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Analysis of CNT Based Hybrid Composite Plate Using Material of Mechanics Approach and Fem

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ABSTRACT
Hybrid composite is a composite of organic and inorganic element which consists of nano particles to enhance the strength as compared to conventional composites. A model has been proposed to determine the elastic properties of hybrid composite. The hybrid composite consists of conventional fiber like carbon fiber and nanocomposite (carbon nano tube and polymer) as matrix. The first step here is to determine the properties of nanocomposite which is done by using Mori – Tanaka method with rule of mixture. The CNTs are considered as cylindrical inclusions in polymer matrix in Mori–Tanaka method. Assuming perfect bonding between carbon fibers and nano composite matrix, the effective properties of the hybrid composite has been evaluated using mechanics of materials approach.

A vibration analysis of simply supported shell element of A 8 layered laminate with stacking sequence [0 -45 45 90]S has been used 8 noded shell element has been used for the finite element analysis having 5 degrees of freedom each node (u , v, w, θx, θy). A finite element mesh, the shell coordinates which are in Cartesian form are converted into parametric form using two parameters (α1, α2) These parameters are again mapped into isoparametric form η , ξ. For vibration analysis of simply supported shell element. The dynamic equations of shell are derived using Hamilton's principle. As the damping characters of the dynamic system are not available, for further investigation damping ratio of first mode and last active mode are assumed. Using Rayleigh damping the damping ratios of intermediate modes can be calculated. The time decay of the system from maximum amplitude to 5% of the maximum amplitude has been used as a parameter to study various shell structures by varying the volume fraction of CNTs in nanocomposite and by varying carbon fiber volume fraction.

Keyword: *CNT's, Nano-composite, Carbon fiber, Epoxy, Elastic Property, Damping ratio, Frequency, Impulse Response.*

1. INTRODUCTION

As long as there is development in the field of aerospace, automobile, healthcare, electronics and consumer industry the demand for new materials will never seize. The demand for new materials has led to continuous research and development of new techniques to satisfy the needs. Nanocomposites consist of reinforcements of nanoscale spread evenly or randomly in polymer matrix. The commonly used polymeric matrix materials are:

- Epoxy
- Nylon
- PEEK – Polyether ether ketone
- Polystyrene
- Polyimide

The commonly used nano fillers are:

- Carbon nanotubes – SWCNTs and MWCNTs
- Nanoaluminium oxide
- Nanotitanium oxide
- Nanosilica
- Silver nanoparticles
- NanoMagnesium oxide
- NanoZinc oxide

Mainly three materials used in this hybrid composite

- Carbon nanotubes
- Peek
- Carbon fiber

Carbon nano tube are wonder material and contain unusual properties. High strength,much more elasticity, low density etc. carbon nano tubes are cylindrical inclusion of graphene sheet.Graphene are allotrope of carbon and form of hexagonal atomic structure. various types of carbon nano tube are available in different chirality like zig-zag, armchair, chiral form. Carbon nano tubes dimension are measured on the nano scale .and diameter of cnt's are 1 nm to 5nm.Owing to the material's exceptional strength and stiffness, nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material.

