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Analysis Elastic Properties of Hybrid Composite Plate for Different Volume Fraction of CNT

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ABSTRACT

Hybrid composite is an advanced composite material that is made of inclusion of nano composite with natural or synthesis fiber. Nano composite is inclusion of nano material like carbon nano tube with epoxy or polymer as matrix. The first step here is to Find the Elastic properties and strength of carbon nano tube for different chirality (10,10) for SWCNTs and (25,25) for MWCNTs by using nanotube modeler software. The Second step is find out the elastic properties of nano compositefor different volume fraction of CNTs by using Rule of mixture and Mori – Tanaka method. In the Mori-Tanaka method, CNT is included in cylindrical form in the form of polymer matrix. Here, the effective properties of hybrid composite have been analyzed using material of mechanics. In this, correct bonding between carbon fiber and nano composite has been considered. A hybrid composite consist 8 layered laminate with stacking sequence [0 -45 45 90]Sand analyse elastic properties for different volume fraction of carbon nano tube and carbon fiber.

KEYWORDS: *Nano Composite, Single wall carbon nano tube(SWCNT), multi wall carbon nano tube(MWCNT), Carbon fiber reinforcement, Elastic Property.*

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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.

1.1. Carbon nano tube

Carbon nanotubes are amazing materials with unique characteristics. Incorporating carbon nanotubes (CNTs) into polymers to create composite materials has been a prominent trend in the research community in recent years [1]. The remarkable mechanical, electrical, and thermal properties of carbon nanotubes (CNTs) make them ideal for reinforcing polymer composites. High strength, much more elasticity, low density etc.[2]. A cylindrical component of graphene sheets are carbon nanotubes. Graphene is a carbon allotrope with a 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.Because of the material's remarkable strength and rigidity, nanotubes have been made with a very high diameter to length ratio-roughly 1:132,000,000-when compared to other materials.[3]

Nanocomposite;

Nanocomposite are inclusion of nano material with polymer or epoxy as a matrix. 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 [4]. 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. [6] Nanocomposites have gained a wide popularity among researchers. Because their wonderful properties.

Hybrid Composites

The important properties that are desired from any composite are strength, stiffness, ductility, toughness, damping, energy absorption, thermal stability and low weight. With conventional materials it is not possible to get all the desired properties, but with composite materials we can tailor the properties of material as per our needs. By using reinforcements of nanoscale in polymer composites there has been tremendous increase in mechanical properties as compared to neat polymer matrix. Hybrid composites are new type of three phase composites which have reinforcements of nanoscale in addition to conventional reinforcing fiber in matrix or by growing reinforcements of nanoscale on the surface of fiber. Hybrid composites as composites consisting of different fibers. The main purpose of using hybrid composites is it increases the matrix dominated properties.[10]

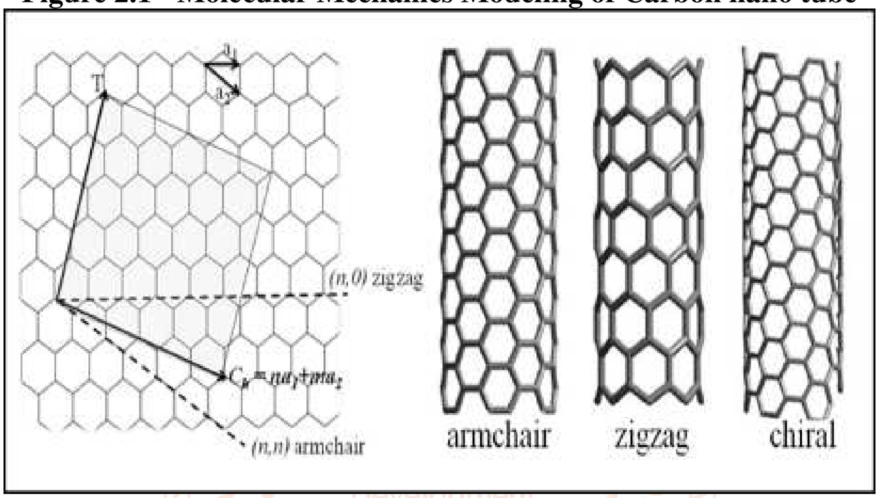
Objectives:

1. Estimate The Elastic Properties & Strength of carbon nano tube.
2. Determine The Elastic properties of hybrid plate by variation of Carbon Fiber and Carbon nano tube Volume Fraction.
3. Observe the Decay Time and impulse response for Thick & Thin Plate by Varying the Cnt Volume Fractions for Different Volume Fractions of Carbon Fiber.

