Design and Finite Element Analysis of Aircraft Wing using Ribs and Spars

Vinay Kumar. P[1], I. Rahul Raj[2], M. Snehith Reddy[2], N. Siva Prasad[2]

[1]Assistant Professor & HOD, [2]UG Scholar, [1,2]Department of Mechanical Engineering
[1,2]Kommuri Pratap Reddy Institute of Technology, Ghatkesar, Hyderabad, Telangana

Abstract: In this paper, project detailed design of trainer aircraft wing structure made by using CATIA. Then stress analysis of the wing structure is carried out to compute the stresses at wing structure. The stresses are estimated by using the finite element approach with the help of ANSYS to find out the safety factor of the structure. In a structure like airframe, a fatigue crack may appear at the location of high tensile stress. Life prediction requires a model for fatigue damage accumulation, constant amplitude S-N (stress life) data for various stress ratios and local stress history at the stress concentration. The response of the wing structure will be evaluated.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. Front spar having „I" 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, the mentor aircraft wing with winglets with at different angles (450 and 250) is thinking about for the itemized investigation. Static and fatigue analysis of the entire wing area is done to figure the burdens and life at various winglet points (25^0 and 45^0) because of the applying weight load.

Keywords: Aircraft wing, FEM, CATIA, Ansys, static analysis, fatigue analysis.

1. 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 airfoils. A wing's aerodynamic efficiency is expressed as its lift-to-drag ratio. The lift 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.

1.1 Aircraft wing

The wing might be considered as the most significant part of a flying machine, since a fixed-wing flying machine can't fly without it. Since the wing geometry and its highlights are affecting all other air ship parts, we start the detail configuration process by wing structure. The essential capacity of the wing is to produce adequate lift power or just lift (L). Be that as it may, the wing has two different preparations, specifically drag power or drag (D) and nose-down pitching minute (M). While a wing architect is hoping to amplify the lift, the other two (drag and pitching minute) must be limited. Actually, wing is expected promotion a lifting surface that lift is created because of the weight distinction among lower and upper surfaces. Streamlined features course readings might be concentrated to revive your memory about numerical systems to figure the weight conveyance over the wing and how to decide the stream factors.

NACA 64215 Lift & drag polar: Many of the airfoils have polar diagrams which can be viewed in the details and comparison section sections of the site. These show the change in lift coefficient (Cl), drag coefficient (Cd) and pitching moment (Cm) with angle of attack (alpha). There is also a graph of lift coefficient (Cl) against drag coefficient (Cd) which gives the theoretical glide angle of the airfoil.

X foil: All the polar diagrams currently available have been produced using Xfoil, an application created by Mark Drela and Harold Youngren for the design and analysis of subsonic airfoils. There is more information and details on the limitations of the analysis on the Xfoil page.

