International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 4 Issue 10 ǁ October. 2016 ǁ PP. 10-15

Modeling and Analysis of Ribs and Spar of an Aeroplane Wing

Gadi Pradeep Reddy[1], K.Ajaya Kumar Reddy
[1]*M.Tech Student, Department of Mechanical Engineering, Annamacharya Institute of Science and Technology, Rajampet*
[2]*Assistant Professor, Department of Mechanical Engineering, Annamacharya Institute of Science and Technology, Rajampet*

Abstract : In a fixed-wing aircraft, the spar is often the main structural member of the wing, running span wise at right angles to the fuselage. The spar carries flight load and the weight of the wings while on the ground. Due to high density of Aluminum the material can be replaced by E glass epoxy and Magnesium lithium alloy. For aerodynamic reasons the wings contours in the chord wise direction must be maintained without appreciable distortion. In the present work finite element analysis for a wing rib and spar subjected to different kinds of loading will be performed. A wing with the rib and spar will be design and modeled in Pro/Engineer. Stress and displacement analysis of the wing structure will be carried out to compute the stresses in wing structure. The stresses will be determined by using the finite element approach with the help of ANSYS.

I. INTRODUCTION

1.1 Introductions to aircraft

An aircraft is a man made flying machine which has finite load carrying capacity. Aircrafts are mainly used for transportation. Aircraft is a complex structure. Aircrafts are built-up structures from basic components of wings, fuselage, tail unit and control surfaces. The major components of an aircraft include wings, fuselage, control surfaces, landing gear etc. In aircraft, the wing is the most important structure that generates the required lift force for flying.

Aircraft design is a complex and multi-disciplinary process that involves a large number of iterations and knowledge in aerodynamic structures. The aircraft wing is the most critical component of an aircraft not only from an aerodynamics point of view but also from a structural point of view. Primary use of word wing is taken from the birds.

An aircraft wing is a surface used to provide an aerodynamic force that is perpendicular to the direction of movement while travelling in air and opposite to the gravity which enables flight. Its aerodynamic quality is expressed as a Lift-to-drag ratio.

The load distribution on the aircraft wing due to air pressure can be calculated using Bernoulli's principle which gives the relationship between the pressure of a fluid and fluid velocity.

material selection

Due to the high density of Aluminum alloy, the weight of the component is also high. So it is necessary to reduce the weight of the component by considering high strength to weight ratio materials like E-Glass epoxy and Magnesium lithium alloy. The materials properties of these alternatives are shown in table 2.1.

Table 2.1: Material Properties

Material	Density (kg/m^3)	Young's modulus (MPa)	Poisson's ratio
Aluminium alloy-6065	2.7e-09	68900	0.33
E Glass Epoxy	2.54e-09	72400	0.2
Magnesium-lithium alloy	1.74e-09	42000	0.34

II. MODELING

3.1 Introduction To Pro/E

In this study, Pro/ENGINEER (Pro/E) is used as the modeling software. Pro/E is a professional CAD/CAM package that is extensively utilized in the engineering and research both by industry and academia for CAD/CAM applications. It is one of the new frameworks that in addition to providing features for 3-D model generation also provide parametric representation of the models for rapid modification of the designs. This means that certain features of the geometries can be setup as configuration variables and changes can be made any time by changing these configuration parameters and thereby the entire model will be redesigned by a simple procedure.