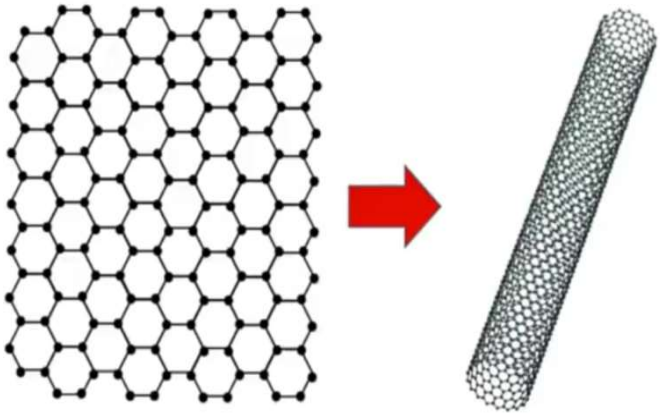

Figure 1: Graphene Sheets Are Rolled In Cylindrical Shape in the Form Of Cnt's

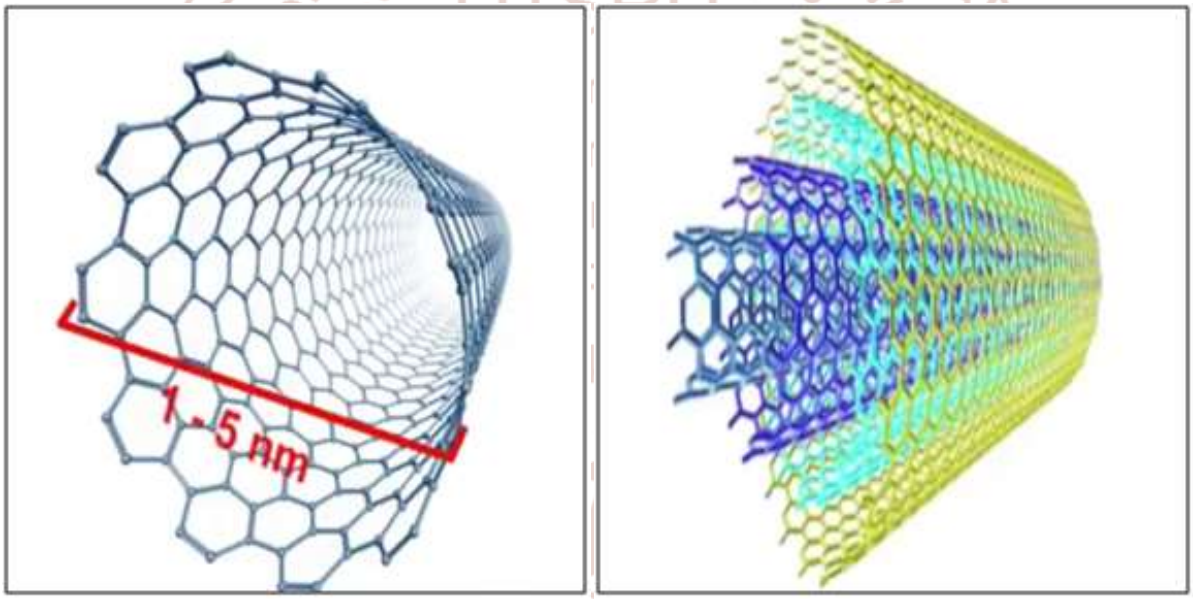

Figure 2: Single wall And Multi wall carbon nanotube structure

Elastic modulus (E)	1 Tpa
Tensile Strength (σ)	63 Gpa (9,100,000 Psi)
Endure Tension (W)	62,980 N/mm2 (6422 Kg/mm2 on a cable)
Specific Strength	48000 KN-m/Kg (154 of HC steel)
Aspect Ratio (L/D)	132,000,000:1
Density (ρ)	1300 Kg/m3
Electric Current Density	4×10^9 A/cm2 (1000 > copper)
Diameter Range (D)	0.4 – 40 nm
Thermal Conductivity (k)	3500 W/m-k (along the tube axis)
Thermal Conductivity (k)	1.52 W/m-k (across the tube axis)
Thermal Stability	2800^0 C (in Vacuum), 750^0 C (in Air)

Table 1: Properties of Carbon Nanotube

The reinforcements can be particles or fibres of size of few nanometers. The nanocomposite has a wide range of materials from 3-D metal matrix composites, 2-D laminated composites and nano-wires of small dimension representing variations of nano reinforcements.Using nanoscale reinforcements built a nanocomposite using polyimide and organophilic clay. The nanocomposite formed had twice the tensile modulus as compared to neat polyimide with just 2% volume fraction of nano reinforcement. Nanocomposites have gained a wide popularity among researchers. Researchers have discovered that the properties of the nanocomposite are better when compared to the individual components of the composite. Properties such as increased tensile strength, increased thermal conductivity are observed.