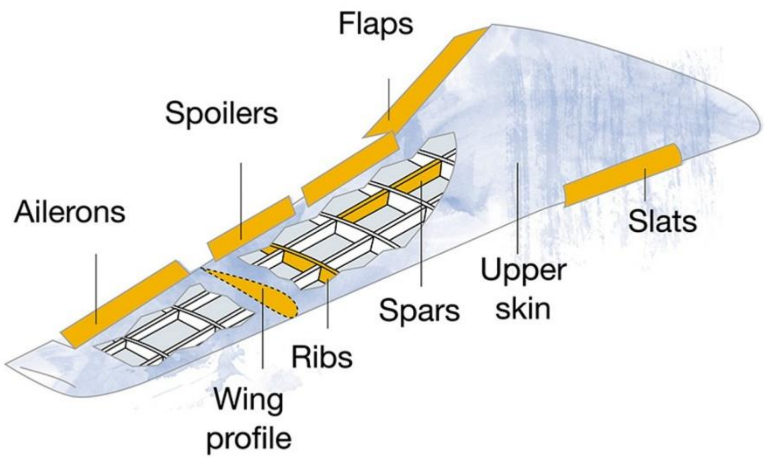


Fig. 1: aircraft wing

2. LITERATURE REVIEW

Design and Structural Analysis of the Ribs and Spars of Swept Back Wing[1] The aim of this paper work is to design and analyse the ribs and spars of a 150 seater regional aircraft for the stresses and displacements due to the applied loads. For this we did a comparative study on particular 150 seater regional aircraft. The optimum design parameters are suitably selected and then the model was designed using the CATIA software. The airfoil coordinates for the model to be designed, were generated by design foil software. The major wing design parameters were explained in detail and the wing configuration has been described. Different types of loads acting on the aircraft and the wing are determined and the moments, displacements, etc., are also determined. The wing structure was also explained and functions of each component and their arrangement are also studied. The methodology of finite element method and the detailed description about various FEM tools have been studied and implemented in this work.

Structural design of a uav wing using finite element method [2] This paper presents the structural design methodology for the wing of an Unmanned Aerial Vehicle. In this study, the application of computational methods in design is successfully explored. The strength and stiffness analysis of the UAV wing was performed using an FEA software ANSYS. The available CAD model and aerodynamic CFD analysis of the vehicle were used as design input. The aerodynamic loads were applied on the structure as pressure functions using a novel approach employing Artificial Neural Networks. Effects of variability in geometry, material and lay-up were also analyzed to find the best possible combination with optimal strength and stiffness amid minimum weight and cost. The finally designed wing has two spars and used an all composite structure. The wing is lighter in weight as compared to a similar wing made from Aluminum, and sufficiently strong enough to meet all in-flight load conditions and factor of safety.

Design and Analysis of Wing of an Ultralight Aircraft [3] The paper deals with the structural design and analysis of high wing of an ultralight aircraft. The wing design involves its initial considerations like planform selection, location to the aircraft and the structural design involves the design calculations for the selection of airfoil, area of the wing, wing loading characteristics and weight of the wing. The design is done corresponding to the calculated values with the help of designing software CATIA and the analysis is done to show the structural deformations and stress for the applied loading conditions with the help of ANSYS 14.0, also the drag polar for the applied flow conditions is shown with the help of ANSYS FLUENT a flow analysis software. The objective of this project is to compare the results obtained for different materials like Al 2024- T3, Al 6061-T6, Al 7075-T651 & Al 7075 + 15% FLY ASH MMC using analysis software. From the results we will conclude which material is having better properties.

3. MODELING AND ANALYSIS

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Its use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

CATIA is an acronym for Computer **A**ided **T**hree-dimensional **I**nteractive **A**pplication. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative. Since Dassault Systems did not have an expertise in marketing, they had revenue sharing tie-up with IBM which proved extremely fruitful to both the companies to market CATIA. In the early stages, CATIA was extensively used in the design of the Mirage aircrafts; however, the potential of the software soon made it a popular choice in the automotive sector as well. As CATIA was accepted by more and more manufacturing companies, Dassault changed the product classification from CAD / CAM software to Project Lifecycle Management. The company also expanded the scope of the software.