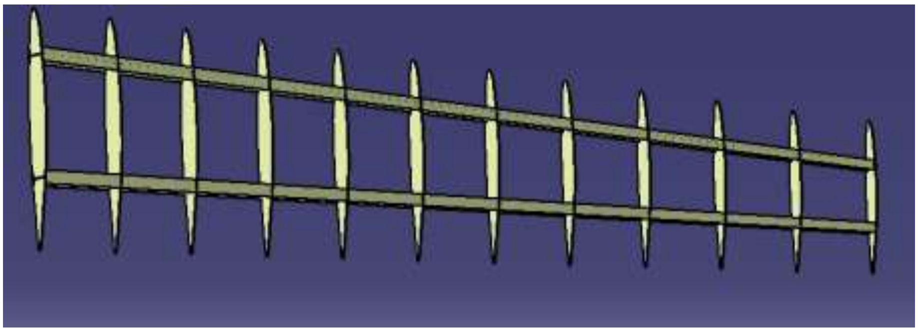

Fig (3a): Skeleton of wing without stringers

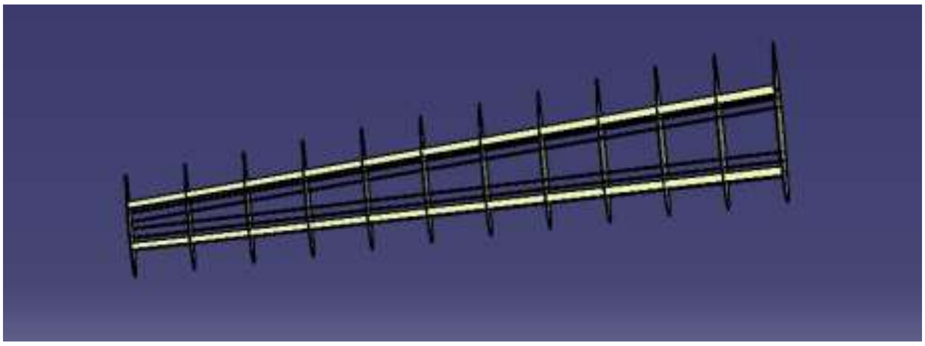

Fig (3b): Skeleton of wing with stringers

The skin part is imported and aligned to the spars and ribs assembly and the combination is saved as an assembly is shown

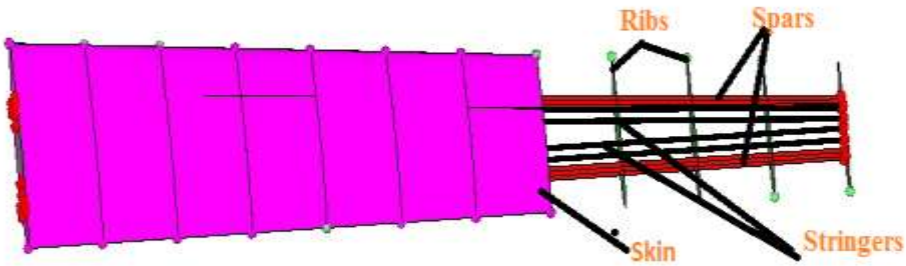

Fig (3c): Parts of wing

III. LOAD CALCULATIONS

In an aircraft wing one end is fixed and other end is free. Varying loads are applied on the wing from fuselage to free end.

Considering load is distributed varying from the root to tip of the bottom wing surface.

Mass of the aircraft	: 680Kg
Weight of the aircraft	: 680*9.81 = 6670.78 N
Load factor of the wing in design	: 3g
Design limit load on the structure	: 3*6670.78 = 20012.35 N
Design ultimate load	: 1.5*20012.35 = 30018.52 N

Total load acting on the aircraft is considered as 100%. Then 80% of load is applied on the aircraft wings, 20% of load is applied on the fuselage.

Total load acting on the wings: 0.8*30018.52 = 24014.82 N

Each aircraft is having two wings so load acting on each wing: (24014.82 / 2) = 12007.41 N

Total lift load is taken.

Lift=$\frac{\pi K a L^2}{4}$

Where L= length of the wing

Ka=Coefficient of lift profile

12007.41=$\frac{\pi * 5.73^2}{4}$ *Ka

Ka=465.64

To find the total varying load along the length of the wing the following equation is used

$$\text{Lift} = \int_0^L \text{ka}\sqrt{L^2 - x^2}\,dx$$

The load distribution calculated using the above equation for the present case is given in Table 4.1.