Improving the strength of Hybrid composite material for related component instead of traditional material.

2. METHODOLOGY

Figure 2.1 - Molecular Mechanics Modeling of Carbon nano tube



2.1. Carbon Nano Tube Structure Modelling.

According to Molecular Mechanics Modelling Dresselhaus described SWNTs in terms of the tube diameter (d) and its chiral angle (θ). 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 Geometry, the nanotube diameter (d) is found by following equation:

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

Where a = 0.246 nm The properties of SWNTs are dependence on the chiral angle (θ),[between 0 and π/6 radian] and (n, m) values, was described by Dresselhaus:

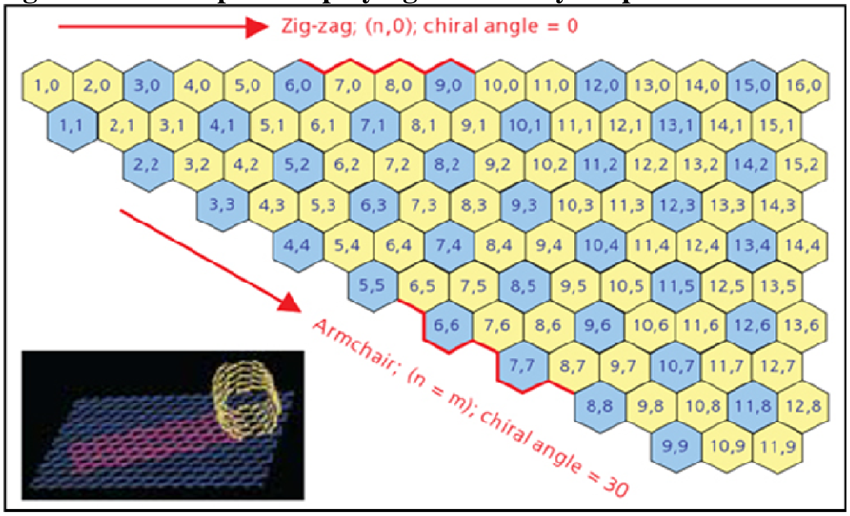
$$\sin\theta = \frac{1.73m}{2\sqrt{n^2 + nm + m^2}}$$

$$\cos\theta = \frac{0.5m + n}{\sqrt{n^2 + nm + m^2}}$$

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

2.2. The nanocomposite modelling for Epoxy or Polymer matrix inclusion of CNTs.

Figure 2.2-A Graphic Displaying A Chirality Map &Nomenclature



The nanocomposite consists of epoxy or polymer matrix with randomly distributed straight MWCNT as reinforcements. As the CNTs are randomly distributed the nanocomposite can be modelled as isotropic material. Mori – Tanaka method is used for evaluated the property of nanocomposite. Assuming perfect bonding between fiber and nanocomposite the hybrid composite can be modelled similar to conventional composite using mechanics of materials approach.The Mori – Tanaka method was used to estimate the elastic properties of the CNTs in matrix. The procedure to determine the isotropic properties of randomly oriented MWCNTs dispersed in epoxy matrix is as follows: The Hill's elastic constants for the MWCNT can be obtained by equating the stress – strain matrix of MWCNT with the Hill's elastic matrix.

$$[C_{cnt}] = \begin{bmatrix} C_{11}^{cnt} & C_{12}^{cnt} & C_{13}^{cnt} & 0 & 0 & 0 \\ C_{21}^{cnt} & C_{22}^{cnt} & C_{23}^{cnt} & 0 & 0 & 0 \\ C_{31}^{cnt} & C_{32}^{cnt} & C_{33}^{cnt} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44}^{cnt} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55}^{cnt} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66}^{cnt} \end{bmatrix} \quad (1)$$

$$[C_{cnt}] = \begin{bmatrix} n_r & l_r & l_r & 0 & 0 & 0 \\ l_r & k_r + m_r & k_r - m_r & 0 & 0 & 0 \\ l_r & k_r - m_r & k_r + m_r & 0 & 0 & 0 \\ 0 & 0 & 0 & m_r & 0 & 0 \\ 0 & 0 & 0 & 0 & p_r & 0 \\ 0 & 0 & 0 & 0 & 0 & p_r \end{bmatrix} \quad (2)$$

Eqn (1) and eqn. (2) are Hill's elastic matrix also known as the stress – strain matrix of MWCNTs.

