

STRUCTURAL BEHAVIOUR OF AIRCRAFT WING EMBEDDED WITH GRAPHENE NANOPlates

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ABSTRACT

In recent years the usage of graphene nanoplates for aeronautical applications is more because of its superior properties. The graphene nanoplates are used in aeronautical applications to overcome the problems like lightning strike and ice accumulation and other structural impact loads. The addition of graphene nanoplates to the aircraft wing structure enhance the anti-corrosion properties of the structure. Aircraft wing is subjected to tensile and compressive loads during flight and structure can fail before the yield point because of the loads acting on the wing structure. In the present project the graphene nanoplates are incorporated on to the aircraft wing structure to enhance the structural behaviour of the wing structure. The wing structure is modelled using catia where ribs and spars are made of different composites and graphene nanoplates are incorporated on to the skin of aircraft wing and results such as deformation, stress, strain, and other mechanical properties are plotted.

INTRODUCTION

The wings of an aircraft are designed to lift it into the air and they carry the weight of the aircraft. The wing design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft, desired speed in flight and at landing, and desired rate of climb. The wings of aircraft are designated left and right, corresponding to the left and right sides of the operator when seated in the cockpit.

Often wings are of full cantilever design. This means they are built so that no external bracing is needed. They are supported internally by structural members (spars and ribs) assisted by the skin of the aircraft. Other aircraft wings use external struts or wires to assist in supporting the wing and carrying the aerodynamic and landing loads. Wing support cables and struts are generally made from steel. Many struts and their attach fittings have fairings to reduce drag. Short, nearly vertical supports called jury struts are found on struts that attach to the wings a great distance from the fuselage. This serves to subdue strut movement and oscillation caused by the air flowing around the strut in flight.

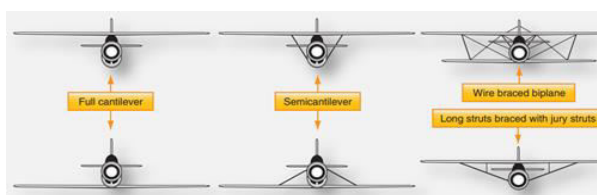


Figure: Different Methods of Wing Support

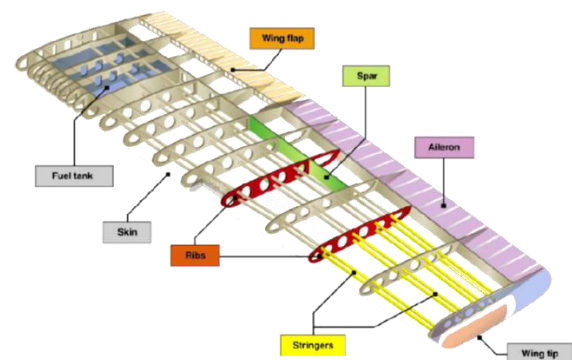


Figure: Various Wing Layout and Major Components

LITERATURE REVIEW

Yii-Mei Huang et al [1] tackles the technique of passive sound management systems. Their main objective was to design dynamic dampening absorbers to eliminate fuselage vibrations generated from external influences like propellers etc. They evaluated the appropriate parameters to be chosen in design process of the absorbers, to optimally keep the vibrations and noise generated it a minimum. They primarily constructed mathematical algorithms for the motion, vibrations, interior sound field and the external forces that affect the cylindrical fuselage. These were further used to determine the optimal design and placement of the absorbers. By considering kinetic energy and potential energy of the fuselage and the sound field as objective functions, they concluded that their approach had a major impact in reducing the undesirable noise in the fuselage structure.

ParthaDey et al [2] understands the stability of composite skew plates when subjected to loads. The dynamic stability of composite skew plates was analyzed using four-noded shear flexible quadrilateral plate. Finite element equations of the plate were formulated. Gaussian integration rule was used to calculate matrices for elemental mass and linear-geometric stiffness. First and second order dynamic instability boundaries were then identified. The identified principal stability region was four times the secondary instable region. As load amplitude increased, the first and the second order approximations differed. Region of instability increased with the increase in skew angle. The paper lays out the influence skew angle, lay-up and static in plane loads have on dynamic stability.

