iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.37070

Free Vibration Analysis of Hybrid Laminated Composite Plate

Bajirao B. Lamkhade[1], Nikita S. Nagmoti[2], Maruti Khot[3]
[1, 2, 3]Department of Mechanical Engineering Walchand College of Engineering, Sangli 416415 Maharashtra, India

Abstract: ***In past decade a new manufacturing and Design technology developed across the globe because of that it possible to manufacture and analyses a hybrid laminated composite plate which is used in the various applications like aerospace, marine, spacecraft application were its subjected to dynamic loading so it is necessary estimate the response of the system under free vibration. Aim of this paper is Dynamic analysis of laminated composite plate which is made of hybridization of carbon epoxy and glass epoxy material. Natural frequencies are evaluated by FEM with the help of abaqus software for of hybrid laminated composite plate. The Parameter like aspect ratio, fiber orientation, boundary condition and mesh size of the FEA elements and stacking sequence affects natural frequencies of the plate. A hybrid laminated composite in which carbon fiber on top as well as bottom and glass fiber in inters layer gives maximum natural frequency at any boundary condition. FEM uses first order shear deformation theory.***

Keywords: Free Vibration, Hybrid laminated composite, Natural frequency, Finite element Method, Abaqus.

I. INTRODUCTION

In recent year past there is increasing the demands of reducing the weight of the system to increase the fuel economy as well as increases the mechanical performance without compromising the strength and functionality of the components. The properties like greater strength to weight ratio, wear resistance, fatigue resistance and many more can achieve by using laminated composite material. For example carbon epoxy laminated composite plate are used in aerospace application due to higher strength to weight ration and flexural strength but it is brittle in nature and having higher cost that's why it's not used in normal application like automobile sector. To optimize the cost and improve mechanical performance hybrid laminated composite are material are easily developed because of advancement in manufacturing and design engineering technology. Such hybrid laminated composite materials in the form of plate are widely used in aircraft, pressure vessel, marine and energy storage applications were its subjected dynamic loading. Free vibration analysis gives the response of the system prior to avoid resonance. Resonance causes the unwanted deformation at extreme state cause failure of system.

Carbon epoxy composite is used ion structural application but it having poor impact strength, toughness and susceptible to stress concentration. Adding or partially replacing brittle carbon fibre with aramid or glass fibre can improve impact strength and toughness. In case of hybrid composite lower density material like glass or aramid used in inner side to improve the strength without increase in weight of the body. Hybridization of composites can considerably improve the flexural characteristics necessary for aeronautical applications. The brittleness of the carbon fibre matrix is responsible for the reduction in energy absorption and impact strength. Using aramid fibre on the outer lamina and carbon fibre on the inner lamina gives better performance in impact loading. Energy absorption increases by 20 to 30% when aramid fibre is used in the inter ply, but flexural strength is 50% less than all carbon fibre ply. [1]. Most of the static as well dynamic properties of hybrid laminated composite plate position of ply, fiber orientation, length of the fiber, fiber material and fiber shape. So it is challenging to manufacture the hybrid composite plate with proper characteristic. In general it is manufacturing by vacuum assisted resin transfer molding (VARTM) at an temperature of near about 650C and pressure about 80kpa. In this way of manufacturing laminate was cure about 2 hours at given temperature and pressure. By altering the stacking sequence of composite materials, hybrid composite may adapt the mechanical properties of hybrid composite plate according to target application, boundary conditions, and loading situations. [2]. Because of internal damping of hybrid laminated composite plate it is used in structural application to absorb shock and impact. Damping properties of the plate were affected stacking sequence of the ply in the laminate. [3] Several researchers have developed analytical methods for dynamic analysis of laminated composite plates, such as free vibration analysis and forced vibration analysis, which are subjected to various types of excitation forces, such as impact load, simple harmonic excitation, and arbitrary excitation, among others. But in case of impact load causes internal damage in the laminate.

