MODAL ANALYSIS OF NACA 4412 AIRFOIL BASED AIR-WING USING DIFFERENT COMPOSITE MATERIALS

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ABSTRACT

In making of air craft wing the study of aerodynamic characteristics and the weight reduction in air wing place a vital role for improving the efficiency and performance. The designis largely depends on type of aerofoil profile and material to be used. In this project an attempthas been made to calculate the natural frequencies on NACA 4412 aerofoil profile blade and the light weight composite materials used for making this NACA 4412 are Alpha-Beta TitaniumAlloy, Carbon Fiber, Al-Zn-Mg Alloy and it is observed that by increasing the frequency in allthe modes the vibrations increases and there is an optimum value of frequency at which natural frequency vibrations minimum there is some optimum value of frequency at which natural frequencies in different modes of vibration are minimum. The model developed by using SOLIDWORKS has been imported to ANSYS workbench; the modal analysis has been carriedout by putting the required parameters. The objective of the study is to find out which materialwill be suitable for withstanding frequencies of NACA 4412 among Carbon Fibre, Alpha-BetaTitanium Alloy and Al-Zn-Mg Alloy.

I. INTRODUCTION TO NACA 4412 AEROFOIL:

A wind turbine is acted upon by four aerodynamic forces; Thrust, Drag, Lift, and Weight. Wind turbines are able to produce torque due to the aerodynamic force produced whena fluid passes over the airfoil. An Airfoil is defined as the cross-section of a body that is placedin an airstream in order to produce an aerodynamic force in the most efficient manner possible.If the pressure below the wing is higher than the pressure above the wing, there is a net force upwards and this upward force generates lift. In this project NACA 4412 aerofoil and its modified designs are used to analyze the factors like lift and drag coefficients, however, the term NACA is an abbreviation of (National Advisory Committee for Aeronautics), and the first digit in 4412 denotes the maximum camber, C max, as a percent of the chord. the second digit denotes the chord wise position of the maximum camber, XC max, in tenths of the chord. the last two digits denote the maximum thickness of the airfoil section, t, as a percent of the chord.

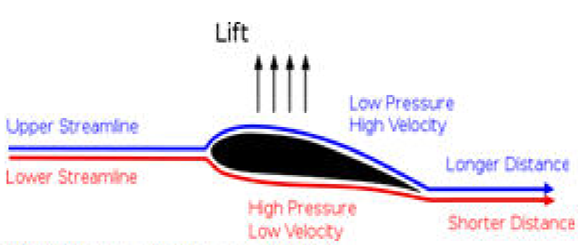


Fig.1 Forces Acting on Airfoil

The airs flowing below the wing moves in a comparatively straighter line, so its speed and air pressure remain the same. Since high air pressure always moves toward low air pressure, the air below the wing pushes upward toward the air above the wing. The wing

is in the middle, and the whole wing is "lifted." The faster an airplane moves, the more lift there is. And when the force of lift is greater than the force of gravity, the airplane is able to fly.

Aerodynamic is a study of the powers and moments vital to possess a sustainable aerialmovement. The aerodynamic force functioning on the flying vehicle can be described as "lift indirection normal to the flight" with "drag in the same direction". Hence, various factors such as aircrafts' load, size, rate of climb, and required landing speed need to be heavily considered to design wings. With that, this study aims to find drag and lift contribution in wing's aircraft by analysis approach by investigating the better performance of the wing at various wing aspect ratio and its aerodynamic achievement; which can be analyzed by observing not just the coefficients of drag and lift, but also the lift drag ratio. It is a reality of general expertise that body in moving through a fluid covering with a resultant force that by and hugged in a very primarily movement of the resistance. A category of the body exists, regardless, that the fragment of the resultant force ordinarily to the orientation of the event is sometimes additional clear than the contradicting the event to boost the likelihood of the flight of a plane depends upon the usage of the body of this category for wing structure. The approach is that the purpose between the approach air or relative breeze and a reference line on the plane or wings. As this nose of the wing turns up, approach increments and raise a force in addition increased. Drag goes up, however, additionally not as fast as a raise. Within the interior of activity, a briefing creates a specific speed and after the pilot flips the plane, that's the pilot controls with the controls that the nose of the plane returns up and, at some approach, the wings create enough toraise to bring the plane into the air. An airfoil is the shape of a wing, blade of a propeller, rotor, or turbine, or sail as seen in cross-section to generate aerodynamic force.

