

Design, Optimization and Analysis of Aircraft Composite Wing for Aerospace Application

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Abstract

The objective of this research is to develop an accurate model for an optimized wing design by configuring the arrangement of compound materials (skins) and isotropic materials. A comparison is made between optimized wing and another wing created by adjusting parameters such as skin thickness, number of ribs, rib positions, spar measurements, and more, in order to achieve the best possible results. After evaluating the different properties of composite materials for wing structures that satisfy desired requirements and criteria by referring the previously designed wing structures available, analysis of the same was done by using isotropic as well as composite material and results were noted. During the analysis phase, various structural parameters of the aircraft wing, such as total deformation, Von-Mises stress (also known as equivalent stress), shear stress, and shear intensity on the wing's skin, were determined. Simultaneously, an optimization process was conducted to refine the wing design. This involved making changes to parameters like skin thickness, number of ribs, rib positions, spar dimensions, and other relevant factors, in order to achieve the most favorable outcomes. The objective was to find the optimal configuration that would yield the best results for the wing design. After optimization, the best configuration was selected and analysis report for best composite material that can be used for future wing design is generated. Validation of results obtained was done by hand calculation by using formulae of simplified beam theory. The result was expected to have 35-45% weight saving using composites for wing design compared to isotropic materials.

Keywords—FEA, Composite materials

1. Introduction

Composite materials are one of the main criteria for designing the aircraft structural components. depending upon the fracture methods, procedure is adopted. This part of the research explores the background of composite material. The objective of this study is to develop a more precise model for an ideal wing design by focusing on the composite structure using composite materials [1-3]. This wing design is then compared to a wing of the same configuration made from isotropic material in order to achieve a high strength-to-weight ratio and find the optimal design. Various key parameters are determined by making comprehensive assumptions to simplify the problem and optimize the wing design [4-7]. To study about various wing designs available for straight rectangular wing and finding relations between various dimensions and conditions of the composite structure of wing, and this can be replicated to get the most approximate results. To create the FE model using 2D shell elements with QUAD4 element topology to the dimensions generated from relations according to our requirements. Investigate structural behavior of a wing during loading using isotropic as well as composite materials and selecting most suitable materials out of it [8-12]. The ideal configuration for each wing, considering various thicknesses, is determined by analyzing stress and deformation. CATIA V5 is used for structural modeling, with 2D shell components utilizing QUAD4 element topology. Optimization of design based on different fiber orientation and volume fraction to obtain suitable design that satisfies our requirements [13, 14]. Apart from all this methods regressions and ANN models also can be utilize for this data sets extracted

from the ANSYS work bench for different combinations considered [15-17]

2. Methodology

To undertake this project, it is necessary to gather sufficient information about the wing design parameters. The initial step involves designing the wing based on our requirements. Although not all the required design parameters may be available, we can utilize data from previously designed straight wings with rectangular planforms by different manufacturers. This data will provide us with the external features of the wing. The internal structure of the wing will be assumed and simplified to obtain approximate results for the wing's skin. Once the dimensions for the wing design are selected, we use ANSYS Software to design the wing. Structural analysis is then conducted using the same software. ANSYS allows us to perform calculations and analyze the structural loads on the wings during various flight conditions. The wing model is established in ANSYS Software, including the ribs, front and aft spars, and the skin. Design parameters are generated by referencing the structures of previously designed wings, while suitable assumptions and simplifications are made for the internal structure.

2.1. Wing Design Data:

The wing design as per the standards has been adopted and is tabulated in table 1.

TABLE 1: Wing geometrical data.

Characteristics	Wing
Wing profile	NACA 2412
Wing Span	5m
Wing Chord	1m
Wing area	5m ²
Aspect ratio	5
Taper ratio	1

2.2. Material Data:

The wing is normally manufactured by using aluminum sheets for the outer surface as it weighs less in comparison with other metals. The properties of the aluminum [6] are tabulated in Table 2.

TABLE 2: Material properties of Aluminum 7075-T651.