Due to the internal damage in the laminate stiffness and strength of the laminated decreases which in turn changes the dynamic behavior of hybrid laminated composite plate likw natural frequency , displacement etc Aniket chand et. Al. suggests the layer wise zigzag theory for deriving displacement filed equation in such a way that displacement components are zero at boundary. Along with displacement shear function also zero at boundary. From the result they predicted that in case hybrid laminate max displacement are reduced by 50% as compare to single fiber laminate. [26]. Aside from the hybridization of two different fibers, other researchers look at a hybrid laminated composite plate made up of three different fiber ply, such as E glass epoxy Kevlar epoxy, and basalt fabric. for simply supported plate by using FEA method with the help of ansys software. And predicted that as damping factor increases vibration frequency increases but deflection amplitude decreases in that case basalt fabric is at outer layer to avoid effect temperature due to blast wave. Natural frequency also affected by aspect ratio and pick pressure [5]. The traditional laminated plate theory for free vibration analysis of laminated composite plates provides a quick and easy solution, but it is not suitable for thick plates since it ignores the influence of shear at the interplay surface. To overcome the drawback of CLPT first order shear deformation theory come into picture which consider the shear effect by accounting the shear correction factor as 5/6. This FSDT used in FEA method to predict the response of the system. In higher order shear deformation theory, a shear function, which is a function of thickness coordinates, is employed instead of a shear correction factor. Shear function choice in such a way that it should satisfy the zero shear condition at bottom and top of laminate. Sayyad et al. used several shear functions to predict the free vibration analysis of a simply supported laminated composite plate.[16] Some application carbon are replaced by carbon are substituted by Kevlar epoxy because of its greater longitudinal tensile strength and having greater weight reduction potential but cost is high. Zeno Michael , Irfan Mahisham at al. perform the static analysis of composite plate by using numerical method with the help of Shell128 element with mesh size of 20*20 and validated by using analytical theories such as max stress theory and Tsai-Wu theory. They predicted that displacement in longitudinal direction decreases as orientation increases from 0 to 10 after that decreases slightly. In that case highest displacement occurs at 0^0 and lowest at 90^0[7]. Light weight of system improves fuel efficiency and reducing the environmental Burdon. [8].It is necessary to optimize this hybridization parameter for maximum natural frequency, minimum weight and minimum cost. Minimum weight and maximum natural frequency optimization problem can be solved by recursive linear programming method in which each node having 5 degree of freedom. Nonlinear optimization problem can also be solving by using recursive linear programming method by scaling so it reduces the number of iteration [9]. In hybridization along with synthetic fiber biodegradable and renewable cuff fiber are hybridized with glass fiber polymer matrix. Such hybrid laminated composite are manufactured by resin transfer molding (RTM) Method.in that methyl ethylene used as catalyst. Tensile strength of laminated composite plate depends on position of fiber and rate of fiber. When glass fiber is on outer layer it absorbs more water as compare to loft fiber [11].

Light weight design is important in railway wind energy and automobile. But CFRC susceptible to stress concentration cracking or delamination which largely scarifying the load carrying capacity and also alter the dynamic response of the plate hybridization of laminated composite overcome this disadvantages and improve mechanical properties. There are various approach of optimization of laminated composite plate for maximum natural frequency by optimizing stacking sequence such as simulated annealing (SA), Genetic Algorithm (GA) and Differential Evaluation (DE) with help of such optimization technique we can reduce cost of laminated composite so it can use for low cost application such as automobile [14]. Introduction composite material in number of practical application required the development of analytical method with help of weighted function.in analytical method galrkin method used to obtain differential equation.

As aspect ratio decreases deflection increases and if fiber angle increases bending stiffness decreases. [15] The dynamic response of the system under arbitrary dynamic load is calculated using first order shear deformation theory, which includes the effects of transverse shear strain and rotating inertia. FSDT predicted that excitation frequency decreases with increasing of layer thickness ratio, stacked layer number [17]. Hybrid laminated composite material also used for curve panel like turbine blade.in that case natural frequency decreases with decrease in thickness and decrease with increase in curvature [19].

The primary goal of this study is to investigate the free vibration characteristics of a hybrid laminated composite plate utilizing the finite element method and Abaqus software. for different boundary condition of the plate such as simply supported, fixed and cantilever also the effect of mesh size on the natural frequency are also prescribed in this article by using FEA method. Apart from boundary condition natural frequency of the plate are also affected by fiber orientation, stacking sequence, ply position and size of the fiber FSDT theory used in FEM of plate by considering shear effect.in FSDT shear effect can accounted by using shear correction factor as 5/6.

II. METHOD

Generally hybrid laminated composite plate are manufactured by using hand layup technique. For given analysis 8 layer hybrid mixture of glass epoxy and carbon/epoxy ply are used in that top two and bottom two layers are made of carbon epoxy and inter 4 layer are made up of glass epoxy. For the hybrid laminated composite plate stacking sequence are shown in figure1.