2. Literature Survey

Raifee et al et al.[1991] Estimated mechanical properties of epoxy based nanocomposite with SWCNT, MWCNT and graphene platelets were compared for weight fractions of 0.1%. The material properties measured were Young's modulus, fracture toughness, ultimate tensile strength. The tensile strength of graphene based nanocomposites showed better properties as compared to CNT based nanocomposites.

F. H. Gojny et al [1993] observed mechanical properties resulted in an increase in Young's modulus, strength at weight fractions of 0.1%. There was good agreement between experimental observed data and results from modified Halpin-Tsai relation.

Florian H et al.[1993] proposed choosing appropriate type of CNTs (SWCNTs or DWCNTs or MWCNTs) has been a problem ever since they are being used in composites. They evaluated the properties of nanocomposite for different nano fillers. The nanocomposites exhibited greater strength, stiffness and fracture toughness. They found that DWCNT based nanocomposite exhibited greater fracture toughness.

Seidel et al [1994] Effective elastic properties of composites consisting of aligned SWCNTs or MWCNTs using Mori-Tanaka method. The effects of an interphase layer between CNTs and the polymer is also investigated using a multi-layer composite cylinders approach.

Liu and Chen et al.[1996] Estimated effective elastic properties of the nanocomposite are evaluated using continuum modelling and finite element method. The extended rule of mixture is used to determine the properties of the continuum model.

Dutra et al et al.[1998] made a hybrid composite consisting of carbon fiber and Polypropylene fiber and mercapto-modified polypropylene blend fiber (PPEVASH). They found that hybrid composites showed better impact resistance than CFRP composite.CNTs were grown on unidirectional carbon fiber. These fibers were used as reinforcements in matrix material. They found that the mechanical properties improved with increase in amount of CNT deposition as compared to neat CFRP composite.

Garcia et al [1999] CNTs were grown on alumina fiber cloth. These fibers were used as reinforcements in matrix material. The growth of CNTs led to an increase in inter-laminar shear properties of the order of 69% as compared to alumina cloth composite the elastic properties of FFRC (Fuzzy fiber reinforced composite) using mechanics of materials approach and Mori-Tanaka method considering with and without the interphase between CNT and polymer.

Gibson et al [**2000**] used vibration used modal vibration response measurements to characterize the mechanical properties of laminated structures. They showed that vibration in either first mode or multiple modes can be used to determine the elastic properties and damping ratios. Modal testing was done by impulse excitation methods found damping ratio using experimental methods and by FEM. The FEM uses Rayleigh damping method and particularly mass proportional damping. even a small volume fraction of CNT can increase the sound absorption capabilities.

Suleyman Basturk et al [**2014**] Nonlinear demped vibration of a hybrid laminated composite plate subjected to blast load used Finite element analysis for investigate vibration frequency of three layer hybrid laminate composite made by glass fiber ,Kevlar/Epoxy, basalt fiber, and varies outcomes Found ply material property, damping ratio using experimental methods and by FEM. The FEM uses Galerkin damping method for time domain and aspect ratio & different peak pressure value.

N. K. Gavade et al [**2016**] A Review on Hybride composite: Fabrication, Properties and Application.

This work with Introduce to hybrid composite and investigate properties of hybrid composite and natural fiber /epoxy composite

Kyriazoglou and Guild et al [**2016**] A Research of Damping measurement in composite material using combined FEM & frequency response method. In this works investigate the natural frequency and various node shape and also found damping ratio using experimental methods and by FEM. The FEM uses Rayleigh damping method and particularly mass proportional damping.

