DESIGN AND COMPUTATIONAL ANALYSIS OF AN AIRCRAFT WING UNDER AERO-DYNAMIC LOADING

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Abstract— *Aircraft structure generally experiences different type of loads under running conditions. These loads may be of static or dynamic. Many experiments have undergone to investigate the behavior of the aircraft under these loading. In general Structural, Thermal and CFD analysis were performed to analyses the stresses and deformations that occur under these loads. In addition to the normal loads, aircraft structure undergoes Aero-Dynamic loads which mainly lead to the failure of the structure. Our present work is intended to analyses an aircraft wing structure that is experiencing aero-dynamic loads. Residual stress, deformation are observed under structural and thermal loads. Design of the structure is carried out in SOLID WORKS and analysis is done by using ANSYS software. Finally a comparison between the performance of Aluminum and structural steel is discussed.*

Keywords— Computational Fluid Dynamics; Structural Analysis; Aero-Dynamic

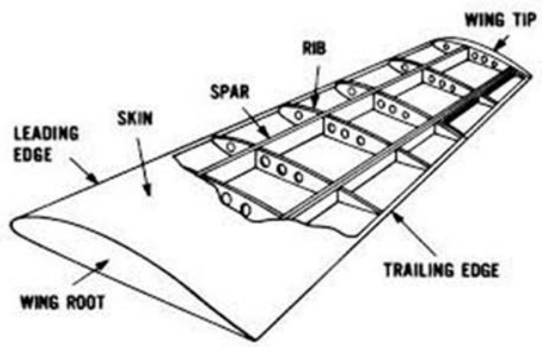
1. INTRODUCTION

The design of an aircraft is a prolonged process that has mainly three phases; the first is the conceptual design phase. This phase deals with the layout of the aircraft and what major characteristics it must have in order to achieve its design goals. If the conceptual design is to be a success no major changes should be implemented on it in future phases. Hence, the conceptual design engulfs the major characteristic of the aircraft while delivering a layout of its major components. The second and third phases of the design process are the preliminary and detail design phases. These phases deal with the analysis of the aircraft components in all major aspects of aerospace such as structures, dynamics, control and others.

The method is highly statistical based on data of other aircraft of the same category. First, a set of design goals is set to provide a baseline for the design. Second, a sketch of the airplane is created along with a design mission profile. By using a simple cruise mission profile consisting of five segments which are take-off, climb, cruise, loiter and landing. A crude method of weight estimation based on the sketch and mission profile is conducted to achieve an estimate of the weight of the airplane.

Acoustic analysis of the airplane wing is conducted to define the geometry of the wing spars, ribs and skin. The wing section is designed to have two spars, one at a quarter of the cord position and one at the three quarters of the cord.. It is assumed that the stringers and spar flanges only carry the directs stresses while the skin and spar webs carry shear stresses, this enables the idealization of the stringers and flanges areas into a concentrated area named booms to carry the direct stresses along with the thin skin to carry the shear stresses. Proper fatigue analysis is used to calculate the area of the booms and the thickness of the skin. The finite element software AERODYNAMICS is utilized to verify the results of the fatigue analysis by employing the finite element method to calculate the residual stresses in the wing due to the acoustic loading.

2. SEGMENTS OF AIRCRAFT WING



Ribs

The wing ribs are the forming and shaping structural member of an aircraft wing. The ribs provide the necessary aerodynamic shape which is required for generation of lift by the aircraft. They are attached to the wing spars and thus provide structural stiffness. Ribs also act as a member for transfer or distribution of loads from wing panel to spars.

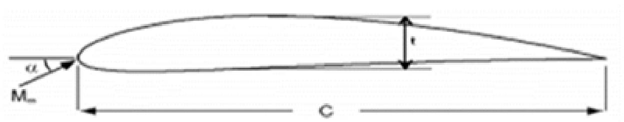
Spars

The wing spars are the main load carrying structural member of the aircraft wing. The wing spars are used to carry the loads that occur during the flight (flight loads) as well as carry the weight of the aircraft wing while on the ground (ground loads). The spars are the longitudinal load carrying members which are connected to the ribs.

Stringers

Stringer is a stiffening member which supports a section of the load carrying skin, to prevent buckling under compression or shear loads. Stringers keep the skin from bending. Longitudinal members are sometimes referred to as stringers.