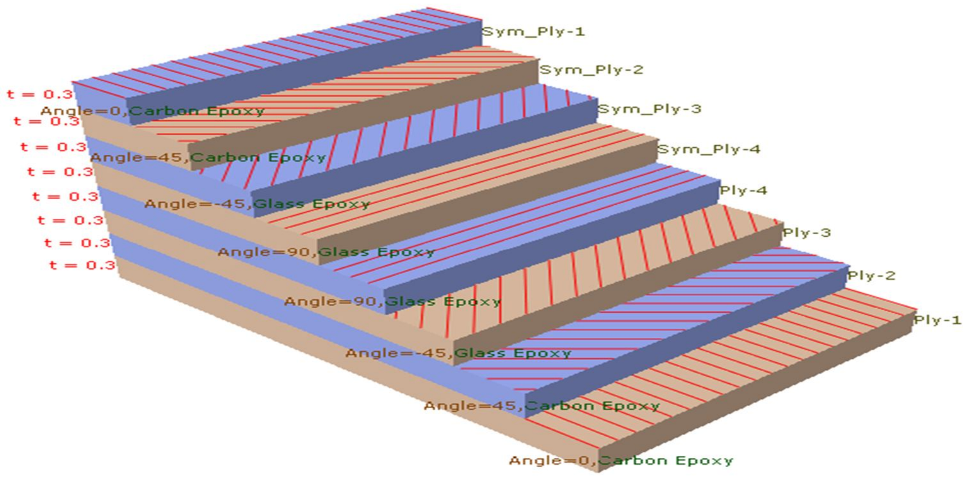


Figure 1 Hybrid laminated composite plate

Aaqus CAE software used for laminated composite plate to evaluate natural frequency by using conventional shell elements. Mesh element used are linear quadrilateral having 4 nodes. The input properties for free vibration analysis are evaluated by using micro mechanical analysis of hybrid laminated composite plate.

Consider the lamina in which reinforcing fibre are embedded in the matrix as shown in figure then cut the section such a way that in consist of one fibre , here the cut section having height h and width t_c and length L_c and area $A_c = t_c h$ as shown in figure for this section area of the fibre become $A_f = t_f h$ and that matrix will be $A_m = t_m h$, microscopic study shows that the properties of lamina are varies with matrix and fibre volume fraction so it can be calculated as follows

$$v_f = \frac{A_f}{A_c} = \frac{t_f}{t_c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

$$v_m = \frac{A_m}{A_c} = \frac{t_m}{t_c} = 1 - v_f \ldots\ldots\ldots\ldots\ldots.(2)$$

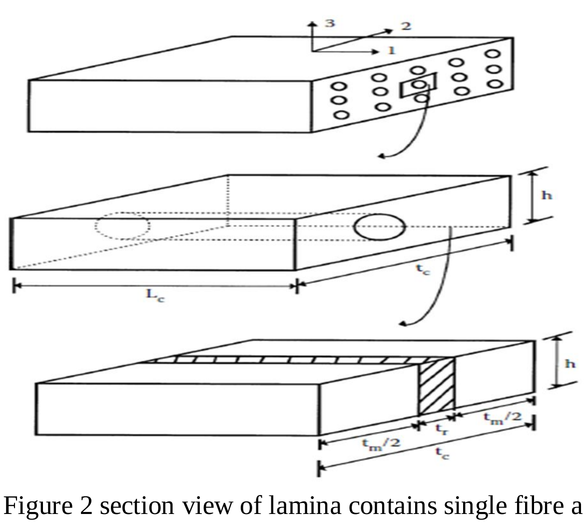


Figure 2 section view of lamina contains single fibre a

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

In microscopic study following observation should be taken into consideration as

1) Fibre are continuous and parallel to each other
2) Elastic modulus, diameter and space between fibres are uniform
3) Matrix and fibre bond is perfect.
4) Fibre and matrix follows hooks law
5) Fibre passes uniform strength
6) Composite is free from void

A. *Longitudinal Young Modulus(E_1)*

From the equilibrium of forces in longitudinal direction

$F_C = F_f + F_m$ ……………………………………(3)

The loads taken by the composite fiber, the matrix, are

$F_c = \sigma_c A_c, F_f = \sigma_f A_f, F_m = \sigma_m A_m$ ……………………. (4)