Mr. N. Subramani et al [**2017**] Review on Hybrid Composite Materials and its Applications The following studies help us to know the recent technology aided with the composite materials manufacturing and its applications. It will give an outline to the researches to carry out their research effectively in this stream.

3. Problem Identification & Research Objective

The basic problem definition is as follows

- Kevlar based fiber that is to be high tensile strength but it is absorb moisture and low weather resistance, for cutting used special tools.
- E-glass fiber reinforces polymer composite poor rigidity and stiffness, GFRP are brittle and low impact resistance.
- Basalt fiber are also high strength but only used in the field of structure.
- Traditional material is very low strength weight ratio, and part element create maximum noise, vibration, and harshness dampening.

The main research objectives is as follows

- Reduction in weight to aid enhanced the same strength for related component
- Reduction in vibration to aid enhanced fatigue life for parts product
- Improving the strength of Hybrid composite material for related component instead of tradition material
- Improving mechanical property, Minimize the strength weight cost ratio of material

4. Methodology

- Material modelling and material characterization
  - Carbon nanotubes Structural modeling using nanotube modeler @ 2018 Jcrystalsoft
  - Nanocomposite has been modelled using Mori – Tanaka method. And rule of mixture for found elastic property.
  - Hybrid composite consisting of Carbon fiber ,Carbon nano tubes, polymer matrix(epoxy) has been modelled using mechanics of materials approach.
- 8 noded shell element formulation
  - Mindlin theory of plates and shells has been used to model shell.
- Modelling damping and Impulse response
  - Rayleigh damping has been used to model the damping of MDOF system.
  - Impulse response of the system has been carried out using the state space model.
- The material modelling is divided in three phases:
  - Carbon Nano Tube Structure Modelling.
  - CNT based nanocomposite modelling.
  - Hybrid composite modelling.

According to Molecular Mechanics Modelling Dresselhaus described SWNTs in terms of the tube diameter (d) and its chiral angle (θ). The chiral vector (C_h) was defined in terms of the graphene sheet lattice translation integer indices (n,m) and the unit vectors (a_1,a_2) represented in figure, and it is defined as follows:

$$\overrightarrow{C_h} = n\overrightarrow{a_1} + m\overrightarrow{a_2} \quad (1)$$

Where the unit vectors in (x,y) coordinates are defined as:

$$\overrightarrow{a_1} = \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)a \quad , \quad \overrightarrow{a_2} = \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)a$$

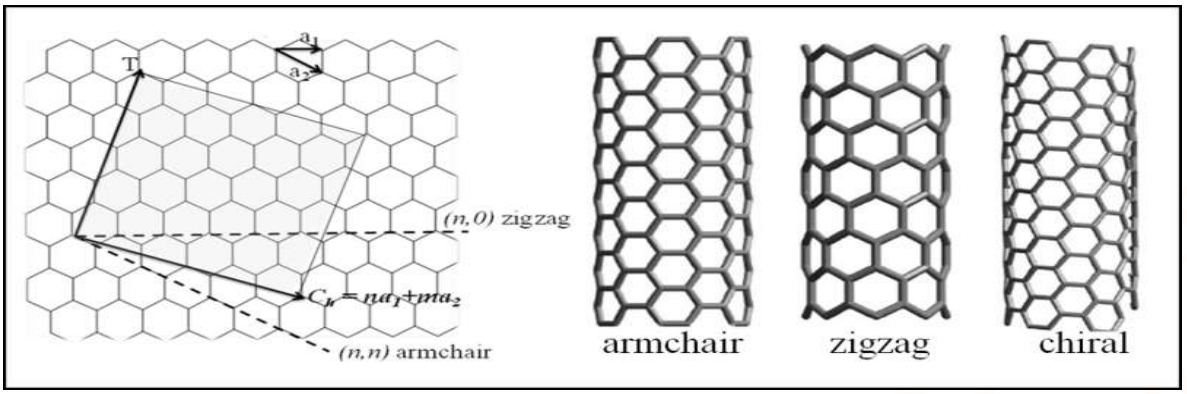

Figure 3: Molecular Mechanics Modeling

The length of the unit vector a is defined as 2.46 angstroms, or 1.73 times the carbon-carbon distance (1.421 angstroms). The nanotube circumference (p) was defined by:

$$p = |C_h| = a\sqrt{n^2 + m^2 + nm}$$

From simple geometry, it is possible to obtain the nanotube diameter (d) as:

$$d = \frac{p}{\pi} = \frac{a}{\pi}\sqrt{n^2 + m^2 + nm}$$

Where a = 0.246 nm

SWNTs are an important variety of carbon nanotube because most of their properties change significantly with the (n,m) values, and this dependence is non-monotonic and the chiral angle (θ), between 0 and π/6 rad, was described by Dresselhaus:

$$\sin\theta = \frac{\sqrt{3}m}{2\sqrt{n^2 + nm + m^2}}$$

$$\cos\theta = \frac{2n + m}{2\sqrt{n^2 + nm + m^2}}$$

5. Result and Analysis

Property Analysis through nanotube modeler @ 2005-2018 Jcrystalsoft

1. Property of nano tube are depend on given value

Chirality (n,m) = (8,8)
Tube length (L) = 100 nm
Bond length (A) = 0.142 nm
No. Of wall = SWNT's

Outcomes

Diameter of nanotube = 0.542 nm (from diameter calculator)
No. Of atoms = 1312
No. of bonds = 1952
Atom coordination X = 0.5427, Y = 0.0000, Z = 9.598
Moulus of elasticity (E) = 1Tpa
Strength (σ) = 62300 Mpa

2. Property of nano tube are depend on given value

Chirality (n,m) = (25,25)
Tube length (L) = 100 nm
Bond length (A) = 0.142 nm
No. Of wall = 2
Property Analysis through carbon nanotube modeler @ 2005-2018 Jcrystalsoft

Outcome:

Diameter of nanotube = 1.62 nm (from diameter calculator)
No. Of atoms = 12407
No. of bonds = 8340
Atom coordination X= 1.657, Y = 0.0000 , Z = 9.598
Modulus of elasticity (E) = 1180 Gpa
Strength (σ) = 63000 Mpa

