CFD Study on Structural Parameters of Airwing beased on NACA 2412 Profile using Different Composite Material

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***Abstract*— Weight is one of the important factors in aerodynamics; we need to reduce the weight of any flying object in order to get the higher lift force. Wight reduction of wing helps us to get better air craft efficiency and high performance. Aluminum alloys are used to make aircraft wing as it is suitable but in this study, we have used few light weighted composite materials for making the aircraft wing and other alloys as well where aluminum is used as the base material and it is mixed with other materials with different proportions for testing the performance. In this study, NACA 2412 airfoil has been chosen and the wing has been designed in Design Modeler 19. The model has been imported to ANSYS Workbench; the static structural analysis has been carried out by putting the required parameters. The objective of the study is to find out which material will be suitable for making aircraft wing among Carbon Fibers, Alpha-Beta Titanium alloy and Al-Zn-Mg alloy.**

Keywords—* *NACA 2412, Composite Materials, Airwing, ANSYS.

I. INTRODUCTION

In this study, investigation has been done on air-wing materials and the best suited material has been identified after doing the structural, thermal and modal analysis in ANSYS Workbench 19.2. The materials which have been chosen for this study are Carbon Fiber, Alpha-Beta Titanium alloy and Al-Zn-Mg alloy. These three materials having the property to be used as aircraft materials. The parameters which have been analyzed are Total Heat Flux, Von-Mises Stresses, Total Deformation, Equivalent elastic strain and three mode shapes. Depending upon the total deformation, the material has been identified but analysis has been done on all materials to observe the outputs. Steady state thermal analysis has been done on three airwings made of different materials by putting requisite input parameters like thermal conductivity, heat transfer coefficient, ambient temperature etc. All the results which have been fetched from the thermal, structural and modal analysis have been compared in this study.

Richard M. Wood [1], 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 leading edge 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 [2]**, 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, they 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). **Li Jixinga,Ning Taoa, Xi Pinga, Wang Tiana [3]**, This paper presents an approach to implement rapid design, modelling, 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. Finally, an instance was presented to illustrate that this method is feasible and effective. **S.Ravikanth, KalyanDagamoori, M.SaiDheeraj**

etc. all [4], 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.

II. METHODOLOGY

- Modelling
- Meshing (Grid Independent Study has been done)
- Formulation of properties to each element and concerned nodes.
- 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 and contours in the form of graphs.

We need to check whether the outputs are varying with the no. of elements or not, it is desired that output data will remain constant irrespective of no. of elements. We have grid independent study to show the independency of output data on no. of elements, here we have taken total deformation of wing as output data for carrying out this study.

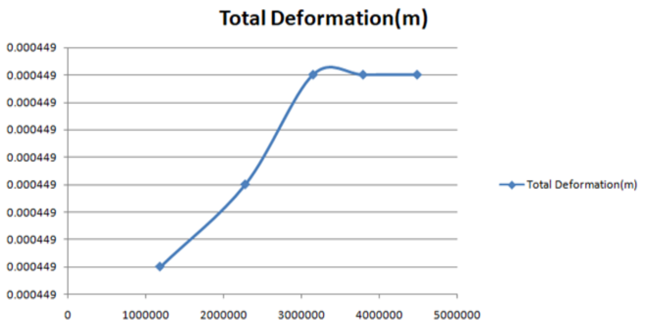

Fig. 1. Grid Independent Study

III. MODELLING OF AIRCRAFT WING

Modelling has been done in Design Modeler which is integral modeling software in ANSYS Workbench.

