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Vibration Analysis of Laminated Hybrid Composite Material for Racing Car Panels

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Abstract: ***The present study deals with the vibration analysis of the E-Glass fiber (60%) and Kevlar (40%) composite material plate subjected to free vibrations. The analysis commences with the review of the previous works done in order to gather a rough idea regarding the said matter. The study proceeds with the determination of elastic constants of the bar used for characterization, prepared in the laboratory by performing the mechanical testing of the specimen. Vibration behavior of composite materials using FFT analyzer, using impact hammer for excitation. The modal testing of the Composite material is done in the laboratory and the results obtained experimentally are compared with the results obtained from the program based on FEM. The analysis further proceeds with the study of the effects of the various parameters such as increase in the strength, Different ply orientation, changing the layer of composite material etc. using FEA. From the convergence studies, a mesh is found to supply good accuracy. The vibration behavior of Composite material plate studied. This paper elaborates the design and analysis of car body panel of team NBN Sinhgad which has participated in 2019 racing.***
Keywords: Natural frequency, Hybrid composite materials (E-glass and Kevlar-29fibre), finite part methodology (FEM), excitation frequency, Solid Works Simulation, etc.

I. INTRODUCTION

Composite materials Kevlar Fiber- 29 (40%) and E-Glass Fiber (60%) are extending the horizons of all branches of engineering as they have marked their presence in different engineering structures with the domain ranging in the field of mechanical, aerospace, marine, civil, and biomedical, Oil and petroleum industry, mining process, etc. The Composite undergo the process of optimization where materials are combined in such a way that their virtues such as very well specific strength, good fatigue resistance, and good resistance, can be put to use in a better way while reducing the effect of their deficiencies. The term “car chassis panel” is a quite a renowned one owing to its applications in chassis cover panels, car dashboard , engine safety guards, etc. composite plate play a pivotal role as the structural units in the heavy machinery and tools used in product manufacturing heavy engineering industries. Static structures employing cantilever panels have significant applications used in car decor, fan blades, interior design parts, home appliances and industrial instruments, particularly in design for racing car chassis cover panels.

A. Importance of The Present Study

The structures implementing of car chassis panel are subjected to high Static loadings. The composite plates are also subjected to different types of loads due to transverse loads. The bar is constantly subjected to axial periodic forces as they form the part of the axial components of aerodynamic or hydrodynamic forces acting on the plates.
It is therefore, quite significant for design, safety and life of the machinery. Failure of bar often occurs as a result of sustained bar vibration at or near natural frequencies; hence knowledge of these frequencies is of fundamental importance. Moreover, to ensure reliable and economic delivery of the designs of the structures, it is necessary to estimate the vibration characteristics of those structures accurately.

B. Problem Statement

Vibration analysis of plate is required for efficient performance prediction and high specific strength. Complexity of configuration such as reduced weight of material, increased strength of plate etc. need to be studied for better functioning of such bar. Its validation using experimental and FEA approach.

1) Objectives

a) Experimental analysis of plates using free vibration testing at Static conditioning using FFT analyzer.
b) FEA modal vibration analysis of composite plates.
c) To find out the good alternate composite material as compare to previous material.

2) Scope

a) In this project element considered is a thin plate.
b) The present study is aimed to analyze the Static properties of composite material.
c) Find vibration parameters of plates analyzed for computational simplicity.
d) Find natural frequency of plate testing free vibration test.
e) Find natural frequencies hybrid composite material plates will be found using experimental and FEA approach, no external load is applied to the plate element.
f) Tests to study the effect of parameters such changing layer sequence, ply orientation of material.
g) In this project, main aim is to find out high strength of material after testing the 2 different composite materials combination samples. Selected the best material result we are found in these 2 different composite materials. We are using these experimental results to compare with FEA model.

3) Limitations

a) To analyzed the vibration in composite plates in set at particular set parameter.
b) The plate's element is restricted to be flat and uniform in thickness without changing the length and thickness.
c) For this project the plates is single sectors with rectangular shape.

II. LITERATURE REVIEW

A. R. Chandra et al "Damping studies in fiber-reinforced composites" [18] research on damping in fiber-reinforced composite material and structures with polymer composites has been reviewed in this paper. Selecting composites material checking which methodology applicable is to damping analysis is described. Further, paper presents some important works related to improving the damping models, improving the damping composite material are reviewed.

