Dynamic Characterisation of Honeycomb CNT Reinforced Sandwich Composite Structure

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Abstract. The dynamic characterization of honeycomb sandwich structure with CNT reinforced hybrid composite face sheet is performed using Finite element simulation. The element simulations. The Potential and Kinetic energies of the honeycomb sandwich beam were derived using classical laminate beam theory and Mindlin theory. The governing equations of motion for the sandwich composite beam is made up of Nomex material with a hybrid composite face sheet reinforced with CNT are obtained by applying the Hamilton rule in the finite element model. The functionality of current finite element modeling has been investigated to proving the dynamic properties acquired from the improved finite element model with the solution obtainable in the previous literature. A further various parametric study is performed to understand the effect of CNT content, thickness ratio, and boundary constraints on the honeycomb sandwich composition of dynamic properties with reinforced CNT of the hybrid composite face sheet is performed using finite element simulation. The CNT content in the honeycomb sandwich beam containing a remarkable effect on the natural frequency.

Keywords. Honeycomb sandwich structure, CNT reinforced composite beam, model analysis, dynamic characteristic.

1. Introduction

From recent decades, Engineering construction is excepting for lightweight materials with high stiffness and low-density properties. Other Important properties which are expected are to be present are large energy-absorbing capacity and tolerances to damage. To acquire these properties every industry is opting for composite materials and lightweight structures. The integration of two or multiple materials with various physical along with chemical properties categorized as a composite material. There are many types of composite materials available which has large energy absorbing capacity and damage tolerances. The one such composite material which is used is a combination of CNT epoxy glass Fiber-reinforced faced sheets and Honeycomb core with Nomex material. The tensile and compressive Loads are primarily carried by face sheets and these face sheets are supported by the core which is the Nomex honeycomb core to avoid resistance out of the plane shear load and buckling. Honeycomb windmill blades, helicopter blades, Automobile Industries, Satellites, Aircraft, marines, and bridge constructions, these composite sandwich structures are used. Nomex honeycomb core which is manufactured by aramid paper saturated is bionic material which is produced using poly fiber paper (m-phenylene isophthalamide) [1] with heat-resistant phenolic resin and this Nomex honeycomb core is a non-metallic product combination of superior electrical insulation good resilience and absorbent to shocks. In this study, the core of the honeycomb is processed as an orthotropic uniform material. The design of honeycomb structure using finite element method to acquire the natural mechanical characteristics of the honeycomb sandwich composition [2]. The studies related to Nomex honeycomb have increased in...
the recent decades. However, the properties for outer plane shear are reliant on properties with core geometry as well as material for Nomex honeycomb. In order to attain the required corresponding elastic limits of the structure of the Nomex honeycomb is the finite element (FE) model is formed. The whole geometrical property of the honeycomb is not considered because the cost of computation will be more.

In engineering applications where rotating composites are found such as windmill rotor blades, turbine blades helicopter tail, and main blades, there exist adverse vibrations to the structure due to high levels of dynamic loads. The improvised mechanical characteristics can be achieved to the matrix by the addition of a small amount of multiple walled carbon nanotubes (MWCNT) was acknowledged by various literature work. Further, these studies show the comparison between CNT- Reinforced polymer rotating structures and carbon-fiber-reinforced where CNT-Reinforced structure showed great dynamic performance compared to the latter [3]. The effect of CNTs proportion is set up to be more clear in nonrotatable structures instead of the rotatable structures because of enhancing the CNT-FRP nanohybrid composites of dynamic properties. The primary natural frequency of rotatable CNT reinforced nanocomposites is enhanced almost by 5% while present angular speed varies from 0 to 500 rpm [4]. The dynamic performance of CNT -reinforced hybrid composite is studied in which also explains the dynamic instability features for main and subsidiary rotatable CNT- reinforced non-uniform composite plates [5].

