Design And Analysis of BOEING-747 Aircraft Wing Rib Using Composites

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Abstract*- A wing is a type of fin with a surface that produces aerodynamic forces facilitating movement through air and other gases, or water and other liquids. As such, wings have an aerofoil shape, a streamlined cross-sectional shape producing lift.*

Wing design is constantly evolving. If you were to compare the wing of the Wright Flyer with that of a modern aircraft, such as the Boeing 747, the difference is remarkable. The number of lifting surfaces, shape, size and materials used all contribute to an aircraft's performance.Day by day need for stronger and lighter materials is increasing rapidly .So many studies are going on to check the feasibility of latest materials in aeronautics. In this study, we are intended to contribute some work regarding material feasibility requirements in aeronautics

In this study the static behaviour of an aeroplane wing is studied under flight conditions with several composite materials and different wing models. Drag and lift values are calculated based on the wing surface area, relative velocity of plain and density of the air (based on altitude). Simulation is done using Ansys Fluent module.

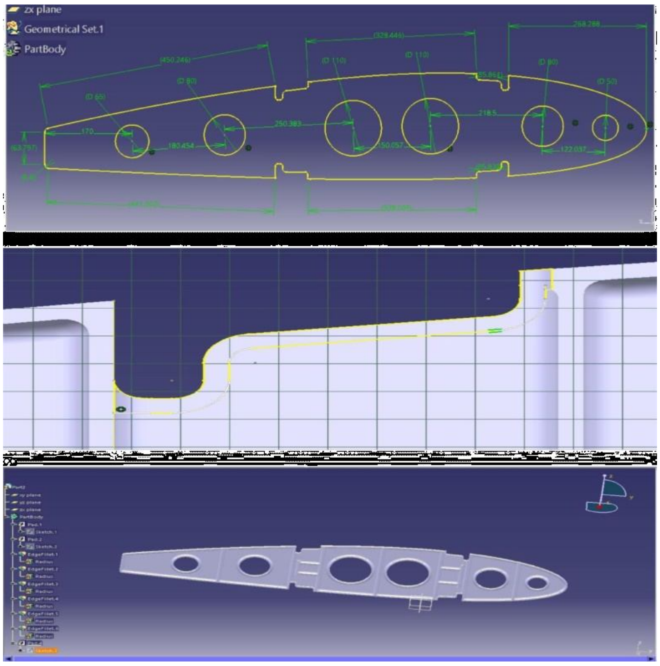
I. INTRODUCTION

A wing is a type of fin that produces lift, while moving through air or some other fluid. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as an airfoil. A wing's aerodynamic efficiency is expressed as its lift-to-drag ratio. The lift of a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift.

Lifting structures used in water, include various foils, including hydrofoils. Hydrodynamics is the governing science, rather than aerodynamics. Applications of underwater foils occur in hydroplanes, sailboats and submarines.

CAD

computed aided design (CAD) can be defined as the use of computer systems in conceptualizing the idea to create and modify the design. Computer aided design is a process in which interaction between designer and computer is made as simple and effective possible. Various engineering activities like planning, analysis, detailing, manufacturing, construction, modelling, process control and management can be improvised by CAD.



Model of Wing design

ANSYS: Ansys is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behaviour of the product, be it electromagnetic, thermal, mechanical etc.

Input properties of aluminium2024 in ANSYS

Properties of Outline Row 3: Aluminum 2024-T4

	A	B	C
1	Property	Value	Unit
2	Density	2.78	g cm^-3
3	Isotropic Elasticity		
4	Derive from	Young's M...	
5	Young's Modulus	73100	MPa
6	Poisson's Ratio	0.33	
7	Bulk Modulus	7.1667E+10	Pa
8	Shear Modulus	2.7481E+10	Pa

Input properties of carbon fiber epoxy in ANSYS

Properties of Outline Row 4: cabonfiber

	A	B	C
1	Property	Value	Unit
2	Density	1.6	g cm^-3
3	Isotropic Elasticity		
4	Derive from	Young's M...	
5	Young's Modulus	70000	MPa
6	Poisson's Ratio	0.1	
7	Bulk Modulus	2.9167E+10	Pa
8	Shear Modulus	3.1818E+10	Pa