B. E.C. Botelho et al "Damping behavior of continuous fiber/metal composite materials by the free vibration method" [16] researcher has improved the current material Fiber metal laminates (FML) for aircraft structure with their mechanical characteristics and low density. Vibration testing was conducted and that experimental results were compared with experimental values showed good as compare to theoretical values.

C. J. Chandra das et al "Effect of nano-clay addition on vibration properties of glass fiber reinforced vinyl ester composites" [15] researcher represents the experimental study of hybrid nano-composite laminates by reinforcing materials free vibration and damping characteristics. Dynamic results show that the nano-scale dispersion in the matrix and E-glass fiber enhances the internal damping of hybrid composites.

D. Thingujam Jackson Singha et al "Characterization of Kevlar Fiber and Its Composites: A Review" [10] interest of using fiber reinforced composite has to replacing the traditional materials in various applications. Kevlar fiber, due to its unique properties and strength of material and modulus has become very common for reinforced composite material.

E. Mehmet Bulut et al "Experimental investigation on influence of Kevlar fiber hybridization on tensile and damping response of Kevlar/glass/epoxy resin composite laminates" [9] to study the investigation of tensile and damping behavior of this composite materials. To calculating the damping propriety forms logarithmic decrement method to determine the dynamic characteristics samples. Examine the fiber angle and frequencies using ANSYS.

F. Mohit Sinha et al "Design, Material Selection and Fabrication of a Race Car Body Panel" [6] researcher aims at the developed of FRP body panel for FSAE race car. Without losing the strength of vehicle to achieve the high power. Body panel is an internal part of body but main aim is to improve the aesthetic look of vehicle. Weight reduction in this are also become important factor.

III. METHODOLOGY

A. The project aims to study the vibration characteristics of plates with different composite materials. Experimental analysis of composite plate element using FFT analyzer for plate vibration analysis with respect to boundary conditions.

B. The study commences with the development of a model of the composite material which is subjected to free-free vibrations and cantilever type boundary conditions.

C. FEA analysis using plates for comparing the Experimental results and FEA results and location as specified in above point where is the maximum stress
Developed and finding natural frequencies with respect to respective mode shapes.

D. The modal analysis is done with a frequency range of 0 Hz to 2500 Hz. The above procedure is adopted to investigate the influence of various parameters.

IV. MATERIALS DETAILS

Table.1 Material properties

Sample 1: Glass fiber-E and Kevlar-29

Tensile strength	ASTM D 638-2014	2900 Mpa
Modulus of Elasticity	ASTM D 638-2014	70 Gpa
Shear strength	ASTM D 5379-12	36.84 Mpa
Izod impact test	ASTM D 256-2005	450 kj/ m^2
Density	ASTM D 792-2000	1.44g / cm^3
Poisons ratio	-	0.3

Table.2. Sample 2: Glass fiber-E and Kevlar-29

Tensile strength	ASTM D 638-2014	2758 Mpa
Modulus of Elasticity	ASTM D 638-2014	62 Gpa
Shear strength	ASTM D 5379-12	30.5Mpa
Izod impact test	ASTM D 256-2005	300 kj/ m^2
Density	ASTM D 792-2000	1.66g/ cm^3
Poisons ratio	-	0.3

Table.3.Sample 3: Glass fiber –E (Source-internet)

Tensile strength	3450 Mpa
Modulus of Elasticity	76 Gpa
Shear strength	34 Mpa
Izod impact test	-
Density	2.58g/ cm^3
Poisons ratio	0.2

Before starting the Experiment testing on hybrid composite plates, we are testing the design model in FEA software. Required such Mechanical properties in E-glass fiber and Kevlar fiber-29 to analyzing the composite material. We are manufacturing specimen plates as per standard dimensions for testing and after getting testing results value we have used values in FEA software.

V. SPECIMEN DESIGN

When selecting final Hybrid composite material we have manufacture composite material specimen for solving the modal analytical results. We have manufactured specimen which are basic sample at different ply orientation, different layer sequence. While getting the mechanical properties of hybrid composite materials to solve in FEA. We are analyzing 3 samples by using FEA with same methods to finding the best frequency of material which is suitable for manufacturing racing car panels.