Various studies and experiments have been conducted on CNTRC which influenced the uses in different fields of engineering. The reinforcement of CNT face sheets of a sandwich plate having the thickness ratio and CNT volume fraction causes instability in width. The sections of dynamic instability of laminated composites are determined using Higher-order shear deformation theory [6]. However, the rotatable fiber-reinforced laminated composites considerably control the design principles about stability properties by entrenching MWCNT is appreciable. The potential, as well as kinetic energy equations, are derived using Mindlin and Reissner also called First-order shear deformation (FSDT). The governing equation of motions was calculated using the Hamilton rule. To obtain outstanding elastic properties, as well as damping properties effectively by adding a small amount of CNT will improve the vibrational characteristics of CNT- based composite structure. Several research works suggested that to produce good mechanical properties containing the dynamic characteristics of the structures by combining CNT into stationing the composite matrix and in addition because of slippage among inner and exterior graphene plies of a composite structure having damping properties of MWCNT with enhanced stiffness. At higher frequencies, from 0 to 2 % CNT volume fractions were raising incrementally because of the source of dynamic instability [7]. The sandwich plate having increasing core thickness will increase the natural frequencies. The comparison in mode shape for a minimal three vibration of the sandwich plate was noted with an enhanced CNT which presents the potency of CNT in honeycomb sandwich plate which reduces the vibrational amplitude [9]. The various parametric studies were also carried out in the CNT composite plate to examine the result of CNT volume fractions and static load factors on the region for dynamic instability.

2. Numerical representation of CNT reinforced Nomex honeycomb composite beam.

2.1. Kinematics of Euler Beam

- The transverse normal perpendicular to the midplane of the beam remains straight and perpendicular even after deformation.
- The transverse normal does not undergo any extension.
The shear strain is zero and the angle between the midplane and transverse normal after bending is $90^\circ$

\[
\therefore \gamma_{xz} = 0
\]

\[
\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} = 0
\]

Where $u$ and $w$ are deformation and deflection along $x$ and $z$ direction respectively.

\[
\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} = 0
\]

Assuming $z=0$ (i.e Midplane of the beam) and $u= u_0$ (i.e Midplane deformation along $x$ - direction )

\[
\therefore u = u_0 - z \frac{\partial w}{\partial x}
\]  \hspace{1cm} (1)

Transverse normal is not undergoing any deformation. So,

\[
\therefore \epsilon_{zz} = 0
\]

\[
\frac{\partial w}{\partial z} = 0
\]

Assuming $z = 0$ (i.e Midplane of the beam) and $w= w_0$ (i.e Midplane deflection ).

$w = w_0$
2.1.1 Strain field in the Beam

\[ \varepsilon_x = \frac{\partial u}{\partial x} \]  

From equation (1),

\[ \varepsilon_x = \frac{\partial u_0}{\partial x} - z \frac{\partial^2 w_0}{\partial x^2} \]  

2.1.2 Stress field in the Beam

\[ \sigma_x = E \varepsilon_x \]  

From equation (3),

\[ \sigma_x = E \left( \frac{\partial u_0}{\partial x} - z \frac{\partial^2 w_0}{\partial x^2} \right) \]  

---

**Figure 3.** Force and moment per unit length of the sheet.

\[ N_x = \int \sigma_x \, dz \]  
\[ M_x = \int Z \sigma_x \, dz \]  

Where \( N_x \) and \( M_x \) are force acting per unit length and moment acting per unit length.

\[ N_x = \int \sigma_x \, dz \]  

From equation (4), We know that

\[ \sigma = Q(\varepsilon_0 + z K_x) \]  

Where \( Q = E \)
Midplane strain

\[ \varepsilon_0 = \frac{\partial u_0}{\partial u} \]  

(6)

Midplane curvature

\[ K_x = -\frac{\partial^2 w_0}{\partial x^2} \]  

(7)

\[ N_x = \int Q \varepsilon_0 dz + \int QZ K_x dz \]  

(8)

\[ M_x = \int Z \sigma_x dz \]  

(9)

Representing the midplane strain and curvature

\[ \therefore \begin{bmatrix} N_x \\ M_x \end{bmatrix} = \begin{bmatrix} A & B \\ B & D \end{bmatrix} \begin{bmatrix} \varepsilon_0 \\ K_x \end{bmatrix} \]  