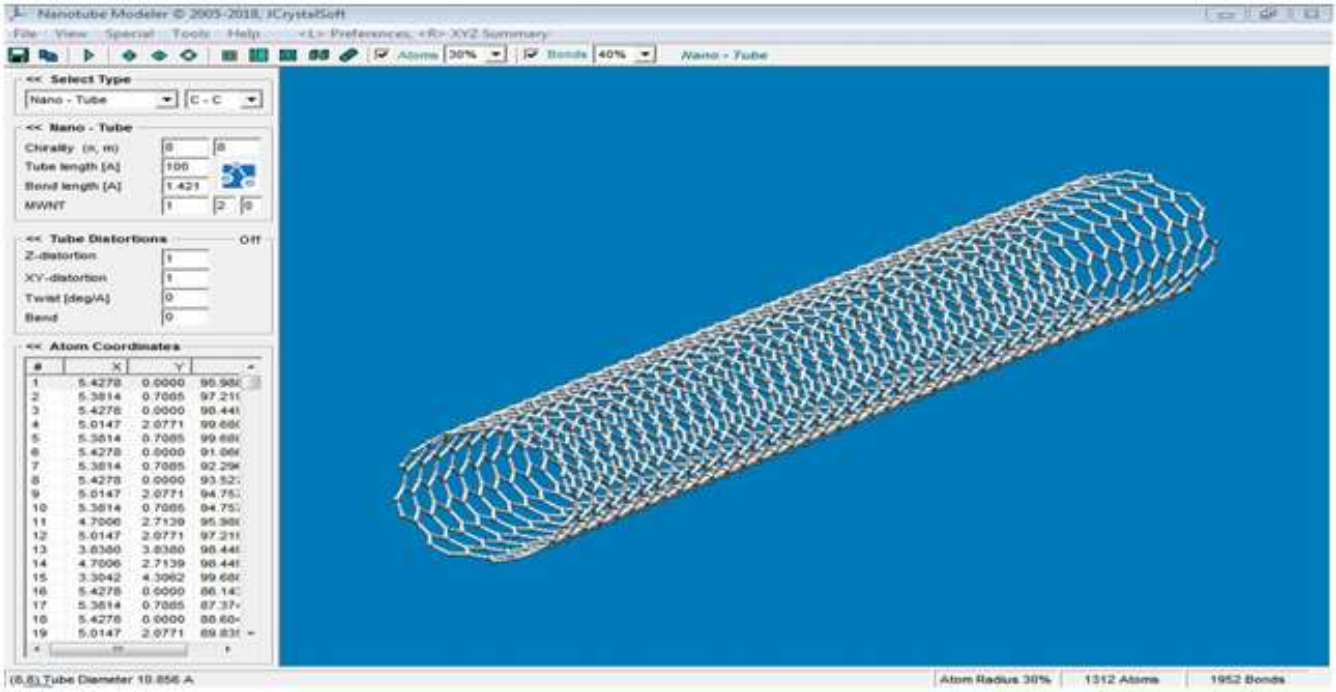

Figure 4: Represents geometrical parameter of SWCNT with (8, 8) Chirality

It can be seen that as the carbon nano tube properties are depend on the chirality configuration and diameter. If diameter of the tube are increase the elastic property and strength are also increase. When chirality is (8, 8) then diameter 0.542 nm and elastic modulus is 1 Tpa , It is increase with chirality (25,25) then dia. 1.62 nm and E = 1180 Gpa.