Fig. 1. Tensile strength testing (ASTM D638-2014)

Fig. 2. Shear strength (ASTM D5379-12)

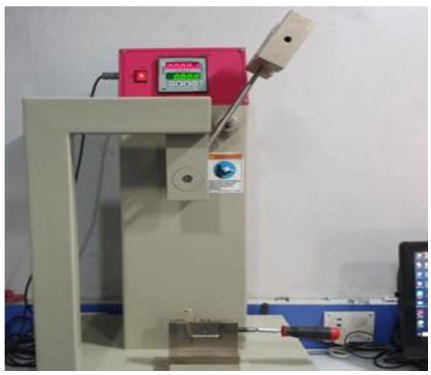
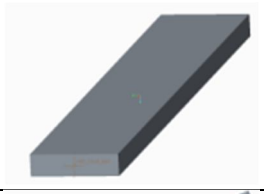
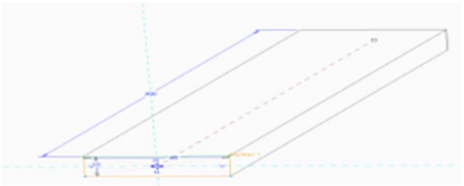
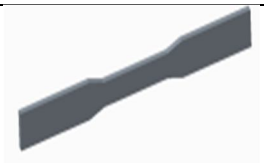
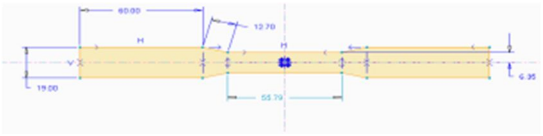
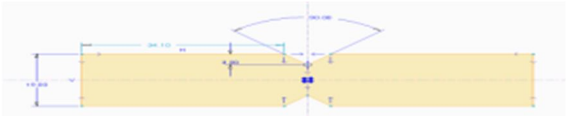
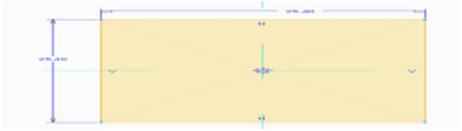
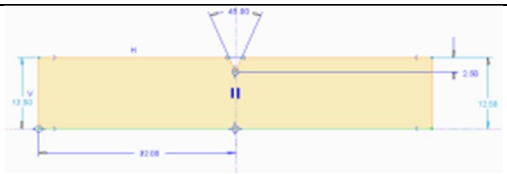


Fig.3. Izod impact test (ASTM D 256 - 2005)

As shown in above (fig.1,2 and 3) our hybrid composite material testing experiment required material properties is tensile strength, modulus of elasticity, shear strength, density of material and poison's ratio etc. this specimen plate test has done by material laboratory.

Table.4. Specimen design

Name	Testing Specimen	Specimen Dimensions (CAT Part)
Hybrid Composite plate		
Tensile test		
Shear strength		
Density		
Izod impact test		

VI. FEA RESULTS

When selecting final Hybrid composite material we have manufacture composite material specimen for solving the modal analytical results. We have manufactured specimen which are basic sample at different ply orientation, different layer combination. While getting the mechanical properties of hybrid composite materials to solve in FEA. We are analyzing 3 samples by using FEA with same methods to finding the best frequency of material which is suitable for manufacturing racing car panels.

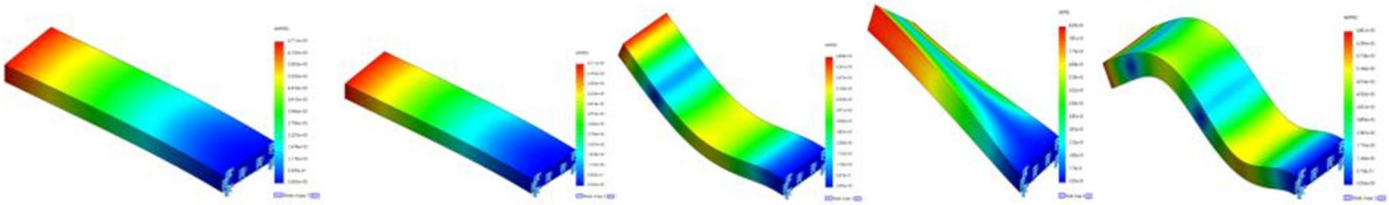


Fig.4. Mode shape of Hybrid composite materials Kevlar - 29 + E- glass fiber-sample 1