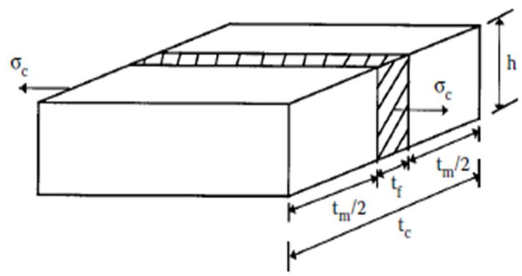


Figure 3 section view of lamina contains single fibre (b)

$\sigma_f = E_f \varepsilon_f , \sigma_c = E_1 \varepsilon_c , \sigma_m = E_m \varepsilon_m$ ……………. (5)

From equation 1,2,3,4 and 5

$E_1 = E_f v_f + E_f v_f$ ………… (6)

B. *Transverse Young Modulus (E_2)*

The composite is assumed to be strained in the transverse direction. The stress in the fibre, matrix, and composite are all identical in the transverse direction in this case, as illustrated in figure.

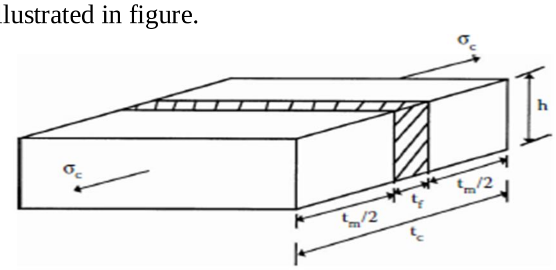


Figure 4 section view of lamina contains single fibre ©

From figure Transverse deformation of composite (δ_c) is sum of deformation in the fibre (δ_f) and deformation in matrix (δ_m)

$\delta_c = \delta_f + \delta_m$ ………………….. (7)

By definition of normal strain

$\delta_c = \varepsilon_c t_c, \delta_f = \varepsilon_f t_f, \delta_m = \varepsilon_m t_m$ ………….. (8)

By using hooks law

$\varepsilon_c = \frac{\sigma_c}{E_1}, \varepsilon_f = \frac{\sigma_f}{E_f}, \varepsilon_m = \frac{\sigma_m}{E_m}$ ……………….. (9)

From above equation

$\frac{1}{E_2} = \frac{v_f}{E_f} + \frac{v_m}{E_m}$ ………………. (10)

In the given finite element analysis natural frequency are evaluated at different ply position and different fibre orientation of hybrid composite plate and among that the combination that gives max natural frequency are selected as best choice for dynamic loading condition application to give better mechanical properties at low cost without compromising in the strength of composite t low weight.

III. RESULTS AND DISCUSSION

Given carbon/epoxy and glass epoxy ply are used to make a hybrid laminated composite plate having $[0/45/-45/90]_s$ as stacking sequence in that carbon epoxy ply are used at top and bottom of the plate to increase the flexural strength and impact strength and glass epoxy used at interior layer to increase damping characteristic of plate. in both the ply volume fraction of fibre and matrix is 50:50.thickness of each ply is 0.3mm hence total thickness of plate is2.4mm and length of plate is about 380mm and width is 75mm. The plate's mechanical qualities are listed in the table1.

Table 1 mechanical properties of hybrid laminated composite plate

Properties	Carbon epoxy	Glass epoxy
Orientation of lamina	0/45	-45/90
Longitudinal Young Modulus E_1 Gpa	115.75	40.25
Transverse Young Modulus $E_2 = E_3$ Gpa	6.8941	6.695
Shear Modulus G_{23} Gpa	3.56	3.3475
Shear modulus $G_{13} = G_{12}$ Gpa	4.1346	4.017
Poison ratio $\mu_{12} = \mu_{13}$	0.24	0.265
Density gm/cm^3	1.44	1.83
Volume fraction	50%	20%
Thickness of each lamina mm	0.3	0.3

In finite element analysis complex system is discretised into small elements and hence out of the analysis is strongly depends on the type and size or number of discretised elements it also called as mesh. Fine meshing gives accurate results but consume more time and memory likewise course meshing gives least accurate result and consume less time. So in is necessary to find the optimize mesh size.