(10)

\[ A = \sum_{i=1}^{N} \int_{z_b}^{z_t} Q dz = \sum_{i=1}^{N} Q (Z_t - Z_b) \]  

(11)

\[ B = \sum_{i=1}^{N} \int_{z_b}^{z_t} Qz dz = \sum_{i=1}^{N} \frac{Q}{2} (Z_t^2 - Z_b^2) \]  

(12)

\[ D = \sum_{i=1}^{N} \int_{z_b}^{z_t} Qz^2 dz = \sum_{i=1}^{N} \frac{Q}{4} (Z_t^3 - Z_b^3) \]  

(13)

**Figure 4.** Interpretation of sandwich structure with thickness of beam

2.1.3 Strain energy due to midplane strain and curvature

\[ U = \frac{1}{2} \int N_x \varepsilon_0 dx + M_x \sigma_x K_x dx \]  

(14)
2.1.4 Kinetic energy

\[ T = \frac{1}{2} \int \rho \mathbf{v}^T \mathbf{v} \, dv \]

Where

\[ \mathbf{v} = \begin{pmatrix} \dot{u} \\ \dot{w} \end{pmatrix} \]

Therefore,

\[ T = \int \begin{pmatrix} \dot{u}_0 \\ \dot{w}_0 \\ \frac{\partial \dot{w}}{\partial x} \end{pmatrix}^T \begin{pmatrix} \mathbf{I}_I & 0 & \mathbf{I}_C \\ 0 & \mathbf{I}_T & 0 \\ \mathbf{I}_C & 0 & \mathbf{I}_R \end{pmatrix} \begin{pmatrix} \dot{u}_0 \\ \dot{w}_0 \\ \frac{\partial \dot{w}}{\partial x} \end{pmatrix} \, dx \]

2.2. Kinematics of sandwich beam

Figure 5. Nomex Honeycomb with CNT reinforced sandwich layers

Figure 6. Assembled image Sandwich Composite structure

2.2.1 Assumptions

- No slippage was assumed between the face sheets and sandwich core
- All three layers experience the same transverse deflection
- The normal stresses are negligible in the sandwich core as compared with the face sheets
- Rotary inertia effects are negligible
- No shear strain in the face sheets
Figure 7. Depiction of layers of sandwich composite structure

Figure 8. Mid-plane deformation of layers

\[ \gamma_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \]  

\[ N_{x1} = \int_{\frac{h_1}{2}}^{\frac{h_1}{2}} Q\left(\epsilon_0 + zK_x\right)dz \]  

\[ N_{x2} = \int_{\frac{h_2}{2}}^{\frac{h_2}{2}} Q\left(\epsilon_0 + zK_x\right)dz \]  

Then,

\[ \gamma_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \]  

\[ \gamma_{xz} = \frac{u_{01} + u_{03}}{h_2} + \frac{h_1}{h_2} \frac{\partial w}{\partial x} \]  

\[ u_{02} = \frac{u_{01} + u_{03}}{2} + \frac{h_1 - h_3}{4} \frac{\partial w}{\partial x} \]  

where \( u_{01} \), \( u_{02} \), and \( u_{03} \) are the midplane deformation of layer 1, layer 2, and layer 3 respectively.
Figure 9. Representation of force and moment action per unit length with for two facesheets.

\[ N_{x1} = \int_{h_1}^{h_2} \sigma_x \, dz \quad (23) \]

\[ N_{x2} = \int_{h_3}^{h_2} \sigma_x \, dz \quad (24) \]

\[ M_{x1} = \int_{h_1}^{h_2} Z \, \sigma_x \, dz \quad (25) \]

\[ M_{x2} = \int_{h_3}^{h_2} Z \, \sigma_x \, dz \quad (26) \]

\[ T_2 = \frac{1}{2} \int_{h_2}^{h_3} z^2 \rho \, \dot{\gamma}_{xz} \, dx \, dy \, dz \]

