Investigation of Nonlinear Damped Vibrations of a Hybrid Laminated Composite Plate Subjected to Blast Load

Anup Kumar Garg, H. S. Sahu

Department of Mechanical Engineering, Millennium Institute of Technology, Bhopal, Madhya Pradesh, India

How to cite this paper: Anup Kumar Garg, H. S. Sahu "Investigation of Nonlinear Damped Vibrations of a Hybrid Laminated Composite Plate Subjected to Blast Load" Published in International Journal of Trend in Scientific Research and Development (IJTSRD), ISSN: 2456-6470, Volume-3 | Issue-4, June 2019, pp.1077-1081, URL: https://www.ijtsrd.com/papers/ijtsrd24035.pdf

ABSTRACT
Hybrid composite is a composite which contains of nanoparticles to improve the strength as related to conventional composites. A model has been projected to define the elastic properties of hybrid composite. The hybrid composite contains of predictable fiber and nanocomposite as matrix. The first step here is to define the properties of nanocomposite which is done by using Mori – Tanaka method. The CNTs are deliberated as cylindrical inclusions in polymer matrix in Mori – Tanaka method. Arrogant perfect bonding among carbon fibers and nanocomposite matrix, the actual properties of the hybrid composite has been estimated using mechanics of materials approach. An 8 nodded shell element has been used for the finite element analysis taking 5 degrees of free do mesh node (u, v, w, θx, θy). A10×10 finite element mesh proceed sum remitting happening the convention of characteristic the shell element. The shell coordinates which are in Cartesian form are transformed into parametric form using two parameters (α1, α2). These parameters are over mapped into isoperimetric form (ν, ζ). A 16 layered enclose with stacking arrangement [0-454590] has been recycled for vibration investigation of simply supported shell element. The dynamic equations of shell are resultant using Hamilton's principle. As the damping types of the dynamic system are not available, for further analysis damping ratio of first mode and last active mode are presumed. Using Rayleigh damping the damping ratios of intermediate modes can be considered. The time decay of the structure from maximum amplitude to 5% of the maximum amplitude has been used as a parameter to study some shell structures by varying the volume fraction of CNTs in nanocomposite and by changing carbon fiber volume fraction.

Keywords: Carbon nanotubes, Single walled carbon nanotube, Double walled carbon nanotubes, Multi walled carbon nanotubes

I. INTRODUCTION
Vibration needs to be reduced in most of the rotor-shaft system so that an effective functioning of the rotating machines is attained. Almost all rotating parts should be vibration free so as to sources a lot of problems leading to instability of the system. Therefore there is a necessity to reduce the vibration level in rotating bodies for proper functioning of the system and different researchers are aiming for this. In the present days, composite materials are commonly used for the manufacturing of rotor. It is because composites have light weight, high strength, high damping capacity. Weight of the composite materials is less because long stiff fibers are surrounded in very soft matrix. Composites are made by at least two materials at macroscopic level. This type of unique reinforcement gives a lot of improvement for different applications. Fiber reinforced polymer (FRP) composite is a polymer matrix now which the reinforcement is fiber. The reinforcement of fiber can be done either by continuous fiber or by intermittent fiber. Active materials like piezoelectric material, magneto-strictive material, electromagnetic actuator and micro fiber carbon are also used for the vibration control of rotating parts. Piezoelectric material property to improve charge when mechanically stressed is utilized to bring control of vibration in moving parts. It is used as actuator as well as sensor in the system. Magnetostictive materials are like ferromagnetic material. Materials like cobalt, nickel and iron are magnetostictive materials and therefore change in the shape and size occurs when they are magnetized. Electromagnetic actuator is used very often as it gains the magnetic property when its coils are provided with current and the displaced position of the rotor can be attuned according to the current supply. A sensor measures the displacement of the rotor from its reference position, a microcontroller as a controller derives a control signal from the measures and gives signal to a power amplifier into a control current, and the control current generates the
magnetic forces within the actuating magnet in such away
that the rotor remain sin its hovering position. This enables
very high rotational speed to be realized. Active magnetic
bearing is free of lubricant, which avoids servicing and also
enables use in clean room environment. Maintenance is also
decreased due to absence of surface wear, so that as long as
the control system functions as intended, there could be no
maintenance. One major disadvantage to using magnetic
bearing sis their complexity. A very knowledgeable person
in the field is generally required to design and implement a
successful system. Because of the large amount of effort and
time required for development and the increase in the
number of components, compared to a traditional bearing, the
initial costs are much higher. However, depending on the
application, the return on investment for these initial costs
could be relatively short for a system, for example, that runs
with a much higher efficiency due to the lack of bearing
friction resistance,[1].