Table 2 Natural frequency for different mesh size

Mode number	Mesh size (mm)			
	2*2	4*4	8*8	12*12
1	51.181	51.569	53.119	55.795
2	56.451	56.810	58.239	60.703
3	66.764	67.096	68.405	70.651
4	82.860	83.213	84.587	86.945
5	104.67	105.15	106.99	106.21
6	131.58	132.36	135.35	139.22

For hybrid laminated composite plate natural frequencies are depends on plate boundary condition. Boundary condition like Simply supported and clamped are gives near about same results and natural frequency for cantilever boundary condition are deviated far apart from clamped and simply supported boundary condition. Hence to get proper response of plate in practical application one must should know the boundary condition of the plate.

Table 3 Natural frequency for different Boundary condition of the plate

Mode number	SSSS	CCCC	CFFF
1	51.569	52.336	1
2	56.810	57.549	4.78
3	67.810	67.782	5.74
4	83.213	83.840	14.994
5	105.15	105.72	16.290
6	132.36	132.92	18.473

Results of finite element analysis are validated by using analytical method like higher order shear deformation theory (HSDT). Displacement field suggested by kant and sayyad are taken for HSDT to evaluate natural frequency of the plate.

Table 4 Comparison of Numerical method and Analytical method

Mode number	Natural frequency in Hz			
	CLPT	Higher order shear deformation theory(HSDT)		Numerical method
		T.Kant Disp. Field	Sayyad Disp. Field	FEA (4*4 mess size)
1	39.41	52.02	53.54	51.579
2	48.54	57.46	57.65	56.810
3	54.57	59.799	63.74	67.96

The ply, Position and fibre material of the ply for hybrid laminated composite plate affects the natural frequency. Hence for hybrid laminated composite plate the stacking sequence are optimizes by considering different ply combination such as all ply made up carbon epoxy(C8) , glass epoxy(G8) , carbon on outer layer and glass in inter layer (C2C4G2) and alternate layer of carbon and glass like CGCG and GCGC. Among the given combination C2G4C2 gives higher value of natural frequency as compared to other hence it is best stacking sequence for application were system subjected dynamic load.

Table 5 Natural frequencies for different stacking sequence

Mode number	C8	G8	C2G4C2	CGCG	GCCGGC
1	125.26	68.417	116.03	115.18	75.241
2	300.43	182.72	249.74	240.27	205.97
3	344.88	189.27	319.64	316.88	232.86
4	636.04	368.20	536.88	520.96	404.08
5	678.15	386.77	627.88	620.51	483.10
6	1037.0	605.68	887.90	869.29	66.35

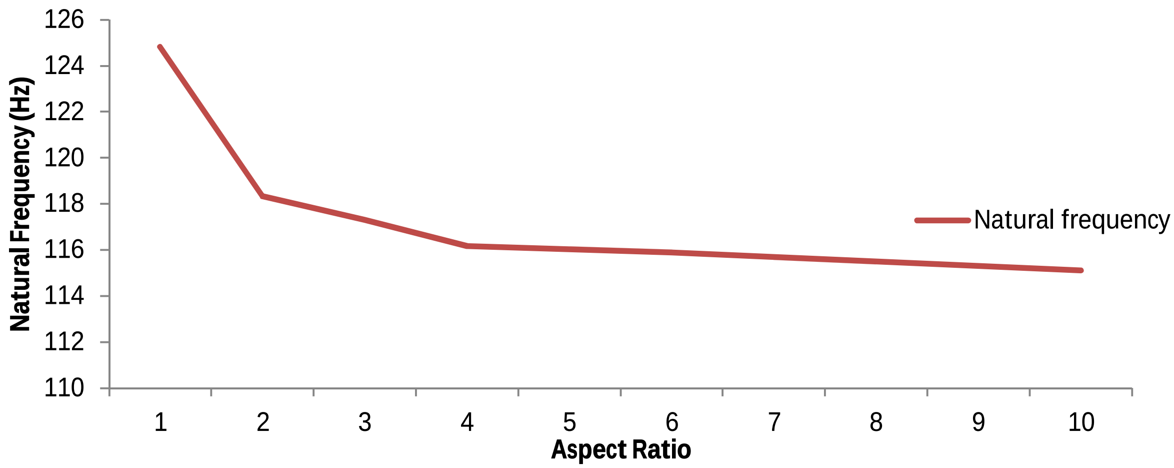


Figure 5 Natural frequency changes as a function of aspect ratio

Natural frequencies of hybrid laminated composite plates changed with changes in aspect ratio in free vibration analysis. The inherent frequency of the plate decreases as the aspect ratio increases. Natural frequency declines at the fastest pace for aspect ratios up to 2, and at a slower rate for ratios 2 to 4. For aspect ratio more than 4 natural frequency decreases very slowly.