Material	Aluminum 7075-T651
Density	2810 [kg/m ³]
Young's Modulus,	71.7 [GPa]
Shear Modulus, G	26.9 [GPa]
Poisson's Ratio, ν	0.33
Ultimate Strength	572 [MPa]
Yield Strength	503 [MPa]
Shear Strength	331 [MPa]

Table 2 shows that Aluminium 7075-T651 material is a high strength material used for highly stressed structural parts. T651 temper offers improved stress corrosion resistance.

In order to obtain the airfoil shape, the initial step involves utilizing the ANSYS Software. A commercially available software, specifically designed for airfoil design and known as "design foil software," is utilized. This

software is accessible as a trial version for a period of five days. Using this software, all the coordinates of the airfoil shape are plotted within the ANSYS workbench. One notable advantage of this software is its capability to define the coordinates as functions of the chord length, denoted as $(x/c, y/c)$, where 'x' represents the distance along the chord and 'c' denotes the chord length.

NACA 2412 airfoil with the chord length of 1m is exported to ANSYS. This step is done by using 3D curve Command under Concept Toll bar in design modeler and then uploading co-ordinate file that we have generated in notepad. The 3D Curve will appear as shown below.

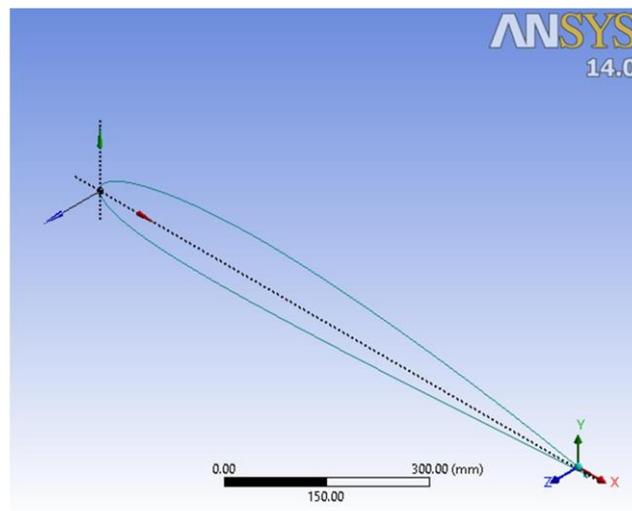


Fig 1: NACA 2412 Airfoil Shape designed according to co-ordinates obtained from design foilsoftware.

2.3. Mapped Face Meshing

FE model of the wing gathering is as shown in Figure 2. Lattice is done by utilizing QUAD shell components. Check before applying the limit conditions and peculiarities are done. The materials and their separate properties are allocated to each part in the sequential arrangement. The anxiety investigation of the arrangement is completed and utilizing the limited component examination.

The skin and the ribs were connected by utilizing the comparability module; and the skin-flight affiliations are appeared by strategy for RBE2 (Inflexible Body Section 2) utilizing multi point necessities. The relationship between the general population from the internal structure of a wing torque encase practice were things being what they are done utilizing catch.

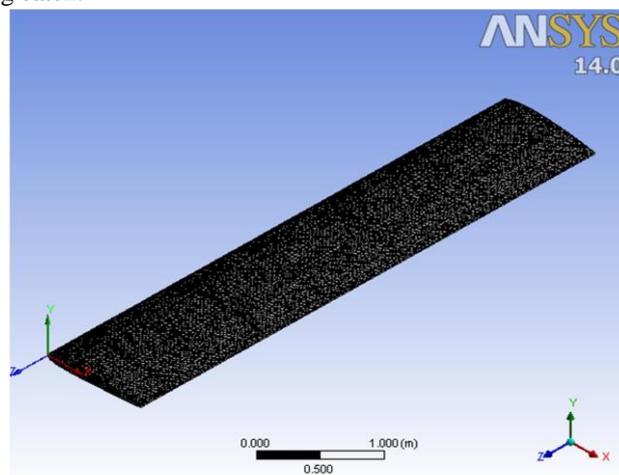


Fig 2: Meshed Wing Surface generated using mapped face Meshing option.

3. Results and Discussion:

Total displacement shown in Figure 3 represents the uprooting field of composite wing structure. The more prominent dislodging of 175.3 [mm] occurred at the tip of the wing.