Zhiqian LI et al [3], with previous research on tiltrotors as a basis, intended to construct a full-span model tiltrotor followed by its analysis along the parameter of aeroelastic stability in flight. They also established the differences between a semi and a full span model and nailed down the reasons for its instability and monitored the effects of external structures on its aeroelastic stability. After constructing a theoretical model of the tiltrotor, they constructed algorithms to represent various structures and features of the tiltrotor. These equations were used to validate the various parameters, and the results indicated that elastic blades invariably led to more instability than rigid winged aircrafts did, and when these were coupled with fuselage motions, the instability was found to have increased further. Natural laminar flows (NLF) wings are capable of maintaining flow under laminar conditions over relatively large portions of wing surface. But imperfections produced during the manufacturing process (grooves between joints and fixtures) have an adverse effect on aerodynamic performance due to a disruption in air flow over the wing surface.

METHODOLOGY

There are many problems facing aircraft in the air during flight, such as lightning strikes and ice accumulation on aircraft surfaces. These problems usually reduce aircraft efficiency and lead to serious accidents and fatalities. However, the current protection systems used to solve these problems of aircraft represent excessive energy usage, a hazard to the environment, and they are generally bulky, heavy and costly. Therefore, there are new conductive composites containing an embedded layer of conductive fibers such as

graphene and carbon nanotube designed to carry lightning currents, in addition to that, there is a new deicing heater element made of graphene nanoribbons films to be used in ice protection systems.

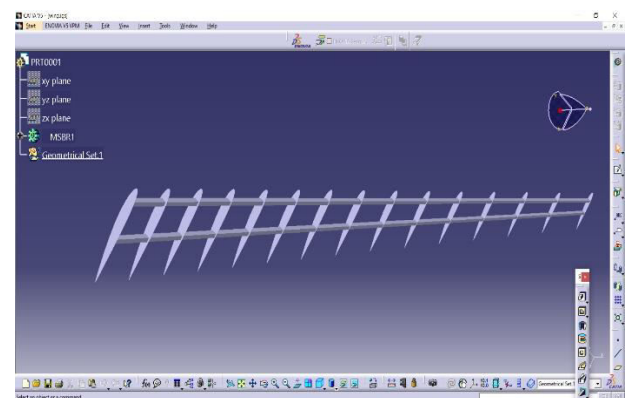
Static analysis to determine the deformation, stress and strain at different materials graphite epoxy, Kevlar epoxy and glass fiber. Harmonic analysis to determine the frequency of the wing, random vibrational analysis to determine the directional deformation at different materials. The graphene coating on skin of the wing.

Material properties

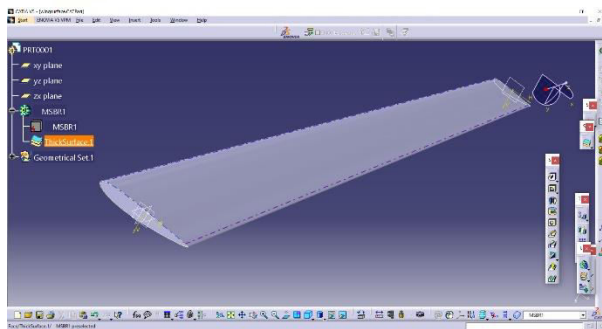
Materials	Density (kg/m ³)	Youngs modulus (MPa)	Poisson's ratio
Aluminium alloy	2770	71000	0.33
Graphite epoxy	1824	138600	0.34
Glass fiber	2580	72300	0.22
Kevlar epoxy	1380	30000	0.34

WING WITH RIBS AND SPARS

**Wing model designed in CATIA 3D software.
The wing profile created by NACA2412**



TOTAL ASSEMBLY OF WING



Boundary conditions

For static analysis, pressure and fixed supports are boundary conditions. Given fixed support one end of the wing and pressure applied on the bottom of the wing skin. Pressure applied 2.84×10^{-3} MPa.

5.1 CASE-1 ANALYSIS OF AIRCRAFT WING WITHOUT GRAPHENE COATING

To import a file from CATIA to ANSYS Workbench, the model is to be prepared in CATIA so as to analyze it in ANSYS Workbench.