Two Euler angles *a* and *b*are orientation of the CNT. The base vectors e_i and e_j of the global and local co-ordinates can be related by the relation.

$$K_{nc} = K_m + \frac{v_{cnt}(\delta_{cnt} - 3K_m \alpha_{cnt})}{3(v_m + v_{cnt}\alpha_{cnt})} \quad (3)$$

$$G_{nc} = G_m + \frac{v_{cnt}(\eta_{cnt} - 2G_m \beta_{cnt})}{2(v_m + v_{cnt}\beta_{cnt})}$$

$$E_{nc} = \frac{9K_{cn}G_{nc}}{3K_{nc} + G_{nc}}$$

$$v_{cnt} + v_m = 1 \quad (4)$$

Here, ν_{cnt} = Volume fraction of carbon nano tube. V_m = volume fraction of matrix material.

Where,

$$g_{ij} = \begin{bmatrix} cos\beta & -cosasin\beta & sin\alpha cos\beta \\ sin\alpha & cos\alpha cos\beta & -sin\alpha cos\beta \\ 0 & sin\alpha & cosa \end{bmatrix}$$

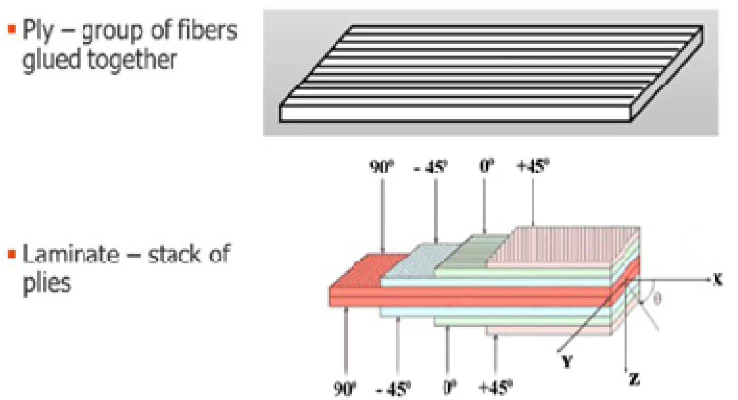
Here the stresses and strains of Nano composite obtained by rule of mixture. And other properties like The bulk modulus, shear modulus, Young's modulus of the nanocomposite are obtained by following equations with different volume fraction of CNTs.

2.3. Hybrid composite modelling.

1. Using the above calculated nanocomposite properties, the properties of the transversely isotropic hybrid composite can be evaluated by the formulation of fuzzy fiber.
2. Assuming perfect bonding between carbon fiber and nanocompostie, the normal strains in hybrid composite, carbon fiber and nanocomposite are equal along the fiber direction.
3. Using rules of mixture one can express the longitudinal and transverse stresses and strains in terms of volume fractions of nanocomposite and carbon fiber.

Hybrid Composite Geometry: A vibration analysis of simply supported plate element of A 8 layered laminate with stacking sequence [450 -45 90]shas been used 8 node element has been used for the finite element analysis Thick plate 8 layered laminate with stacking sequence [450 -45 90]s

Figure 2.3. - Stacking sequence of fiber [450 -45 90]s



Dimension of HC plate:

Total Length of plate = 30 cm

Width of plate = 100 mm

Thickness of plate = 2.4 mm

Length & Thickness ratio = 1:10

Radius curvature &Length Ratio = 1:500

RULE OF MIXTURES

Elastic properties and stiffness of hybrid composite are find out by using rule of mixtures (mechanics of material approach).