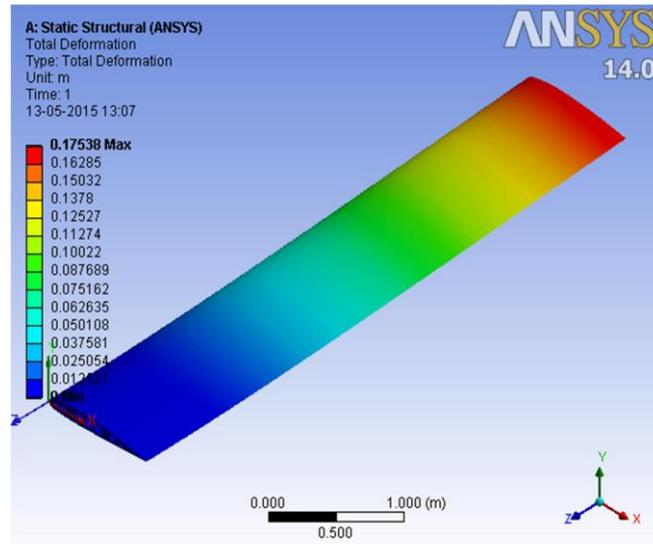


Fig 3: Deformation of composite wing surface for Aluminum 7075-T651 Material.

3.1. Equivalent Stress (Von Misses Stress):

Figure 4 demonstrates the Von Misses stress dispersion on the inward structure at the most extreme anxiety area separately. The greatest anxiety at the limit of the fundamental fight was observed to be 129.8 N/mm²[MPa].

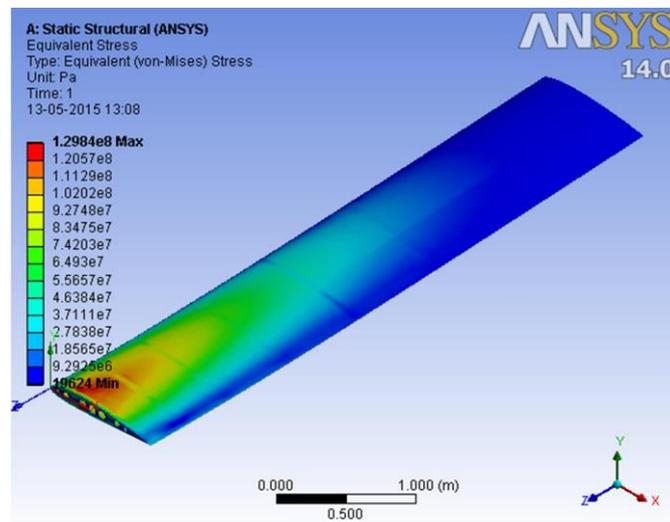


Fig 4: Equivalent stress distribution of wing surface for Aluminium 7075-T651 Material.

Figure 5 demonstrates the shear stress dispersion on the inward structure at the most extreme anxiety area separately. The greatest anxiety esteem at the limit of the fundamental fight was observed to be 7.29/mm²[MPa].

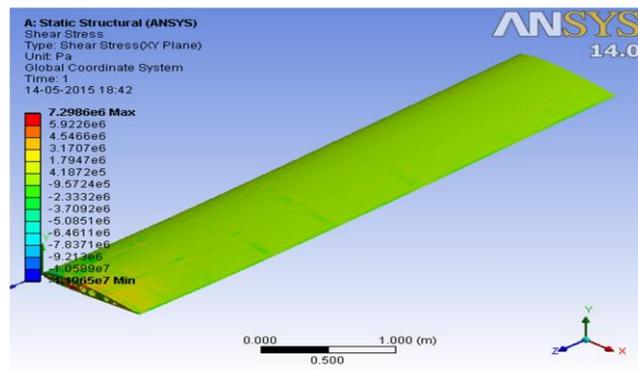


Fig5: Shear Stress distribution of wing surface for Aluminium 7075-T651 Material.

The following Figure 6 shows graph of various composite materials used for wing structure vs. Deformations.