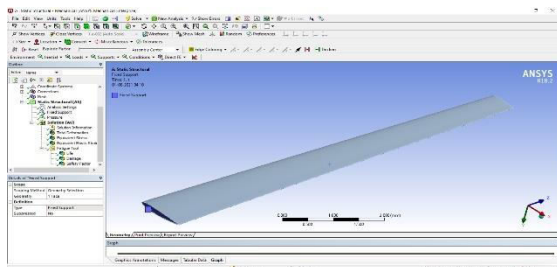
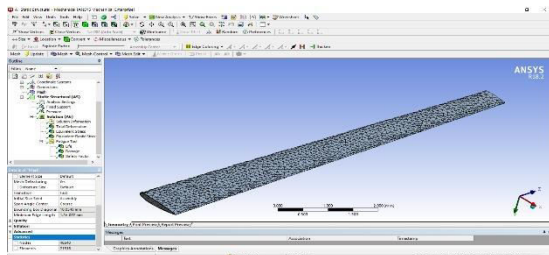


Fig 5.1.1 imported model

Meshing is an integral part of the computer-aided engineering (CAE) simulation process. The **mesh influences the accuracy, convergence and speed of the solution**. Furthermore, the time it takes to create a mesh model is often a significant portion of the time it takes to get results from a CAE solution.

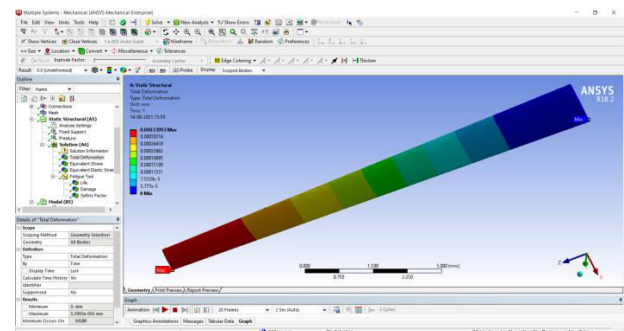


Finite element analysis or FEA representing a real project as a “mesh” a series of

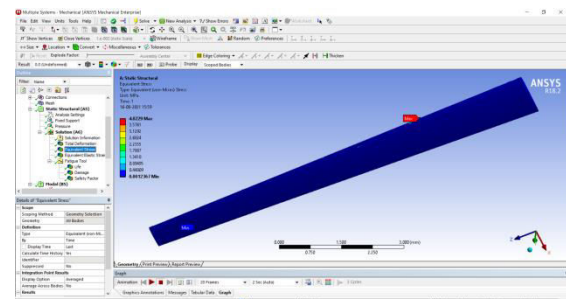
small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required. No of nodes 46640 and no of elements 21516.

Material- Aluminium alloy

Deformation



Stress



MATERIAL- GRAPHITE EPOXY

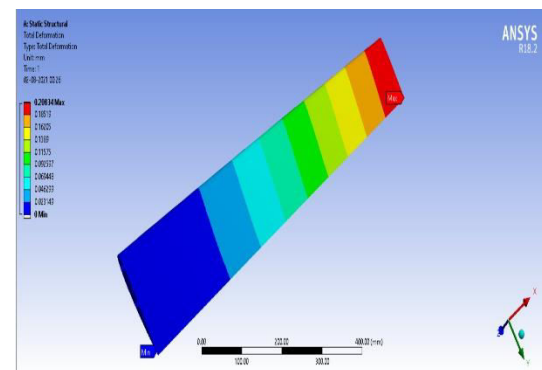


Fig: Deformation of graphite epoxy

We get to know this technique gives the deformation of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of deformation of the wing . When the loads applied i.e., pressure is imported and applied on wing, the maximum deformation value is 0.20834mm.

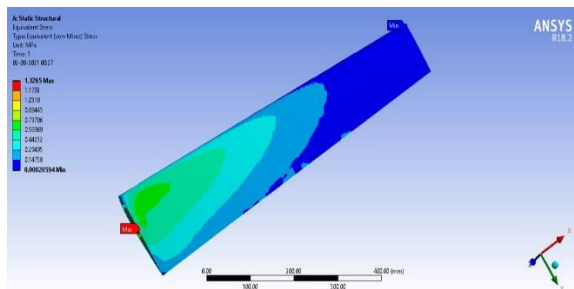


Fig: Stress of graphite epoxy

We get to know this technique gives the stress of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of stress of the wing . When the loads

applied i.e., pressure is imported and applied on wing, the maximum stress value is 1.3265MPa.