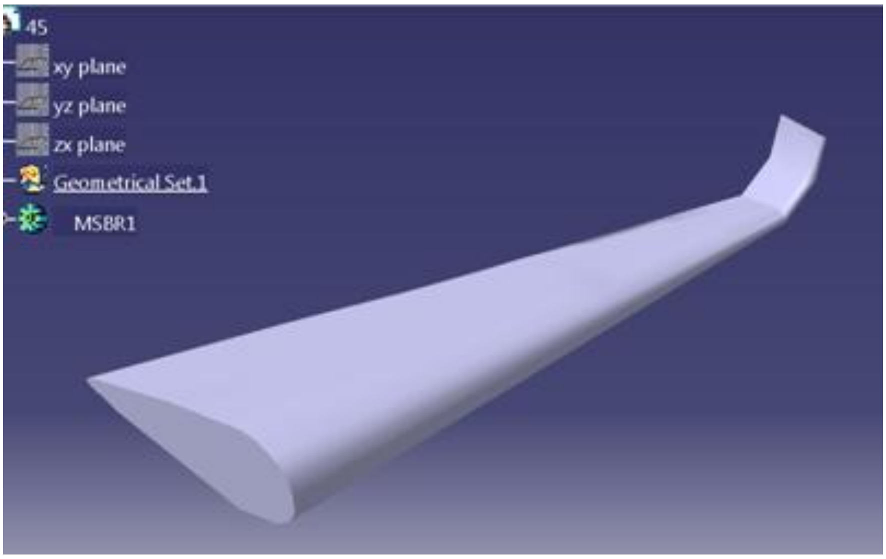


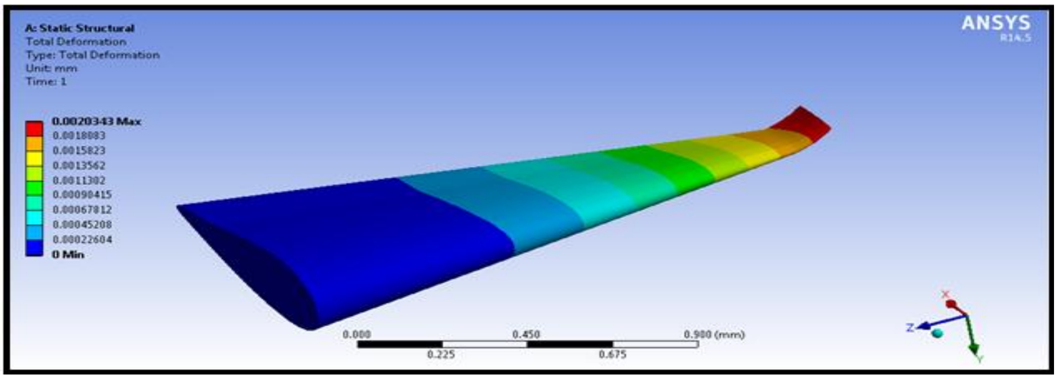
Fig. 2: 3D Model of ribs and spars

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in. Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure. Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Material properties

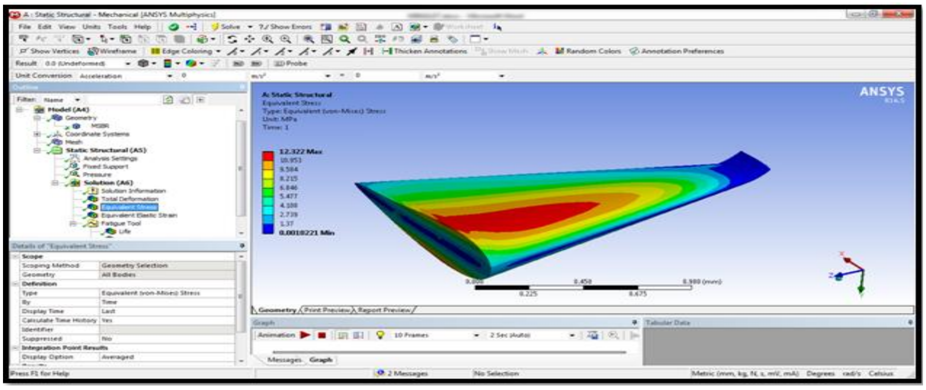
Properties	S2-glass	Kevlar-49	Boron fiber
Density (g/cc)	2.495	1.44	2.60
Young’s modulus (MPa)	86900	112000	400000
Poisson’s ratio	0.23	0.36	0.13