Table 4.1:

Distance from root, x (m)	Local Load (N/m)	Local Chord Length, W (m)	Local Pressure on wing surface, p (N/m^2)
0	2668.117	1.25	2134.494
0.52	2657.108	1.207347	2200.782
1.04	2623.802	1.164695	2252.781
1.56	2567.332	1.122042	2288.089
2.08	2486.121	1.079389	2303.266
2.6	2377.634	1.036736	2293.383
3.12	2237.908	0.994084	2251.226
3.64	2060.598	0.951431	2165.788
4.16	1834.84	0.908778	2019.018
4.68	1539.467	0.866126	1777.417
5.2	1120.723	0.823473	1360.971
5.72	157.5626	0.78082	201.7911

Where x=position along the wing.
Qx=Weight of the part.
W=Width of the wing.
P=Pressure applied on the wing.

IV. STRUCTURAL ANALYSIS

5.1 ALUMINIUM ALLOY WITHOUT STRINGER

The aircraft wings are generally made of aluminum alloys due to their high compression strength, wear resistance, excellent machinability, good casting characteristics and their low cost. The first simulation is performed by taking the material of the wing to be Al 6065 alloy. Also in this simulation stringers are not included in the wing. The aircraft wing behaves like a cantilever beam, so that the maximum deflection occurs at free end. From the figure it is clear that the maximum displacement occurred at the free end.

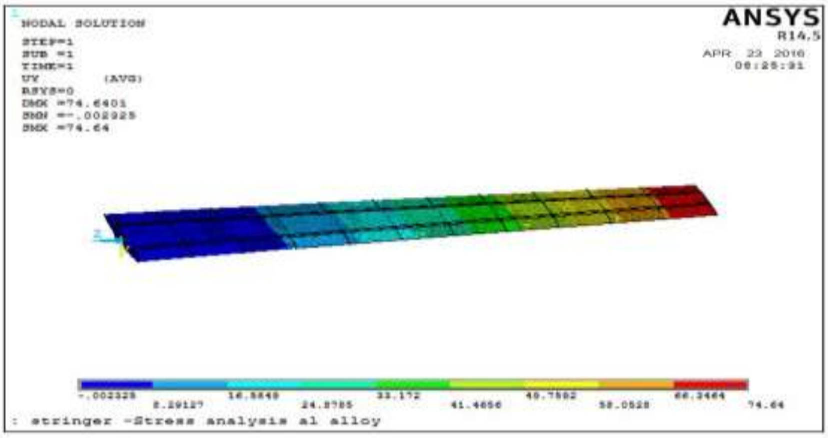

Fig (5a): Displacement (in mm) of Al 6065 alloy without stringers

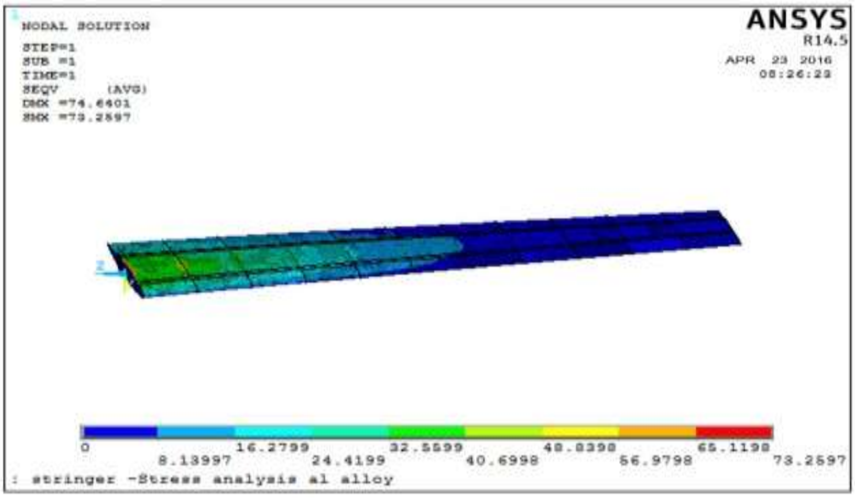

Fig (5b): Stress (in N/mm^2) of Al 6065 alloy without stringers

5.2 Aluminium Alloy With Stringers

Aluminum alloy 6065 is used as the wing material for the second simulation as well. But in this case stringers are added to the wing geometry. The displacement and von Mises stress contours for this case are shown in figures (5c and 5d) respectively. Comparing these results with those for the first case without the stringers, it can be seen that both the deflections and the stress levels in the wing are reduced when the stringers are added.