Input properties of e-glass epoxy in ANSYS

Properties of Outline Row 5: e-glass

	A	B	C
1	Property	Value	Unit
2	Density	1.9	g cm^-3
3	Isotropic Elasticity		
4	Derive from	Young's M...	
5	Young's Modulus	25000	MPa
6	Poisson's Ratio	0.2	
7	Bulk Modulus	1.3889E+10	Pa
8	Shear Modulus	1.0417E+10	Pa

Input properties of Kevlar epoxy in ANSYS

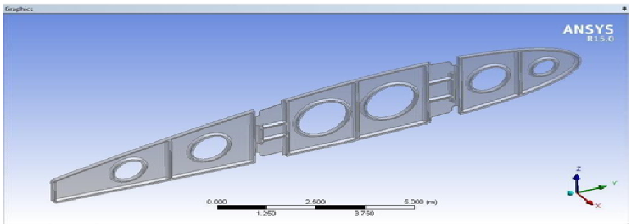
Properties of Outline Row 6: kevlar

	A	B	C
1	Property	Value	Unit
2	Density	1.4	g cm^-3
3	Isotropic Elasticity		
4	Derive from	Young's M...	
5	Young's Modulus	30000	MPa
6	Poisson's Ratio	0.2	
7	Bulk Modulus	1.6667E+10	Pa
8	Shear Modulus	1.25E+10	Pa

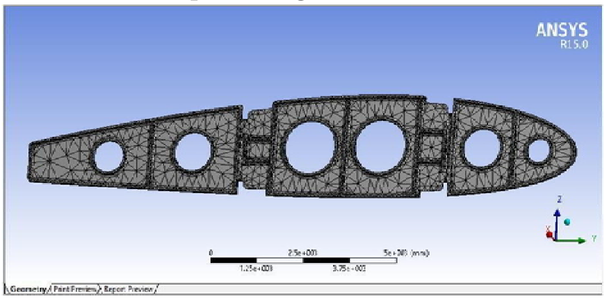
Material comparison

material	density (g/cm3)	young's modulus (Mpa)	Poisson's ratio	bulk modulus (Mpa)	Shear Modulus (Mpa)
aluminium 2024	2.78	7.31E+10	0.33	7.17E+10	2.75E+10
Carbon fiber epoxy	1.6	7.00E+10	0.1	2.92E+10	3.18E+10
e-glass epoxy	1.9	2.50E+10	0.2	1.39E+10	1.04E+10
kevlar epoxy	1.4	3.00E+10	0.2	1.67E+10	1.25E+10