Deformation



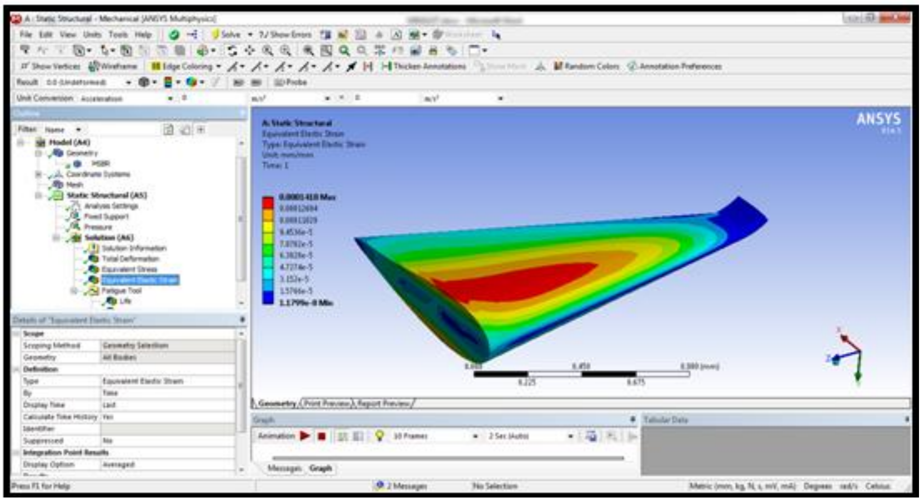
According to above figure the maximum deformation indicated in red color and minimum deformation indicated in blue color. The minimum deformation at starting of the wing and the maximum deformation at end of the wing let because we are applying the boundary conditions like a cantilever beam application.

Stress



According to above figure the maximum stress indicated in red color and minimum stress indicated in blue color. The minimum stress at end of the wing and the maximum stress at starting of the wing let because we are applying the boundary conditions like a cantilever beam application.

Strain



According to above figure the maximum strain indicated in red color and minimum strain indicated in blue color. The minimum strain at end of the wing and the maximum strain at starting of the wing let because we are applying the boundary conditions like a cantilever beam application.

4. RESULTS

Models	Materials	Deformation (mm)	Stress (MPa)	Strain
Winglet angle 25^0	S2 glass	0.0020343	12.322	0.0001418
	Kevlar-49	0.001551	13.078	0.00011677
	Boron fiber	0.000444	12.254	0.0000306
Winglet angle 45^0	S2 glass	0.0021336	12.271	0.00014121
	Kevlar-49	0.0016311	12.636	0.00011283
	Boron fiber	0.00046619	12.236	0.00003058

5. CONCLUSION

- The aerofoil's NACA 64215 structured in CATIA and experienced stream reenacted in ANSYS.
- We are developed modeling of anaircraft wing with winglet at two different angles (250& 450) wing models with various winglets was completed distortion, anxiety at various materials (s2-glass, Kevlar-49 and boron fiber).
- By observing the static analysis results the less stress have boron fiber material at aircraft winglet angle 450.
- So, it can be concluded the boron fiber material at aircraft winglet angle 450 is the better model and suitable material boron fiber.

REFERENCES

[1] Yates,J. E., and Donaldson, C., "Essential Study of Drag and an Assessment of Conventional Drag-Due-To-Lift Reduction Devices", NASA Contract Rep 4004, 1986

[2] Whitcomb, R. T., "A Design Approach and Selected Wind-Tunnel Results at High Subsonic Speeds for Wing-Tip Mounted Winglets", NASA N D-8260, 1976

[3] Whitcomb, R. T., "Techniques for Reducing Aerodynamic Drag", NASA Conference Publication 2211, Proceedings of Dryden Symposium, California 1981

[4] Maughmer, M. D., Timothy, S. S., and Willits, S. M., "The Design and Testing of a Winglet Airfoil for Low-Speed Aircraft", AIAA Paper 2001-2478, 2001

[5] McLean, D., "Wingtip Devices: What They Do and How They Do It" displayed at the Boeing Performance and Flight Operations Engineering Conference, 2005.

[6] Lambert, D., "Numerical Investigation of Blended Winglet Effects on Wing Performances, report" Liege University; 2007.

[7] http://www.boeing.com/business/757family/pf/pf_facts.html.

[8] http://www.winggrid.ch/2014

[9] Smith, M. J., Komerath N., Ames, R., and Wong, O., "Execution Analysis OF A Wing with Multiple Winglets" American Institute of Aeronautics and Astronautics (AIAA-2407), 2001.

[10] Versteeg, H., and Malalasekera, W. "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" Longman, 1995.