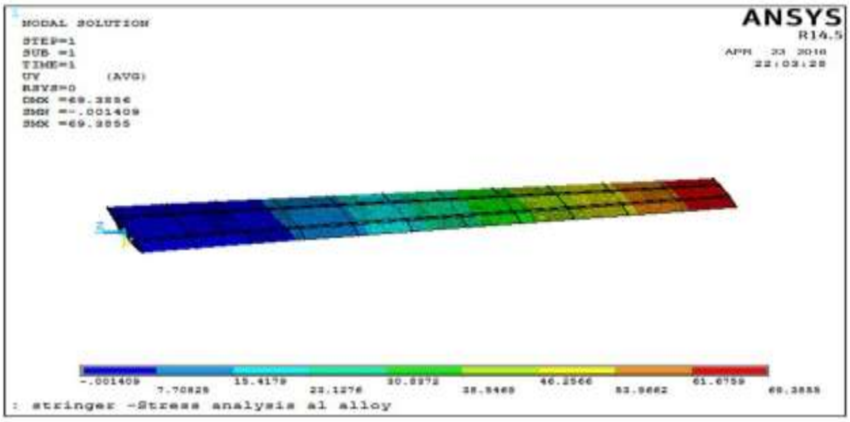

Fig (5c): Displacement (in mm) of Al 6065 alloy with stringers

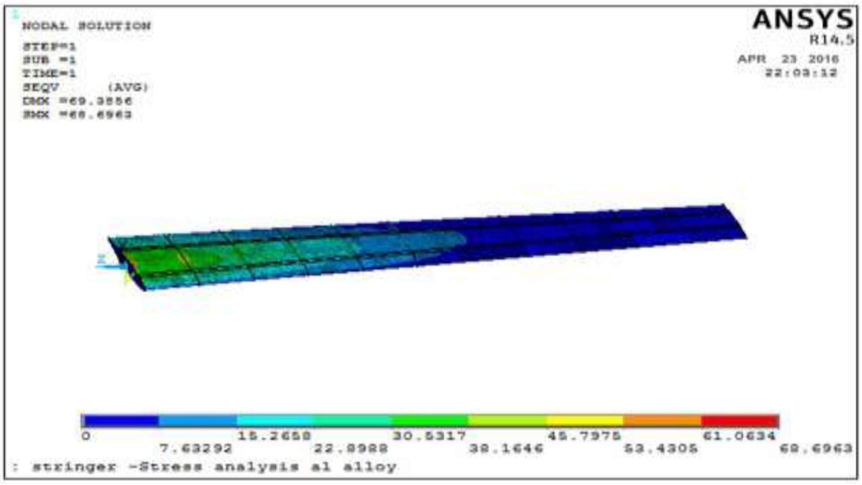

Fig (5d) : Stress (in N/mm^2) of Al 6065 alloy with stringers

Table 5.1: Final results

Material	Stress(N/mm^2)		Deformation(mm)	
	With stringers	Without stringers	With stringers	Without stringers
Aluminium6065 alloy	68.693	73.786	69.383	74.64
E glass epoxy	60.648	65.1647	66.384	72.06
Magnesium lithium alloy	69.388	74.5221	113.46	123.76

5.3 Comparison Of Stress

The comparison of the maximum stress across the six different cases considered here shows that E Glass Epoxy wing with stringers gives least maximum stress while Mg-Li alloy wing without stringers gives highest maximum stress. However, considering the weight of the wing, Mg-Li wing may be the best choice given its low density.