By solving the above expression, we get,

\[ T_2 = \frac{1}{2} w \left\{ \left( \frac{u_0_1 - u_0_3}{h_2} \right) + \frac{h \, \ddot{\omega}}{h_2} \right\} \left[ 1 + \frac{h_2}{h_1} \right] \left\{ \left( \frac{u_0_1 - u_0_3}{h_2} \right) + \frac{h \, \ddot{\omega}}{h_2} \right\} \quad (27) \]

Here, \( T_1 = \) Translation kinetic energy of the three layered Beam

\( T_2 = \) Rotational kinetic energy of the sandwich core
2.3. Finite element formulation

\[ u_{01} = N_1 u_{01} + N_2 u_{02} \]  \hspace{1cm} (28)
\[ u_{03} = N_1 u_{01} + N_2 u_{02} \]  \hspace{1cm} (29)
\[ w_0 = N_{w_1} w_{01} + N_{w_2} w_{02} + N_{\theta_2} \theta_{\theta_2} \]  \hspace{1cm} (30)

\[ \begin{bmatrix} u_{01} \\ u_{02} \\ w_0 \end{bmatrix} = \begin{bmatrix} N_1 & 0 & 0 & 0 & N_2 & 0 & 0 & 0 \\ 0 & N_1 & 0 & 0 & 0 & N_2 & 0 & 0 \\ 0 & 0 & N_{w_1} & N_{\theta_1} & 0 & 0 & N_{w_2} & N_{\theta_2} \end{bmatrix} \]  \hspace{1cm} (31)

![Element formulation diagram](image)

**Figure 10.** Element formulation

### 2.3.1 Strain energy

\[ U = \frac{1}{2} \int N_{x_1} dy \varepsilon_{01} dx + \int N_{x_2} dy \varepsilon_{02} dx + \int M_x dy K_x dx \]

\[ U = \frac{1}{2} \int W \begin{bmatrix} \varepsilon_{01} \\ \varepsilon_{02} \\ \theta_1 \\ \theta_2 \end{bmatrix}^T \begin{bmatrix} N_{x_1} \\ N_{x_2} \\ M_x \end{bmatrix} dx \]  \hspace{1cm} (32)

### 2.3.2 Kinetic energy

\[ T = \frac{1}{2} \int \rho V^T V dv \]  \hspace{1cm} (33)

\[ V = \begin{bmatrix} u_{01} \\ u_{02} \\ \dot{w} \end{bmatrix} = \begin{bmatrix} u_{01} - Z \frac{\partial \dot{w}}{\partial x} \\ u_{02} - Z \frac{\partial \dot{w}}{\partial x} \\ \dot{w} \end{bmatrix} \]  \hspace{1cm} (34)
\[
\begin{align*}
\begin{bmatrix}
\frac{\partial u_{01}}{\partial x} \\
\frac{\partial u_{03}}{\partial x} \\
\frac{\partial^2 w}{\partial x^2}
\end{bmatrix} &= \begin{bmatrix}
N_{11} x & 0 & 0 & 0 & N_{21} x & 0 & 0 & 0 \\
0 & N_{11} x & 0 & 0 & 0 & N_{21} x & 0 & 0 \\
0 & 0 & -N_{w11} x & -N_{011} x & 0 & 0 & -N_{w21} x & -N_{021} x
\end{bmatrix}
\begin{bmatrix}
\dot{u}_{01} \\
\dot{u}_{03} \\
\dot{w}
\end{bmatrix} \\
- \frac{\partial}{\partial x} \begin{bmatrix}
\frac{\partial u_{01}}{\partial x} \\
\frac{\partial u_{03}}{\partial x} \\
\frac{\partial^2 w}{\partial x^2}
\end{bmatrix} &= \left[B\right]\{d\}
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
\dot{u}_{01} \\
\dot{u}_{03} \\
\dot{w}
\end{bmatrix} &= \begin{bmatrix}
N_1 & 0 & 0 & 0 & N_2 & 0 & 0 & 0 \\
0 & N_1 & 0 & 0 & 0 & N_2 & 0 & 0 \\
0 & 0 & N_{w1} & N_{01} & 0 & 0 & N_{w2} & N_{02} \\
0 & 0 & -N_{w11} x & -N_{011} x & 0 & 0 & -N_{w21} x & -N_{021} x
\end{bmatrix}
\begin{bmatrix}
\ddot{u}_{01} \\
\ddot{u}_{03} \\
\ddot{w}
\end{bmatrix} \\
\begin{bmatrix}
\dot{\theta}_{1} \\
\dot{\theta}_{2}
\end{bmatrix} = \left[N\right]\{d\}
\end{align*}
\]