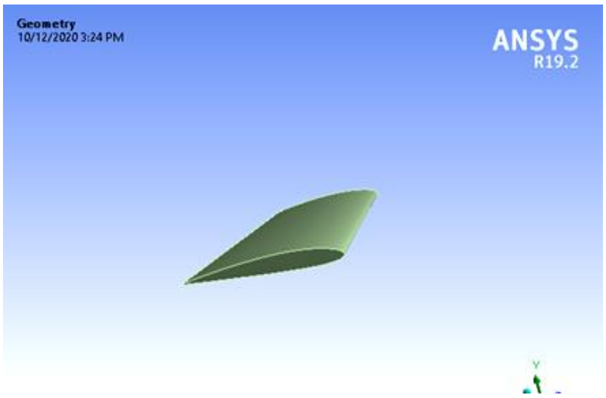

Fig. 2. (a) Modelling of the wing

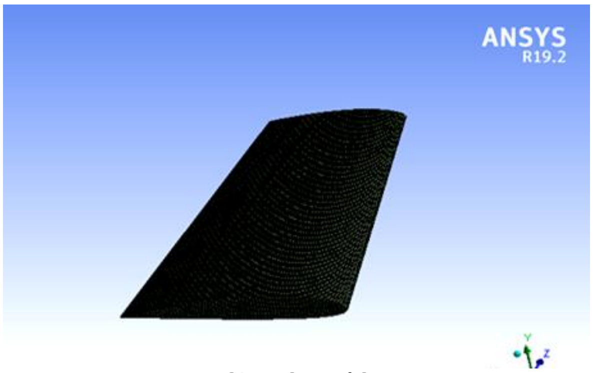

Fig. 2. (b) Meshing of the wing

A. *Material Selection*

In this study, three different materials namely Carbon Fibers, Alpha-Beta Titanium alloy and Al-Zn-Mg alloy have been chosen based on previous literatures, for airwing material and for carrying out the thermal and structural analysis.

Table 1. Properties of Materials

Material Name	Density (Kg/mm^3)	Young's Modulus (MPa)	Thermal Conductivity (W/m-K)	Poisson's Ratio
Carbon Fibers	$2.3X10^{-6}$	230000	56	0.21
Alpha-Beta Titanium alloy	$4.43X10^{-9}$	$1.13X10^{5}$	19	0.342
Al-Zn-Mg alloy	$2.83X10^{-6}$	72000	148	0.327

IV. RESULTS

The main objective of the study is to find out which material is best suited for making wing of aircrafts among Carbon Fibers, Alpha-Beta Titanium alloy and Al-Zn-Mg alloy. The analysis has been done and the concerned outputs are total deformation, total heat flux, von-mises stress and von-mises strain. Different contours are shown here.

A. *Total Deformation of NACA 2412 Airfoil based Aircraft Wing*

1) Case 1. Total Deformation When Carbon Fiber is used as Wing Material

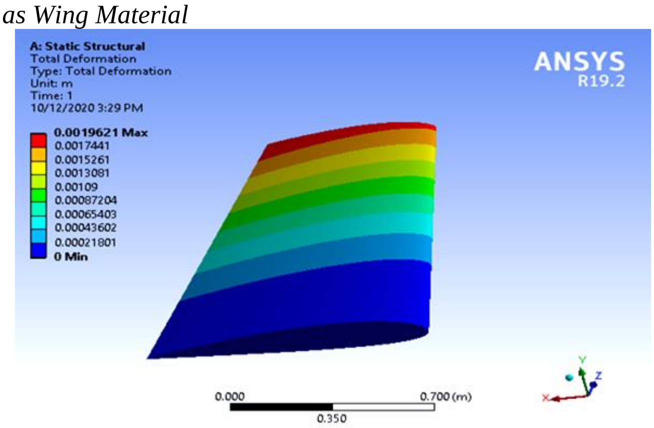

Fig. 3. Total deformation contour

2) Case 2. Total Deformation When Alpha-Beta Titanium alloy is used as Wing Material