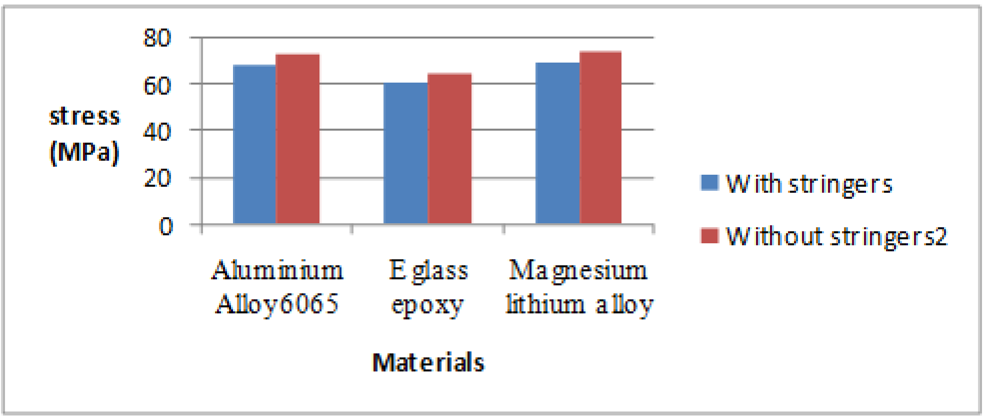

Fig (5e): Stress comparison

5.4 Comparison Of Deflection

A comparison of maximum deflection in all the cases considered here shows that's E Glass Epoxy gives the least deflection while the Mg-Li alloy wing gives largest deflection. Also, for each wing material, addition of stringers has reduced the maximum displacement.

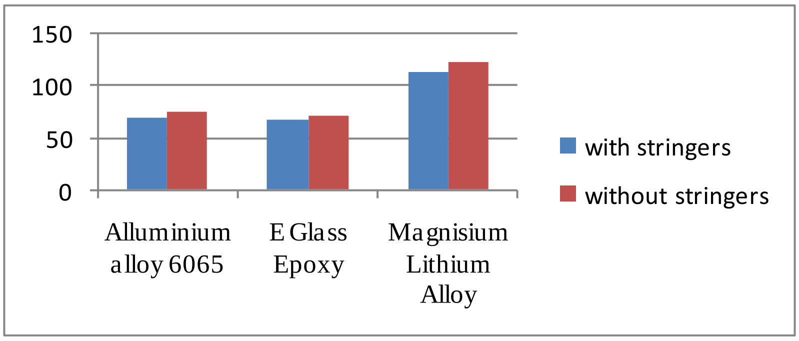

Fig (5f): Displacement Comparison

V. CONCLUSION

In this study, design and analysis approach is presented to create an innovative design of an aircraft. Final comparison between the aircraft wing with the stringers and without stingers in terms of stress and the performance of component.

In this study, by changing the material properties we are reducing the weight and also to increase the wing deformation.

VI. FUTURE SCOPE

The future scope of this work focuses on the cost of reduction of the material without varying the weight of the component. After the careful analysis of the better material the product is further undergone to topology optimization using Hyper works software. The manufacturability of the component is been analyzed using the Ansys.

REFERENCES

[1]. ''Statistic and Dynamic Analysis of Typical Wing Structure of Aircraft using Nastran'' by Mr. P. K. Jadhav, Mr. S. S. Bansode Volume 2, Issue 7, July 2013 ISSN 2319 – 4847.
[2]. ''Optimal Topology of Aircraft Rib and Spar Structures under Aero elastic Loads'' by Peter D. Dunning2 AIAA journal VA, 23666 2011.
[3]. ''Optimization of Aircraft Wing with Composite Material'' by Shabeer KP, Murtaza M A June 2013 IJIRSET Volume 2 issue 6 ISSN: 2319-8753.
[4]. ''Static Stress Analysis for Aircraft Wing and Its Weight Reduction using Composite Material'' by HaleshKoti March2014 IJERT Volume 3 Issue 3 ISSN: 2278-0181
[5]. ''Stress Analysis and Weight Optimization of a Wing Box Structure Subjected to Flight Loads'' by Senthil Kumar S 2014 IJES journal Volume 3 Issue 1 ISSN 2319-1813.
[6]. ''Design and Structural Analysis of the Ribs and Spars of Swept Back Wing'' by Mohamed Hamdan 2014 Journal Volume 3 Issue 12 ISSN 2250-2459, ISO 9001.