\[
\begin{align*}
\frac{\dot{u}_{01} - \dot{u}_{03}}{h_2} + \frac{h}{h_2} \frac{\partial \dot{w}}{\partial x} &= \frac{1}{h_2} \left[N_1 - N_1 Nw_{11} x + hNw_{1} x & N_2 - N_2 Nw_{21} x + hN0_{21} x\right]\{d\} \\
\frac{\dot{u}_{01} - \dot{u}_{03}}{h_2} + \frac{h}{h_2} \frac{\partial \dot{w}}{\partial x} &= \left[N_2\right]\{d\}
\end{align*}
\]

\[2.3.3 \text{ Strain energy}\]

\[
U = \frac{1}{2} \int w \{d\}^T \left[B\right]^T \left[ABD\right] \left[B\right]\{d\} dx
\]

\[
U = \frac{1}{2} \{d\}^T \left[K_d\right] \{d\}
\]
2.3.4 Kinetic energy

\[ T_1 = \frac{1}{2} \int w \{ d_{\text{el}} \}^T [N1]^T[I][N1] \{ d_{\text{el}} \} \text{d}x \]  \hspace{1cm} (39)

\[ T_2 = \frac{1}{2} \int w \{ d_{\text{el}} \}^T [N2]^T[I\gamma_2][N2] \{ d_{\text{el}} \} \text{d}x \]  \hspace{1cm} (40)

\[ T = T_1 + T_2 \]  \hspace{1cm} (41)

After Assembly,

\[ U = \frac{1}{2} \{ d \}^T[K] \{ d \} \]  \hspace{1cm} (42)

\[ T = \frac{1}{2} \{ d \}^T[M] \{ d \} \]  \hspace{1cm} (43)

Lagrange,

\[ L = T - U \]  \hspace{1cm} (44)

From lagrange Equation,

\[ -\frac{d}{dt} \left( \frac{\partial L}{\partial q_i} \right) + \left( \frac{\partial L}{\partial \dot{q}_i} \right) = 0 \]  \hspace{1cm} (45)

Hence we can obtain,

\[ [M] \{ \ddot{d} \} + [k] \{ d \} = 0 \]  \hspace{1cm} (46)

3. Affirmation of finite element formulations

The dynamic properties were evaluated for the Nomex honeycomb core with CNT composite plates and to validate the Finite element model through performed MATLAB simulation.

| Table 1. material properties of Nomex Honeycomb Structure [3]. |
|---------------------------------------------------------------|
| Parameter | Value         |
|-----------|--------------|
| E1        | 5000 Mpa     |
| E2        | 4000 Mpa     |
| G12       | 1250 Mpa     |
| \( \mu \) | 0.3          |
| \( \rho \) | 48 kg/m\(^3\) |
Table 2. Material properties of CNT

| Name of the material | Literature reference | Indication | Numerical Value | Description |
|----------------------|----------------------|------------|-----------------|-------------|
| CNT                  | [10]                 | $E_{11}^{cn2}$ | 640000 Mpa     | Modulus of elasticity of CNT |
|                      |                      | $E_{22}^{cn2}$ | 10000 Mpa      | Modulus of elasticity of CNT |
|                      |                      | $G_{12}^{cn2}$ | 17000 Mpa      | Modulus of rigidity of CNT |
|                      |                      | $\rho^{cn2}$  | 1350.0 Kg/m$^3$ | Mass per unit volume of CNT |
|                      |                      | $\nu^{cn2}$   | 0.33           | Poisson’s ratio of CNT |
|                      |                      | $t^{cn2}$      | 0.34 nm        | The thickness of CNT |
|                      |                      | $d^{cn2}$      | 1.4 nm         | The diameter of CNT |
|                      |                      | $l^{cn2}$      | 25 $\mu$m      | Length of CNT |

