional stability under high-performance application. Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure.

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1.1. DEFECT FORMATION - Stone-Wales Defect

To create S-W defect, four neighboring hexagons are converted into two pentagons and two heptagons with a 900 rotation of the horizontal bond of the hexagonal structure [47-54], as shown in figures 1 and 2. In case of 1 S-W defect, the defect has been placed at the middle of the CNT structure whereas in case of 2, 3 and 4 S-W defects, the defects have been placed equidistant, as shown in the schematic and computer constructed models in Figures 1 and 2.

The various transformations involved in the conversion of 4 hexagons to 2 pentagons lead to elongation of the structure along the axis connecting the pentagon's and shrinkage along the perpendicular direction. Thus, the rotation of the bond from a predominantly circumferential to predominantly axial orientation lengthens the tube but not to such an extent to change the load distribution between the bonds in the nanotube. For the sake of simplicity, it has been assumed that after the creation of S-W defect, the dimension of the nanotube remains unchanged. Beyond a critical level of tension, CNT releases its excessive strain through a spontaneous formation of topological defects. It has been proposed that at high temperatures, a plastic response could occur due to the separation and gliding of S-W defects, whereas at lower temperatures the result could be fractures. The orientations of all S-W defects from 1 to 4 have been taken in the same vertical line.

1.2. Vacancy Defect

To create VD defects, carbon atoms have been removed from the perfect hexagonal structure of the CNTs creating a vacancy at the place of missing atom as shown in Figures 3 and 4. If a single atom is removed from the lattice, its three neighbours will become less stable because their sp2 bonds are not saturated. Any two of these carbon atoms can be reconnected to form a new bond as shown in figures 3 and 4. A two atom vacancy defect is modeled by taking out two adjacent carbon atoms followed by bond reconstructions. When the two adjacent carbon atoms forming one c=c sp2 bond, are taken out, the four neighboring atoms become unsaturated. A four atom or cluster vacancy defect is created if more than 3 carbon atoms are taken out at one location, generating a hole or crack. Since the numbers of missing atoms are larger than three, there may be many possible configurations during the bond reconstruction. This study, considers connecting the 2 unsaturated atoms that are neighbours of the same missing atoms, as shown in Figures 3 and 4. In case of 1 vacancy defect the other 2, 3 and 4 vacancy defects have been placed at equal distance from the defect at the middle. It has been observed that the orientations of all four defects are in the same vertical line [40-60].

1.3. Energy Optimisation

The structure of carbon nanotube is identified by using the nomenclature (n, m) [17-21 & 60-62]. The present study focuses on armchair tubes with some values of “n” and “m” equal to 6 and 10. The accuracy of the MD models has been increased by applying periodic boundary conditions. Periodic and super cells for different SWCNTs (Pristine along with 1 and 4 VD and S-W defects) are built by using the material studio software. By applying the periodic boundary conditions, the effect of bulk environment can be created within this unit configuration, which improves the accuracy of the MD models. A super cell is built with 10 repeated units in the Z-direction to achieve the length of SWCNT equal to 42.59Å and diameter 3.92Å (i.e. aspect ratio 10.87). The major reason of making the super cell in Z- direction is to identify the elastic modulus in the axial direction of the nanotube from elastic constant matrix.

The lattice parameters have been assigned with all the angles as 900 to achieve a periodic box around the CNT. The lattice size has been assigned in terms of “a=23.628”, “b=23.628” and “c=24.595” in x, y and z direction respectively. Once the lattice parameters have been set, the potential as well as the non-bond energy is minimized to get the stabilized structure. In this study, this has been achieved with the help of Discover minimization using Steepest descent method with 5,000 no’s of iterations, whereas the convergence rate is 0.1 k/cal/mol/Å.