2.3.1. Longitudinal Modulus Unidirectional;

The total resultant force on the element must equal the sum of the forces acting on the fiber and matrix for static equilibrium.

$$\varepsilon_c = \varepsilon_f = \varepsilon_m$$

$$\sigma_c A_c - \sigma_f A_f + \sigma_m A_m$$

Where, A_c=*cross section area of composite*, A_f=*area of fiber*, A_m=*area of* Then,

we can also say that:

$$\sigma_c - \sigma_f V_f + \sigma_m V_m$$

Invoking Hooke's Law, we get

We know

E=σ/ε or σ = Eε

$$E = \frac{\sigma}{\varepsilon} \; or \; \sigma = E\varepsilon$$

$$E_c\varepsilon_c = E_f \varepsilon_f V_f + E_m \varepsilon_m V_m$$

Here assume $\varepsilon_c = \varepsilon_f = \varepsilon_m$

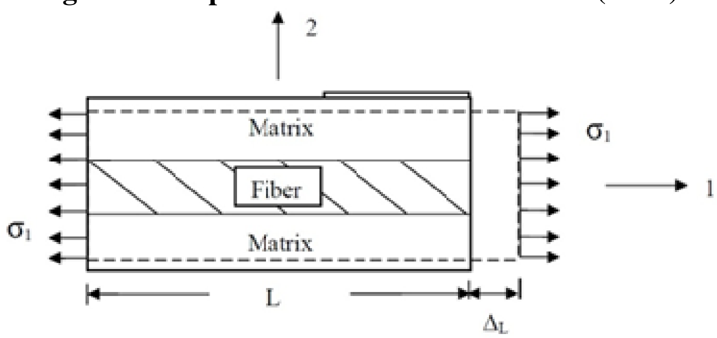
Therefore,

$$E_c = E_f V_f + E_m V_m$$

$$E_c - E_f V_f + E_m(1 - V_m)$$

Parallel combination rule of mixtures.

Figure 2.4 Representative Volume Element (RVE)



2.3.2. Transverse Modulus Unidirectional;

Equal displacements assumption: the total transverse composite displacement in the 2-direction, δ_{C2}forGeometric compatibility, must equal the sum of the corresponding transverse displacements in the fiber, δ_{F2}, and the matrix, δ_{M2}.

Therefore;

$$\delta_{C2} - \delta_{F2} + \delta_{M2}$$

Volume Fraction

$$\frac{1}{E_c} = \frac{V_f}{E_F} + \frac{V_m}{E_m}$$

E_c is Equation of modulus Series combination rule of mixtures

$$\varepsilon_c = \varepsilon_f V_f + \varepsilon_m V_m$$

Then,

$$E_c = \frac{E_f V_f}{\left(E_f V_f + E_m(1 - V_f)\right)}$$

we can write the is o field conditions

$$v_f + v_{nc} = 1$$

3. RESULTS AND DISCUSSION

3.1. A Model Has Been Proposed To Determine The Elastic Properties & Strength Of CNT

Property Analysis through nanotube modeler @ 2005-2018 J crystal soft

1. Property of nano tube are depend on given value

Table 01: Input parameters and Outcome of carbon nanotube for chirality (n,m)

Input Parameters For Chirality		**(10,10)**	**(25,25)**
1	Tube length (L)	100 nm	100 nm
2	Bond length (A)	0.142 nm	0.142 nm
3	No. Of wall	SWCNT's	MWCNT's
Outcomes		**(10,10)**	**(25,25)**
1	Diameter of nanotube	1.35 nm	3.5 nm
2	No. Of atoms	820	8340
3	No. of bonds	1210	12407
4	Atom coordination	X=6.78, Y=0.0, Z= 46.7	X=16.9, Y=0.0, Z= 95.3
5	Modulus of elasticity (E)	1Tpa	1180 Gpa
6	Strength (σ)	62300 Mpa	63000 Mpa

It can be seen that as the carbon nano tube properties are depend on the chirality configuration and diameter. If diameter of the tube is increase the elastic property and strength are also increase. When chirality is (10,10) then diameter 1.35 nm and elastic modulus is 1 Tpa , It is increase with chirality (25,25) then dia. 3.5 nm and E = 1180 Gpa.

