



OPTIMIZATION OF PASSENGER AIRCRAFT FUSELAGE

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ABSTRACT

An aircraft's centre fuselage, which joins key parts such as the front, after, and wings, is designed to maximise efficiency and be lighter in weight. Comparing and applying hybrid composite materials, such as carbon fibre, glass fibre, and Hex ply 8552, over the fuselage's skin is done through material optimisation techniques. When compared to traditional aluminium alloy material, this improves the fuselage's structural and physical characteristics. Using a mathematical technique called topology optimisation, the fuselage's design space's material distribution is maximised while taking functionality, loads, and boundary conditions into account. The fuselage's cross-section is modified to save weight without sacrificing structural integrity. Using ANSYS WORKBENCH software, a static structural analysis indicates enhanced performance for the fuselage skin made of hybrid composite material and the newly optimised cross-section, resulting in material and topology optimisation and impacting the overall weight of the aircraft.

Keywords: Fuselage, Composite, Material optimization, Structural analysis, Topology optimization

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I. INTRODUCTION

In order to balance performance, durability, and fuel efficiency, this research focuses on optimising the structural composition of an aircraft fuselage utilising hybrid composite materials. In particular, carbon fibre and glass fibre bonded with cutting-edge epoxy resins provide composite materials with unusual strength-to-weight ratios as well as resilience to fatigue, corrosion, and severe stress.

These properties are utilised by the study. The purpose is to design a fuselage structure that not only satisfies but beyond the stringent requirements of the aviation sector, addressing goals like decreased weight, increased fuel efficiency, higher mechanical qualities, and raised safety standards.

Computational simulations, material testing, and structural analysis are used in the research to arrive at an ideal design that optimises the benefits of hybrid composites. The processes employed, the qualities of composite materials analysed, structural simulations, and optimisation approaches are all intended to improve the aeroplane fuselage's performance and design. The study emphasises how hybrid composite materials have the potential to be the pinnacle of engineering brilliance and technological innovation in the aerospace sector.

Topology optimization of a fuselage is a mathematical method that optimizes the distribution of material within the fuselage's design space. This optimization takes into account the functionality, loads, and boundary conditions of the fuselage. The goal is to maximize the performance of the system and also to reduce the weight. In this technique we have changed the cross section of the fuselage in order to reduce its weight without compromising the strength of the fuselage.

II. METHODS AND MATERIAL

The project aims to optimize the skin of the fuselage using composites and to optimize the fuselage cross section which has been done using Ansys software. The fuselage model has been made in the Creo by taking the Airbus A-350 as a reference. Further the skin made by composite materials is being designed in the ACP module of ANSYS. Then the several structural tests have been performed in the Ansys itself.

The fuselage has been optimized using two methods:

A. Material Optimization:

This process involves the strategic use of composite materials, such as carbon fibre and glass fibre. The constraints of conventional materials like aluminium are exceeded by these hybrid composites, which offer better strength-to-weight ratios and resilience to fatigue, corrosion, and severe stress. To find the optimal composition that optimises the benefits of these composites, a rigorous computational modelling and material testing method are used in the optimisation process. The ultimate objective is to create a fuselage that is efficient, strong, and light enough to satisfy the stringent requirements of the aviation sector while simultaneously increasing safety and fuel efficiency. The materials selected for Fuselage are given below:

A. Carbon fiber:

It is a strong, light polymer made mostly of carbon atoms. Its strength is five times greater than that of steel, and it is twice as rigid. The fibres, which are thinner than a human hair strand, are made of carbon crystalline filaments that become significantly stronger when twisted together like yarn. High stiffness, tensile strength, resistance to chemicals, and temperature tolerance are characteristics of carbon fibre. It also exhibits negligible thermal expansion and a low weight-to-strength ratio.

B. Glass fiber:

They combine excellent insulating qualities, high tensile strength, and chemical resistance at an affordable price. A variety of applications are served by the range of glass fibres, each of which has unique mechanical and physical characteristics. Specialised forms of fibreglass have a variety of distinctive characteristics, such as a low density, resistance to chemicals and biological impacts, resilience to high temperatures and humidity, and great resistance to bending, tensile, and compressive pressures.

C. HexPly 8552 Epoxy matrix (resin):

High performance strong epoxy matrix HexPly 8552 is intended for use in main aerospace structures. For a variety of uses, it demonstrates good damage tolerance and impact resistance. HexPly 8552 is an epoxy resin system that has been hardened by amine curing and is equipped with woven or unidirectional carbon or glass fibres.

Sr. No.	Properties	Carbon fibre	Glass fiber (S Glass)	HexPly 8552 Epoxy matrix
1	Density (kg/m ³)	1750	1857	1301
2	Thermal Conductivity(W/m.k)	6	0.04	low
3	Tensile Strength (MPa)	3000-7000	2000-4000	60-120
4	Young's Modulus (GPa)	230	70-80	2.5-5
5	Comp. Strength (MPa)	3000	3000-4000	80-150
6	Flexural Strength (MPa)	3000-7000	1000-2000	80-150

Table 1: Material Properties

2. Topology Optimization:

Topology optimisation in fuselage design refers to the deliberate placement of materials to attain the ideal ratio of performance to weight. It involves changing the cross section of the fuselage in order to improve its physical properties such as its load carrying capacities, increase in strength and stiffness. The optimized fuselage cross section should also be lighter and withstand all loading conditions.

III. MODEL AND BOUNDARY CONDITIONS

Creo Parametric 10.0 has been used to design the fuselage model. The Fuselage cross section model is of a Passenger aircraft containing all major components like skin, stringers, beams, ribs, bulkhead etc. Airbus A350 has been considered for the reference and the reason behind choosing Airbus A-350 is its unprecedented levels of fuel efficiency and exceptional comfort are both provided by it.



Fig. 3.1: Optimized Fuselage cross section model

Ansys software is used for analysis of the model. For the analysis, step loads were applied. These step loads were Independent of time factor as analysis was performed in a static condition, comprising a cabin pressure of 18.4 psi, a passenger floor/beam load of 1 psi, and a cargo load of 2 psi. With respect to these loading conditions fixed supports were applied on the edges of the cylindrical cross section of fuselage to constrain the motions of the body under static loading. This setup allowed us to assess the structural integrity and performance of the fuselage under these specified loading conditions and boundary conditions.

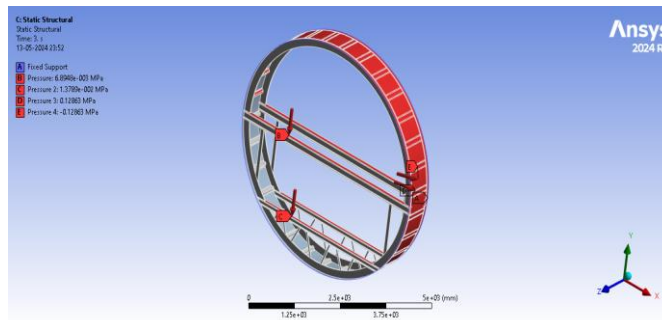


Fig 3.2 Boundary Conditions

IV. RESULTS AND DISCUSSION

After applying the pressure loads and necessary boundary conditions, following are the results which we got for stress, strain and deformation.

A. Max. Equivalent stress: 106.87 MPa

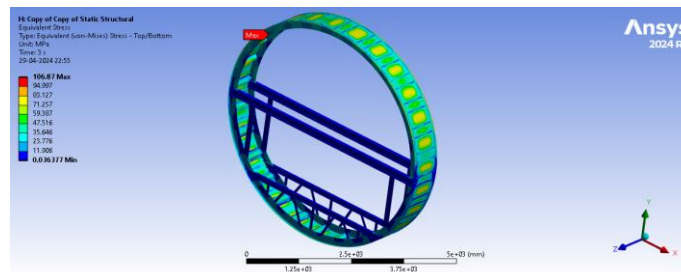


Fig. 4.1 Equivalent Stress of Optimized model

B. Max Equivalent Strain: 2.6804e-003 mm/mm

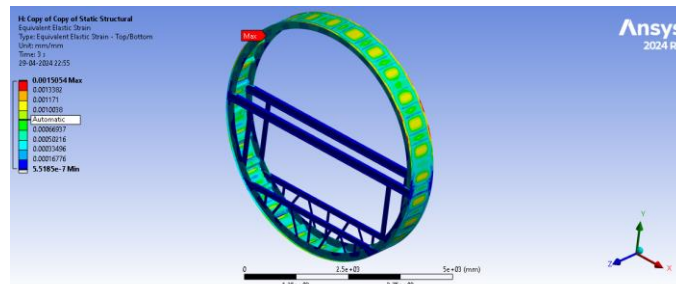


Fig. 4.2 Equivalent Elastic Strain of Optimized model

C. Max. Total Deformation: 3.9055 mm

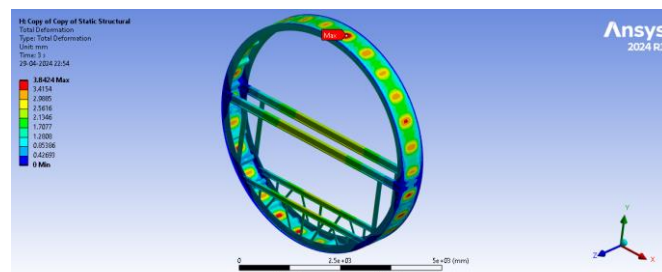


Fig. 4.3 Total Deformation of Optimized model

D. Weight

Mass of Optimized fuselage cross section: 1108 kg

V. CONCLUSION

We have optimized the fuselage with respect to the skin by using composite materials and also performed the topology optimization by changing its cross section. After performing structural analysis on the entire cross section, we conclude that the new optimized fuselage cross section has superior structural properties than the conventional one. Fuselage made from composite materials performs better than conventional materials in all tests and the weight of fuselage is also been reduced by 10.7%.

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