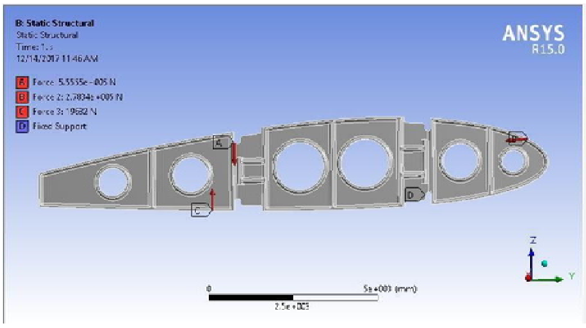
Modal of aircraft wing rib



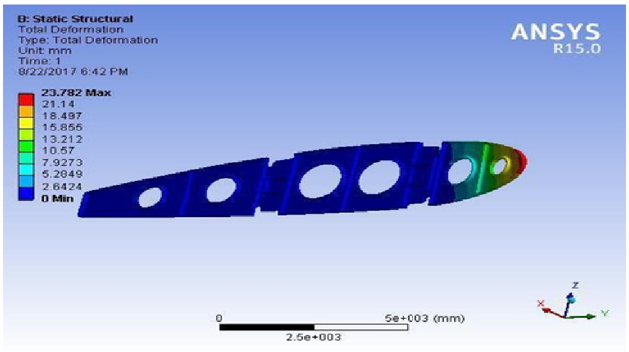
Picture representing mesh from ANSYS



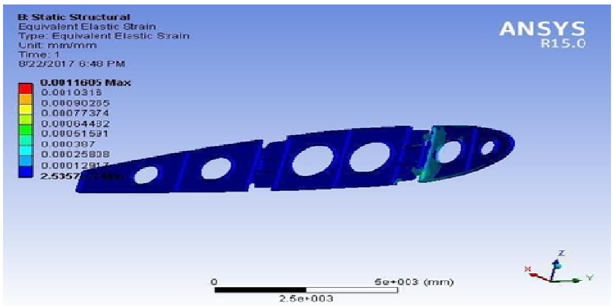
Forces applied at different points



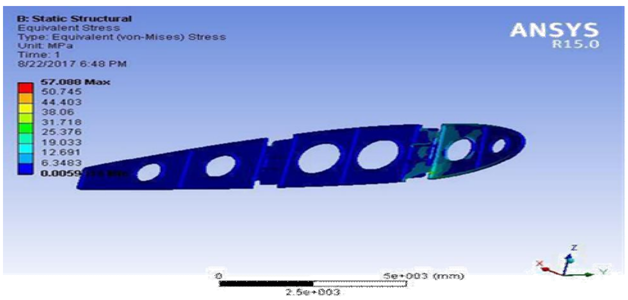
Static structural analysis of basic 747 wing structure using aluminium 2024



Total deformation using aluminium 2024

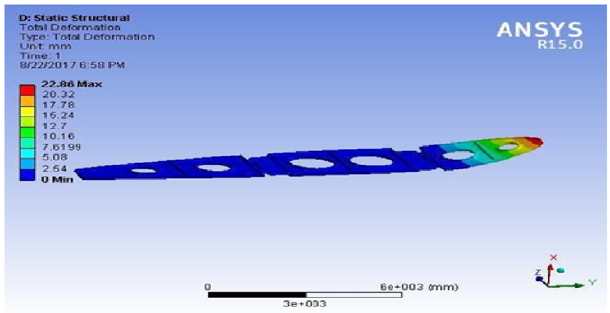


Elastic strain using aluminium2024

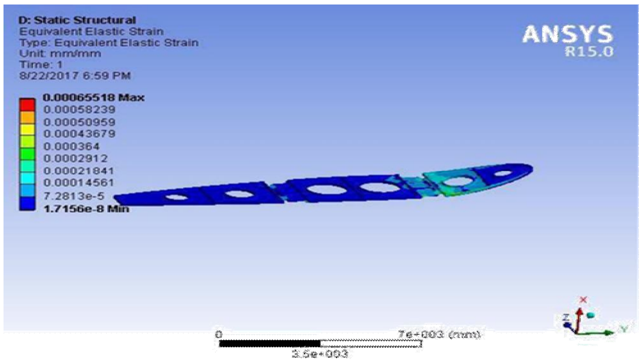


Equivalent stress using aluminium2024

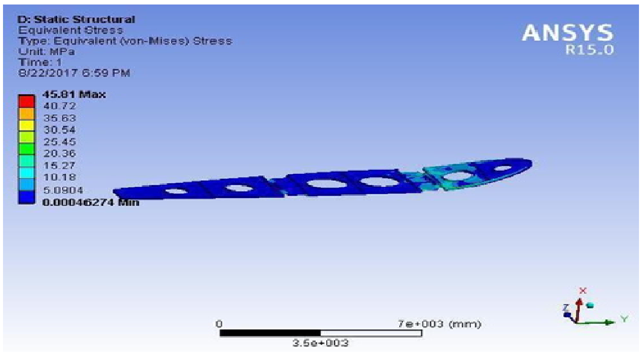
Static structural analysis of basic 747 wing structure using carbon fibre epoxy