Figure 3.1 – Represents geometrical parameter of SWCNT with (10, 10) Chirality

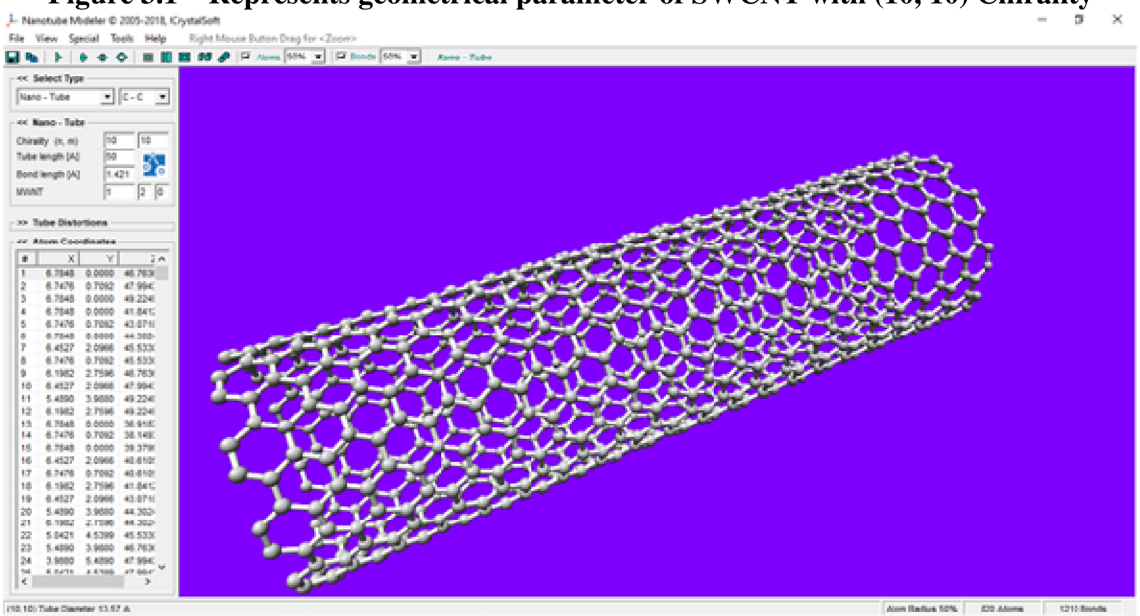


Figure 3.2 – Represents geometrical parameter of MWCNT with (25, 25) Chirality

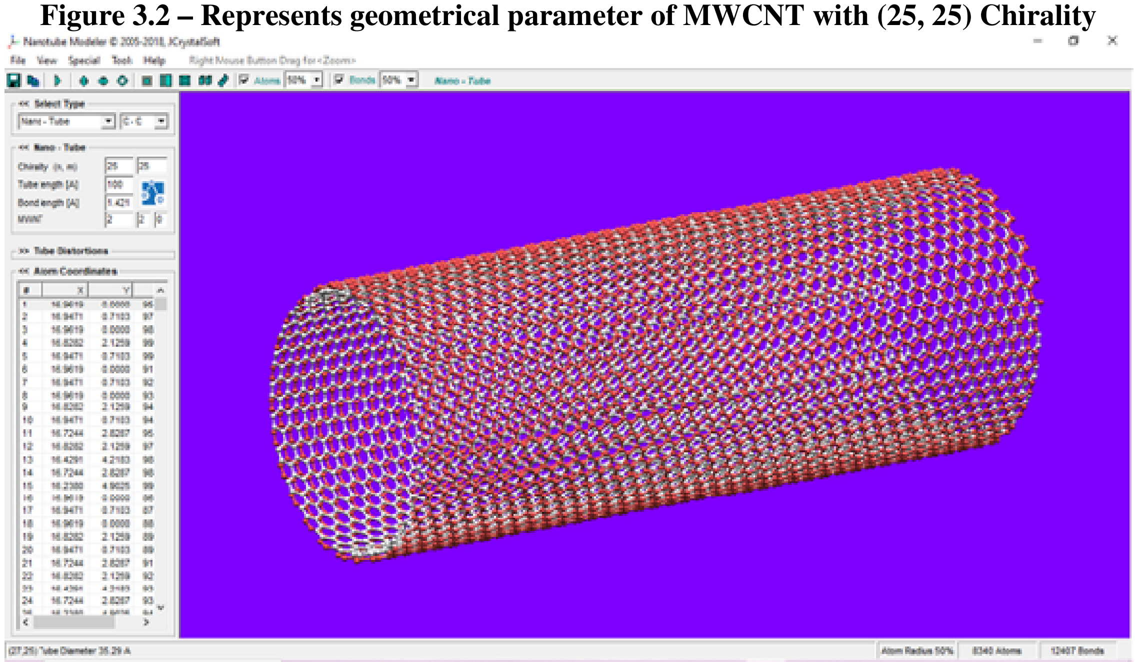


Table 02: Relation b/w Young modulus and diameter of cnts according to Pantano A[6]

