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

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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 noded shell element has been used for the finite element analysis taking 5 degrees of free do mesh node $(u, v, w, \theta_x, \theta_y)$.A10×10 finite element mesh proceed sun remitting happening the convention of characteristic the shell element. The shell coordinates which are in Cartesian form are transformed into parametric formusing twoparameters$(\alpha_1,\ \alpha_2)$. Theseparametersare over mapped into isoperimetric form(η,ξ). A 16 layered enclose with stacking arrangement [0-454590]$_{2S}$ 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: *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 as it 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

Raifee 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 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 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 definethe 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 ($\alpha 1, \alpha 2$) 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 vectoras,

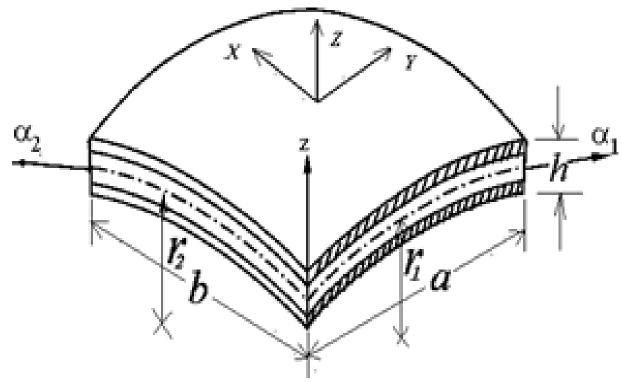

Figure1.Geometry of Shell Structure In Cartesiancoordinates

IV. Resultsand 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, w, θx , θy). A 10×10 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 ($\alpha 1, \alpha 2$) These parameters are over recorded into is oparametric form (η, ξ). A16 layereden close with stacking sequence $[0\ -45\ 45\ 90]_{2S}$ 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 types 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]

Panel	a/h	R/a							
		1	2	5	10	20	50	100	**500**
0/90	10	14.481	10.749	9.2302	8.9841	8.9212	8.9035	8.9009	**8.9001**
0/90	100	125.93	67.369	28.826	16.706	11.841	10.063	9.7825	**9.6873**
0/90/0	10	16.115	13.382	12.372	12.215	12.176	12.165	12.163	**12.162**
0/90/0	100	125.99	68.075	30.993	20.347	16.627	15.424	15.244	**15.183**
0/90/90/0	10	16.172	13.447	12.437	12.280	12.240	12.229	12.228	**12.226**
0/90/90/0	100	126.33	68.294	31.079	20.38	16.638	15.426	15.245	15.184

Present Formulation

Panel	a/h	R/a							
		1	2	5	10	20	50	100	**500**
0/90	10	15.51217	11.1521	8.906713	8.373873	8.166252	8.061078	8.027878	7.990367
0/90	100	136.0635	73.90925	31.89584	18.20593	12.12838	9.353029	8.72118	8.358714
0/90/0	10	15.5545	12.22585	11.01655	10.82998	10.78238	10.76802	10.7647	10.75471
0/90/0	100	142.7383	76.47821	32.7317	19.15716	13.78834	11.85253	11.54031	11.43834
0/90/90/0	10	14.8861	11.99612	10.95903	10.79977	10.75936	10.74652	10.74316	10.73102
0/90/90/0	100	134.838	72.67357	31.29011	18.50931	13.52047	11.74193	11.45988	11.35508

Material Properties

Constituet	C_{11}(GPa)	C_{12}(GPa)	C_{22}(GPa)	C_{23}(GPa)	C_{55}(GPa)	Density(kg/m^3)
Carbon fiber	236.4	10.6	24.8	10.7	25	1800[2]
(25,25),5 Walled CNT[6]	1180	146	411	133	189	1740[2]
Epoxy[18]	13.4615	5.7692	13.4615	5.7692	3.8462	1150

➢ **C11**

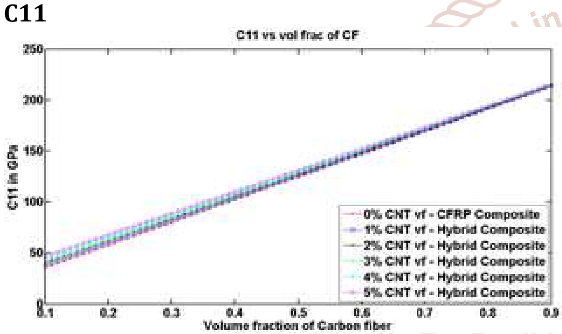

Figure 2variation of C11 w.r.t variation of carbon fiber and cntvolumefraction

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**

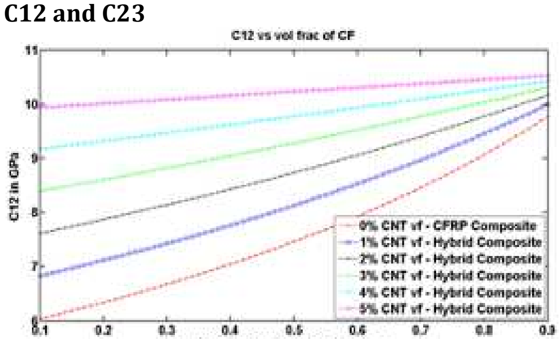

Figure.3 variation of C12w.r.t variation of carbon fiber and cntvolumefraction

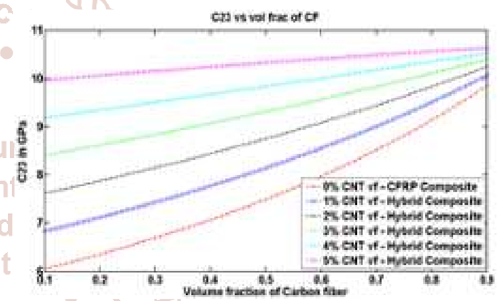

Figure 4 Variation of C23w.R.Tvariation of Carbon Fiber and Cnt Volumefraction

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.