Total deformation using carbon fibre epoxy

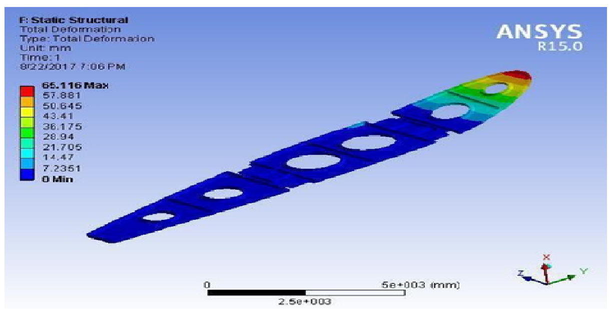


Elastic strain using carbon fibre epoxy

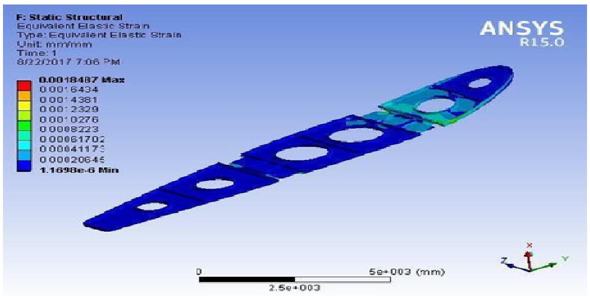


Equivalent stress using carbon fibre epoxy

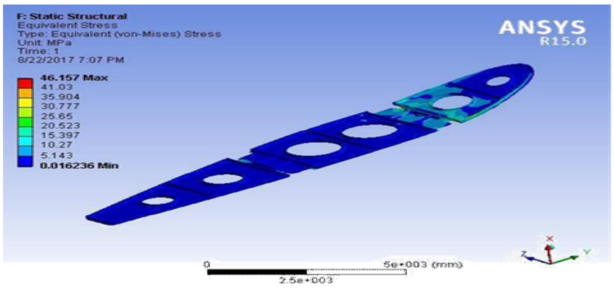
Static structural analysis of basic 747 wing structure using e-glass epoxy



Total deformation using e-glass epoxy

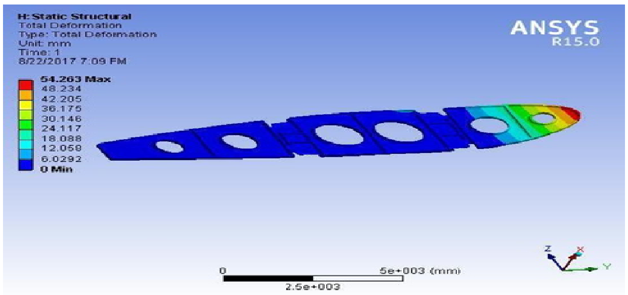


Elastic strain using e-glass epoxy

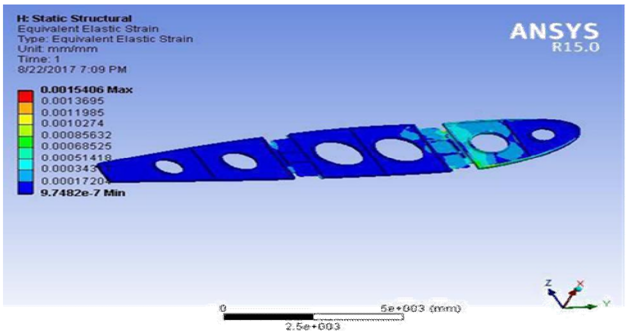


Equivalent stress using e-glass epoxy

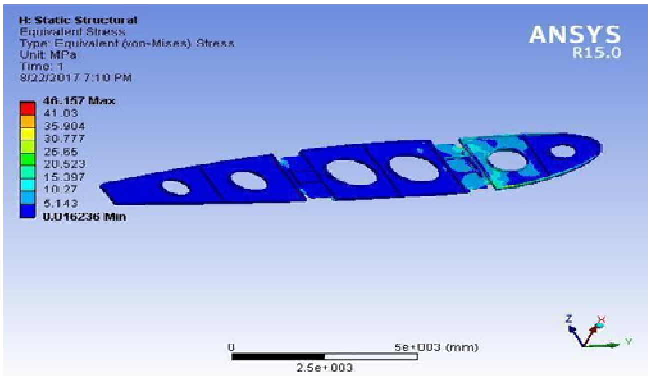
Static structural analysis of basic 747 wing structure using Kevlar epoxy



Total deformation using Kevlar epoxy

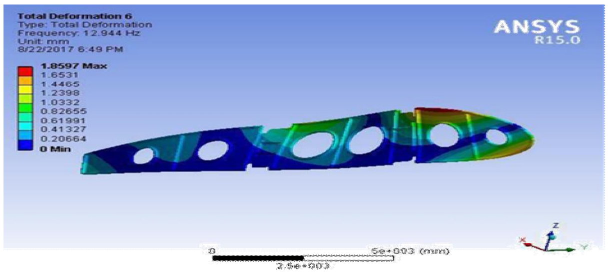


Elastic strain using Kevlar epoxy

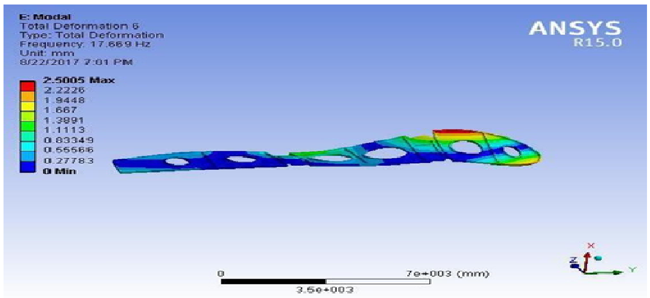


Equivalent stress using Kevlar epoxy

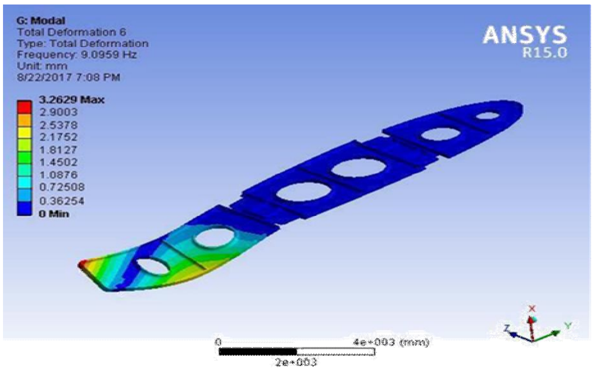
NATURAL FREQUENCYS



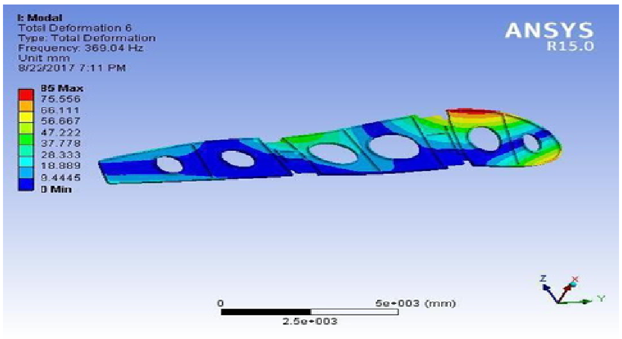
Aluminium 2024



Carbon fibre epoxy



E-glass epoxy



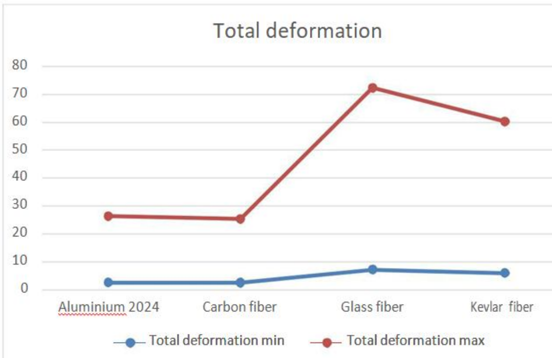
Kevlar epoxy

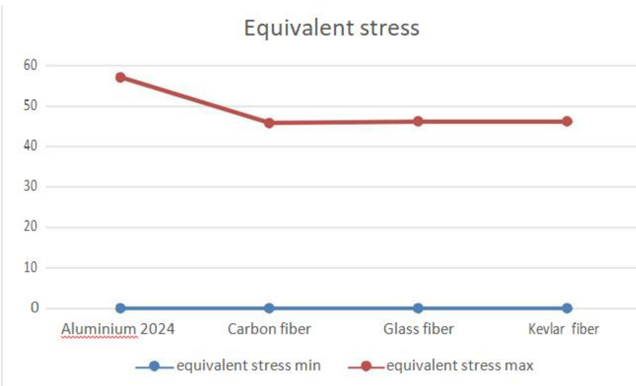
Model 1	Total deformation		Elastic strain		equivalent stress	
	Min	Max	min	Max	Min	max
Aluminium 2024	2.6424	23.782	2.54E-07	0.001161	0.005911	57.088
Carbon fiber epoxy	2.54	22.86	1.72E-08	0.000655	0.000463	45.812
E-Glass epoxy	7.2351	65.116	1.17E-06	0.001849	0.016236	46.157
Kevlar epoxy	6.0292	54.263	9.75E-07	0.001541	0.016236	46.157

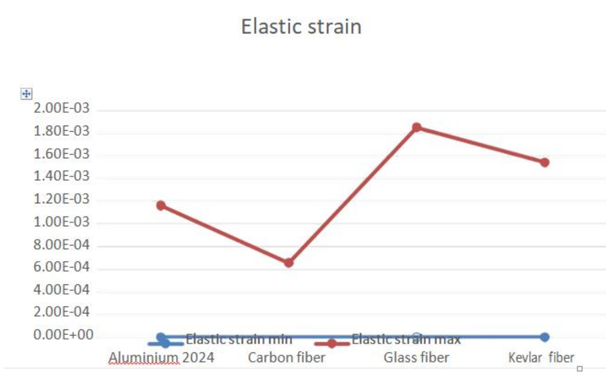
NOTE:

Deformation is in – mm.
Strain in- mm/mm.
Stress in – Mpa.
Natural frequency in – Hz.