	Young's Modulus E (TPa)		
Diameter	Armchair	Zig-zag	Chiral
0.5	1.01	0.99	0.97
1.0	1.022	1.025	0.985
1.5	1.02	1.028	0.988
2.0	1.018	1.03	0.99

3.2. Material Properties of Various Influence of Coefficient:

Properties of various constituents of Hybrid composite From Fig. 3.3, it can be seen that as the carbon fiber volume fraction increases the longitudinal elastic properties increase. At lower volume fractions of carbon fiber (20%) it can be observed that for carbon fiber reinforcement composite the elastic modulus is around 60GPa, but with the increase in volume fraction of CNT from 1% to 5% the elastic modulus has increased from 63GPa to 74GPa. With the increase in carbon fiber volume fraction, the volume fraction of nanocomposite goes on decreasing; as a result the elastic properties almost converge at higher volume fractions of carbon fiber.

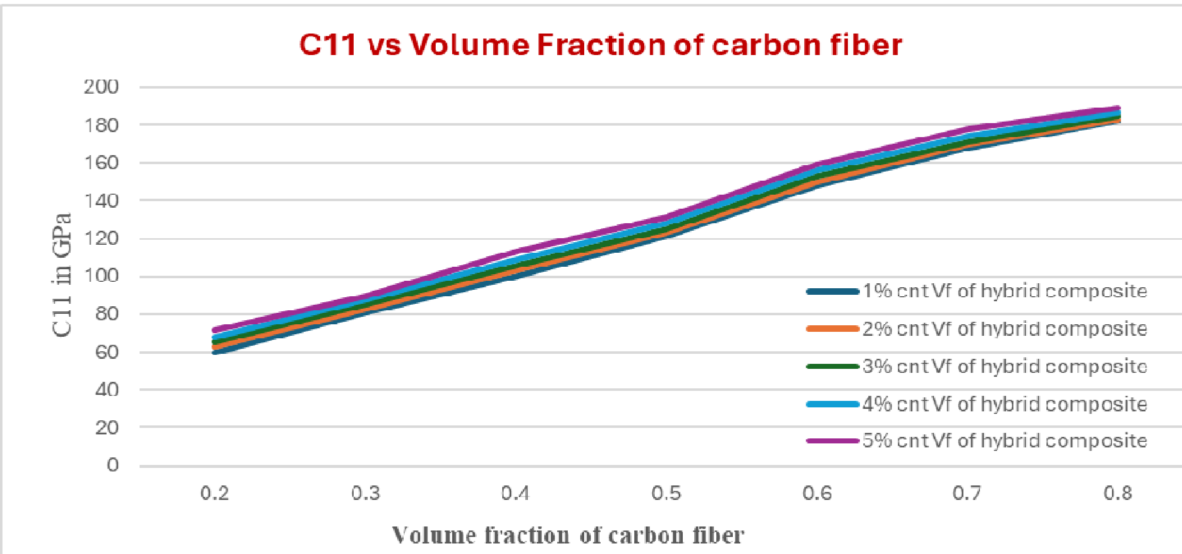


Figure 3.3 Variation Of C_{11} W.R.T Variation Of Carbon Fiber AndCnt Volume Fraction

From Fig. 3.4 and Fig. 3.5, similarly as C11, the elastic properties along 1-2 direction also increase with the increase with in volume fraction of carbon fiber. At lower volume fractions (20%) it can be observed that CFRP has elastic modulus of 6Gpa, but with increase in CNT volume fraction from 1% to 5%, the elastic properties have increased from 6.8Gpa to 10Gpa. With the increase in carbon fiber volume fraction, it can be observed that composites having lower CNT volume fractions show steep increase in elastic properties than compared to composites having higher CNT volume fractions.