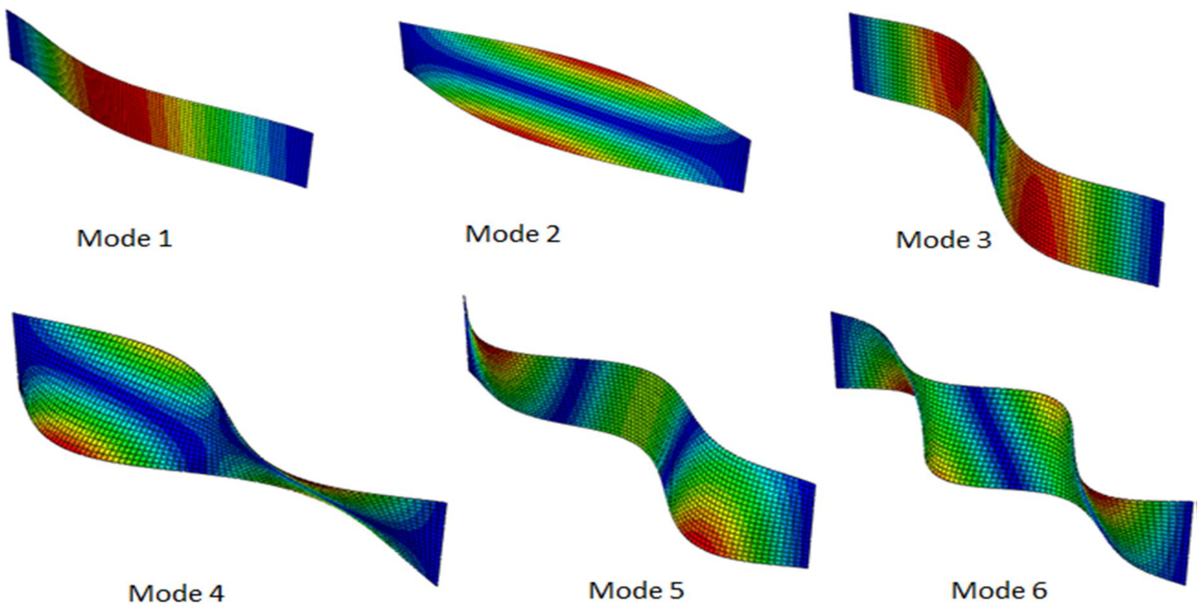


Figure 6 mode shape of laminated hybrid composite plate

IV. CONCLUSION

ABAQUS software was used to perform a free vibration study of a hybrid laminated composite plate made of a hybridised blend of carbon epoxy and glass epoxy with a staking sequence of [0/45/-45/90]s. The following observations are made based on the finite element analysis:

A. With increasing aspect ratio, the natural frequency of hybrid laminated composite plates drops.
B. The greatest natural frequency is achieved by using a hybrid laminated composite plate with carbon top and bottom layers and a glass epoxy intermediate layer.
C. Simply supported and clamped boundary condition of the plate gives near about value of natural frequency but natural frequency for cantilever boundary condition are to much less than other
D. From the mesh convergence study mesh size of 4*4 mm gives closer results with analytical results as compare to other meshing size.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

REFERENCES

[1] Sojan Andrews Zachariah, B. Satish Shenoy, Jaison Jayan, K. Dayananda Pai, "Experimental investigation on dynamic and static transverse behaviour of thin woven Carbon/Aramid hybrid laminates", Journal of King Saud University – Engineering Sciences (2020) pp1-9.

[2] I.D.G. Ary Subagia , Yonjig Kim , Leonard D. Tijing , Cheol Sang Kim , Ho Kyong Shon . "Effect of stacking sequence on the flexural properties of hybrid composites reinforced with carbon and basalt fibers", Composites: Part B (2014) pp215-258.

[3] Jin Zhang, Khunlavit Chaisombat, Shuai He, Chun H. Wang. "Hybrid composite laminates reinforced with glass/carbon woven fabrics for lightweight load bearing structures", Materials and Design (2012) pp75-80.

[4] Dhiraj Biswas, Chaitali Ray. "Comparative study on transient response analysis of hybrid laminated composite plates with experimental verification", Journal of Sound and Vibration (2019) pp43-64.