3. DESIGN MODEL AND DATA



Chord Length, c = 200.25mm
Wing Span, l = 1495mm
Wing Width, w = 25.55mm

The design part of aircraft was done using the SOLID WORKS and the design data of the wing is taken form the UIUC aerodynamics group and it give design of the foil and through that we developed the wing and in the project we used the NACA 4412 aircraft wing

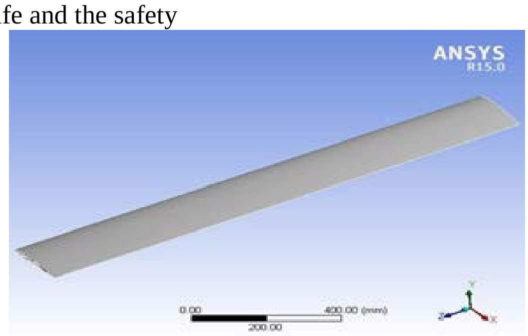
Skeleton diagram of the wing

4. ANALYTICAL RESULTS

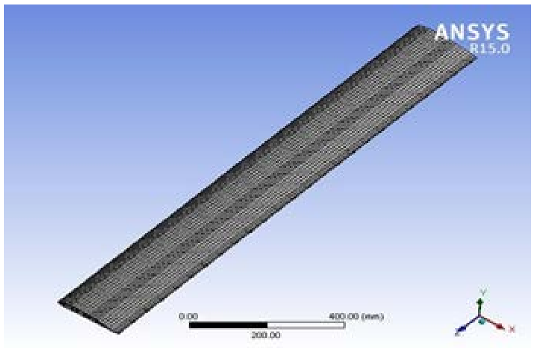
a) MODAL ANALYSIS OF AN AIRCRAFT WING

Modal analysis is the study of the dynamic properties of structures under vibrational excitation. Modal analysis is the field of measuring and analyzing the dynamic response of structures and or fluids during excitation. Modal testing is the form of vibration testing of an object whereby the natural (modal) frequencies, modal masses, modal damping ratios and mode shapes of the object under test are determined. A modal test consists of an acquisition phase and an analysis phase.

In modal analysis the work is done on different material and they are Aluminum and Structural Steel is use to determine their characteristics and find out the stability of the life and the safety

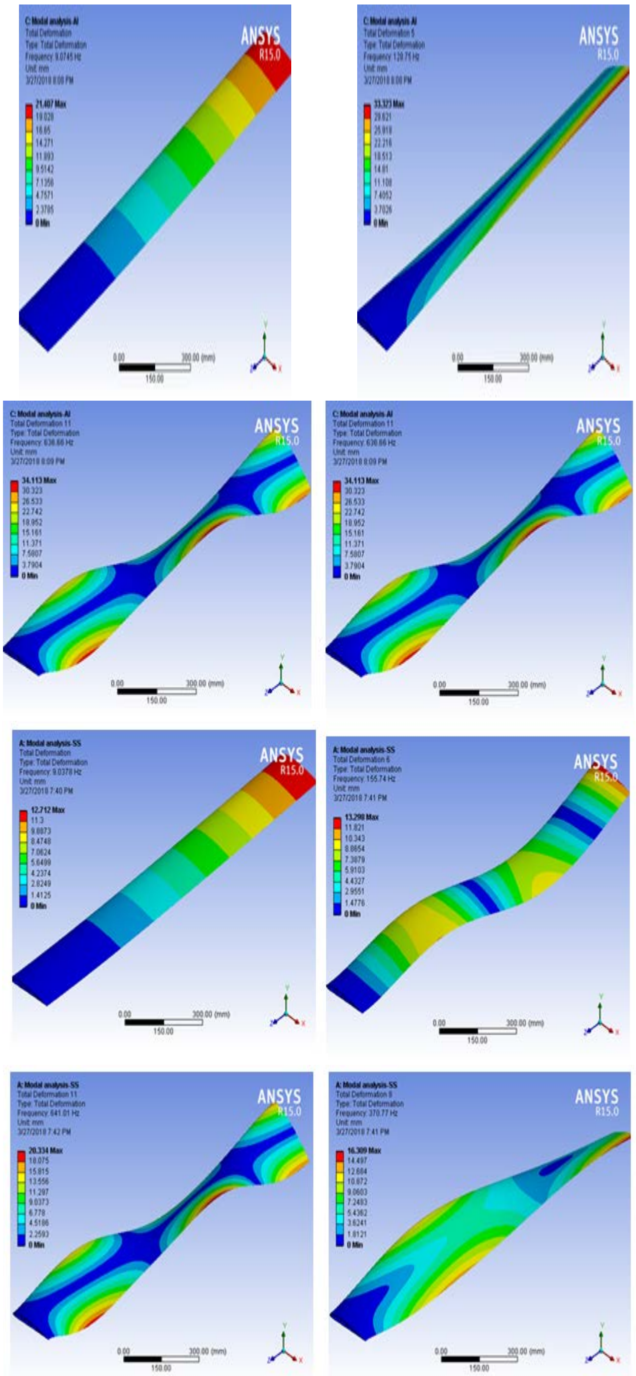


Solid diagram for Modal Analysis



Meshed Diagram for Modal Analysis

5. DEFROMATION OF WING WITH ALUMINUM MATERIAL



6. DEFORMATION OF THE WING WIH STRUCTURAL STEEL MAATERIAL

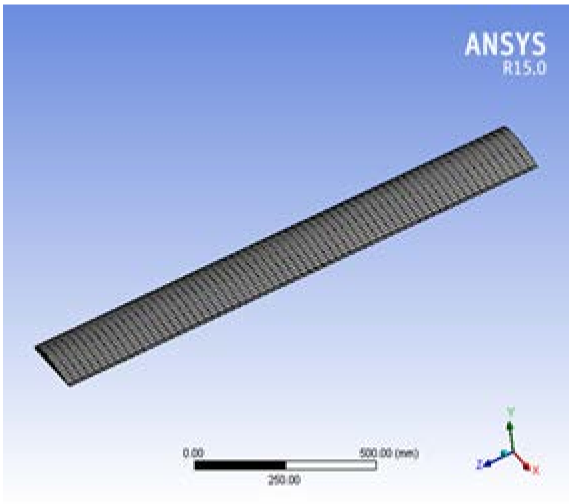
Results summary of the Aluminium and Structural Steel

S. No	Frequency	Deformation in mm
1	8.98	21.408
2	55.9	21.65
3	65.25	21.35
4	127.5	33.33
5	154.86	22.31
6	298.5	22.64
7	366.8	27.97
8	397	27.58
9	483.35	24.9
10	633.64	34.21

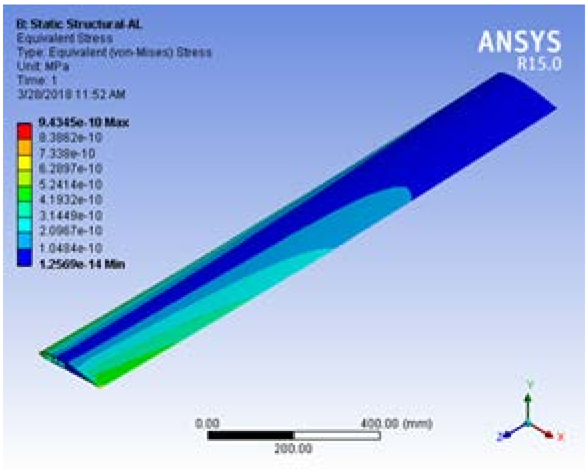
S. No	Frequency	Deformation in mm
1	9.0378	12.712
2	56.231	12.851
3	65.815	12.684
4	129.77	19.812
5	155.74	13.298
6	300.04	13.449
7	370.77	16.309
8	402.58	15.45
9	405.52	14.845
10	641.01	20.334

b) FATIGUE ANALYSIS

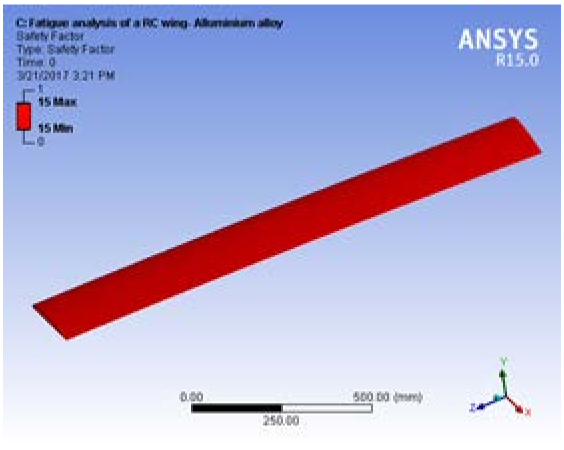
Fatigue may occur when a member is subjected to repeated cyclic loadings (due to action of fluctuating stress, according to the terminology used in the EN 1993-1-9). The fatigue phenomenon shows itself in the form of cracks developing at particular locations in the structure. Cracks can appear in diverse types of structures such as planes, boats, bridges, frames, cranes, overhead cranes, machines parts, turbines, reactors vessels, canal lock doors, offshore platforms, transmission towers, pylons, masts and chimneys Structures subjected to repeated cyclic loadings can undergo progressive damage which shows itself by the propagation of cracks. This damage is called fatigue and is represented by a loss of resistance with time. The physical effect of a repeated load on a material is different from the static load. Failure always being brittle fracture regardless of whether the material is brittle or ductile. Mostly fatigue failure occurs at stress well below the static elastic strength of the material