HISTORY OF AIRFOIL:

The historical evolution of airfoil sections, 1908-1944. The last two shapes are low-drag sections designed to have laminar flow over 60 to 70 percent of chord on both the upper and lower surface. The Wright brothers had done some of the earliest research on the most effectivecurvature, or camber, of a wing, known as an airfoil. But during the early years of powered flight, airfoils for aircraft were essentially hand-built for each airplane. Before World War I, there had been little research to develop a standardized airfoil section for use on more than one aircraft. The British government had performed some work at the National Physical Laboratory (NPL) that led to a series of Royal Aircraft Factory (RAF—not to be confused with the Royal Air Force) airfoils. Airfoils such as the RAF 6 were used on World War I airplanes.

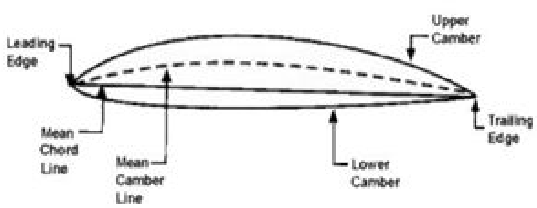


Fig. 2 NACA Airfoil

When the National Advisory Committee on Aeronautics (NACA) was established in 1915, its members immediately recognized the need for better airfoils. The first NACA Annual Report stated the need for "the evolution of more efficient wing sections of practical form, embodying suitable dimensions for an economical structure, with moderate travel of the center of pressure and still affording a large angle of attack combined with efficient action." NACA explained its first work with airfoils in 1917 NACA Technical Report No. 18, "Aero foils and Aero foil Structural Combinations

NOMENCLATURE OF AN AIRFOIL:

An airfoil is a body of such a shape that when it is placed in an airstream, it produces an aerodynamic force. This force is used for different purposes such as the cross sections of wings, propeller blades, windmill blades, compressor and turbine blades in a jet engine, and hydrofoils are examples of airfoils. The basic geometry of an airfoil is shown in Figure Basic nomenclatureof an airfoil The leading edge is the point at the front of the airfoil that has maximum curvature. The trailing edge is defined similarly as the point of maximum curvature at the rear of the airfoil. The chord line is a straight line connecting the leading and trailing edges of the airfoil.

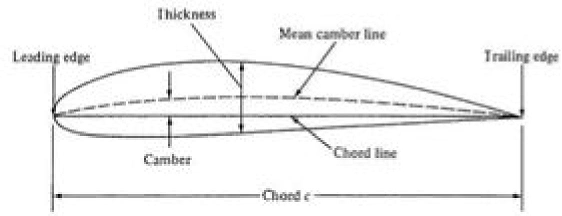


Fig. 3 Nomenclature of Air Foil

NACA 4412 SYMMETRIC AEROFOIL:

The reason to choose the NACA 4412 symmetric aerofoil is that it produces a more lift-to-drag ratio at low wind speed and is the most common kind used for research purposes in most cases. Symmetrical aerofoil reduces the complexity of design and imparts easiness in the designmodifications of the aerofoil. The center of pressure remains at a constant position as the upperand lower surfaces are identical in a symmetrical aerofoil. This reduces problems of Cp variations with varying angles of attack of airflow over the aerofoil. With changes in the positions of maximum thickness in percentages of chord and along the chord, the following profiles have been named as per their specification criteria. It is to be noted that the amount of maximum thickness is not disturbed in this research content.

II. LITEREATURE REVIEW

Energy is essential to human civilization development. With the progress of economics and socialization, there's an expanding demand for renewable energy resources to secure energy supply, like solar energy, wind generation, tide and wave power, etc. As a clean natural resource,wind generation plays a more and more important role in modern life. according to Wikipedia Wind power accounts for nearly 10% of India's total installed power generation capacity and generated.