II. Literature Review
Raife et al [7] 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 [8] detected 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 [9] proposed choosing appropriate type of CNTs
(SWCNTs or DWNTs 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 DWNT based nano
composite displayed greater fracture toughness; Seidel et al
[10] estimated actual elastic properties of composites consisting of aligned SWCNTs or MWCNTs using Mori-Tanaka
method. The effects of an inter phase layer between CNTs and
the polymer is also investigated using a multi layer
composite cylinders approach.

Liu and Chen [11] estimated effective elastic properties of the
nanocomposite are evaluated using continuum modeling and
finite element method. The extended rule of mixture is used
to define the properties of the continuum model.

III. Finite Element Formulation
The shell geometry used in the present formulation has been
developed using an orthogonal curvilinear coordinate
system with the mid-plane of the shell assumed to be the
reference surface as shown in Fig.4.1. The shell mid-surface
in the Cartesian rectangular coordinate system has been first
mapped into a parametric domain through the suitable exact
parameterization. Two liberated coordinates (a1, a2) in the
parametric space have been measured as the mid-surface
rounded coordinates of the shell. The normal direction
coordinate to the middle surface of the shell has been
represented by z. The reference surface or the shell mid-
surface can be described in the global Cartesian coordinates
in terms of the position vector a,

![Figure1.Geometry of Shell Structure In Cartesian coordinates](image)

IV. Results and Discussion
Hybrid composite is a composite which consists of
nanoparticles to develop the strength as related to
conventional composites. A model has been proposed to
define the elastic properties of hybrid composite. The hybrid
composite contains of conventional fiber and nanocomposite
as matrix. The first step here is to define the properties of
nanocomposite which is done by using Mori – Tanaka
method. The CNTs are measured as cylindrical inclusions in
polymer matrix in Mori – Tanaka method. Assuming flawless
bonding among carbon fibers and nanocomposite matrix, the
active properties of the hybrid composite has been estimated
using mechanics of materials approach.

An 8 noded shell component has been used for the finite
element analysis having 5 degrees of freedom each node(u, v, v, \theta, \theta).
A 10x10 finite element mesh takes been support to just right the shell section. The shell coordinates which are in
Cartesian form are transformed into parametric form using
two parameters (a1, a2) These parameters are over
recorded into is oparametric form (\eta, \xi). A16 layered close
with stacking sequence [0 -45 45 90]28 has been used for
vibration analysis of simply supported shell component. The
dynamic equations of shell are resultant using Hamilton’s
principle. As the damping type of the dynamic system are
not available, for additional analysis damping ratio of first
mode and last active mode are assumed. Using Rayleigh
damping the damping ratios of intermediate modes can be
considered. The time decay of the system from maximum
amplitude to 5% of the maximum amplitude has been used as
a stricture to reading various shell structures by varying the
volume fraction of CNTs in nanocomposite and by
changing carbon fiber volume fraction.

- Validation of formulation
Free vibration analysis is done to certify the above
formulation. A 2, 3 and 4 layered cross ply laminate has been
used to carry out free vibration analysis by varying the a/h
ratio and R/a ratio of the spherical shell.
TABLE 1 NON-DIMENSIONAL FREQUENCY[REF:23]

<table>
<thead>
<tr>
<th>Panel</th>
<th>a/h</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/90/0</td>
<td>100</td>
<td>125.99</td>
<td>68.075</td>
<td>30.993</td>
<td>20.347</td>
<td>16.627</td>
<td>15.424</td>
<td>15.244</td>
<td>15.183</td>
</tr>
<tr>
<td>0/90/90/0</td>
<td>100</td>
<td>126.33</td>
<td>68.294</td>
<td>31.079</td>
<td>20.38</td>
<td>16.638</td>
<td>15.426</td>
<td>15.245</td>
<td>15.184</td>
</tr>
</tbody>
</table>