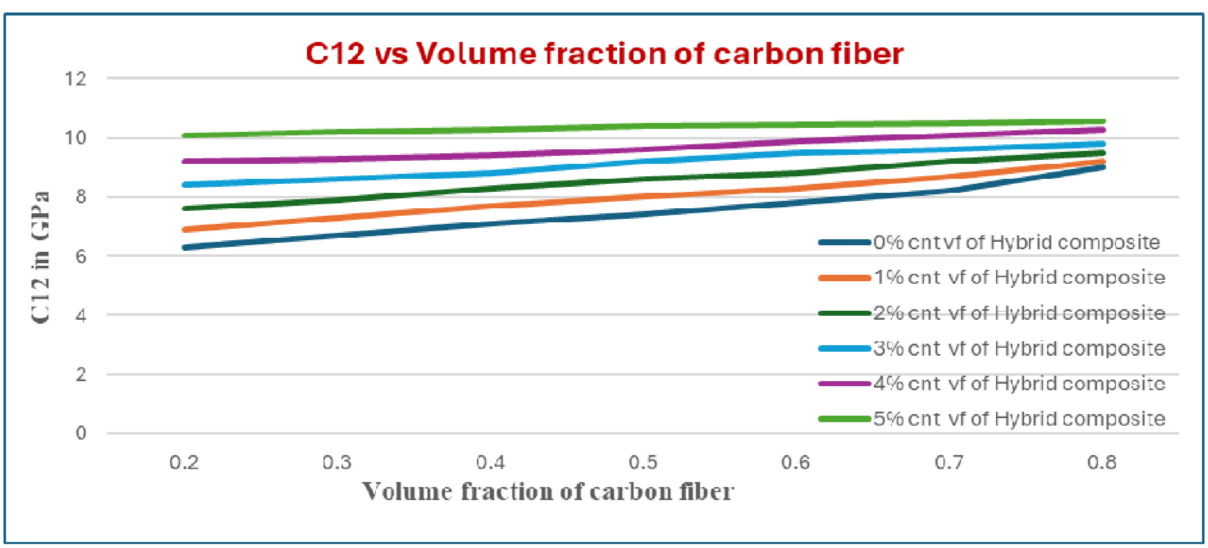


Figure 3.4 Variation Of C_{12} W.R.T Variation Of Carbon Fiber AndCnt Volume Fraction

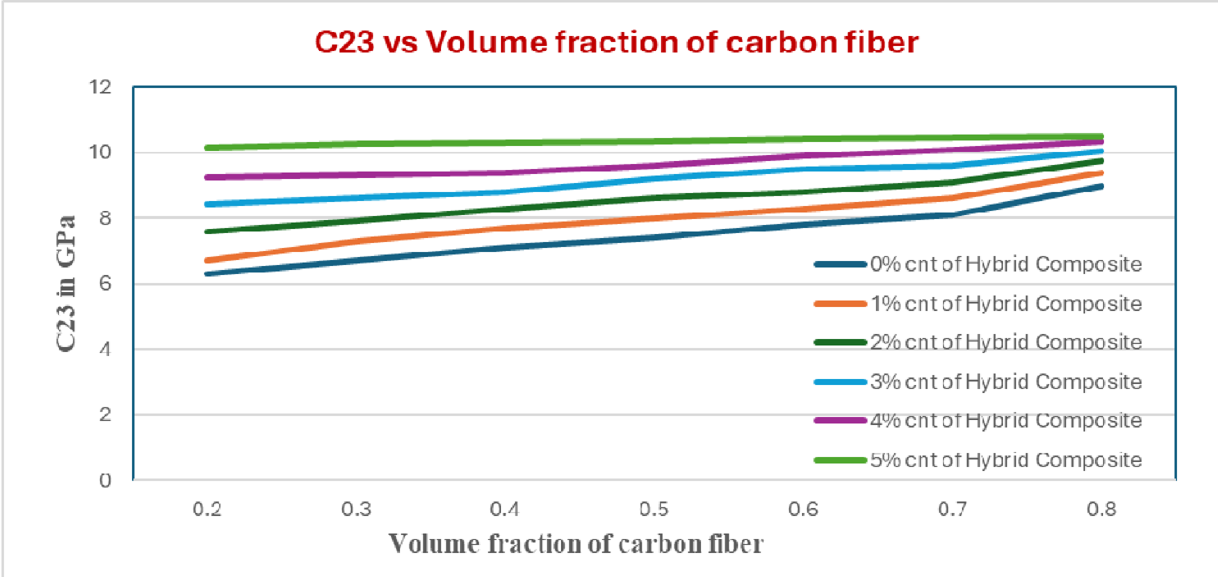


Figure 3.5 Variation Of C_{23} W.R.T Variation Of Carbon Fiber AndCnt Volume Fraction

From Fig. 3.6, it can be seen that the transverse elastic properties have improved with the addition of CNT in matrix material for lower volume fractions of carbon fiber. This increase in elastic properties can be attributed to the randomly distributed CNTs. With the increase in carbon fiber volume fraction the composites having lower volume fractions of CNT have shown an increase in transverse elastic modulus, but for composites having higher volume fractions of CNT with the increase in carbon fiber volume fraction there is decrease in transverse elastic modulus.