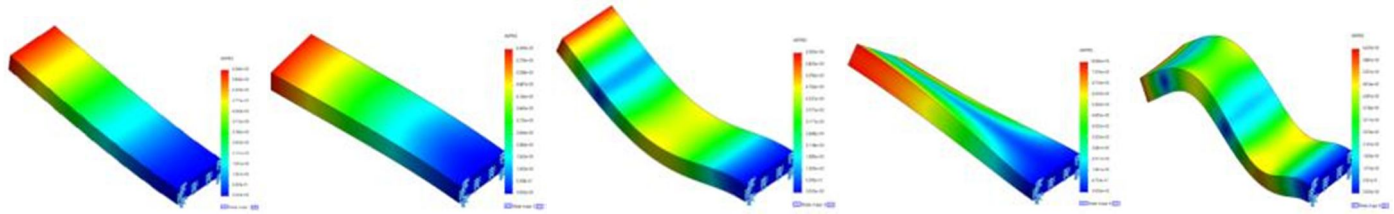


Fig.5. Mode shape of Hybrid composite materials Kevlar - 29 + E- glass fiber-sample 2

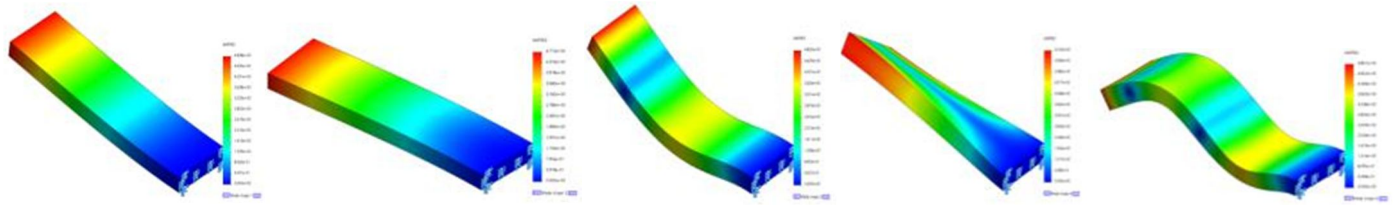


Fig.6. E-Glass fiber results

Table.5. Mode shape of Hybrid composite materials Kevlar - 29 + E- glass fiber

Materials	Frequency (HZ)				
Kevlar-29 + E-Glass fiber (Sample 1)	1.28	60.2	305.8	380.1	1648.1
Kevlar-29 + E-Glass fiber (Sample 2)	1.34	28.9	141.2	385.1	1422.7
E- Glass fiber	2.44	80.1	175.3	345.1	1210.8

Above the Mode shape table. 5. FEA results we are analyzing, Kevlar-29 + E-Glass fiber (Sample 1 and sample 2) hybrid composite materials results is better frequency given as compare to the E-Glass fiber. We are selecting the Kevlar-29+ E-Glass fiber hybrid composite materials for experimental testing. In this FEA results we have help to find out another best composite material which is used in manufactured racing car front panels to protect chassis.

A. Weight Reduction

Table.6.Weight reduction

Plates	Mass	Weight
Kevlar-29 + E-Glass fiber (Sample 1)	0.0996 kg	0.97608 N
Kevlar-29 + E-Glass fiber (Sample 2)	0.0702 kg	0.68796 N
E- Glass fiber	0.171 kg	1.6758 N

As shown in above weight reduction table 6.Indicate that the hybrid composite Kevlar -29 + E-glass fibre material weight reduced in sample-1is 0.996 kg and sample-2 is 0.0702 kg as compared to previous composite E-glass fibre material weight is 0.171kg. Above table prove that the selecting material is good and reduced weight as compare to existing material.