Present Formulation

<table>
<thead>
<tr>
<th>Panel</th>
<th>a/h</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/90</td>
<td>10</td>
<td>15.51217</td>
<td>11.1521</td>
<td>8.906713</td>
<td>8.373873</td>
<td>8.166252</td>
<td>8.061078</td>
<td>8.027878</td>
<td>7.990367</td>
</tr>
<tr>
<td>0/90</td>
<td>100</td>
<td>136.0635</td>
<td>73.90925</td>
<td>31.89584</td>
<td>18.20593</td>
<td>12.12838</td>
<td>9.353029</td>
<td>8.72118</td>
<td>8.358714</td>
</tr>
<tr>
<td>0/90/0</td>
<td>10</td>
<td>15.5545</td>
<td>12.22585</td>
<td>11.01655</td>
<td>10.82998</td>
<td>10.78238</td>
<td>10.76802</td>
<td>10.7647</td>
<td>10.75471</td>
</tr>
<tr>
<td>0/90/0</td>
<td>100</td>
<td>142.7383</td>
<td>76.47821</td>
<td>32.7317</td>
<td>19.15716</td>
<td>13.78834</td>
<td>11.85253</td>
<td>11.54031</td>
<td>11.43834</td>
</tr>
<tr>
<td>0/90/90/0</td>
<td>100</td>
<td>134.838</td>
<td>72.67357</td>
<td>31.29011</td>
<td>18.50931</td>
<td>13.52047</td>
<td>11.74193</td>
<td>11.45988</td>
<td>11.35508</td>
</tr>
</tbody>
</table>

Material Properties

<table>
<thead>
<tr>
<th>Constituent</th>
<th>C11(GPa)</th>
<th>C12(GPa)</th>
<th>C13(GPa)</th>
<th>C22(GPa)</th>
<th>C23(GPa)</th>
<th>Density(kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon fiber</td>
<td>236.4</td>
<td>10.6</td>
<td>24.8</td>
<td>10.7</td>
<td>25</td>
<td>1800</td>
</tr>
<tr>
<td>(25,25) 5 Walled CNT</td>
<td>1180</td>
<td>146</td>
<td>411</td>
<td>133</td>
<td>189</td>
<td>1740</td>
</tr>
</tbody>
</table>

- **C11**

![Figure 2 variation of C11 w.r.t variation of carbon fiber and cntvolumefraction](image1)

From Fig.2, it can be seen that as the carbon fiber volume fraction increases the longitudinal elastic properties rise.

At lower volume fractions of carbon fiber (10%) it can be observed that for CFRP composite the elastic modulus is around 35GPa, but with the increase in volume fraction of CNT from 1% to 5% the elastic modulus has improved from 38GPa to 47.3GPa. 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.

- **C12 and C23**

![Figure 3 variation of C12 w.r.t variation of carbon fiber and cntvolumefraction](image2)

![Figure 4 Variation of C23 w.r.t variation of Carbon Fiber and Cnt Volumefraction](image3)

From Fig. 3 and Fig.4, 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 (10%) 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.
From Fig. 5, 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 around is decrease in transverse elastic modulus.

From Fig. 6, it can be observed that the in-plane shear properties have increased with increase in volume fractions of CNT and carbon fiber. Composites normally fail due to shear. So in order avoid failure it is expedient to use hybrid composite in place of conventional CFRP composites.

**Impulse response**

Fig. 7 and Fig. 8 expression the decay time for thick and thin plates. At lower volume fractions carbon fiber, the decay time of the structure goes on decreasing with increase in CNT volume fraction. As the volume fraction of carbon fiber increases the decay time similarly decreases.

**Conclusions**

The hybrid composite has been modeled using Mori-Tanaka method and procedure 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. There is tremendous increase in elastic properties C12 and C23 of the hybrid composite with the increase in volume fraction of CNT 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.

**Future Scope**

Estimate temperature dependent and hydro the rmal properties. Buckling analysis of hybrid composite covered shell structure. Active vibration control of the covered shell structure. Delamination analysis of laminated shell structure.

**REFERENCES**