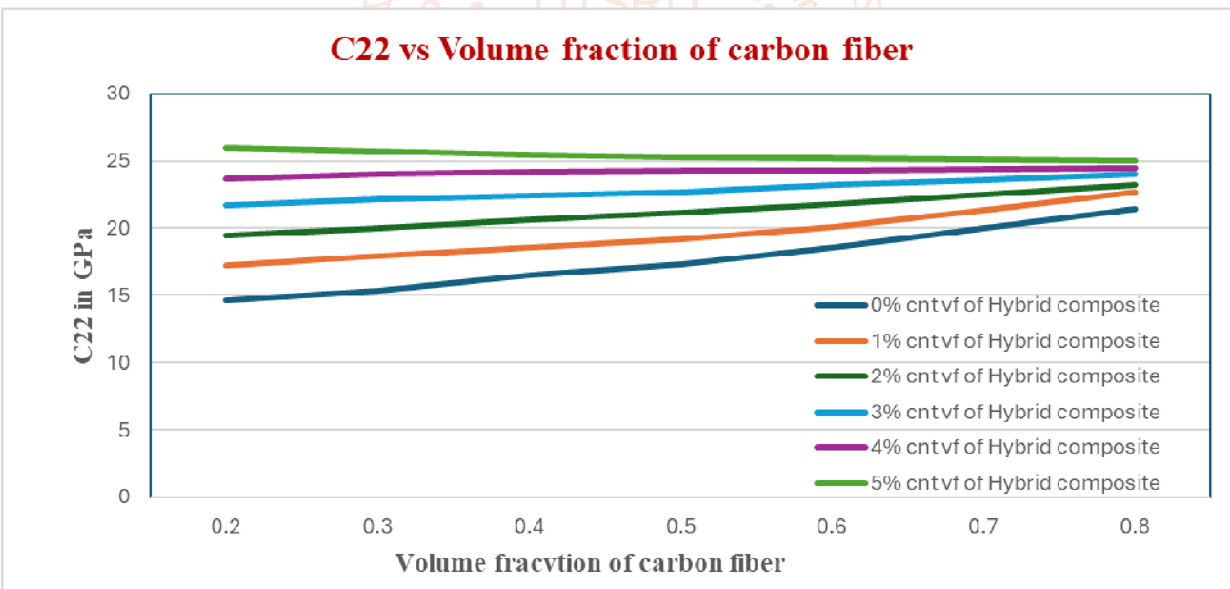


Figure 3.6 Variation Of C_{22} W.R.T Variation Of Carbon Fiber AndCnt Volume Fraction

CONCLUSIONS

This chapter presents important observations on the material properties, In this study, modal analysis was carried out using nanotube modeler software for specify the Carbon nano tube increase elastic property and strength Due to increase in tube diameter. The hybrid composite has been modelled using Mori-Tanaka method and mechanics of materials method. It is found that the longitudinal properties C11 of the hybrid composite increase with the increase in volume fraction of CNT at lower volume fractions of carbon fiber. As the volume fraction of carbon fiber goes on increasing the longitudinal modulus tends to converge because the volume fraction of CNT goes on decreasing. The elastic properties of C12 and C23 of the hybrid composite increase tremendously when the volume fraction of carbo nano tube increase at lower volume fractions of carbon fiber. As the volume fractions of carbon fiber goes on increasing there is slow increase in composites having higher volume fractions of CNT as compared to composites having lower volume fractions of CNTs. The transverse modulus C_{22} of the hybrid increases with the increase in CNT volume fraction but as the volume fraction of carbon fiber increases the composites having lower CNT volume fractions show increase in transverse modulus and composites having higher CNT volume fraction show gradual decrease in transverse modulus.

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