Design and Vibrational Analysis over an Aircraft Wing Section

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Abstract: In our project we are going to analyze the stress distribution over a modern passenger aircraft wing section due to vibrations. We had taken a subsonic passenger aircraft as a reference flight and analyzed using FEA optimization tool (ANSYS WORKBENCH).Due to maximum speed, the maximum lift force is produced across the wing surface. Due to lift force and g-forces, the aircraft wing starts to vibrate and will reduce the stability of an aircraft. The boundary conditions are taken from the passenger aircraft survey reports including maximum lift force distribution over the wing section is calculated. In this project we had taken the load condition because while optimizing an aircraft extreme load condition will be considered.
Keywords: subsonic passenger aircraft, coefficient of lift, coefficient of drag, Aircraft wing.

I. INTRODUCTION

An aircraft life has been depending on the structural behaviour of the wing. But nowadays while optimizing the aircrafts such as dynamic behaviour for the aircraft wing also considered. The aircraft life has been reduced due to unwanted vibrations that take place due to flow of air in the atmosphere. The life of the supporting structures has been reduced due to different mode shapes of the aircraft wings which occur at various frequencies. Due to the different mode shapes, the coupling structures near the wing root and fuselage will undergo high stress. There will be difference if we used to analysis the wing structure statically in FEA. The load distribution will not be same over the wing structures. In the early years of aircraft design, designers generally used analytical theory to do the various engineering calculations that go into the design process along with a lot of experimentation. These calculations were labour-intensive and time-consuming. In the 1940s, several engineers started looking for ways to automate and simplify the calculation process and many relations and semi-empirical formulas were developed. Even after simplification, the calculations continued to be extensive. With the invention of the computer, engineers realized that a majority of the calculations could be automated, but the lack of design visualization and the huge amount of experimentation involved kept the field of aircraft design stagnant. With the rise of programming languages, engineers could now write programs that were tailored to design an aircraft. Originally this was done with mainframe computers and used low-level programming languages that required the user to be fluent in the language and know the architecture of the computer. With the introduction of personal computers, design programs began employing a more user-friendly approach

II. VIBRATION TEST

These simple models can be obtained either by model reduction of complex fluid structure models 3,7 or using a fight dynamics approach.8,9 In either case, a structural model of the aircraft is required, e.g. a finite element method (FEM) based model. Experimental data can be used to both validate and update such FEM models to ensure that they accurately model the actual aircraft structural dynamics.10, 11 The experiments to obtain such data should be designed aiming towards identification of the vibration frequencies and mode shapes across a suitable frequency range.12 This paper focuses on Ground Vibration Test (GVT) procedures and post-processing algorithms to estimate modal frequencies and vibration mode shapes.

1) Free vibration occurs when a mechanical system is set in motion with an initial input and allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and letting it go, or hitting a tuning fork and letting it ring. The mechanical system vibrates at one or more and damps down to motionlessness.
2) Forced vibration is when a time-varying disturbance (load, displacement or velocity) is applied to a mechanical system. The disturbance can be a periodic and steady-state input, a transient input, or a random input. The periodic input can be a harmonic or a non-harmonic disturbance. Examples of these types of vibration include a washing machine shaking due to an imbalance, transportation vibration caused by an engine or uneven road, or the vibration of a building during an earthquake. For linear systems, the frequency of the steady-state vibration response resulting from the application of a periodic, harmonic input is equal to the frequency of the applied force or motion, with the response magnitude being dependent on the actual mechanical system.

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3) Damped vibration when the energy of a vibrating system is gradually dissipated by friction and other resistances, the vibrations are said to be damped. The vibrations gradually reduce or change in frequency or intensity or cease and the system rests in its equilibrium position. An example of this type of vibration is the vehicular suspension dampened by the shock absorber.

III. DESIGN OF AIR WING

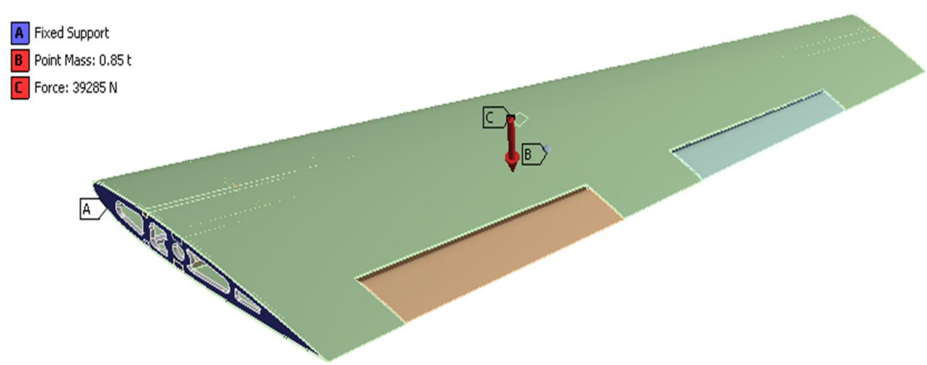
This method is used for the design of the lightly loaded ribs where the web stiffeners are omitted and instead a series of standard flanged lightening holes are introduced. The second method presents a new methodology for the design of the wing rib subjected to moderate to heavy loading (bulkheads).This method is based on the incomplete diagonal tension theory where the rib is forced to be under incomplete diagonal tension field. Uprights are introduced to the rib to support rib buckling. A complete stress analysis for the wing rib as well as web uprights is presented. The analysis procedure is based on theoretical evidence supported by empirical formulations. While the third method is a survey on the design methodology suggested by Paul Kuhn, et.al. in their report 'Summary of Diagonal Tension- Part One, NACA Technical Note 2661'.

A. Lift Force Calculation

$L=1/2(\rho)*v^2*A*C_L$

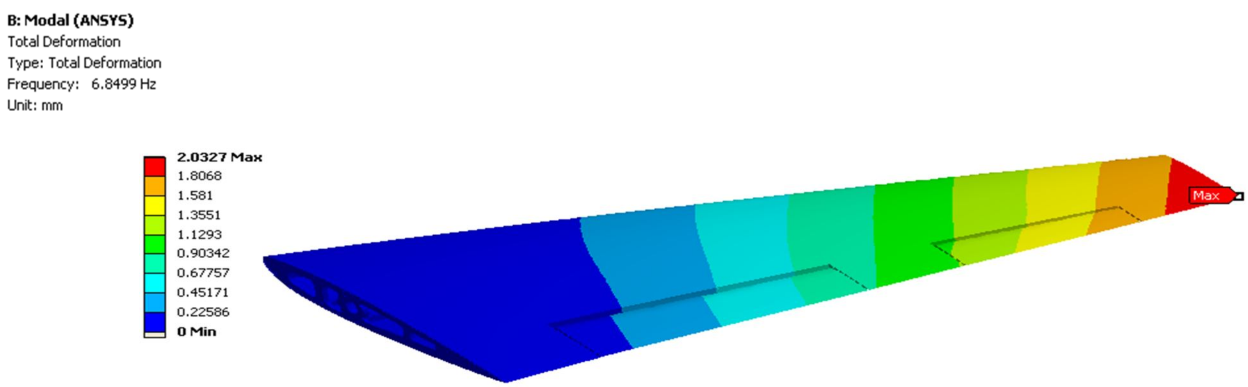
1) Max Lift coefficient CL=0.795
2) Density (air)(ρ)=1.225 kg/m3
3) Velocity v=240m/s
4) s=wing span=2000mm=A
5) c=average chord=674mm
6) Thus lift (L)= 39285N

B. *Catia Design*

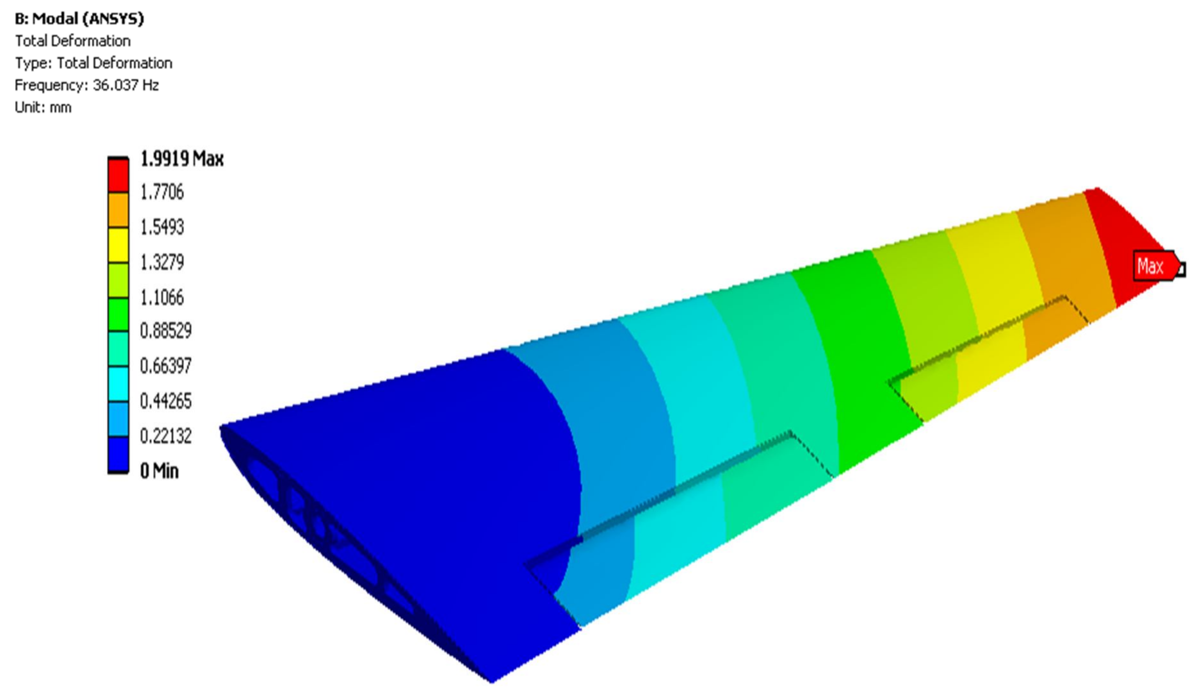


IV. ANSYS MODEL

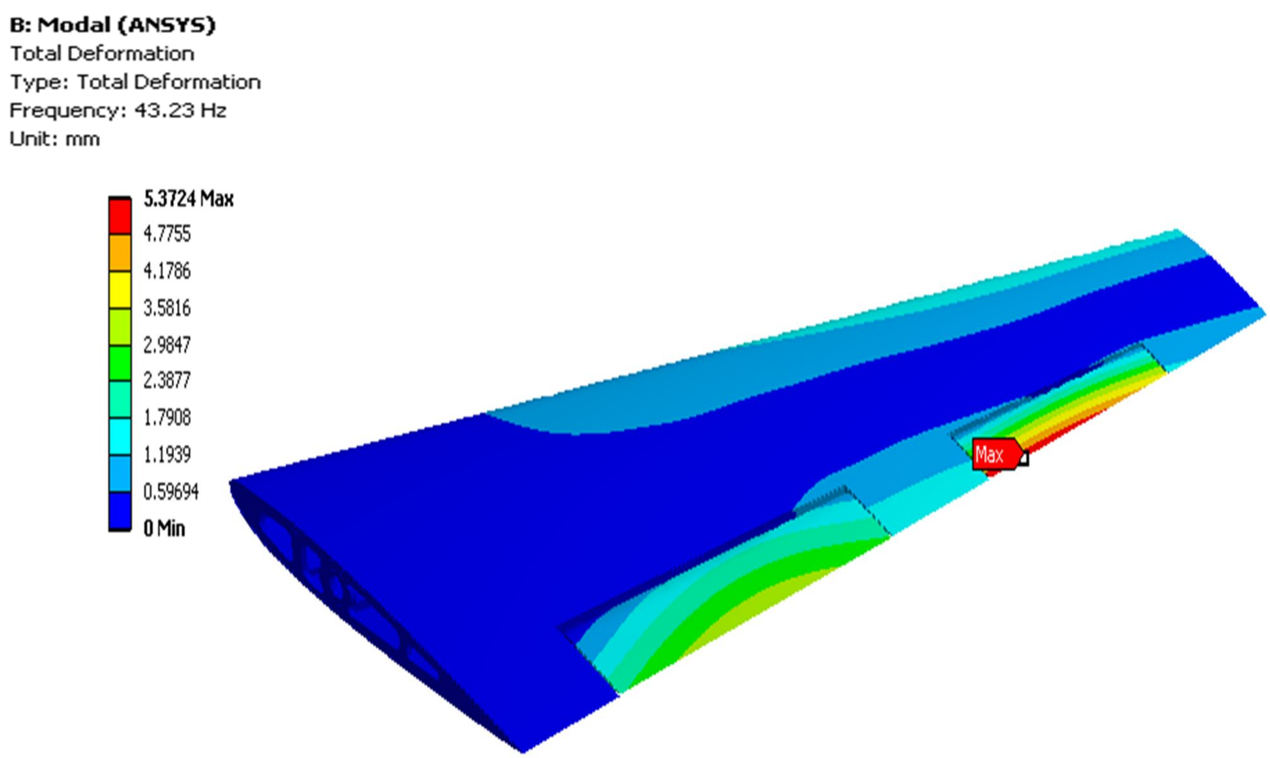
A. *Velocity=300mph*



B. Frequency: 36.037HZ



C. Frequency:43.32HZ



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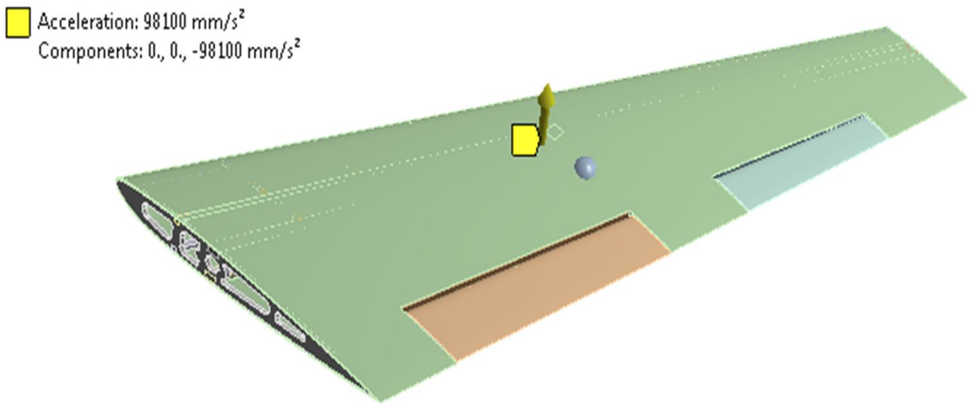
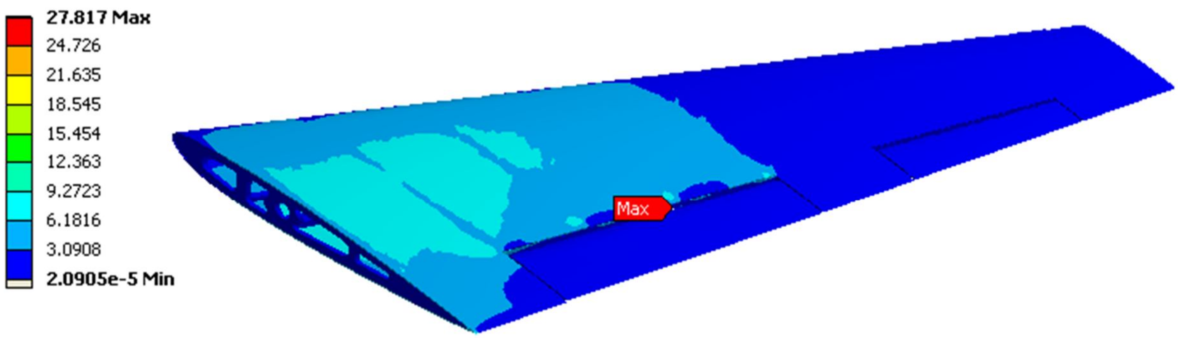
D. Load Case 2



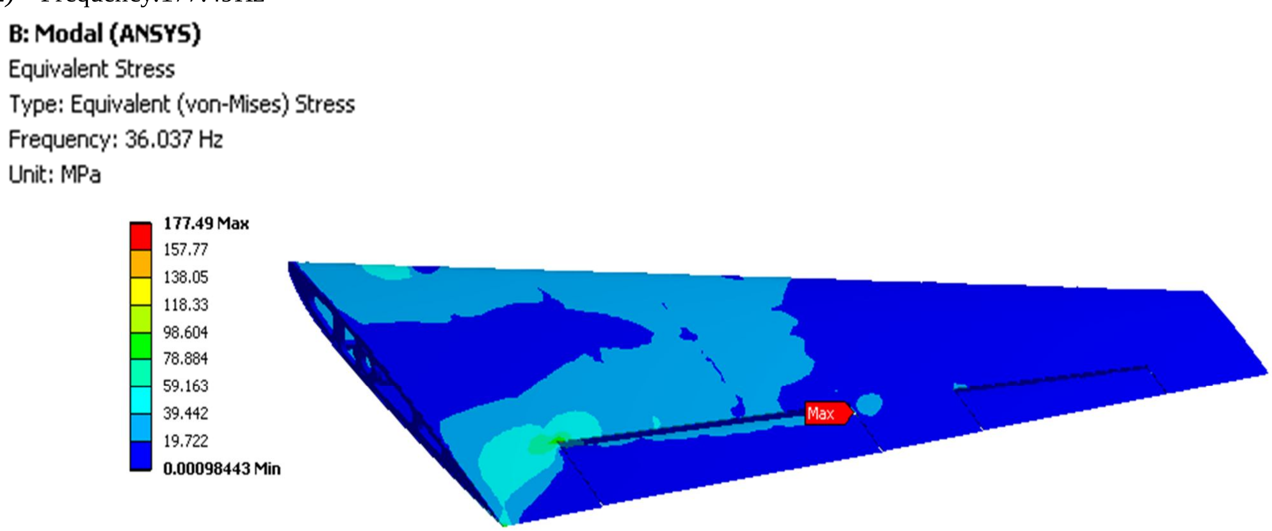
E. Stress Plots Stress Plots (In MPA)

1) Frequency: 27.817Hz



(Magnified view of the stress plots is shown below i.e it represents the maximum stress induced in the frequency 27.817HZ)

2) Frequency:177.49Hz



(Magnified view of the stress plots is shoown below i.e it represents the maximum stress induced in the frequency 177.49HZ)

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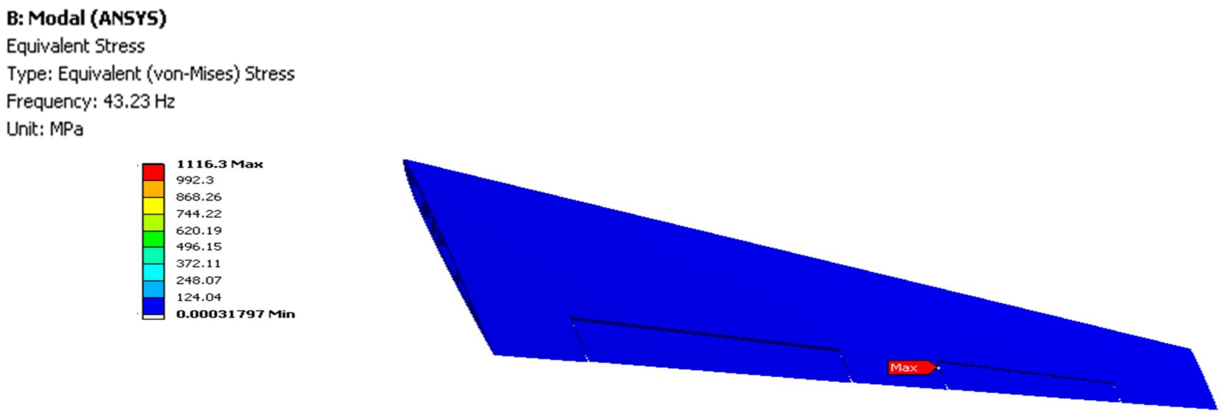
3) Frequency:1116.3Hz



V. RESULT ANALYSIS

1) Thus the spot where the displacement and stress acting will be maximum is found.
2) By comparing the results we can optimize the structure at the required spot to increase the structural life.

Result For Load Case1: Lift Force

S.NO	MODES	DESCRIPTION	TOTAL DEFORMATION	VON MISES STRESS
1	6.8499	Vertical bending	2.03	27.87
2	36.037	Second vertical bending	1.9919	177.49
3	43.23	Flap vertical bending	5.37	1116.3

Result For Load Case 2: Acceleration

S.NO	MODES	DESCRIPTION	TOTAL DEFORMATION	VON MISES STRESS
1	6.8499	Vertical bending	2.03	27.709
2	36.037	Second vertical bending	1.9919	177.64
3	43.23	Flap vertical bending	5.33	1110

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