[5] Süleyman Baştürka , Haydar Uyanıkb , Zafer Kazancı. "Nonlinear damped vibrations of a hybrid laminated composite plate subjected to blast load", procedia engineering88 (2018) pp14-25.

[6] Mehmet S¸enyer, Zafer Kazancı. "Nonlinear dynamic analysis of a laminated hybrid composite plate subjected to time-dependent external pulses", Acta Mechanica Solida Sinica (2012) pp 1-12.

[7] Zeno Michael , Irfan Mahisham , Muhammad Farid Mahadi , Asyraf Naim Mohd Amin , Syed Irsyad Hilmi Syed Ahmad , Jamaluddin Mahmud. "Deformation and failure behavior of hybrid composite laminates made of Glass Epoxy and woven Kevlar Epoxy" , Materials Today: Proceedings (2020) pp 1-8.

[8] Jacob O'Donnell, Vijaya Chalivendra. "Multi-functional glass/carbon fibers hybrid inter/intra laminated composites", Composites Part C (2012) pp110-121.

[9] Young-shin lee, yeol-wha lee "Optimal design of hybrid laminated composite plates with dynamic and static constraints" Compurers & Srructures, (1992) pp797-803.

[10] Rajvinder Karda. "Generation of Light-Emitting SomaticTransgenic Mice for Disease Modelling of Hypoxic Ischaemic Encephalopathy", Molecular Therapy (2015) pp1-8.

[11] A. E. Bogdanovich "Modelling the blast response of hybrid laminated composite plates" Wood head Publishing Limited (2010) pp1-92.

[12] F.Z. Arrakhiz , K. Ben Hamou , F. Erchiqui , D. Hammiche , H. Kaddami. "Development and characterization of hybrid composite laminate based on luffa and glass fibers", Materials Today: Proceedings (2020) pp1-7.

[13] Dongdong Chen , Guangyong Suna, , Maozhou Meng , Xihong Jin , Qing Li "Flexural performance and cost efficiency of carbon/basalt/glass hybrid FRP composite laminates" ,Thin-Walled Structures (20190 pp516-519.

[14] Melih Savrana , Levent Aydin. "Stochastic optimization of graphite-flax/epoxy hybrid laminated composite for maximum fundamental frequency and minimum cost", Engineering Structures (2018) pp675-686.

[15] N. G. R. Iyengar "Deflection Analysis of Hybrid Laminated Composite Plates" Composite Structures (1986) pp15-32.

[16] M. S. Sarma. "Large amplitude vibrations of laminated hybrid composite plates" Journal of Sound and Vibration (1992) pp540-592.

[17] Chun-Sheng Chen, Wei-Ren Chen, Rean-Der Chien. "Stability of parametric vibrations of hybrid composite plates",European Journal of Mechanics A/Solids (2009) pp329-337.

[18] Konrad Dadej , Jarosław Bieniaś ." fatigue stress-cycle curves of carbon, glass and hybrid carbon/glassreinforced fibre metal laminates" ,International Journal of Fatigue (2020)pp1-14.

[19] A. S. Gendyt, A. F. Saleebt and S. N. Mikhailt. "Free vibrations and stability analysis of laminated composite plates and shells with hybrid/mixed formulation" , composite and structure (1997) pp1149-1163.

[20] Pruthwiraj Sahua , Nitin Sharma , Subrata Kumar Pandab. "Numerical prediction and experimental validation of free vibration responses of hybrid composite (Glass/Carbon/Kevlar) curved panel structure", composite structure (2020) pp1-13.

[21] Jianguo Wang, Lei Qu, Feng Qian. "State vector approach of free-vibration analysis of magneto–electro-elastic hybrid laminated plates" composite structure (2019) pp 1218-1324.