[1] Computational investigation of inviscid flow over an airfoil. The drag and lift forces can be determined through experiments using wind tunnel testing, in which the design model has to beplaced in the test section. The experimental data is taken from Theory of Wing Sections by Abbott et al., This work presents a

computational method to deduce the lift and drag properties, which can reduce the dependency on wind tunnel testing. The study is done on air flow over a two-dimensional NACA 4412 Airfoil using ANSYS FLUENT (version 12.0.16), to obtain the surface pressure distribution, from which drag and lift were calculated using integral equationsof pressure over finite surface areas. In addition the drag and lift coefficients were also determined. The fluid used for this purpose is air. The CFD simulation results show close agreement with those of the experiments, thus suggesting a reliable alternative to experimental method in determining drag and lift.

[2] Aerodynamics — as an engineering discipline involved deeply in the aircraft development process — always have been and will continue to be essential for the commercial success of any aircraft programme. Past developments in computing methods and tools as well as in wind tunnel testing technologies have produced clear cost and performance benefits. For this reasonit is absolutely justified to invest in further improvements concerning development of tools andmethods including experimental technologies and facilities, taking advantage of the enormous leverage on both total programme costs and aircraft performance.

[3] Micro air vehicles (MAVs) have the potential to revolutionize our sensing and information gathering capabilities in areas such as environmental monitoring and homeland security. Flapping wings with suitable wing kinematics, wing shapes, and flexible structures can enhance lift as well as thrust by exploiting large-scale vortical flow structures under various conditions. However, the scaling invariance of both fluid dynamics and structural dynamics as the size changes is fundamentally difficult. The focus of this review is to assess the recent progress in flapping wing aerodynamics and aeroelasticity. It is realized that a variation of the Reynolds number (wing sizing, flapping frequency, etc.) leads to a change in the leading edge vortex (LEV) and spanwise flow structures, which impacts the aerodynamic force generation. While in classical stationary wing theory, the tip vortices (TiVs) are seen as wasted energy, in flapping flight, they can interact with the LEV to enhance lift without increasing the power requirements. Surrogate modeling techniques can assess the aerodynamic outcomes between two- and three- dimensional wing. The combined effect of the TiVs, the LEV, and jet can improve the aerodynamics of a flapping wing. Regarding aeroelasticity, chordwise flexibility in the forward flight can substantially adjust the projected area normal to the flight trajectory via shape deformation, hence redistributing thrust and lift. Spanwise flexibility in the forward flight creates shape deformation from the wing root to the wing tip resulting in varied phase shift and effective angle of attack distribution along the wing span. Numerous open issues in flapping wing aerodynamics are highlighted.

[4] In the present study, a general aviation airplane is designed and analyzed. The design processstarts 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 usingRDS software based on conic lofting, then placed in a simulation environment in Matlab whichproved 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, thecalculated aerodynamic loads are applied to the wing to check the wing reliability. It is shown that the designed wing could be a good candidate for similar general aviation airplane implementation.

SPECIFIC OBJECTIVES:

- General evaluation of mechanical reliability for NACA 4412 blade in terms of stressconcentration.
- Determining the proper material using FEM.
- Analyzing the stress concentration on NACA 4412 blade geometry.
- Finally find out stress, total deformation, shear stress and modal analysis.
- Recommending the geometry and the suitable material we should be using in futureNACA 4412 blade material.

III. METHODOLOGY:

Step 1: Collecting information and data related to wind turbine blade.

Step 2: A fully parametric model of the wind turbine blade created in solid works software.

Step 3: Model obtained in igs. Analyzed using ANSYS 18.0 (workbench), to obtain stresses, deformation, Shear stress and mode shapes etc.

Step 4: Taking boundary conditions.

Step5: Finally, we compare the results obtained from ANSYS and compared geometry with different materials.