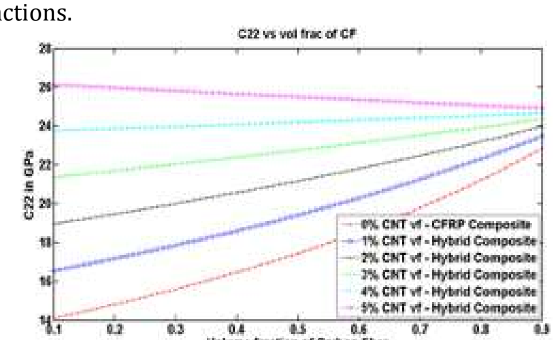

Figure.5variation of C22 W.R.T Variation of Carbon Fiber and Cnt Volumefraction

➢ **C22**

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 elasticmodulus.

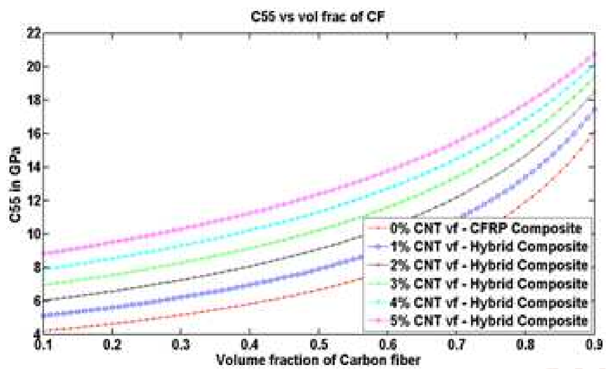

Figure.6 Variation of C55w.R.Tvariation of Carbonfiber and Cnt Volumefraction

➢ **C55**

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 CFRPcomposites.

➢ **Impulse response**

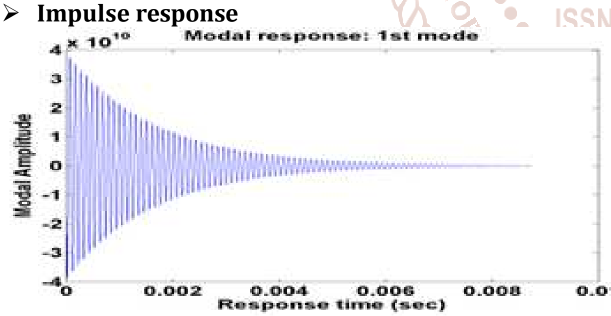

Figure.7 impulse response of cfrpcomposite for thickplate

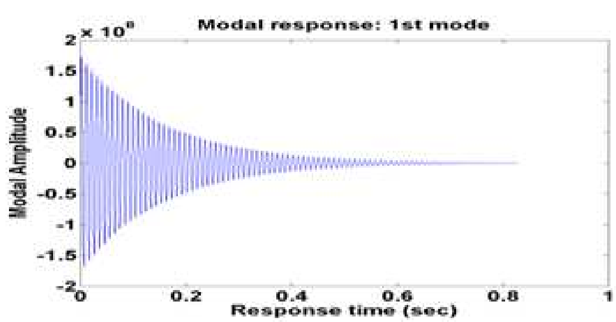

Figure.8 Impulse response of CFRP composite for Thinplate

Fig. 5.6 and Fig. 5.7 indicate the retort of thick plate and thin plate in modal coordinates for the first mode of vibration.

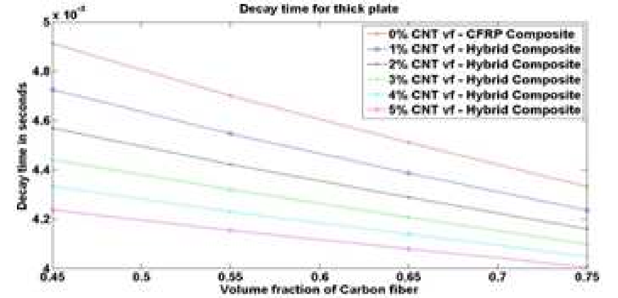

Figure.9 Decay Time for thick plate by varying the cntvolume fractionsfor different

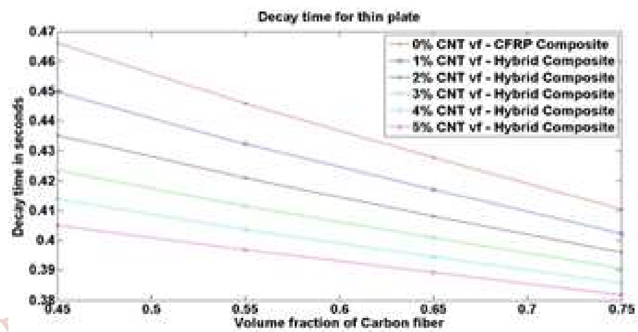

Figure.10 decay time for thin plate by vary in g the cnt volume fractions for different

Fig. 9 and Fig. 10 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 rmalproperties. Buckling analysis of hybrid composite covered shell structure. Active vibration control of the covered shell structure. Delamination analysis. Nonlinear analysis of laminated shell structure.

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