B. Ply Orientation

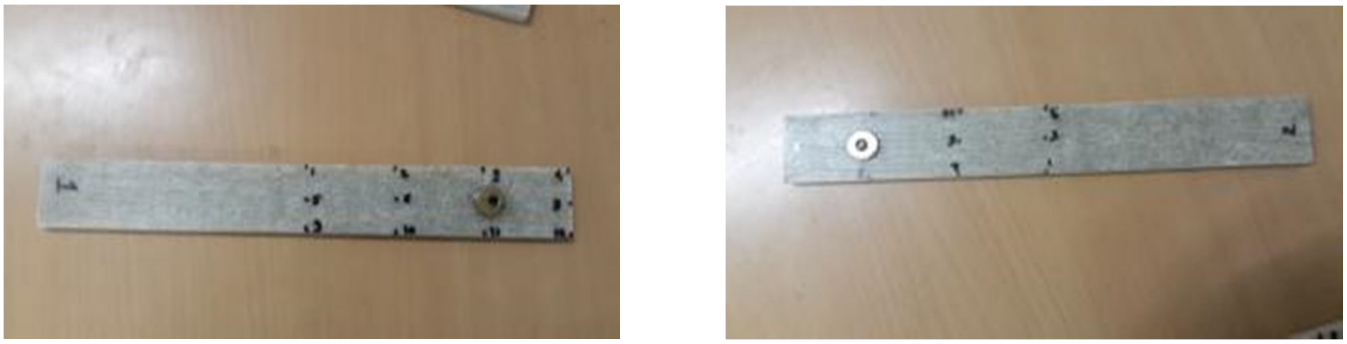
Table.7.Ply orientation

Sr. No.	Ply orientation	Details
1	0°	Makes tubes resistant to longitudinal bending and axial tension/ compression.
2	90°	Resist internal / external pressure.
3	±45°	Resist pure torsion.

We are conducted this test for finding out alternate good hybrid composite material for manufacturing chassis front panels. Complete chassis panels manufacturing is not possible because chassis design are under working process and our main aim to given another suitable composite material. We are only fabricated sample plates of 29-Kevlar fiber (**K**) + E- glass fiber (**G**) material. Required some composite material properties to use in FEA results analyzing, we have fabricated specimens according to their ASTM standard.

Table.8. Fabrication of plate's procedure

Materials	No. of layers	Layer sequence	Ply-Orientation	Aspect ratio of plates
Kevlar29 + E-Glass fiber Sample1	8	G-K-G-K-G-K-G-K	0/+45/-45/90/90/-45/+45/0	1:2
Kevlar-29 + E-Glass fiber Sample2	8	G-G-K-G-G-K-G-G	0/-45/+45/90/90/+45/-45/0	1:2



a)Sample -1 b)Sample -2

Fig.7. Kevlar-29 (K) + E-Glass fiber (G) (sample 1and 2)

VII. EXPERIMENTAL SETUP

After getting the FEA results we have manufactured hybrid composite sample plates. The test frame used in the system is designed for different boundary conditions i.e. free-free, cantilever and fully clamped The procedure began with the proper fitting of the test specimen followed by ensuring of connections of FFT analyzer, transducers, laptop, cables and modal hammer or exciter to the system. Impact hammer was used to excite the plate at selected points and the resulting vibrations were recorded by means of an Accelerometer held to the specimen through the plate. At each selected point, the hammer was made to strike for three times means total length of composite plate is 300 mm, width 40 mm and thickness 10 mm. After 150 mm we are given boundary condition remaining plate divided into 3 part 50mm each plate distance to obtain the Frequency Response Function (FRF).

Fig.8. Experimental setup

The screen displayed the average value of the response. The modal Hammer, Accelerometer, FFT Analyzer and the FRFs, FEA are described and shown in the above Fig.8. The strokes made were ensured to be perpendicular to the surface of the plate. To maintain the coherency of the results, the strokes should be made at approximately same points. The peaks of the FRFs provide the frequencies. Output is shown on the analyzer screen by means of pulse software. Then same procedure is carried out by finite element method, given the boundary condition on this plate and getting the FEA results.

VIII. RESULTS OF VIBRATION ANALYSIS

A. Kevlar-29 + E-Glass fiber (Sample 1)

Table.9: Comparison of the experimental results with the results obtained from numerical analysis in terms of frequencies for plates.

Frequency number	Experimental values (HZ)	Numerical values (HZ)
1	2.44	1.28
2	95.21	60.2
3	361.3	305.8
4	419.9	380.1
5	1945.8	1648.1