MATERIALUSED:

- **Carbon Fiber**
- **Alpha-Beta Titanium Alloy**
- **Al-Zn-Mg Alloy**

MODAL AND ANALYSIS OF NACA 4412 AIRFOIL

The blade profile was chosen as NACA 4412. The profiles were obtained from Design Foil Workshop Software and were exported directly to Solid Works. The modeling was done inSolid Works and shown in figure.

NACA 4412 Data File:

X CORDINATE	Y CORDINATE	Z CORDINATE
100.0167	0.1249	0
99.8653	0.1668	0
99.4122	0.2919	0
98.6596	0.4976	0
97.6117	0.7801	0
96.2742	1.1341	0
94.6545	1.5531	0
92.7615	2.0294	0
90.6059	2.5547	0
88.1998	3.1197	0
85.557	3.7149	0
82.6928	4.3305	0
79.6239	4.9564	0
76.3684	5.5826	0
72.9457	6.1992	0
69.3763	6.7967	0
65.6819	7.3655	0
61.8851	7.8967	0
58.0092	8.3817	0
54.0785	8.8125	0
50.1176	9.1816	0
46.1516	9.4825	0
42.2059	9.7095	0
38.2787	9.8537	0
34.3868	9.881	0
30.5921	9.7852	0
26.9212	9.5696	0
23.4002	9.24	0
20.0538	8.8046	0
16.9056	8.2736	0
13.977	7.6589	0
11.288	6.9743	0
11.288	6.9743	0
8.856	6.2343	0
6.6964	5.454	0
4.8221	4.6485	0
3.2437	3.8325	0
1.9693	3.0193	0
1.0051	2.2209	0
0.3547	1.4471	0
0.0198	0.7052	0
0	0	0
0.2885	-0.6437	0
0.8765	-1.2027	0
1.7579	-1.6779	0
2.925	-2.0704	0
4.3684	-2.3825	0
6.0773	-2.6172	0
8.0396	-2.7782	0
10.2423	-2.8706	0

12.6714	-2.9	0
15.3123	-2.8734	0
18.1496	-2.7986	0
21.1676	-2.6843	0
24.35	-2.5401	0
27.6797	-2.376	0
31.1396	-2.2023	0
34.7115	-2.0295	0
38.3767	-1.8677	0
42.1506	-1.72	0
46.0025	-1.5646	0
49.8824	-1.4038	0
53.7674	-1.2432	0
57.6342	-1.0875	0
61.4595	-0.9404	0
65.2198	-0.8049	0
68.892	-0.6829	0
72.4534	-0.5754	0
75.8815	-0.4826	0
79.1547	-0.4042	0
82.252	-0.3392	0
85.1537	-0.2863	0
87.8408	-0.244	0
90.2958	-0.2109	0
92.5025	-0.1853	0
94.4461	-0.1659	0
96.1137	-0.1514	0
97.4939	-0.1409	0
98.5774	-0.1335	0
99.3567	-0.1286	0

Table. 1 NACA 4412 Data File

Creating this NACA 4412 Aerofoil blade shape developed by using above XYZ through curve coordinates data file. By browsing the text data file on SOLIDWORKS to make a fully parametric aerofoil design as shown as follows.

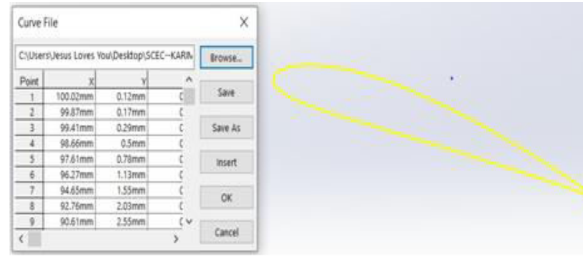


Fig. 3 Aerofoil Blade Shape Developed By Using Above XYZ Through Curve

After creating the NACA 4412 Aerofoil blade shape developed by using above XYZ through curve coordinates data file then apply a extruded boss/base of 1000mm or 1meter. Itslooks like as follows,