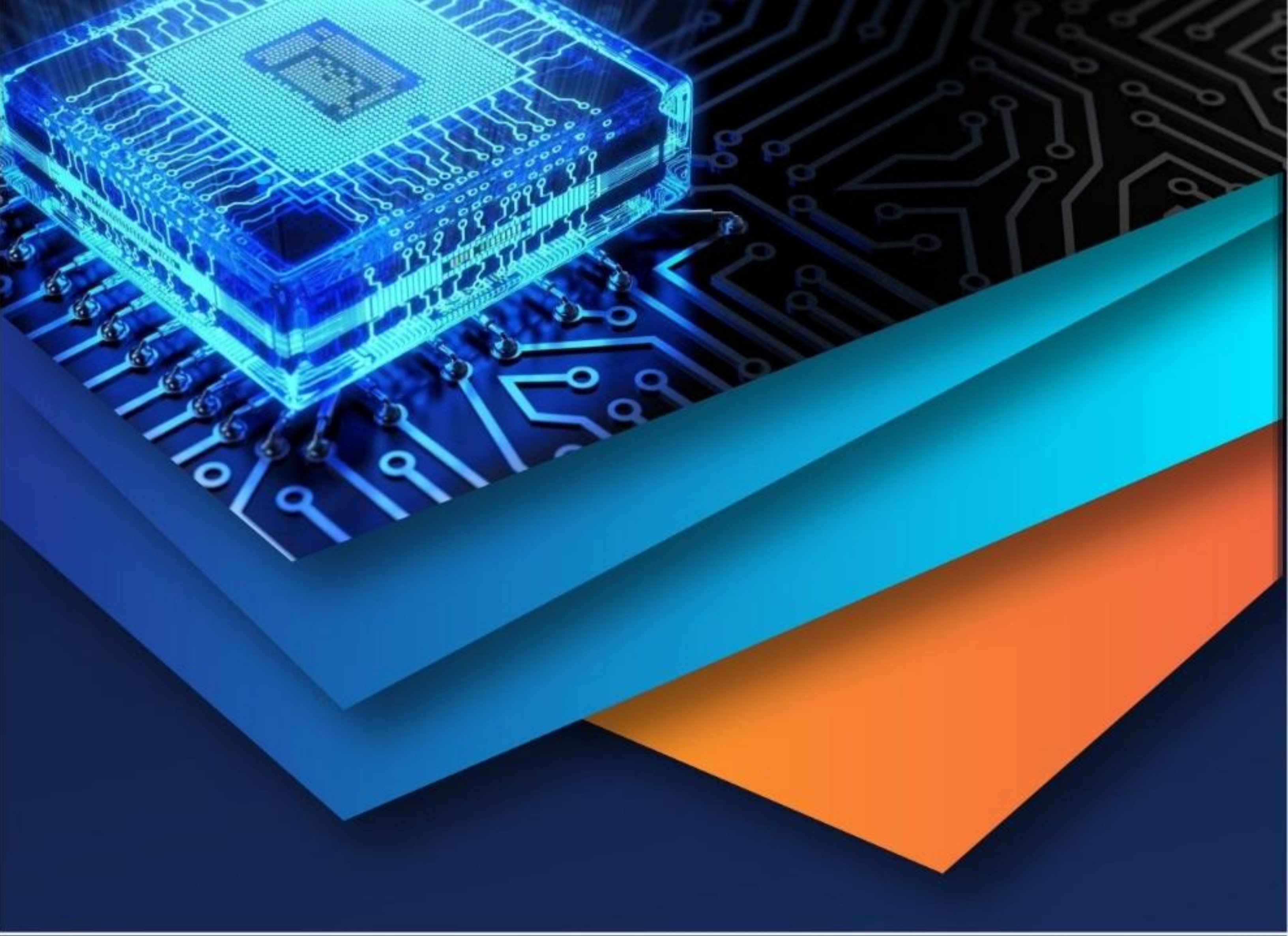
[22] F. Moleiro, E. Carrera, M. Cinefra , J.N. Reddy "Hygro-thermo-mechanical modelling of multilayered plates: Hybrid composite laminates, fibre metal laminates and sandwich plates" Composites Part B (2019) pp1-22.

[23] Ravi Joshi, S.K. Duggal."Free vibration analysis of laminated composite plates during progressive failure", European Journal of Mechanics (2020) pp83-96.

[24] T.Kant ,K.Swaminathan. "Analytical solution for laminated composite and sandwich plate based on higher order refined theory", composite structure 53(2001) pp73-85.

[25] Atteshamuddin S. Sayyad ,Yuwaraj M. Ghugal ," On the free vibration analysis of laminated composite and sandwich plates: A review of recent literature with some numerical results", composite structure 129(2015) pp 177-201.

[26] Aniket Chand, Rosalin Sahoo, "Trigonometric zigzag theory for free vibration and transient responses of cross-ply laminated composite plates "Mechanics of Materials (2021)pp1-14.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY