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# Design, Static Structural and Modal Analysis of Aircraft Wing (Naca 4412) Using Anasys Workbench 14.5

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***Abstract:****The weight reduction of a wing is very important to improve the efficiency of an air craft. out of all the parts of an air craft the wings plays a major role in getting high performance. usually the aluminium aircraft wing structure will suitable , but in my present work some composite materials, in which aluminium as base material and mixed with some other materials at different proportions were selected for the design of wings and also tested for its performance. A suitable wing profile NACA 4412 is selected and modeled in CATIAV5 R20. The generated wing profile is imported to ANSYS WORKBENCH. Static structural analysis is carried out in ANSYS by inputting the properties of the optimum specimen which are obtained experimentally. The main purpose of this project is to find out which material out of the following three such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA TITANIUM ALLOY is best suited for making wing of flight.*

***Keywords:****Air wing, composite materials, NACA 4412, structural and modal analysis, ANSYS, CATIA.*

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## I. INTRODUCTION

An aircraft is a vehicle that is able to fly by gaining support from the air, or, in general, the atmosphere of a planet. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines. Although rockets and missiles also travel through the atmosphere, most are not considered aircraft because they do not have wings and rely on rocket thrust as the primary means of lift. The human activity that surrounds aircraft is called aviation. Manned aircraft are flown by an onboard pilot. Unmanned aerial vehicles may be remotely controlled or self-controlled by onboard computers. Aircraft may be classified by different criteria, such as lift type, propulsion, usage, and others**.**

**Softwares Used :** In this project I will be using the two basic design software's, they are AutoCAD, CATIA , for designing. CATIA - abbreviation is **C**omputer **A**ided **T**hree- dimensional **I**nteractive **A**pplication. Version 5 and revision 20 is used for designing of shock absorber which consists of the following modules.


**Introduction To Ansys** .

ANSYS is the standard FEA tool within the Mechanical Engineering Department and also used in Civil and Electrical Engineering. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs.

**Steps In Finite Element Analysis:**
- Descritization
- Formulation of properties to each element and concern nodes.
- Assemble all elements for structure
- Give input such as load , forces ,temperatures etc based on type of analysis means structural, thermal etc.
- Solve simultaneous line algebraic equations
- Display the results in the form of graphs.

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems.

## II. Literature Review

**K. Sruthi, T. Lakshmana Kishore, M. Komaleswara Rao[1],** This paper deals with the reduction of weight ratio in the wing structure improves the efficiency and performance of an aircraft wing. Amongst all the aircraft parts reduction in the weight of the wing has got higher importance. Generally an aircraft wing structures are design using pure aluminium, but in this project composite material which is a combination of Aluminium LM25 (AL) and Silicon Carbide (SiC) where in aluminium is the base metal and silicon carbide is reinforcement is used to reduce the weight ratio of the wing structure. By varying silicon carbide percentages in aluminium25 four types of specimens are prepared using stir casting process. The young's modulus, Poisson's ratio and density of each specimen are determined experimentally by subjecting the specimen to compression test, hardness test and tensile test. By comparing the material properties obtained experimentally optimum percentage of silicon carbide in aluminium is determined. A suitable wing profile NACA 4412 is selected and modelled in CATIAV5 R20. The generated wing profile is imported to ANSYS WORKBENCH. Static structural analysis is carried out in ANSYS by inputting the properties of the optimum specimen which are obtained experimentally. Similarly by in putting pure AL25 properties. The results obtained from ANSYS for pure AL25 and metal matrix composite (SiC) are compared. By comparing the results it is found that composite material has better material properties and stresses than pure aluminium.

**Kakumani Sureka and R Satya Meher [2**],. In this conventional type of wing is used with two material, they are AL alloy and AL alloy 7068. Because of its versatility in many flight roles and situations. It is generally not limited to certain flying levels or airspeeds and is extremely useful.

The main purpose of this project is to find out which material (AL alloy and Al alloy 7068) is best suited for making wing of flight. In this the CAD model of A300 wing with spares and ribs using the modeling software CATIA V5 R20 and later we made modeling and structural analysis on wing Skelton structure by using ANSYS WORKBENCH.

**Abdulkareem Sh. Mahdi Al-Obaidi*, Eric Tan Nan Kui [3],** The effect of various wing geometry parameters on lift generation at supersonic speeds has been studied and analyzed. These parameters include the aspect ratio, taper ratio, leading edge sweep angle, relative thickness and the airfoil shape. The parametric study considered only four wing plan forms which were the straight rectangular, sweptback, delta and trapezoidal wings. Both analytical and semi-empirical approaches are used for determining the lift curve slope. The obtained results were validated using published experimental results..

**Richard M. Wood [4]**, The aerodynamic characteristics of delta wings at lifting conditions have been evaluated for the effects of wing leading-edge sweep, leading-edge bluntness, and wing thickness and camber and then summarized in the form of graphs which may be used to assess the aerodynamics in the preliminary design process. Empirical curves have been developed for the lift-curve slope, nonlinear lift effects, maximum lift, longitudinal stability, and distribution of lift between the upper and lower surfaces of a wing. In addition, the impact of various airfoil parameters, wing leadingedge sweep, and lift coefficient on the drag-due-to-lift characteristics has been shown theoretically. The various graphs which detail the aerodynamic performance of delta wings at both zero-lift and lifting conditions were then employed to define a preliminary wing design approach in which both the low-lift and high-lift design criteria were combined to define a feasible design space.

**Amiya Kumar Samal[5**], In this work, flow analysis of two airfoils (NACA 6409 and NACA 4412) and effect of angle of attack on airfoil (NACA 0012) was investigated. Drag force, lift force as well as the overall pressure distribution over the airfoil were also analyzed. The outcome of this investigation was shown and computed by using ANSYS workbench 15. The pressure distributions as well as coefficient of lift to coefficient of drag ratio of these two airfoil were visualized and compared. From this result, we compared the better airfoil between these two airfoils. The whole analysis is solely based on the principle of finite element method and computational fluid dynamics (CFD).

**Dr.R.Rajappan, V.Pugazhenthi [6]**, The thesis deals with bending Finite Element Analysis of monocoque laminated composite aircraft (subsonic and supersonic) wing using commercial software ANSYS. Theoretical background, mathematical formulation and finite element solution for a laminated composite shell structure are presented in this study. A monocoque aircraft wing is made of laminated composite with fiber angles in each ply aligned in different direction. Various airfoil thickness and ply angles were considered to study the effect of bending-torsion decoupling.

**Li Jixinga,Ning Taoa,*, Xi Pinga, Wang Tiana[7**],. This paper presents an approach to implement rapid design, modeling, and automated adjustment for missile body structures by describing missile body structures' arrangement information and model information with parameters. A rapid missile body structure design module was developed based on NX environment and method above which can achieve rapid structure design, automated adjustment, as well as automated calculation and update of data such as mass, bary center, and so on. Finally, an instance was presented to illustrate that this method is feasible and effective.

S**.Ravikanth, KalyanDagamoori, M.SaiDheeraj etc. all [8]** , In this paper we are going to derive the different equations related to the longitudinal stability and control. The design of the horizontal stabilizer and elevator is going to do in CATIA V5 and the analysis is going to perform in ANSYS 12.0 FLUENT.

**Youxu Yang, Zhigang Wu, Chao Yang [9],** A multi-plate model based on Ritz method and penalty function technique is developed to model complex wing configurations formed by wing segments in different planes. Each wing segment is modeled as a plate element basing on the first-order shear deformation plate theory. The penalty function technique is used to impose displacement compatibility along sides of adjacent plate elements. The stiffness and mass matrix of the whole configuration are assembled using the equality of total stain energy and kinetic energy. The natural frequencies and the modes are obtained by solving an eigenvalue problem. As a test, a flying wing configuration is modeled using two plates and its structural dynamics and flutter results are compared with finite element model.

**Sudhir Reddy Konayapalli, Y. Sujatha[10**], In the present study, a general aviation airplane is designed and analyzed. The design process starts with a sketch of how the airplane is envisioned. Weight is estimated based on the sketch and a chosen design mission profile. A more refined method is conducted based on calculated performance parameters to achieve a more accurate weight estimate which is used to acquire the external geometry of the airplane. A three-dimensional layout of the airplane is created using RDS software based on conic lofting, then placed in a simulation environment in Matlab which proved the designs adherence to the design goals. In addition, static stress analysis is also performed for wing design purposes. Using the finite element software package COMSOL, the calculated aerodynamic loads are applied to the wing to check the wing reliability.

**Nataraj Kuntoji , Dr. Vinay V. Kuppast [11]**, The wing analysis is carried out by using computer numerical analysis tool, viz., CAD/CAE and CFD. The optimization of the aircraft wing is effectively achieved by considering different material properties, loading conditions and dimensions with different flying conditions. The modal analysis is considered to analyze the wing to determine the natural frequency for vibration characteristics of the wing structure. The proposed work is identified in carrying out the wing analysis for vibration characteristics using computational tools, and then a prototype of wing structure. The validation of the prototype can be done by experimental method for the optimized wing design.

**M. Ganesh, G Hima Bindu, A. Sai Kumar[12],** In this work, failure modes and buckling loads of composite plate under uniformly distributed loading and deflection is investigated by using analytical and theoretical approaches. A 3-D finite-elements model was also built which takes into consideration the exact geometric configuration and the orthotropic properties of the composite plate. Altering the ply sequence for given working conditions alters the deflection of the particular material. Hence analysis is carried out on such various orientations to select the most suitable orientation. The composite plate carries out the theoretical and the FEM results and is found to be around 8-10% difference.

**Nataraj Kuntoji , Dr. Vinay V. Kuppast [13]**, The design of the aircraft wing using NACA standards is been discussed in this work. The wing analysis is carried out by using computer numerical analysis tool, viz., CAD/CAE and CFD. The necessary inputs for carrying out the structural analysis with emphasis on the vibration are obtained by CFD analysis. The deformation of the wing structures are investigated with respect to the standard airflow velocity. The velocity of air at the inlet is taken as 122 m/s (438 km/h), considering service ceiling of 7625 m at moderate temperature. The modal analysis is considered to analyse the wing to determine the natural frequency for vibration characteristics of the wing structure. However the fundamental natural frequency of the wing structure is 10.352 Hz for the deformation of 11.383 mm.

## III. MODELING OF AIRCRAFT WING

I have been modeled aircraft wing using ANSYS design moduler.

**3.1 : ISOMETRIC VIEW OF AIRCRAFT WING:**

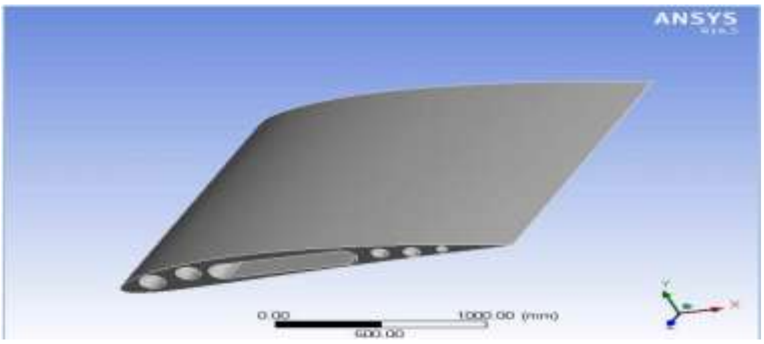


**Fig3.1 : aircraft wing model in ANSYS**

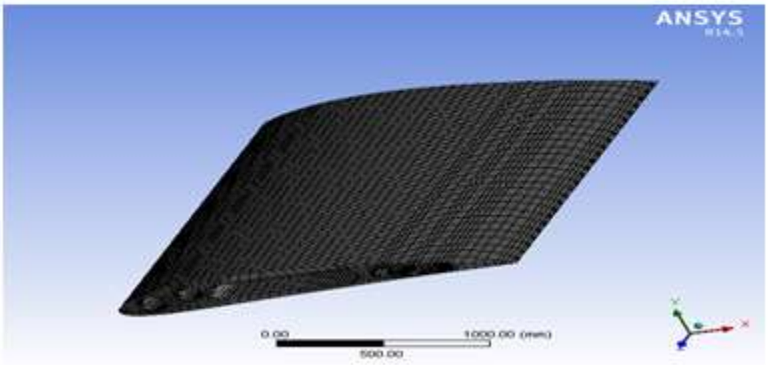


**Fig 3.2 : aircraft wing mesh model in ANSYS**

**3.2 : Material Selection:**

The weight reduction of a wing is very important to improve the efficiency of an air craft. out of all the parts of an air craft the wings plays a major role in getting high performance. usually the aluminium aircraft wing structure will suitable , but in my present work some composite materials, in which aluminium as base material and mixed with some other materials at different proportions were selected for the design of wings and also tested for its performance.. A suitable wing profile NACA 4412 is selected and modelled in CATIAV5 R20. The generated wing profile is imported to ANSYS WORKBENCH. Static structural analysis is carried out in ANSYS by inputting the properties of the optimum specimen which are obtained experimentally. The main purpose of this project is to find out which material out of the following three such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA TITANIUM ALLOY is best suited for making wing of flight. In this the CAD model of NACA4412 wing with spares and ribs using the modeling software CATIA V5 R20 and later we made modeling and structural analysis on wing Skelton structure by using ANSYS WORKBENCH.

**Table 3.1 : properties of materials :**

| S.No | Material name | Density $Kg/mm^3$ | Youngs modulus (E) Mpa | Poissoins ratio (μ) |
|---|---|---|---|---|
| 1 | AL-Zn-Mg alloy 7178 | 2.83e-6 | 72000 | 0.32 |
| 2 | ALIMINIUM LITHIUM A8090 | 2.55e-9 | 77000 | 0.34 |
| 3 | ALPHA BETA TITANIUM ALLOY | 4.43e-9 | 1.138e+5 | 0.342 |

**3.3 : Aircraft Wing Geometry Data :**

Aero foil= NACA4412
Length= 2000mm
Width= 250mm
Depth=3000mm

**3.4 : Observations From Analysis :** The main purpose of this project is to find out, which material out of the following three such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA TITANIUM ALLOY is best suited for making wing of flight.
During analysis the variation of TOTAL DEFORMATION , VON-MISSES STRAIN and VON-MISSES STRESS over the wing with different materials (as mentioned above three materials ) for a duration of one second was observed. and the detailed animations are as fallows.

**3.4.1 : "Total deformation" in Aircraft wing with different materials:**
**Case 1 : Total deformation when Al- Zn- Mg alloy 7178 is used as wing material:**

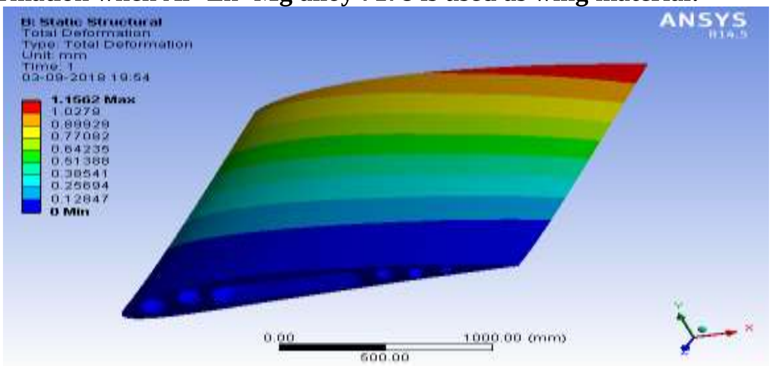


**Fig3.3 : Total deformation when Al- Zn- Mg alloy 7178 is used as wing material**

**Case 2 : Total deformation when Al- Li alloy 8090 is used as wing material:**

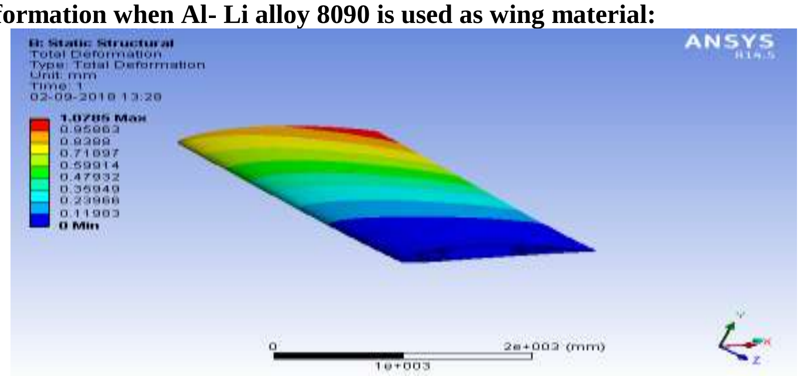


**Fig 3.4 : Total deformation when Al- Li alloy 8090 is used as wing material**

**Case 3 : Total deformation when Alpha- Beta Titanium alloy is used as wing material:**

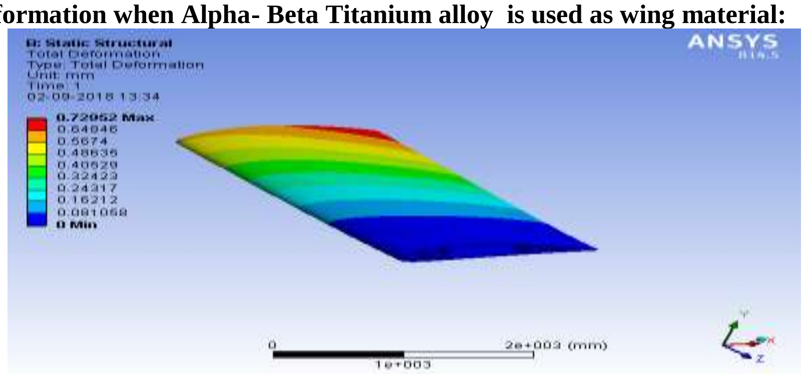


**Fig 3.5 : Total deformation when Alpha- Beta Titanium alloy is used as wing material.**

**3.4.2 : "Von-misses Strain" in Aircraft wing with different materials:**
**Case 1 : Von-misses strain when Al- Zn- Mg alloy 7178 is used as wing material:**

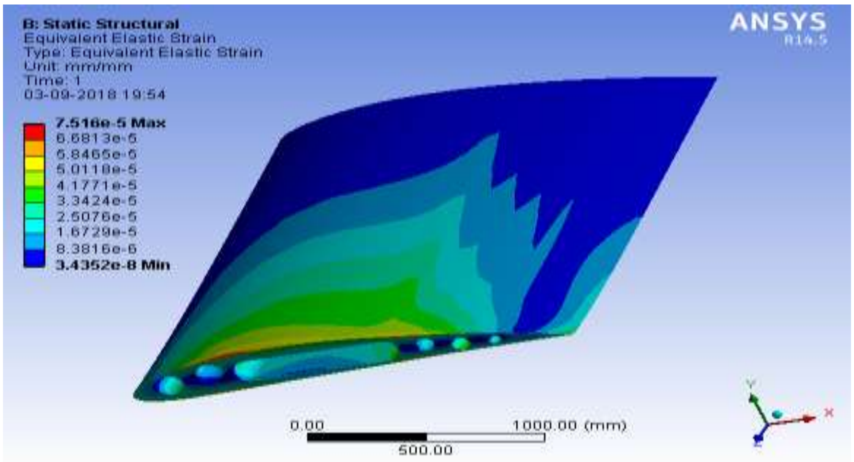


**Fig 3.6 : Von-misses strain when Al- Zn- Mg alloy 7178 is used as wing material**

**Case 2 : Von-misses strain when Al- Li alloy 8090 is used as wing material:**

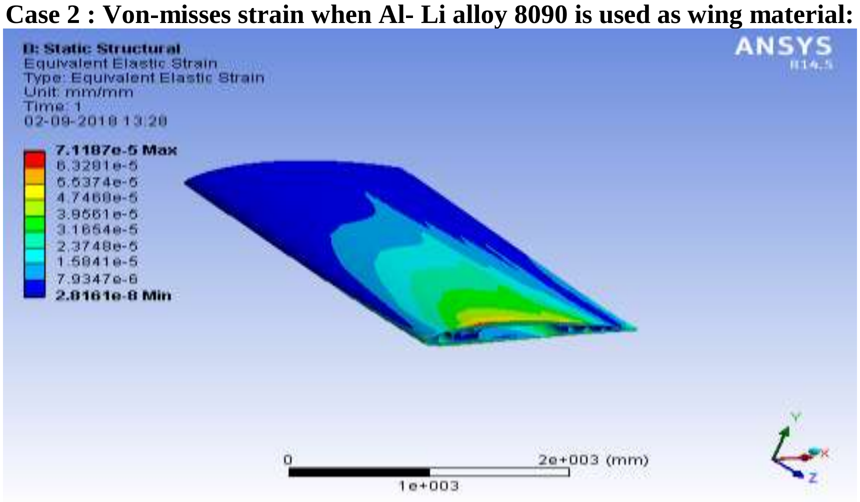


**Fig3.7 : Von-misses strain when Al- Li alloy 8090 is used as wing material**

**Case 3 : Von-misses strain when Alpha- Beta Titanium alloy is used as wing material**

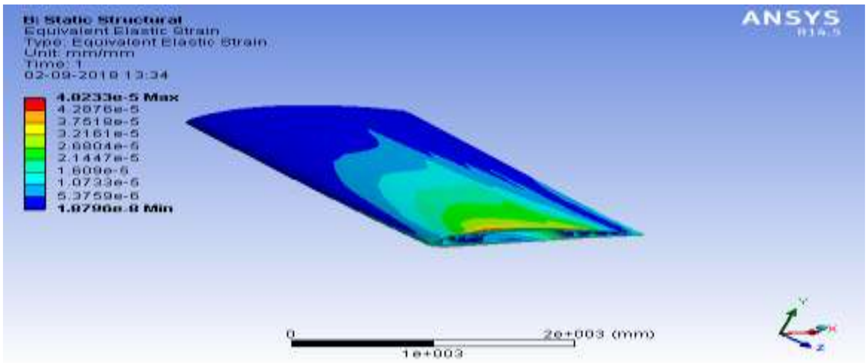


**Fig3.8 : Von-misses strain when Alpha- Beta Titanium alloy is used as wing material**

**3.4.3 : "Von-misses Stresses" in Aircraft wing with different materials**
**Case 1 : Von-misses stresses when Al- Zn- Mg alloy 7178 is used as wing material:**

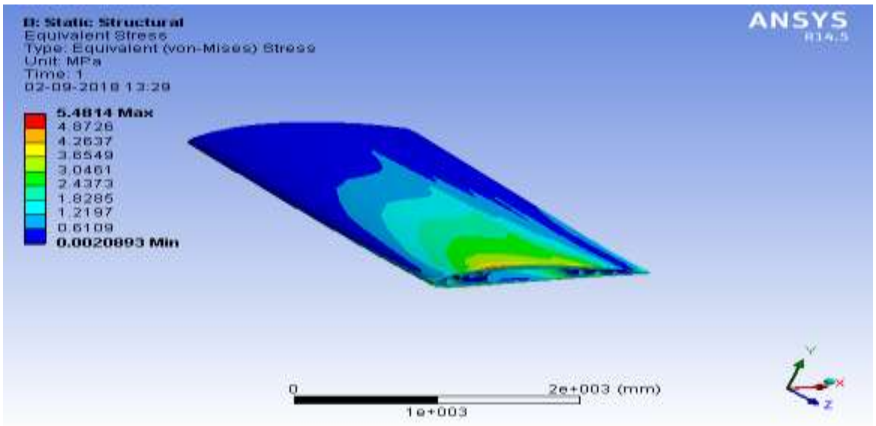


**Fig3.9 : Von-misses stresses when Al- Zn- Mg alloy 7178 is used as wing material**

**Case 2 : Von-misses stresses when Al- Li alloy 8090 is used as wing material:**

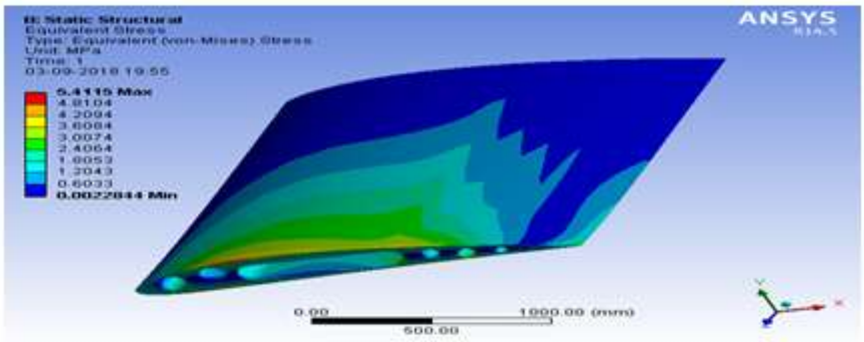


**Fig3.10 : Von-misses stresses when Al- Li alloy 8090 is used as wing material**

**Case 3 : Von-misses strain when Alpha- Beta Titanium alloy is used as wing material**

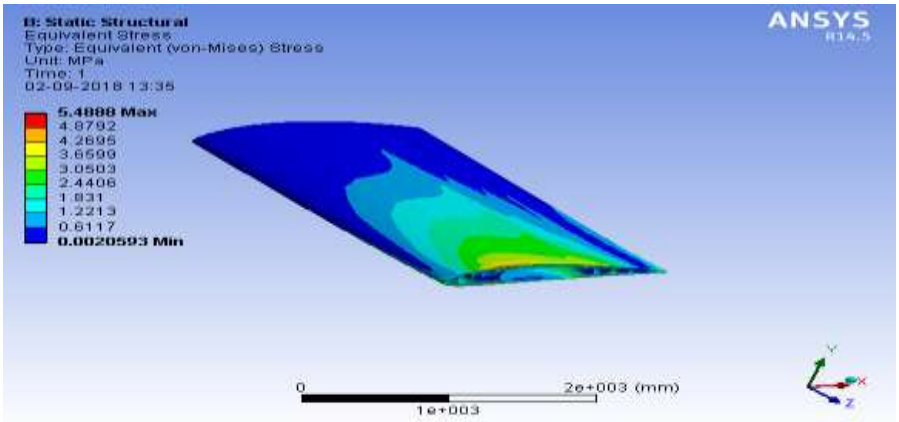


**Fig3.11 : Von-misses strain when Alpha- Beta Titanium alloy is used as wing material**

## IV. Modal Analysis:

From the results obtained with the above analysis it has been observed that among all the three materials which has been used in this work , the air wing manufactured with Alpha- Beta Combination(Titanium) Alloy was sustaining to maximum stresses with a least total deformation.

so, The Air craft wing which is made up of Alpha-Beta Titanium Alloy is selected and apply the Modal analysis and the mode shapes has been observed at different frequencies.

**<u>MODE 1</u> :** First order mode shape has been observed at a frequency of 704.02 Hz .The type of total deformation along the wing during the first mode is latitude deformation as shown below Fig.4.1.

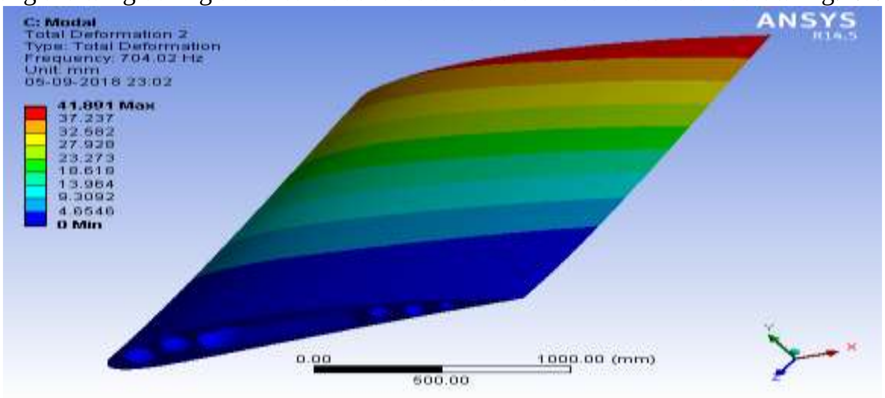


**Fig4.1 : first order mode shape at a frequency 704.2 Hz - latitude deformation**

**<u>MODE 2</u> :** Second order mode shape has been observed at a frequency of 1973 Hz .The type of total deformation along the wing during the first mode is Torsion type of deformation as shown below Fig.4.2.

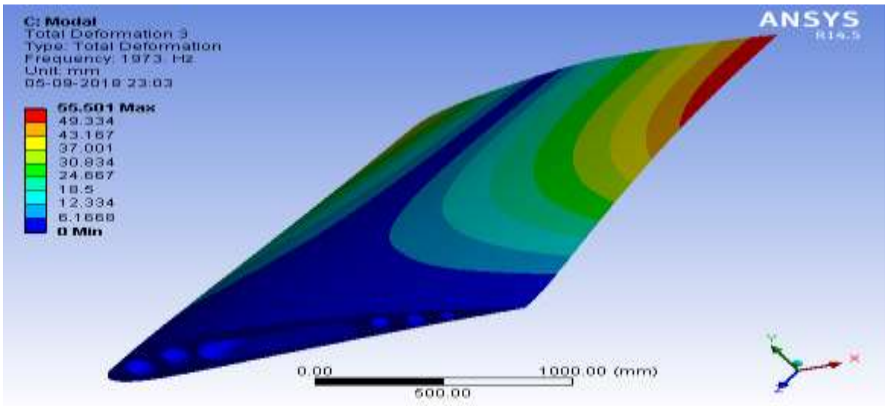


**Fig4.2 : second order mode shape at a frequency 1973 Hz - Torsion type of deformation**

**<u>MODE 3</u> :** Third order mode shape has been observed at a frequency of 3618.6 Hz. The type of total deformation along the wing during the first mode is Bending kind of deformation as shown below Fig.4.3.

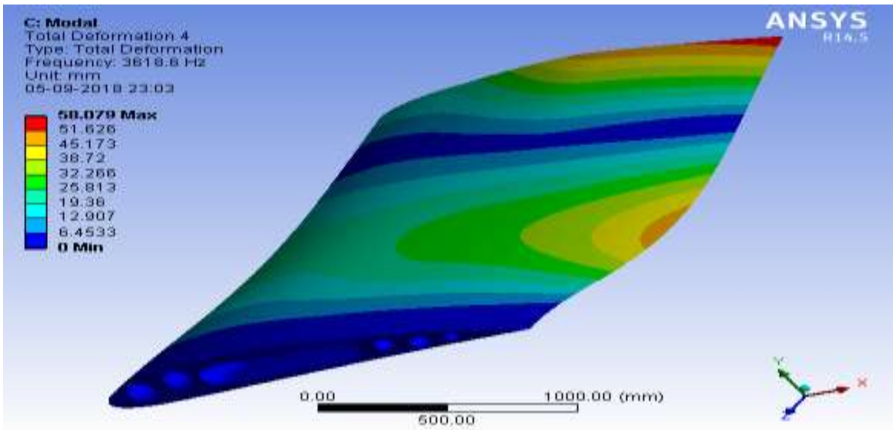


**Fig4.3 : Third order mode shape at a frequency 3618.6 Hz - Bending type of deformation**

**<u>MODE 4</u> :** Fourth order mode shape has been observed at a frequency of 4152.7 Hz. The type of total deformation along the wing during the first mode is Latitude kind of deformation as shown below Fig.4.4.

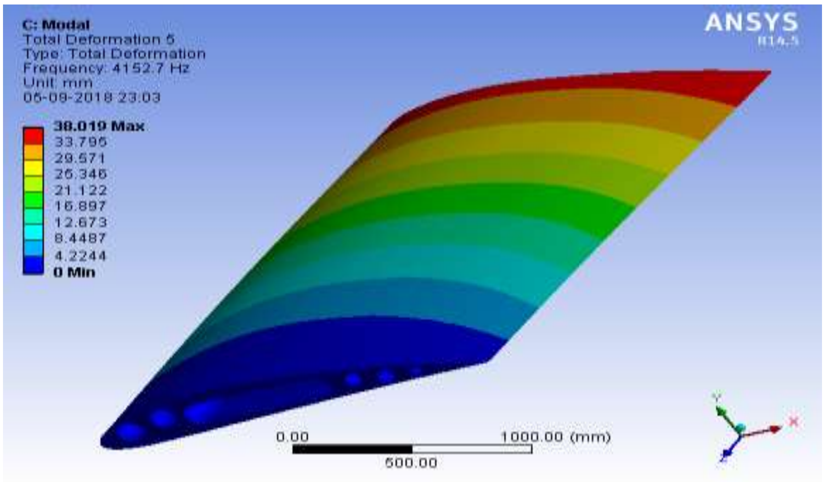


**Fig4.4 : Fourth order mode shape at a frequency 4152.7 Hz - latitude deformation**

**MODE 5 :** Fifth order mode shape has been observed at a frequency of 5518.3 Hz. The type of total deformation along the wing during the first mode is Twisting kind of deformation as shown below Fig.4.5.

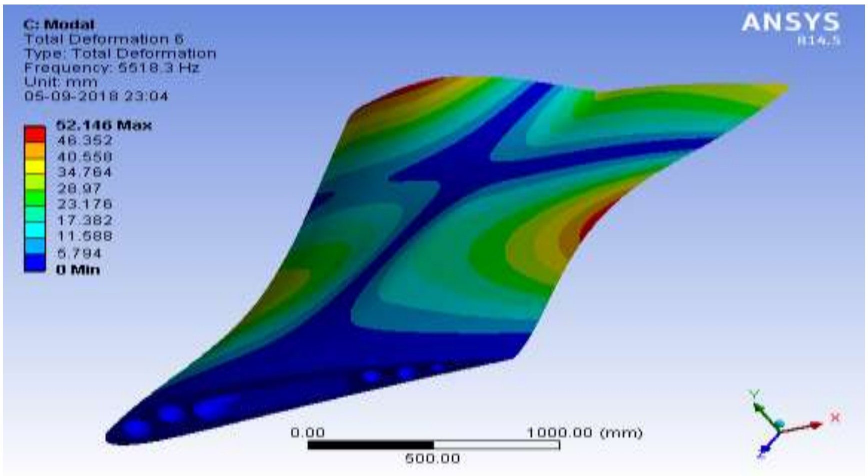


**Fig4.5 : Fifth order mode shape at a frequency 5518.3 Hz -Twisting kind of deformation**

**MODE 6 :** Sixth order mode shape has been observed at a frequency of 6886.8Hz. The type of total deformation along the wing during the first mode is Longitudinal kind of deformation as shown below Fig.4.6.

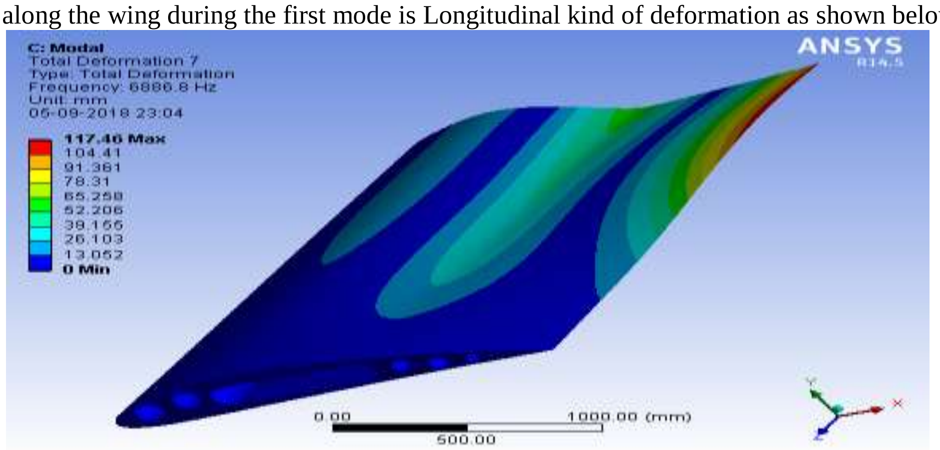


**Fig4.6 : Sixth order mode shape at a frequency 6886.8 Hz - Longitudinal deformation**

## V. Results And Disscussions:

In this project a suitable wing profile NACA 4412 is selected and modeled in CATIAV5 R20 and later we made modeling and structural analysis on wing Skelton structure by using ANSYS WORKBENCH. The weight reduction of a wing is very important to improve the efficiency of an air craft. out of all the parts of an air craft the wings plays a major role in getting high performance. usually the aluminium aircraft wing structure will suitable , but in my present work some composite materials, in which aluminium as base material and mixed with some other materials at different proportions were selected for the design of wings and also tested for its performance.

The main purpose of this project is to find out which material out of the following three such as AL-Zn-Mg alloy 7178, Aluminium Lithium A8090 And Alpha- Beta Combination (Titanium) Alloy is best suited for making wing of flight. The STATIC STRUCTURAL ANALYSIS has been done and calculated three different parameters such as the Total deformation, Von-misses strain and Von-misses stresses by changing the material composition as mentioned above. The results were tabulated below.

**5.1: Static Structural Analysis :**

**5.1.1:Total Deformation**: During analysis the variation of TOTAL DEFORMATION over the wing with different materials such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA COMBINATION (TITANIUM) ALLOY for a duration of one second was observed. and the detailed results were tabulated below.

**Table 5.1 : Variation of Total Deformation of wing with different materials:**

| Material | Total deformation (Max value in MM) |
|---|---|
| AL-Zn-Mg 7178 | 1.562 |
| Al-LITHIUM Alloy -8090 | 1.0785 |
| ALPHA-BETA COMBINATION (TITUNIUM )ALLOY | 0.72952 |

**5.1.2:Von- Misses Strain:**During analysis the variation of VON-MISSES STRAIN over the wing with different materials such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA COMBINATION (TITANIUM) ALLOY for a duration of one second was observed. and the detailed results were tabulated below.

**Table 5.2 : Variation of Von-misses strain of wing with different materials:**

| Material | Von-misse strain (Min value ) | Von-misse strain (Max value ) |
|---|---|---|
| AL-Zn-Mg 7178 | 3.4352e-8 | 7.516e-5 |
| Al-LITHIUM Alloy -8090 | 2.816e-8 | 7.1187e-5 |
| ALPHA-BETA COMBINATION (TITUNIUM )ALLOY | 1.8796e-8 | 4.8233e-5 |

**5.1.3:Von- Misses Strain**:During analysis the variation of VON-MISSES STRAIN over the wing with different materials such as AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA COMBINATION (TITANIUM) ALLOY for a duration of one second was observed. and the detailed results were tabulated below.

**Table 5.3 : Variation of Von-misses stresses of wing with different materials:**

| Material | Von- Misses Stresses (Min value Mpa ) | Von- Misses Stresses (Max value Mpa ) |
|---|---|---|
| AL-Zn-Mg 7178 | 0.0022844 | 5.4115 |
| Al-LITHIUM Alloy -8090 | 0.0020893 | 5.4814 |
| ALPHA-BETA COMBINATION (TITUNIUM )ALLOY | 0.0020593 | 5.4888 |

From the above results it has been observed that the wing made up of ALPHA- BETA COMBINATION (TITANIUM ) ALLOY is sustaining maximum stress with a least total deformation.

**5.2 : Modal Analysis:**

From the results obtained with the above analysis it has been observed that among all the three materials which has been used in this work , the air wing manufactured with Alpha- Beta Combination(Titanium) Alloy was sustaining to maximum stresses with a least total deformation.

so, The Air craft wing which is made up of Alpha-Beta Titanium Alloy is selected and apply the Modal analysis and the mode shapes has been observed at different frequencies and are listed below.

**Table 5.4 : mode shape at different frequency and type of deformation :**

| S.NO | MODE SHAPE | FREQUENCY(Hz) | TYPE OF DEFORMATION |
|---|---|---|---|
| 1. | MODE 1 | 704.02 | LATTITUDE |
| 2. | MODE 2 | 1973 | TORSION |
| 3. | MODE 3 | 3618.6 | BENDING |
| 4. | MODE 4 | 4152.7 | LATTITUDE |
| 5. | MODE 5 | 5518.3 | TWIST |
| 6. | MODE 6 | 6886.6 | LOGITUDINAL |

## VI. Conclusion And Future Scope:

To examine the structural effectiveness of the designed wing, 3-D finite element analysis was performed using ANSYS software to compute the critical stresses, displacements, strains and to test the wings against Von- Misses failure criterion.

### 6.1 Conclusions :

- Based on the finite element results, it was found that the designed wing is a safe at ALPHA-BETA (Titanium) Combination alloy material for the airplane to perform its mission and to meet all the design requirements.
- For accurate modeling of Air craft wing using ANSYS Design Modular, the model was meshed and added constraints, to obtain the first 6 order natural frequency and vibration mode, and the vibration modes are described.
- The results of this analysis for the following dynamic analysis and structure optimization design provides an important basis, also laid the foundation for more in-depth study on the vibration and noise problems, to provide a reference and basis for the practical experiment.

### 6.2 : Future Scope :

- In this project, the wing geometry is selected from NACA4412. The work can be extended by selecting other kind of geometry from different sources.
- The work can be extended by selecting different materials other than AL-Zn-Mg alloy 7178, ALUMINIUM LITHIUM A8090 and ALPHA- BETA TITANIUM ALLOY, those mainly provides weight reduction.
- the project can be extended to thermal analysis and vibration analysis with different load conditions.

## Biblography

[1]. K. Sruthi, T. Lakshmana Kishore, M. Komaleswara Rao,-"Design And Structural Analysis Of An Aircraft Wing By Using Aluminium Silicon Carbide Composite Materials", 2017 IJEDR | Volume 5, Issue 4 | ISSN: 2321-9939, PAGE.NO 949-959.
[2]. Kakumani Sureka and R Satya Meher ,- "Modeling And Structural Analysis On A300 Flight Wing By Using Ansys", ISSN 2278 – 0149, Vol. 4, No. 2, April 2015© 2015, IJMERR, PAGE.NO. 123-130.
[3]. Abdulkareem Sh. Mahdi Al-Obaidi*, Eric Tan Nan Kui,- "The Effect Of Wing Geometry On Lift At Supersonic Speeds", Journal of Engineering Science and Technology, EURECA 2013 Special Issue August (2014) 16 - 27.
[4]. Richard M. Wood,- "Supersonic Aerodynamics of Delta Wings", NASA
[5]. Technical Paper 2771, 1988.
[6]. Amiya Kumar Samal,- "Flow Analysis Over NASA Airfoils Using Fluent", Thesis submitted in PARALA MAHARAJA ENGINEERING COLLEGE, BERHAMPUR, 761003, ODISHA, 2016-17.
[7]. Dr.R.Rajappan, 2 V.Pugazhenthi, -" Finite Element Analysis of Aircraft Wing Using Composite Structure " (IJES) ,Volume 2 ,Issue 2 ,Pages 74-80 2013, ISSN: 2319 – 1813 ISBN: 2319 – 1805.
[8]. Li Jixinga,Ning Taoa,*, Xi Pinga, Wang Tiana,-" Rapid structure design and automated adjustment of missile body ", ELSEVIER, Procedia CIRP 56 ( 2016 ) 84 – 89.
[9]. S.Ravikanth, KalyanDagamoori, M.SaiDheeraj,V.V.S.Nikhil Bharadwaj etc.all -"A Effect of Elevator Deflection on Lift Coefficient Increment ", International Journal Of Modern Engineering Research (IJMER), ISSN: 2249–6645, Vol. 5 | Iss.6 | June 2015 | 9 -25.
[10]. Youxu Yang, Zhigang Wu, Chao Yang,-"Equivalent Plate Modeling for Complex Wing Configurations ", ELSEVIER, Procedia Engineering 31 (2012) 409 – 415, Published by Elsevier Ltd. International Conference on Advances in Computational Modeling and Simulation.
[11]. Sudhir Reddy Konayapalli, Y. Sujatha,- " Design and Analysis of Aircraft Wing ", IJMETMR, ISSN.NO.2348-4845, Volume 2, Issue 9, september 2012, page.no. 1480-1487.
[12]. Nataraj Kuntoji , Dr. Vinay V. Kuppast ,"A Review on Design Optimization of an Aircraft Wing with Emphasis on Vibration Characteristics ", International Journal of Engineering Trends and Technology (IJETT) – Volume 48 Number 3 June 2017, ISSN: 2231-5381 Page 147-151.
[13]. M. Ganesh, G Hima Bindu, A. Sai Kumar,- "Modeling And Analysis Of A Composite Wing For Missile Structure", International Journal of Mechanical Engineering and Technology (IJMET) ,Volume 8, Issue 6, June 2017, pp. 338–347
[14]. Nataraj Kuntoji , Dr. Vinay V. Kuppast- " Study of Aircraft Wing with Emphasis on Vibration Characteristics", IJERA , ISSN : 2248-9622, Vol. 7, Issue 4, ( Part -4) April 2017, pp.01-08.

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