Table 3. Material properties of Epoxy glass fiber

| Name of the material | Literature reference | Indication | Numerical Value | Description |
|----------------------|----------------------|------------|-----------------|-------------|
| E-glass fiber        | [10]                 | $E^{f}$    | 69000 Mpa       | Modulus of elasticity of E-glass fiber |
|                      |                      | $\nu^{f}$  | 0.2             | Modulus of elasticity of E-glass fiber |
|                      |                      | $\rho^{f}$ | 1200 Kg/m$^3$   | Length of E-glass fiber |
4. Parametric study:

The dynamic characteristics of Nomex honeycomb reinforced with CNT epoxy fiber composite structure are affected by the material properties and the geometry of the structures. The effects can also be influenced further by the composition of structures, variation of CNT weight percentage, varying thickness ratios. To understand the effects of these parameters on Nomex Honeycomb with CNT reinforced with CNT epoxy glass fiber, a parametric study is conducted. The orientation of composite beam ply is taken to [0°/90°] by considering an uniform configuration of the structure for geometrical dimensions length (L) 250 mm, Width (B) 25 mm, thickness of lamina is 0.025 mm. The effects on composite beam are studied based on clamped-free and clamped-clamped end conditions. The required material properties of Nomex honeycomb structure along with CNT epoxy glass fiber are presented in the Table 1-3, to serve for the purpose of numerical calculations. The weightage percentage of CNT epoxy glass fiber composite is taken to be 0.0 and 1.0 and the thickness ratio \((t/t_c)\) to be taken as 2 for both boundary conditions.

4.1 Effect on natural frequency due to variation in weight percentage of CNT

The variation of weightage percentage of CNT from 0 to 2.0% is considered to study the effect of natural frequency on uniform configuration of composite structure for clamped-free and clamped-clamped conditions. The outcomes pertaining to the effect are shown in Table 4 and Table 5. The increase in weightage percentage of CNT from 0 to 2% with ply orientation of [0°/90°], increase the natural frequencies for all nodes. This can be interpreted with fact that matrix of CNT used in epoxy glass fiber confinements the movement of chain of polymers which ameliorate the strength and stiffness of the composite structure. The trend can be seen when comparison is done between both of the end conditions, there is an increase in values of natural frequency with the increase in mode shapes which exhibits that there is an improve in the stability of the structure.

Table 4. Effect of natural frequency for cantilever beam by varying weightage percentage of CNT.

| End conditions for Beams | modes | The weight percentage of CNT |
|--------------------------|-------|------------------------------|
|                          | m n   | 0.0  | 0.5  | 1.0  | 1.5  | 2.0  |
| Clamped - free           | 1 1   | 20.4 | 24.6 | 25.6 | 26.5 | 27.5 |
|                          | 1 2   | 273.3| 286.5| 292.5| 298.1| 303.4|
|                          | 1 3   | 864.1| 893.7| 910.0| 929.2| 945.3|
|                          | 1 4   | 1152.2| 1360.1| 1417.4| 1473.4| 1528.2|
|                          | 1 5   | 1531.4| 1567.9| 1590.4| 1610.9| 1629.8|
**Table 5.** Effect of natural frequency for fixed beam by varying weightage percentage of CNT.

| End conditions for Beams | modes | The weight percentage of CNT |
|--------------------------|-------|------------------------------|
|                          | m     | n   | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 |
| Clamped - clamped        | 1     | 1   | 33.4| 34.2| 34.9| 35.56| 36.17|     |
|                          | 1     | 2   | 812.7| 826.3| 838.7| 850.2| 860.8|     |
|                          | 1     | 3   | 1425.2| 1444.5| 1461.9| 1477.8| 1492.6|     |
|                          | 1     | 4   | 2085.7| 2107.4| 2126.7| 2144.4| 2160.6|     |
|                          | 1     | 5   | 2771.7| 2794.6| 2815.0| 2833.6| 2850.9|     |