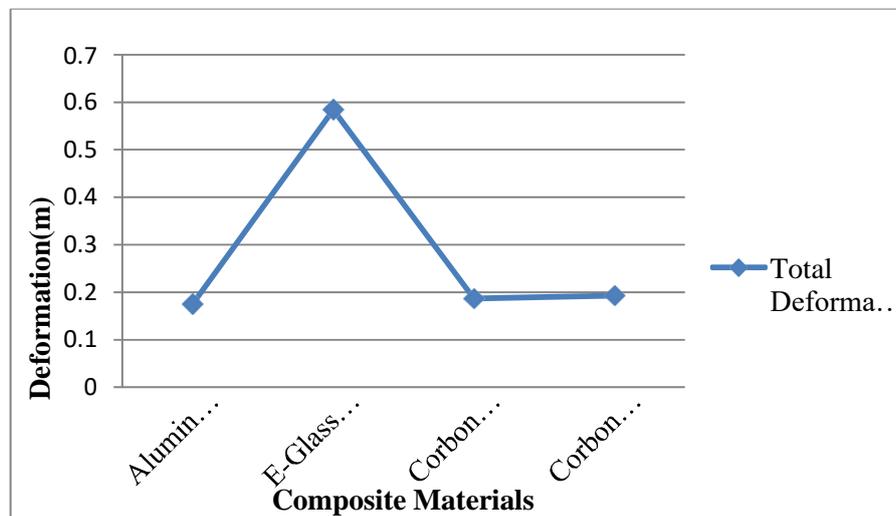


Fig 6: Composite materials vs. Deformations.

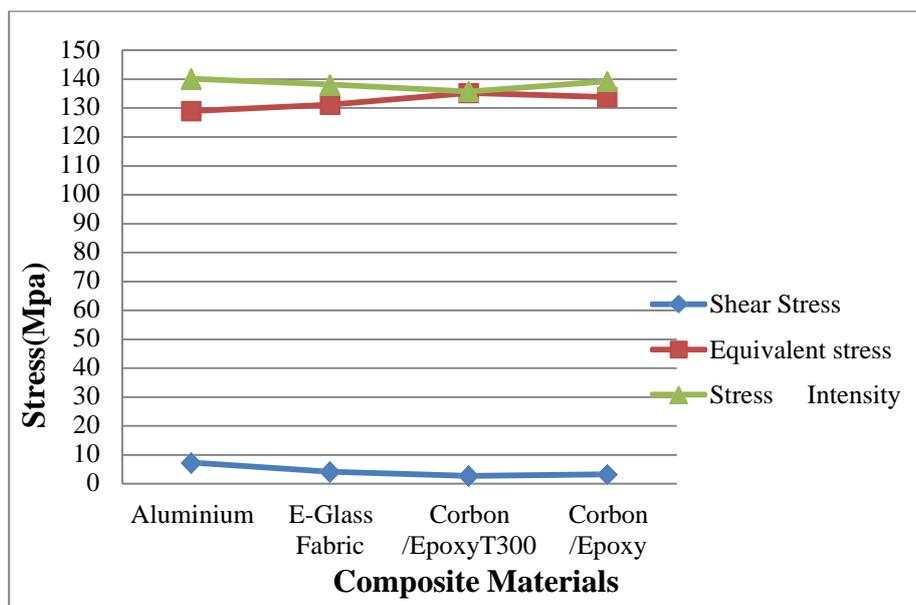


Fig7: Composite materials vs. Shear stress, Equivalent Stress and Stress intensity.

4. Conclusion

From this research work on wing structure we can conclude that by using composites for manufacturing of wing the overall weight reduction of 40% is obtained compared to isotropic materials along with various improved properties. The validation of results shows only 14.3% error which is due to assumptions specified and can be reduced to almost zero on perfect calculation. We have used single composite material for whole wing design. Instead of using single composite material if we use more than one composite material based on properties, then more benefits in properties can be obtained on analysis. According to our results for best wing design 7781 E-Glass Fabric–Araldite LY5052 Resin– Aradur HY5052 composite material can be used for only skin design as it is very elastic in nature and Carbon/Epoxy T300/Fiberite 934(13-mil), Carbon/Epoxy Composite Sheet can be used for design of spar and ribs as it possesses high strength value. By analyzing the gathered readings and comparing them with standard reference data, we can draw reasonable conclusions while making certain significant assumptions. Based on these assessments, we can conclude that under the assumed loading conditions and constraints, our wing structure will not experience failure due to material properties.

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