Graphical-Comparison

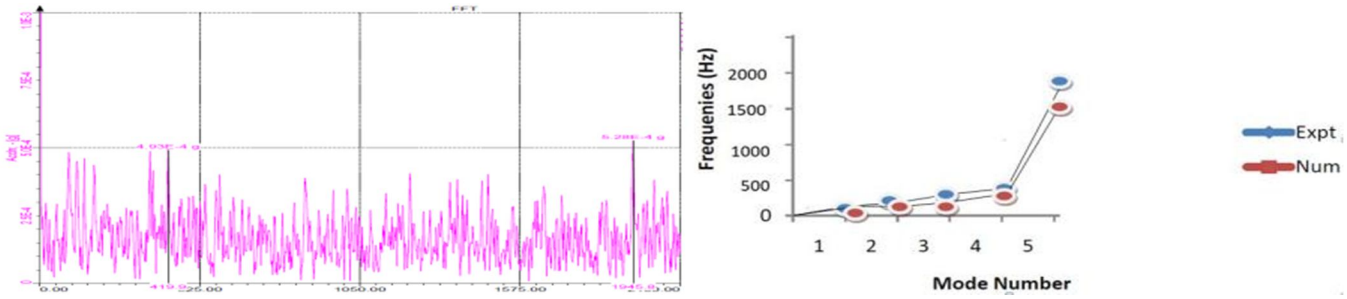


Fig.9. comparison of the experimental results with the results obtained from analysis results

Above Fig.9 shows the comparison between the Experimental and FEA results of various frequency in different mode shapes it's almost near the experimental values but the difference between the frequencies is 9% - 11 %. Which is indicates that the selection of hybrid composite material Kevlar-29 + E-Glass fiber (sample -1) composition is suitable for the practical purpose as compare to E-glass fiber.

B. Kevlar-29 + E-Glass fiber (Sample 2)

Table.10: Comparison of the experimental results with the results obtained from numerical analysis in terms of frequencies for plates.

Frequency number	Experimental values	Numerical values
1	2.44	1.34
2	141.6	128.9
3	151.4	141.2
4	417.5	385.1
5	1989.7	1422.7

Graphical-Comparison

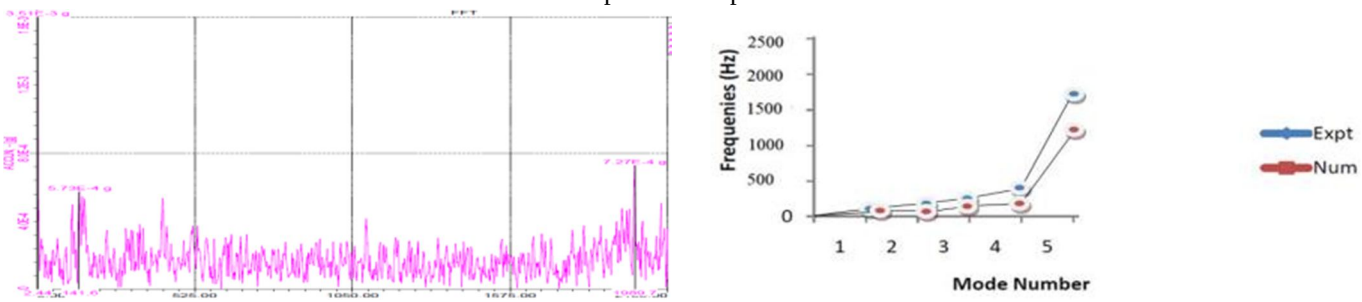


Fig.10. comparison of the experimental results with the results obtained from analysis results

Above fig.10. Shows the comparison between the Experimental and FEA results of various frequency in different mode shapes it's almost near the experimental values but the difference between the frequencies is 6% -8 %. Which is indicates that the selection of hybrid composite material Kevlar-29 + E-Glass fiber (sample -2) its natural frequency of material is less than the sample 1 in different mode shape.

IX. CONCLUSION

The study shows the development of new hybrid composites using Hand-lay-up method with the combination of Kevlar-29 fiber (40%) and E-Glass fiber (60%). The static mechanical, free vibration and chemical resistance properties were examined with the effect of particle strength of material and weight percentage of fiber content by standard experiments. The following conclusions can be drawn.

A. From the results presented it is clear that the change in fiber orientation and laminate stacking sequence yield to different static behavior of the component .Different layers sequence apply different contributions to the overall stiffness of the plate depending upon the location from midline.

B. From FEA mode list sample-2 table 5. show the increase in number of layers sequence from (G-G-K-G-G-K-G-G) an increase in the flexural frequencies and for stacking sequence of (0/45/+45/90/90/-45/+45/0) are observed. Also sample-2 reduced weight and increase strength shown that the FEA Weight reduction table 6.For stacking sequence of sample-1(0/+45/-45/90/90/+ 45/-45/0) decrease in modal frequency and flexural are observed. Which is also sample-2 experimental process shown in Fig.10.Comparison of the experimental results with the results obtained from analysis results 6% - 8% error is occurred as compared to sample-1 is 9%-11%.