**Figure 11.** First five-mode shapes for a clamped-free condition with 0.0 weight percentage of CNT

**Figure 12.** First five-mode shapes for a clamped-free condition with 1.0 weight percentage of CNT.

**Figure 13.** First five-mode shapes for a clamped-clamped condition with 0.0 weight percentage of CNT

**Figure 14.** First five-mode shapes for a clamped-clamped condition with 1.0 weight percentage of CNT.
4.2 Effect on natural frequency due to variation in weight percentage of CNT with change in thickness ratio

The change in thickness ratio has shown significant improvement of increase in natural frequencies for uniform configuration of composite structure with ply orientation of [0°/90°] along with increase in weight percentage of CNT from to 2.0% for increase in mode shapes. These variations are presented in Table 6 and Table 7 for both clamped-free and clamped-clamped conditions of composite beam. There is considerably increase in values of natural frequency in fixed condition of beam compared to cantilever type. This also results in improved dynamic properties of the composite structures.

**Table 6.** Natural frequency for a clamped-free beam of Thickness ratio (t/t<sub>c</sub>)=2 with varying weightage percentage of CNT.

| End conditions for Beams | modes | The weight percentage of CNT |
|--------------------------|-------|-----------------------------|
|                          | m n   | 0.0  | 0.5  | 1.0  | 1.5  | 2.0  |
| Clamped - free           |       |      |      |      |      |      |
|                          | 1 1   | 19.8 | 20.6 | 21.5 | 22.3 | 23.1 |
|                          | 1 2   | 247.5| 253.9| 259.9| 265.4| 270.6|
|                          | 1 3   | 775.9| 794.6| 811.9| 828.2| 843.5|
|                          | 1 4   | 1301.0| 1360.1| 1417.4| 1460.8| 1480.1|
|                          | 1 5   | 1392.3| 1417.2| 1439.9| 1473.4| 1528.2|

**Figure 15.** First five-mode shapes for a clamped-free beam by applying thickness ratio (t/t<sub>c</sub>)=2 with 0.0 weight percentage of CNT.

**Figure 16.** First five-mode shapes for a clamped-free by applying thickness ratio (t/t<sub>c</sub>)=2 with 1.0 weight percentage of CNT.
### Table 7. Natural frequency for a clamped-clamped beam of Thickness ratio (t/t_c)=2 with varying weightage percentage of CNT.

| End conditions for Beams | modes | The weight percentage of CNT |
|--------------------------|-------|-----------------------------|
|                          | m n   | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 |
| Clamped - clamped        | 1 1   | 295.9 | 303.3 | 310.2 | 316.5 | 322.5 |
|                          | 1 2   | 732.3 | 745.9 | 758.3 | 769.7 | 780.4 |
|                          | 1 3   | 1296.7 | 1316.2 | 1334.0 | 1350.2 | 1365.3 |
|                          | 1 4   | 1916.1 | 1938.8 | 1959.1 | 1977.8 | 1994.9 |
|                          | 1 5   | 2566.4 | 2590.9 | 2612.8 | 2632.9 | 2651.5 |

**Figure 17.** First five-mode shapes for a clamped-clamped beam by applying thickness ratio (t/t_c)=2 with 0.0 weight percentage of CNT.

**Figure 18.** First five-mode shapes for a clamped-clamped beam by applying thickness ratio (t/t_c)=2 with 1.0 weight percentage of CNT.

### 5. Conclusion.

In this study, based on FSDT theory we have evaluated the dynamic analysis for MWCNT composite with Nomex honeycomb core considering a cantilever beam. The Mori- Tanaka method and modified model of Hapin- Tsai helps to assess the elastic properties. Using FSDT the governing differential equation of motion for CNT Epoxy Glass Fiber which is derived in Finite element formulation. The amount of CNT add incrementally is an important parameter considering to evaluate the natural frequencies and also by varying the aspect ratio of thickness for core and composite fiber layers. Finally, the observation of this study explains that more dynamic stability will occur when incrementation of the aspect ratio of thickness for honeycomb core and composite e- glass fiber layers and also by adding a small amount of CNT from 0 to 2 weight percentage in the Nomex honeycomb sandwich structure.
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