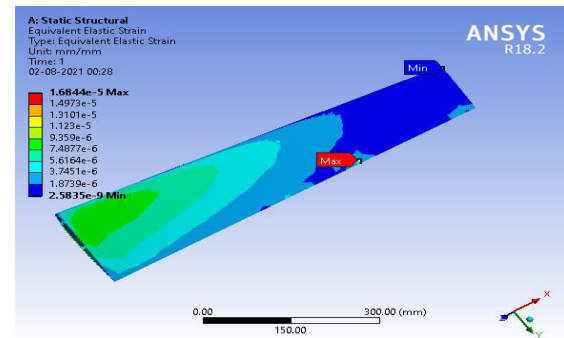


Fig: Strain of graphite epoxy

We get to know this technique gives the strain of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of strain of the wing . When the loads applied i.e., pressure is imported and applied on wing, the maximum strain value is 1.6844e-5.

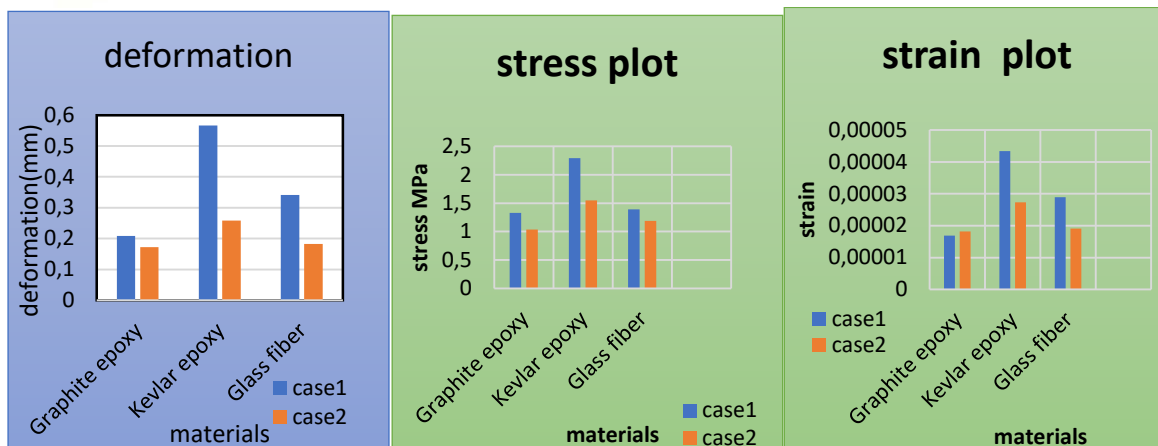
Table 6.1 Static analysis results

Models	Materials	Deformation (mm)	Stress (Mpa)	Strain
Wing with Aluminium alloy	Graphite epoxy	0.20834	1.3265	0.000016844
	Kevlar epoxy	0.56668	2.291	0.00004342
	Glass fiber	0.34092	1.3894	0.00002887
Wing with aluminium alloy and graphene coated	Graphite epoxy	0.1719	1.0339	0.000018204
	Kevlar epoxy	0.25785	1.5509	0.000027306
	Glass fiber	0.18311	1.189	0.000019101

Results for aluminium alloy material

Wing model	Deformation (mm)	Stress (MPa)	Strain	Life	Damage	Safety factor
	0.00033993	4.0229	4.85e-005	E15	E32	0.99045

Graphs



deformation plot

stress plot

strain plot

Fatigue analysis of wing

MATERIAL- GRAPHITE EPOXY

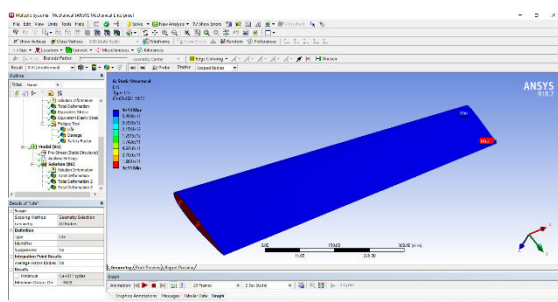


Fig: Life

We get to know this technique gives the life of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of life of the wing . When the loads applied i.e., pressure is imported and applied on wing, the maximum life value is 1e13.