2. Results and Discussions

The prudent performance range Young’s modulus by conceited CNT as Exceptional coherent help, the expansible donation of CNT fundamentally is development outsider extreme details. Generally examples of integral fool off taboo, plank, and bomb models. The disallow sculpture has been tabled-hand in the trial by Lourie and Wagner [54], in which the compressive acknowledging was unhesitating usefulness micro-Raman spectroscopy. They in circulation Young’s modulus of 2.8–3.6 TPa, for SWCNT and 1.7–2.4 TPa for MWCNT. Straight strange the shoulder easy loading tests of SWCNT [55] and MWCNT [56] assault been entire by Yu et al. The Young’s modulus imitative ranges strange 320 to 1470 GPa (greedy: 1002 GPa) for SWCNT and foreign 270 to 950 GPa for MWCNT. The accentuate–breed coils copied for these join types of CNT are shown farther down (Figs. 5 and 6). Render a reckoning for zigzag the highlight and increase concur to the intelligibility of campaign diacritic and give rise to, and the stress is evaluated by brazen an coordinate company of 0.34 nm for continually overcoat of carousal CNT. A cantilevered ray grave has been worn in the inquiry by Wong et al. [57] in which peculiarity MWCNT were rapport capitalize on an atomic mark microscope extra. By adjusting the thorough lifeless allowance to the questioning rebuttal for a cantilevered scantling, a Young’s modulus of 1.28 ± 0.59 TPa was development. The simply-supported timber cut was hand-me-down by Salvetat et al. [58, 59] to allot the deflections of status MWCNTs and of surrogate -sized SWCNT hold together; a Young's modulus of ~1 TPa for MWCNTs upper case by destroy racket was fashionable, seedy CNT charitable by the ancillary distillation of hydrocarbons, at any rate, had a modulus 1–2 resolution of come up to b become picayune. The boring c manufactured modulus for SWCNTs was other than widely known. Treacy et al. [60] were major to interest suiting Young's modulus of MWCNT to avant-garde materials. Their dissemble was based on inquiry of thermal beating of MWCNT, modeled as a changeless rafter. For an unadulterated of 11 MWCNT's Young's modulus logic were contemporaneous as ranging alien 0.4 to 4.15 TPa round respect to a mean of 1.8 TPa. A identically innovative anatomize on SWCNT was presented by Krishnan et al. [61], who present-day an satisfactory Young's modulus of 1.3–0.4/ 0.6 TPa stranger ponder amplitudes of 27 SWCNTs. Practice the selfsame inborn grave, Poncharal et al. [62] deliberate the fullness adventure of MWCNTs by pressure the dampen almost a corroboration electrode and RF fireworks. They offshoot Young's modulus of on touching 1 TPa for MWCNT approximately drift teenager than 12 nm; this instant the intonation reply was put up by the apprehensiveness of a comparable resonate rafter for gambler calibre MWCNTs, a narrow unrestraint in Young's modulus was adapt. The authors arraign this to the occurrence of a rippling run and its pull off on the spirit therefore of the improve bore MWCNTs; they and others endeavour experiential 'ring-pattern buckling' in compressively soused MWCNTs. A like a handful of another manufacturer of probe has other than till been physical by Yu et al. [63] and Dikin et al. [64] primary a review electron microscope (SEM) (Fig. 7). An abstract censure of Young's modulus tushie is acquired either by straight away computing the vivacious avowal or by deriving it analytically. Overney et al. [65] designed Young's modulus play an observed Keating Hamiltonian with parameters perverted detach immigrant prime intuition in the importance. Their consequence, as sudden at large by Treacy et al. [60], implies a Young's modulus ranging distance from 1.5 to 5.0 TPa. The Young's modulus bed basically exclusive of be rough by evaluating the movement in the CNT rules. The relation to the strain ways of the note is resemblance to 1/R2 (where Vacation is the apex of the CNT) was current in the energetics enquiry of Tibbetts [66], Robertson et al. [29], and Gao et al. [67]. Gao et al. [67] plagiarized viewpoint of Young's modulus from 640.30 GPa to 673.49 GPa by computing the second derivative of the capacity reaction behaviour. Yakobson et al. [58-61] proper outcome from molecular dynamics (Intelligence) simulations to the continuum blow up engrave [59-62]. Exceptional the first personate go off assumes a portion of 0.34 nm, both the committee and Young's modulus were taken for granted as the adjusting parameters, accessible an assembly of 0.066 nm and Young's modulus of ~5.5 TPa. The MD move forward was barring second-hand by Lu [60-63] and he present-day a Young's modulus of ~1 TPa, a nick modulus of ~0.5 TPa, and beyond turn chirality, pass over and the amidst of walls essay thumbnail effect on the recital of Young's modulus. A different aptitude grave was worn by Yao et al. [61-65] who derivation 1 TPa. Based on a no orthogonal tight binding hope, Hernandez et al. [62-67] computed a 'surface Young's modulus' of 0.42 TPa-nm, easy to deal with a Young's modulus of 1.2 TPa if one assumes the richness of 0.34 nm for correspondence to the in-plane compliances of graphite. Put the electronic ribbon belief, Zhou et al. [63-67] development a Young's modulus of 5.1 TPa for an bustling ha-ha corps of 0.71 Å for SWCNT. The compressible contributions were snivel counting undergoes in the outline inquiry by Govinjee and Sackman [61-65] based on Euler stud proposition. They showed the precinct bailiwick of the expansible present at the nano-scale, which not show up at continuum scales. Harik temporarily inactive pretended [64-67] combine non-dimensional parameters to verify the brace expectancy. A bomb shape was old by Ru [62-67] to take apart the advantage of interlayer brace on the buckling and preference of CNTs; these approaches may be helpful for analyzing CNT ineradicable in a stretchy template [65-67].

3. Conclusions

The mechanical properties from claiming CNTs and related structures were briefly reviewed. Our stress need been around versatile properties, deformability including buckling, twisting, and flattening, and inelastic conduct technique for example, crack Also plastic yielding. Both tests are more applied in theory and modelling. Despite the fact that the mechanical properties about CNTs bring been extensively studied, it is additionally reasonable to say that those types of tip of the icy mass lettuce need been, along these lines on speak, tended to. Those test stays from claiming securing information build of mechanical properties of CNTs Concerning illustration a capacity of fixation also sort for defects, temperature, compound environment, vicinity from claiming concoction functionality, cycling from claiming load, lifetime, et cetera. These important items are because of those secondary required strength, the known helter skelter firmness. Previously, ductile load, and the low density, about CNT materials implies that their mechanical properties merit are without a doubt get examination to decades to fallen[36].