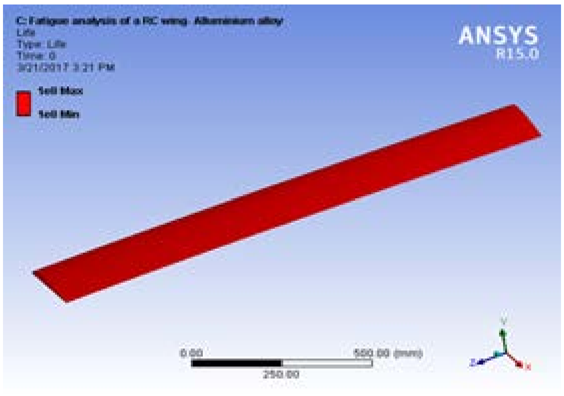
Fatigue analysis on Aluminum materialized wing



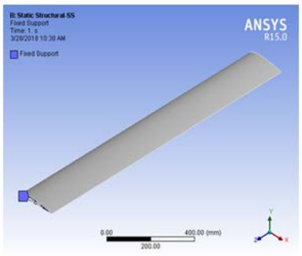
Equivalent Stress

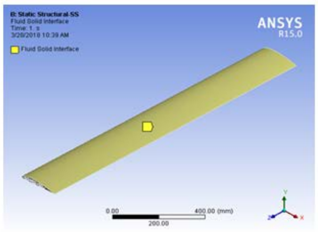


Safety Factor

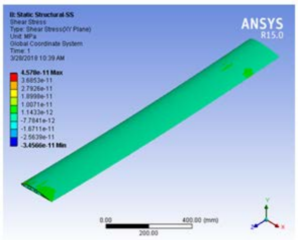


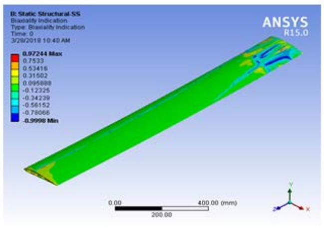
Life of the wing





Solid body of the wing Shear stress





Fluid solid interface Biaxiality indication

Fatigue Analysis Results Summary

FATIGUE ANALYSIS RESULT SUMMARY OF ALUMINIUM			
Material Used Aluminum			
S.NO	**Type of test**	**Result value**	**Units**
1	Equivalent Von- Misses Stress	2.06E-07	Mpa
2	Maximum Principal Stress	1.57E-07	Mpa
3	Minimum Principal Stress	2.63E-08	Mpa
4	Total Deformation	5.10E-09	mm
5	Bi Axiality Indication	9.90E-01	None
6	Equivalent Alternating Stress	1.03E-07	Mpa
7	Life	1.00E+06	Cycles
8	Safety Factor	1.50E+01	None

FATIGUE ANALYSIS RESULT SUMMARY OF STRUCTURAL STEEL			
Material Used：Structural Steel			
S.NO	**Type of test**	**Result value**	**Units**
1	Equivalent Von- Misses Stress	4.485E-10	Mpa
2	Equivalent Elastic strain	2.24E-15	None
3	Strain Energy	2.20E-22	mJ
4	Total Deformation	4.002E-11	mm
5	Bi Axiality Indication	0.9724	None
6	Equivalent Alternating Stress	1.03E-07	Mpa
7	Life	1.00E+08	Cycles
8	Safety Factor	1.50E+01	None

7. CONCLUSION AND FUTURE SCOPE

The design of aircraft wing was designed and made several analysis test on it and studied. The strength it is to find the life estimation. Harmonic and Modal analysis are to defined the behavior of the wing under several frequency values. The real world application like Aero-Dynamic loading conditions loads applied and also conducted and found Fatigue Results of the aircraft wing to determine the exact life and other related values. So in the future we want extended the project by varying the design and changing the material

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