C. The laminate only (0/45) of fibers has lowest frequency than the other lamination schemes and most of the fibers are oriented at 0deg. direction and thus appropriate for flexural modes Infect this can be applied that the fibers oriented at 0deg. Are appropriate for flexural loads and fibers oriented at 45deg. are appropriate for tensile loads. Finally an optimum number of layer sequences are selected to attain increase in strength of hybrid composite material. The desired vibration characteristics can be attained for the blade without modifying the shape.

X. ACKNOWLEDGMENT

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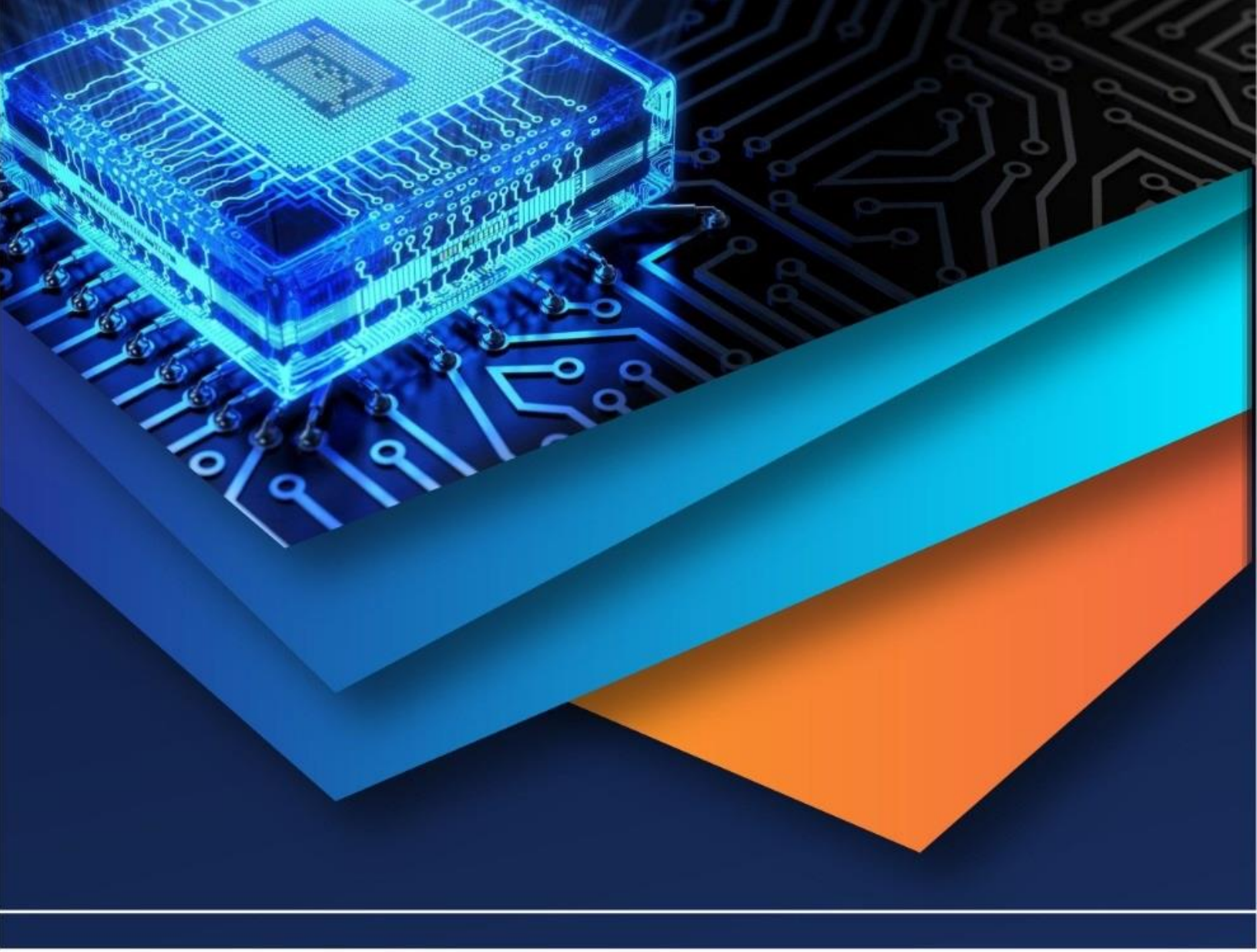

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