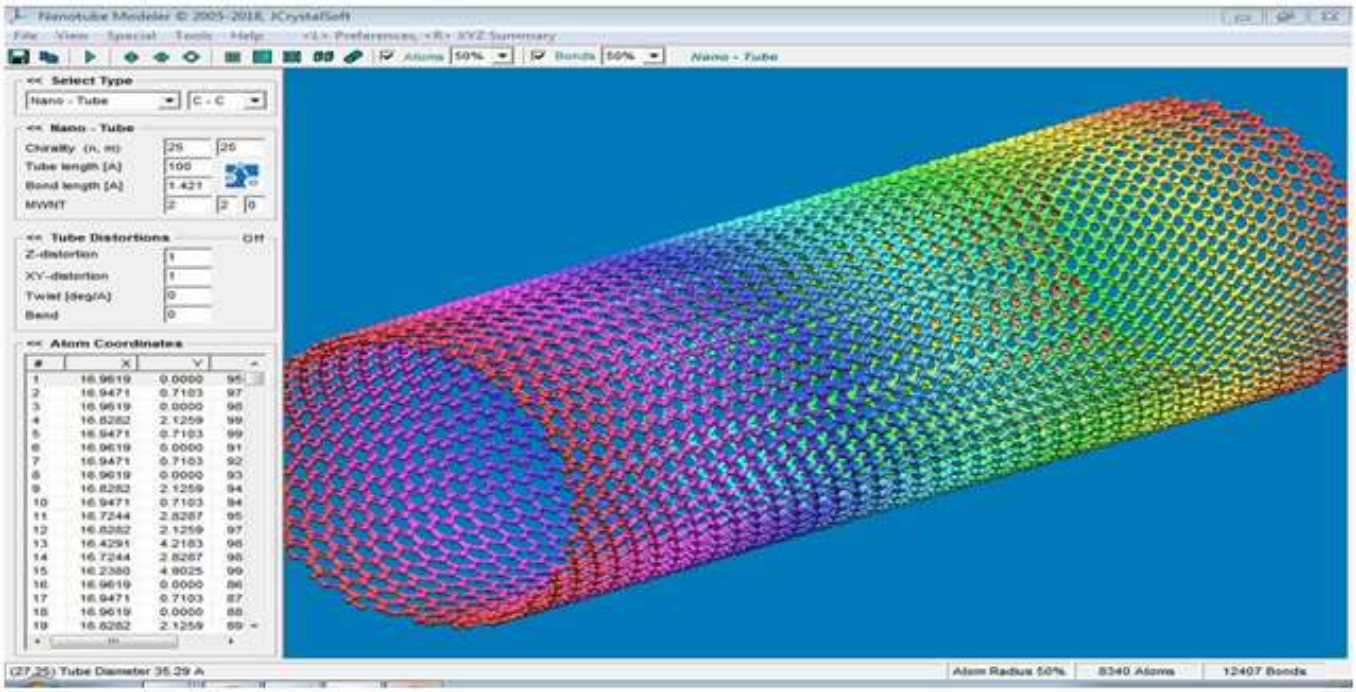

Figure 5: Represents geometrical parameter of MWCNT with (25, 25) Chirality

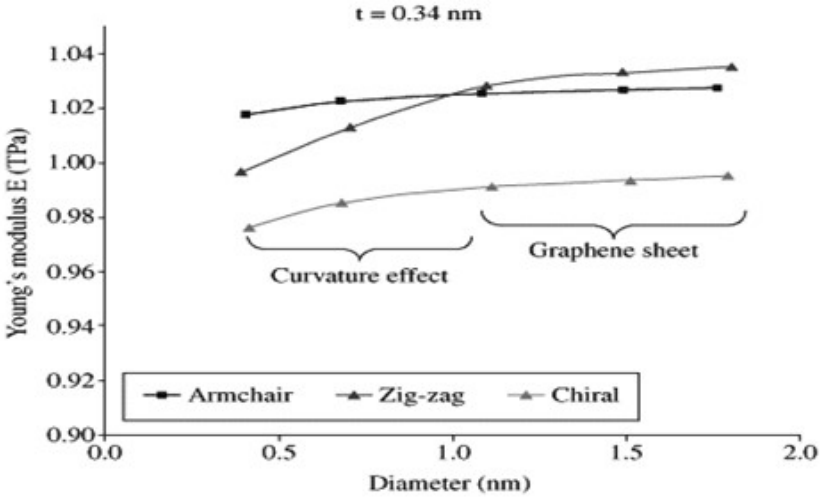

Figure 6: Relation b/w Young modulus and diameter of cnts according to Pantano

Hybrid Composite Material, Strength weight and price ratio Cost analysis of separate material according to indiamart products & supplier and alibaba.com

Material/property	Strength (σ)	Modulus of Elasticity	Density (ρ)	Price in india
Carbon nano tube	63000 Mpa	1000 Gpa	1300 kg/m^3	45000 Rs./Kg
Carbon fiber	7000 Mpa	500-900 Gpa	2000 kg/m^3	10000 Rs./Kg
Poly Ether Ether Ketone	90 - 100 Mpa	3.6 Gpa	1320 kg/m^3	5000 Rs./Kg
Epoxy Resin With Hardener	85 Mpa	10.7 Gpa	1070 kg/m^3	500 Rs/Kg
Steel	210 Mpa	200 Gpa	7800 kg/m^3	50 Rs/Kg

Table 2: Separate Materials and their property with price

6. Conclusions and Future Work

1. In this study, modal analysis was carried out using nano tube modeler software for specify the elastic property and strength of carbon nano tubes who is increase with increase the diameter of tube,
2. Hybrid composite material are very small specific gravity as compare to traditional metallic composite, hybrid composite are six times lighter and five times elastic and 100 time strength then steel
3. The hybrid composite has been modeled using Mori-Tanaka method and mechanics of materials method. It is found that

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