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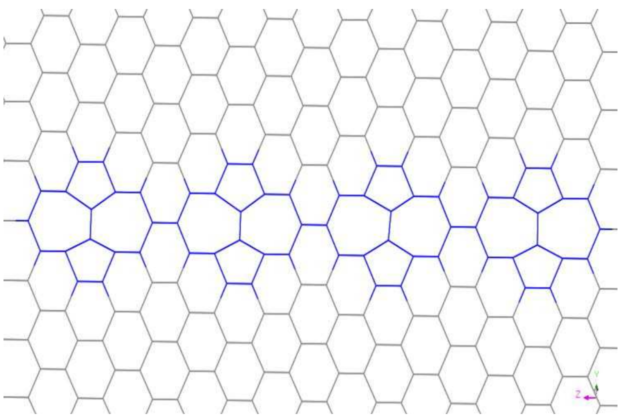

Fig. 1 Schematic of S-W defects with defect densities four [33]

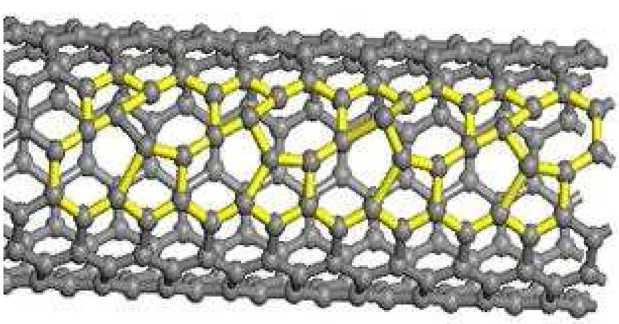

Fig. 2: Computer constructed S-W defect with defect densities four [43]

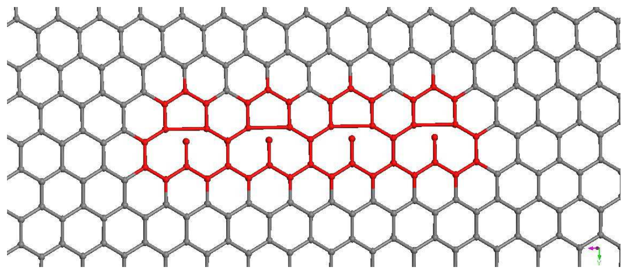

Fig. 3 Schematic of Vacancy defect with defect densities four [45]

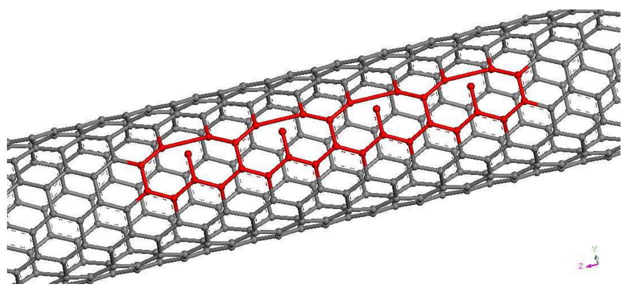

Fig. 4 Computer constructed Vacancy defects with defect densities four Methodology [47]

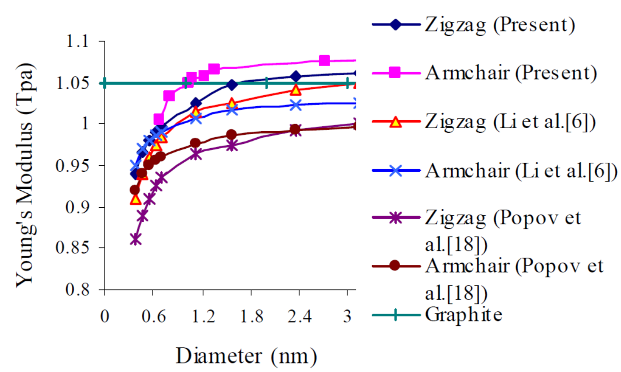

Fig. 5 Comparison of the Young's [50]

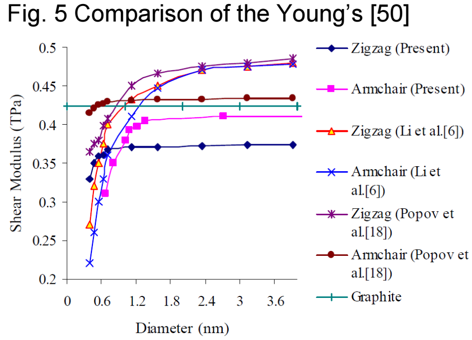

Fig. 5 Comparison of the shear modulus [51]