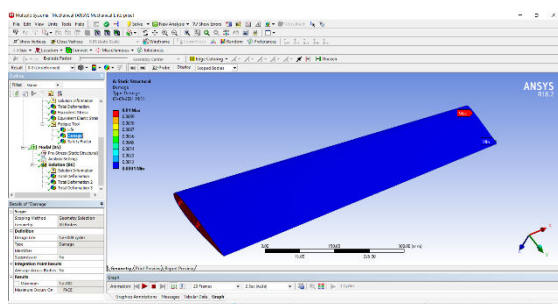


Fig: Damage

We get to know this technique gives the damage of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of damage of the wing . When the loads applied i.e., pressure is imported and applied on wing, the maximum damage value is 0.01.

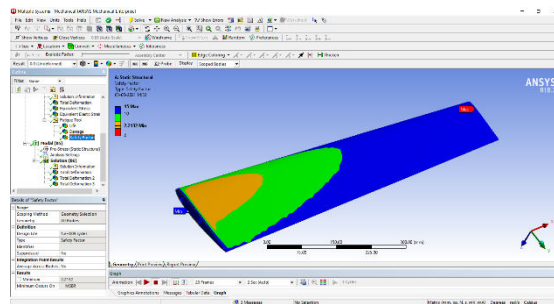


Fig: Safety factor

We get to know this technique gives the safety factor of the wing due to action of forces developed which is important for accurate performance of the wing operation under severe conditions.

It is observed that there is substantial amount of safety factor of the wing . When the loads applied i.e., pressure is imported and applied on wing, the maximum safety factor value is 2.2132.

Table 6.2 Fatigue analysis results

Models	Materials	Life		Damage	Safety factor
		Max.	Min.		
Case1	Graphite epoxy	e13	1.1541e10	0.086645	1.975
	Kevlar epoxy	e13	9.8476e8	1.0155	0.998
	Glass fiber	e13	1.657e10	0.06033	1.647
Case2	Graphite epoxy	e13	e11	0.01	2.213
	Kevlar epoxy	e13	3.3574e10	0.029785	1.475
	Glass fiber	e13	e11	0.01	1.924

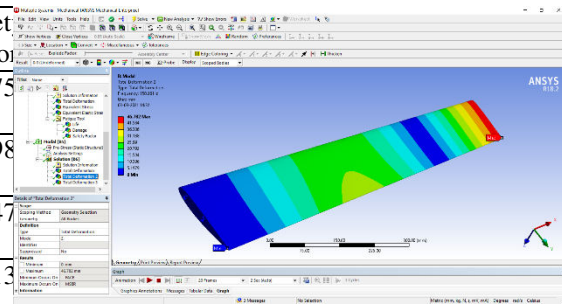
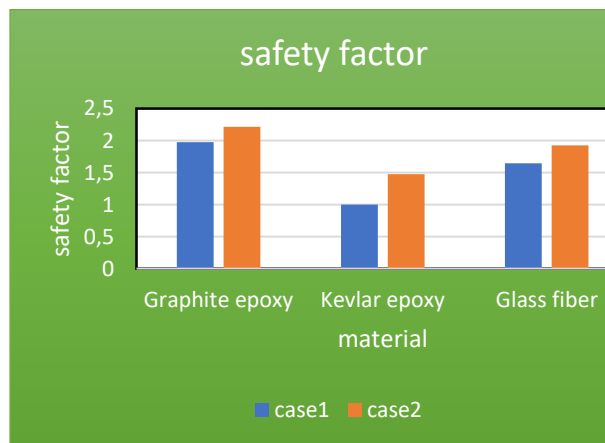


Fig: Mode shape-2

According to above figure the maximum deformation indicated in red colour and minimum deformation indicated in blue colour. The maximum deformation at one end of the wing, the minimum deformation at another end of the wing . The maximum deformation is 46.782mm .