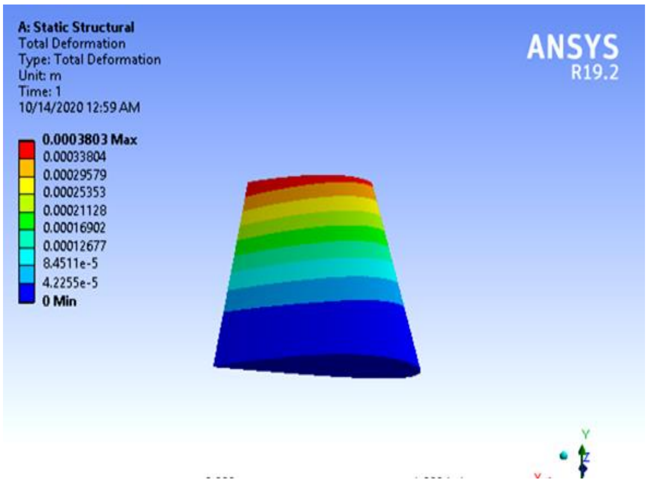

Fig. 4. Total deformation contour

3) Case 3. Total Deformation When Al-Zn-Mg alloy is used as Wing Material

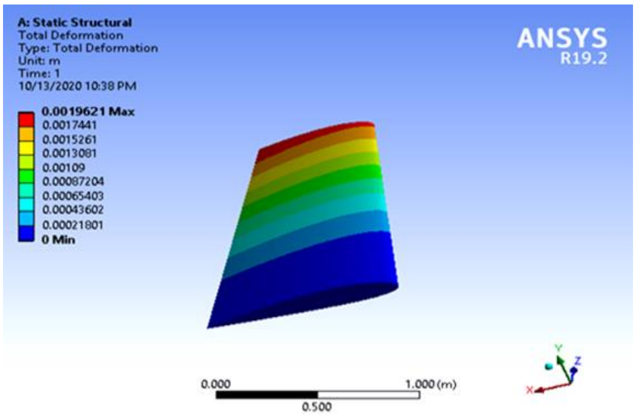

Fig. 5. Total deformation contour

B. Total Heat Flux of NACA 2412 Airfoil based Aircraft Wing

1) Case 1. Total Heat Flux When Carbon Fiber is used as Wing Material

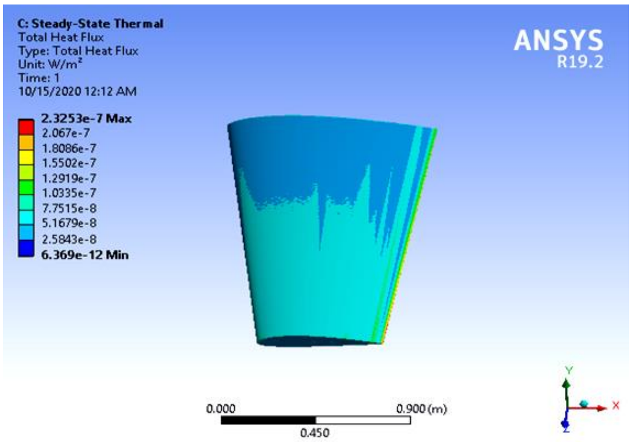

Fig. 6. Total heat flux contour

2) Case 2. Total Heat Flux When Alpha-Beta Titanium alloy is used as Wing Material

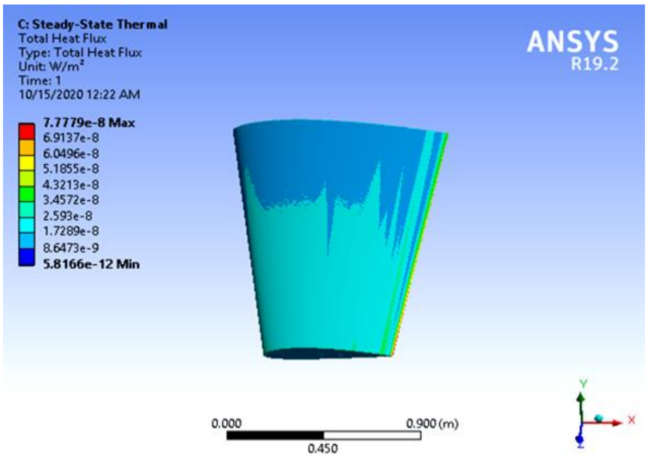

Fig. 7. Total heat flux contour

3) Case 3. Total Heat Flux When Al-Zn-Mg alloy is used as Wing Material

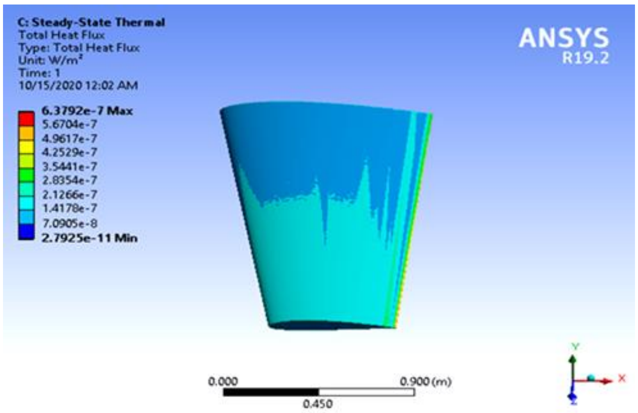

Fig. 8. Total heat flux contour

C. Von – Mises Stress of NACA 2412 Airfoil based Aircraft Wing

1) Case 1. Von – Mises Stress When Carbon Fiber is used as Wing Material

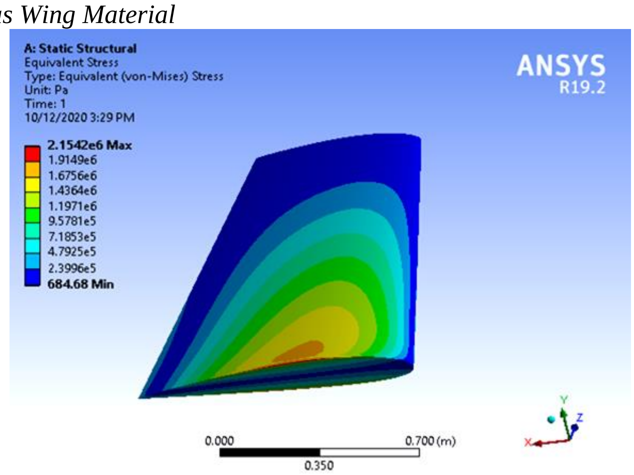

Fig. 9. Equivalent (von - mises) stress contour

2) Case 2. Von – Mises Stress When Alpha-Beta Titanium alloy is used as Wing Material

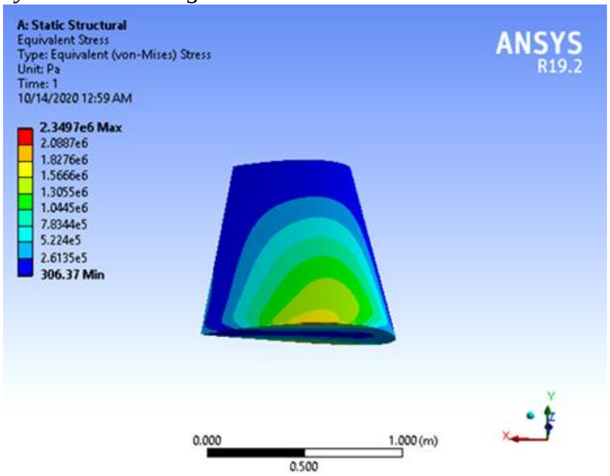

Fig. 10. Equivalent (von - mises) stress contour

3) Case 3. Von – Mises Stress When Al-Zn-Mg alloy is used as Wing Material

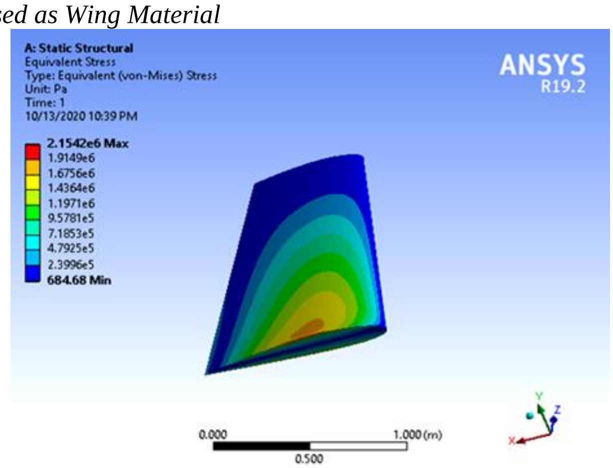

Fig. 11. Equivalent (von - mises) stress contour

D. Von – Mises Strain of NACA 2412 Airfoil based Aircraft Wing

1) Case 1. Von – Mises Strain When Carbon Fiber is used as Wing Material

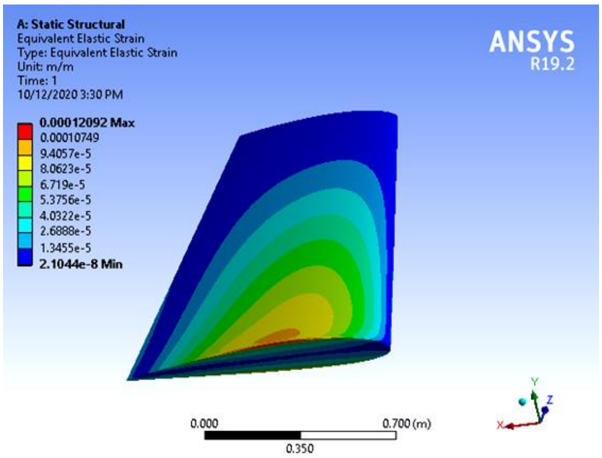

Fig. 12. Equivalent elastic strain contour

2) Case 2. Von – Mises Strain When Alpha-Beta Titanium alloy is used as Wing Material

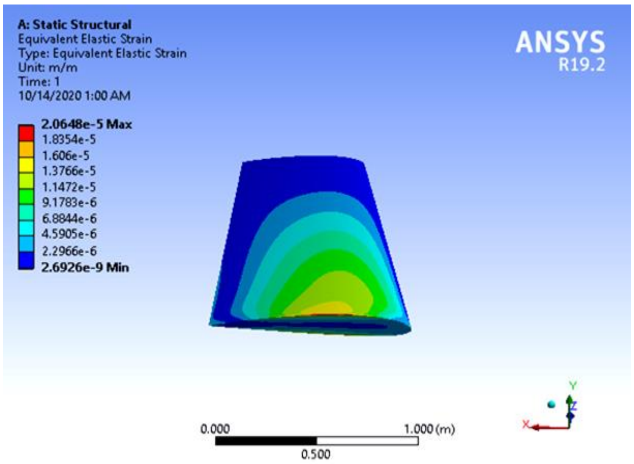

Fig. 13. Equivalent elastic strain contour

3) Case 3. Von – Mises Strain When Al-Zn-Mg alloy is used as Wing Material

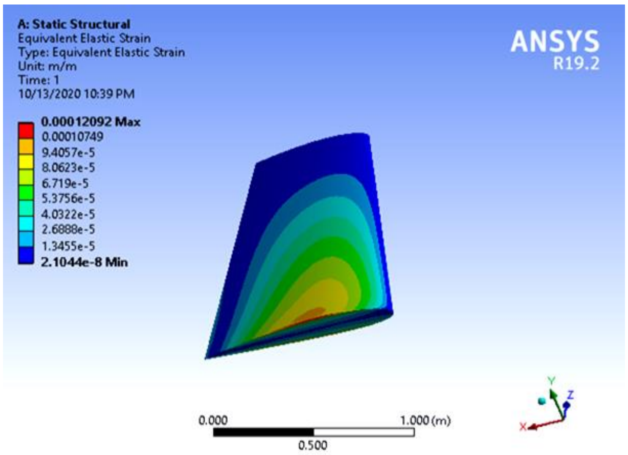

Fig. 14. Equivalent elastic strain contou

E. Modal Analysis

1) Case 1. Modal Analysis of Wing made of Carbon Fiber

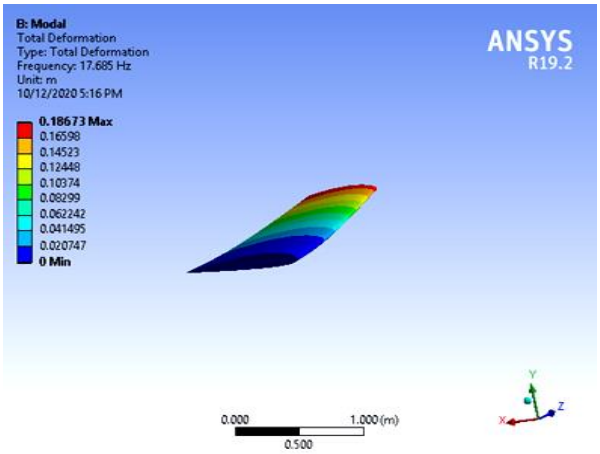

Fig. 15. Contour of Total Deformation

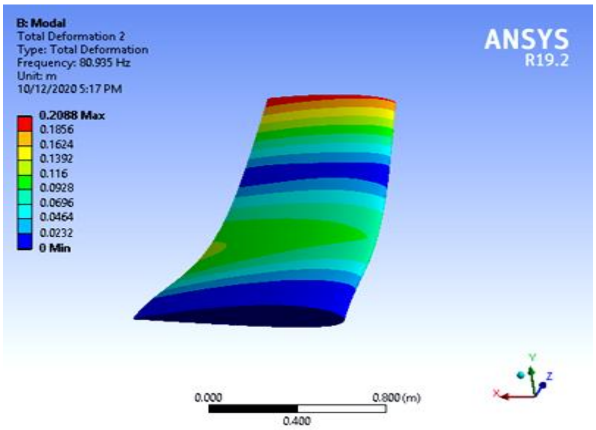

Fig. 16. Contour of Total Deformation

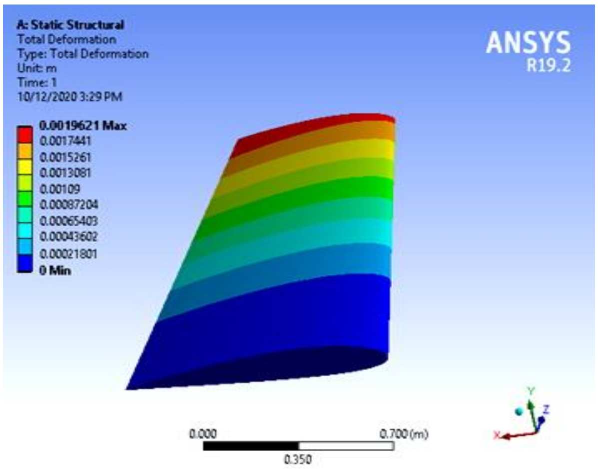

Fig. 17. Contour of Total Deformation

2) Case 2. Modal Analysis of Wing made of Alpha-Beta Titanium alloy

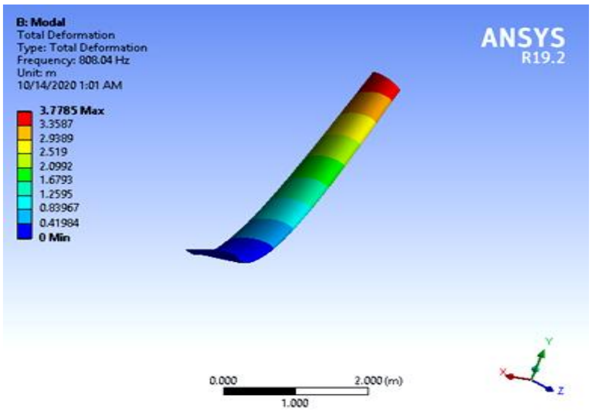

Fig. 18. Contour of Total Deformation

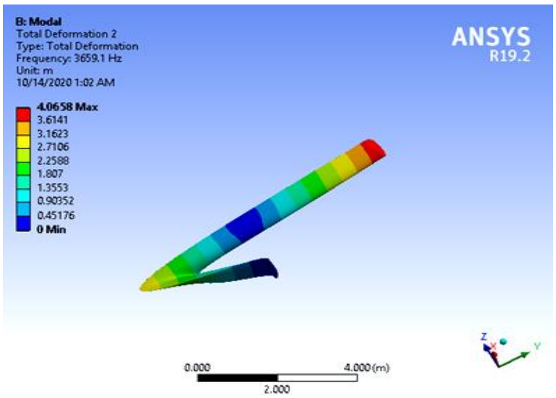

Fig. 19. Contour of Total Deformation

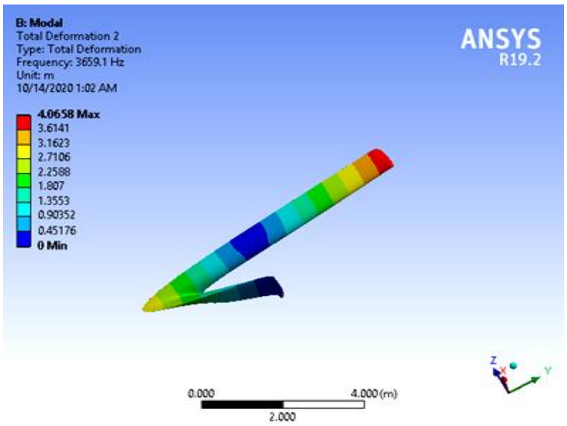

Fig. 20. Contour of Total Deformation

3) Case 3. Modal Analysis of Wing made of Al-Zn-Mg alloy

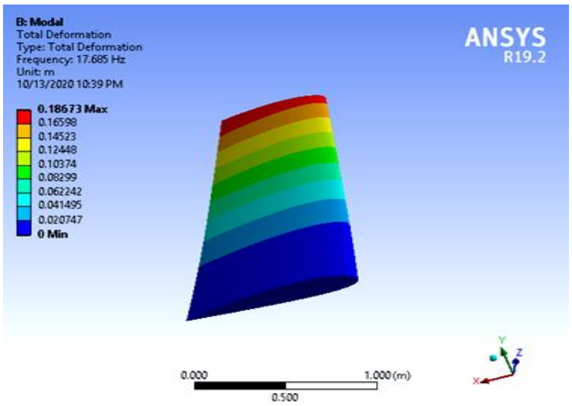

Fig. 21. Contour of Total Deformation

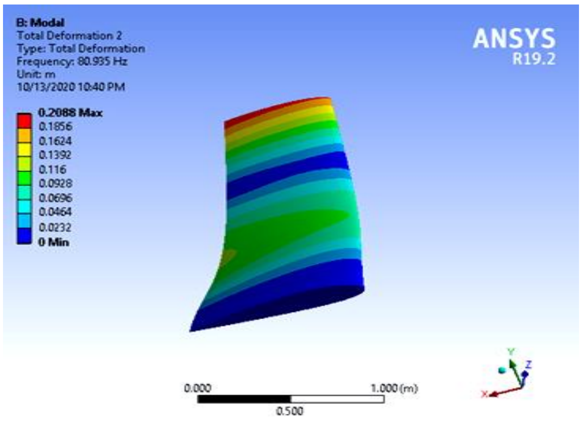

Fig. 22. Contour of Total Deformation

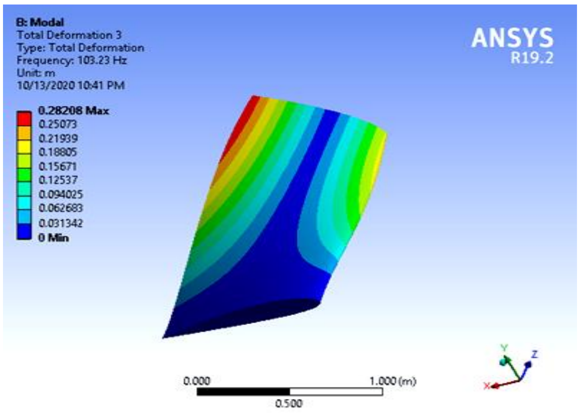

Fig. 23. Contour of Total Deformation

V. DISCUSSIONS

In this study, three different materials have been used for wing material and all the analysis have been carried out on these individually and few outputs have been shown. All the outputs are tabulated below.

Table 2. Outputs

Material Name	Total Deformation (m)	Total Heat Flux (W/m^2)	Von-Mises Stress (Pa)	Von-Mises Strain
Carbon Fibers	0.0019621	Min $6.369X10^{-12}$ Max $2.3253X10^{-7}$	Min 684.68 Max $2.1542X10^{6}$	Min $2.1044X10^{-8}$ Max 0.00012092
Alpha-Beta Titanium alloy	0.0003803	Min $5.8166X10^{-12}$ Max $7.77X10^{-8}$	Min 306.37 Max $2.34X10^{6}$	Min $2.642X10^{-9}$ Max $2.0648X10^{-5}$

As Al-Zn-Mg alloy is not showing better outputs compared to other two materials, this has not been tabulated.

Among these three materials, Alpha-Beta Titanium alloy has been considered to make wing for aircrafts as the value of total deformation is the least and it is showing better result in heat transfer rate, it can be verified from the total heat flux contour. Modal analysis has been done on this particular material by putting higher frequencies. Three modal frequencies which have been used to determine the modal shapes are 808.04 Hz, 3659.1 Hz and 4484.3 Hz whereas for others the frequencies have been 17.685 Hz, 80.935 Hz and 103.23 Hz.

VI. CONCLUSIONS

Structural and thermal effectiveness of the designed wing based on NACA2412 have been analyzed by using 3D finite element method in ANSYS 19 using different materials. Composite materials have been taken for the analysis as well where aluminum is used as the base material with different compositions. Total heat flux has been investigated using steady state thermal analysis. Few important output parameters have been analyzed like total deformation, total heat flux, strength against Von-Mises failure criteria etc. It can be concluded that based on the finite element result Alpha-Beta Titanium alloy is best suited material as the material for aircraft wing. The result of modal analysis on this particular material shows the different shapes at higher frequency there we can observe that the maximum frequency at which the Alpha-Beta Titanium alloy will sustain without deformation is must be less than 808.04 Hz.

ACKNOWLEDGMENT

We are very much thankful to each other for contributing our best in this pandemic and whichever was possible has been done by us. This is an outcome of our research project relevant to the engineering applications. Our team work has inspired us to do research work farther on this particular field.

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