Graphs

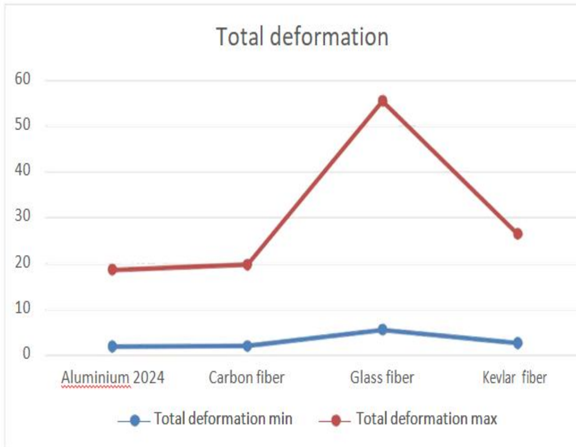


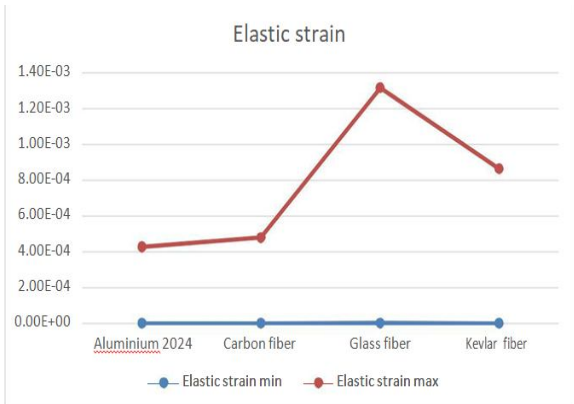


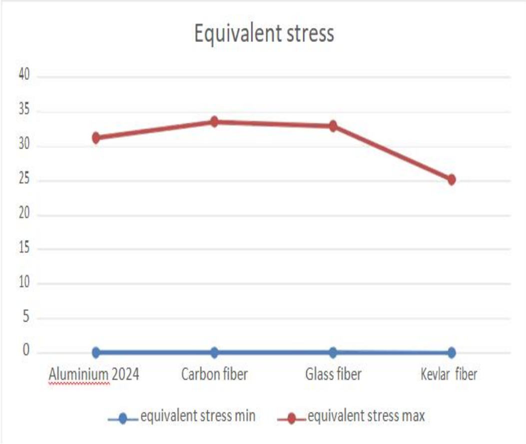


Model 2	Total deformation		Elastic strain		equivalent stress	
	Min	max	min	max	Min	max
Aluminium 2024	1.8686	16.817	6.47E-07	0.000427	0.027783	31.174
Carbon fiber epoxy	1.9786	17.808	6.02E-07	0.000479	0.025253	33.508
e-Glass epoxy	5.5541	49.987	1.77E-06	0.001315	0.02605	32.873
Kevlar epoxy	2.649	23.822	4.10E-07	0.000864	0.007738	25.16

Graphs







II. CONCLUSION

We have conducted structural and modal analysis of Boeing 747 wing rib structure using Anasys workbench 15.0. In the initial case, basic model is studied using different materials. In the later cases, modified structure is studied using different materials. So the following observations are pronounceable from the study.

Induced stresses observed in model 2 are reduced by 20% when compared with model 1.

By adding stiffeners to the modified model, induce stresses decreases to 40% and also equals the performance of rib made with aluminum 2024 with composite ribs

By using carbon fiber epoxy composite we can reduce stress by 50% (**57.088 Mpa**) in aluminum2024 in model 1 to **25.002 Mpa** carbon fiber epoxy in model 3.

By adding edge at cross rail reduces stress by 20% variation in all materials in model 2 an average of **12 Mpa** is reduced

From these observations we can reduce the induced stresses in a structural component by changing its structural design and need for material change can be eliminated but replacing traditional material for wing rib that is aluminium 2024 with composite materials which will increase the life of the rib because of the high ability of the composites to with stand the induces stresses.

This project can be carried forward by conducting experimentation work, a need for development of production process or production facility for producing composite wing ribs have a high importance. Die design and facility for compression moulding can be developed.

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