Safety factor plot



Modal analysis of wing

MATERIAL- GRAPHITE EPOXY

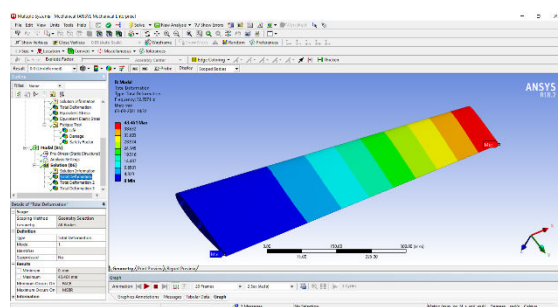


Fig: Mode shape-1

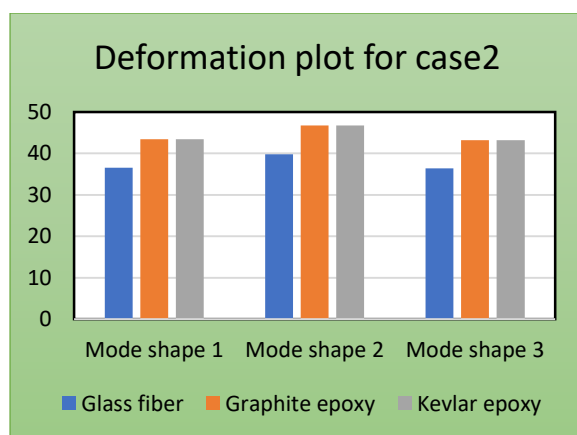
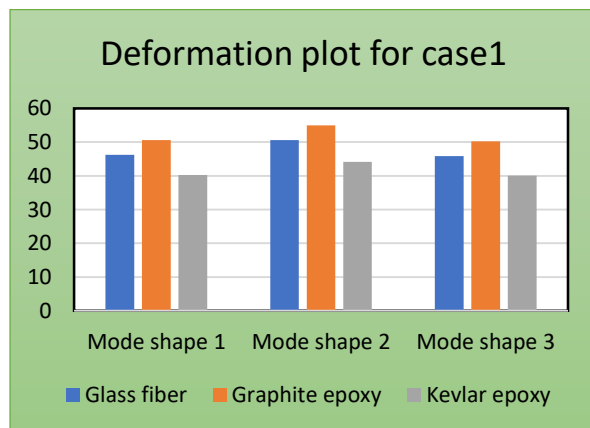
According to above figure the maximum deformation indicated in red colour and minimum deformation indicated in blue colour. The maximum deformation at one end of the wing, the minimum deformation at another end of the wing . The maximum deformation is 41.461mm .

Fig: Mode shape-3

According to above figure the maximum deformation indicated in red colour and minimum deformation indicated in blue colour. The maximum deformation at one end of the wing, the minimum deformation at another end of the wing . The maximum deformation is 41.209mm .

Table 6.3 Modal analysis results

Models	Materials	Mode shape	Deformation (mm)	Frequency (Hz)
Case1	Graphite epoxy	Mode shape 1	46.267	44
		Mode shape 2	50.617	204.45
		Mode shape 3	45.842	330.02
	Kevlar epoxy	Mode shape 1	50.594	29.376
		Mode shape 2	55.005	139.11
		Mode shape 3	50.207	205.13
Case2	Glass fiber	Mode shape 1	40.297	30.096
		Mode shape 2	44.19	140.37
		Mode shape 3	40.029	221
	Graphite epoxy	Mode shape 1	43.461	32.707
		Mode shape 2	46.782	158.26
		Mode shape 3	43.209	211.7
	Kevlar epoxy	Mode shape 1	43.461	32.707
		Mode shape 2	46.782	158.26
		Mode shape 3	43.209	211.7
	Glass fiber	Mode shape 1	36.574	32.577
		Mode shape 2	39.791	154.9
		Mode shape 3	36.438	224.86



CONCLUSION

In this thesis, the trainer aircraft wing structure with skin, spars and ribs is considered for the detailed analysis. The wing structure consists of 15

ribs and two spars with skin. The skin material is aluminium alloy and also coated with graphene. Front spar having „C“ section and rear spar having „C“ section. Stress and fatigue analysis of the whole wing section is carried out to compute the stresses and life at spars and ribs due to the applied pressure load.

In this project, results compared to Wing with Aluminium alloy and Wing with aluminium alloy and graphene coated.

Taken materials Graphite epoxy, Glass fiber and Kevlar epoxy, these materials applied to ribs and spars. The wing skin material aluminium alloy and coated graphene

Compared the deformation, stress and strain values for aluminium alloy present material with composite materials.

The present material has more stress values compare the composite materials.

By observing the static analysis of aircraft wing, the Graphite epoxy material has less stress when compare the Glass fiber and Kevlar epoxy and also compared to models Wing with aluminium alloy and graphene coated has less stress.

By observing the modal analysis of aircraft wing, the deformation and frequency values are more for **Graphite epoxy** material. By observing the fatigue analysis of aircraft wing, the safety factor value is more for **Graphite epoxy** material.

So it can be conclude, the **Graphite epoxy** material and **Wing with aluminium alloy and graphene coated** model is better material for aircraft wing.

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