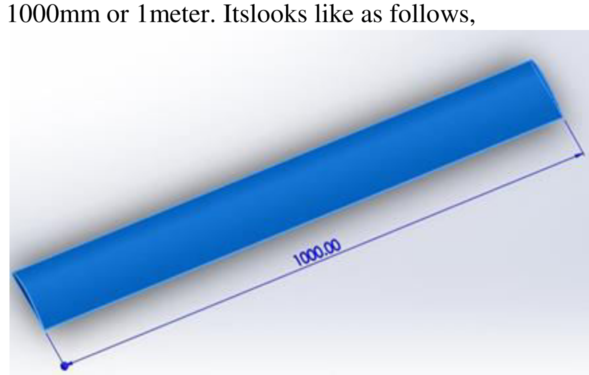


Fig. 4After Creating the Aerofoil

The file created by using NACA 4412 Aerofoil blade shape developed by using above XYZ through curve coordinates data file, after applying some features it should saved with an extension of SOLIDPART as **.sldprt** format.

Later it should be saved as **.igs** format for the ANSYS simulation.

MESHING:

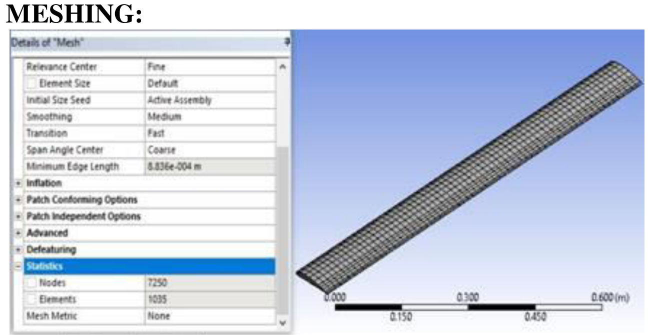


Fig.6 Meshing (Nodes: 7250, Elements: 1035)

BOUNDARY CONDITIONS:

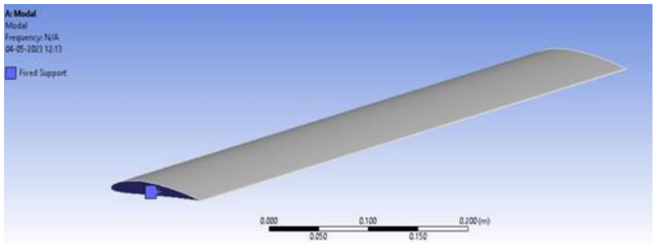


Fig. 7 Fixed Support Indicated with Blue Tag

IV. RESULTS AND DISCUSSION

The following are the modal analysis results obtained by conducting simulation on ANSYS workbench at six different nodes with three different materials like Carbon fiber, Al- Zn-Mg alloy and Alpha-beta titanium alloys are used.

MODAL ANALYSIS ON CARBON FIBER MATERIAL:

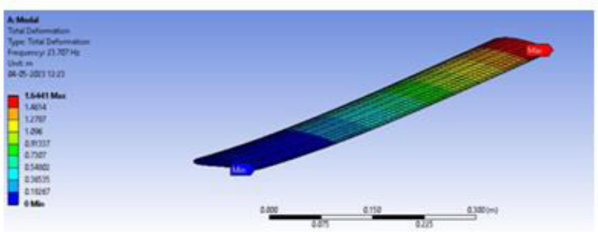


Fig.8 Carbon Fiber Material Total Deformation at Mode 1

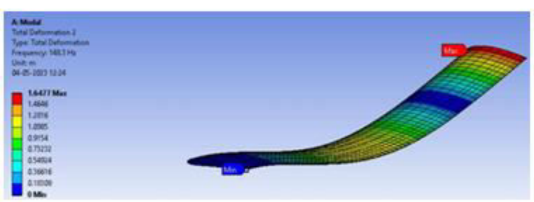


Fig.9 Carbon Fiber Material Total Deformation at Mode 2

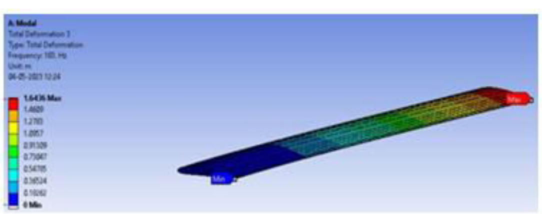


Fig.10 Carbon Fiber Material Total Deformation at Mode 3

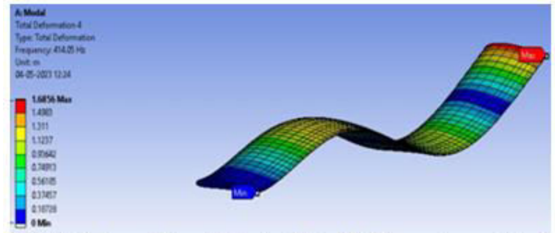


Fig.11 Carbon Fiber Material Total Deformation at Mode 4

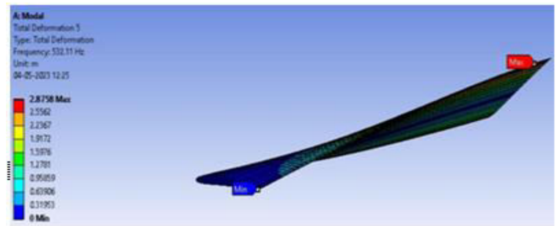


Fig.12 Carbon Fiber Material Total Deformation at Mode 5

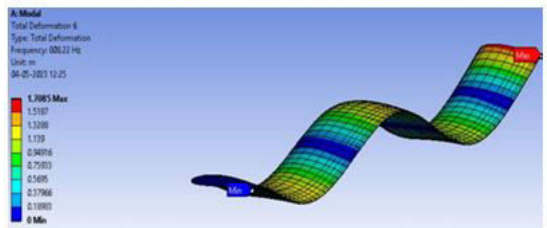
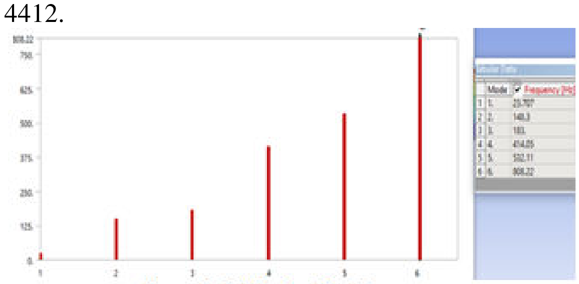


Fig.13 Carbon Fiber Material Total Deformation at Mode 6

The figures 8 to 13 show the distribution of equivalent stress, equivalent strain, total deformation on Carbon Fiber material under the load of 100N respectively. The maximumvalue is labeled in red color and minimum value is labeled is blue color. The following graph despites the MODE VS FREQUENCY on carbon fiber material total deformation at six different modes. On each direction of mode, the frequency parameters are changed as per profile NACA 4412.



Graph 1 Mode Vs Frequency

MODE	FREQUENCY
1.	23.707
2.	148.3
3.	183.
4.	414.05
5.	532.11
6.	808.22

Table 2 Mode Vs Frequency for Carbon Fiber Material

MODAL ANALYSIS ON ALPHA-BETA TITANIUM ALLOY:

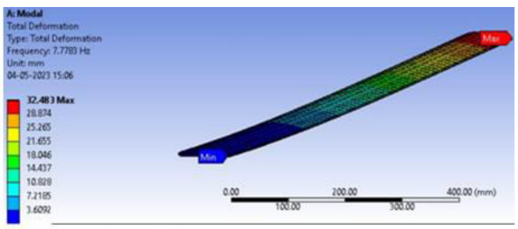


Fig.14 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 1

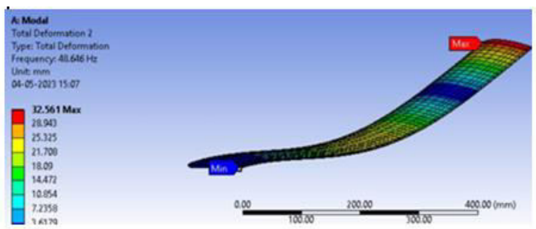


Fig.15 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 2

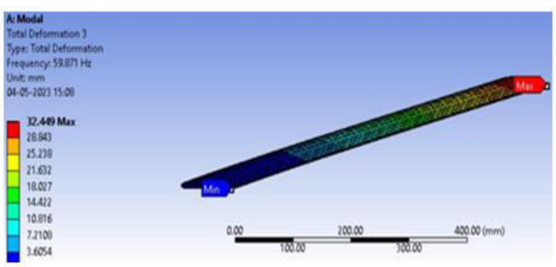


Fig.16 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 3

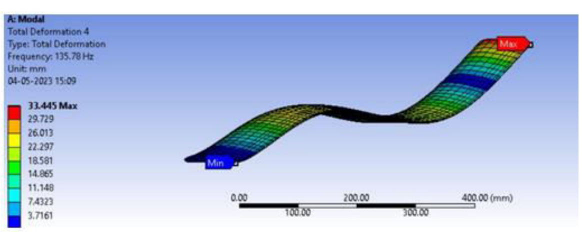


Fig.17 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 4

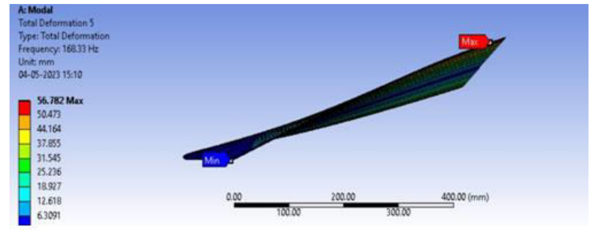


Fig.18 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 5

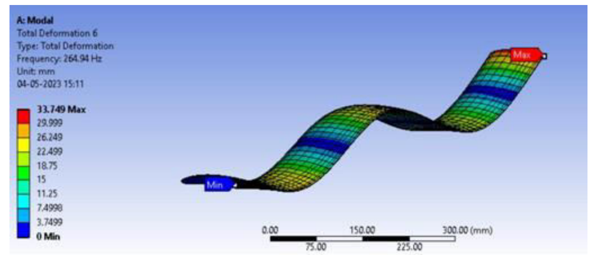
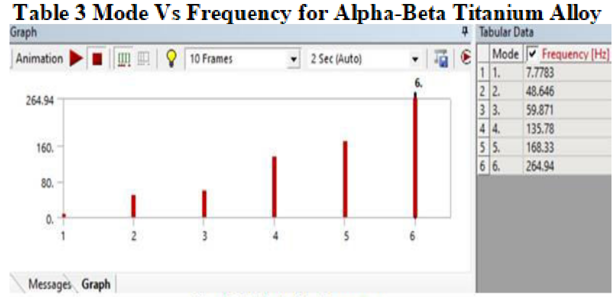


Fig. 19 Alpha-Beta Titanium Alloy Material Total Deformation at Mode 6

The figure 14 to 19 shows the distribution of equivalent stress, equivalent strain, total deformation on Alpha-Beta Titanium Alloy material under the load of 100N respectively.The maximum value is labeled in red color and minimum value is labeled is blue color.

MODE	FREQUENCY
1.	7.7783
2.	48.646
3.	59.871
4.	135.78
5.	168.33
6.	264.94

Table 3 Mode Vs Frequency for Alpha-Beta Titanium Alloy



Graph 2 Mode Vs Frequency

Modal Analysis on Al-Zn-Mg Alloy:

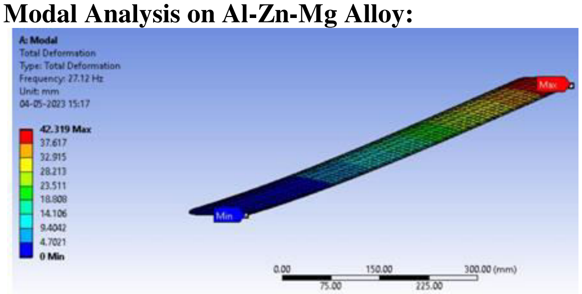


Fig. 20 Al-Zn-Mg Alloy Material Total Deformation at Mode 1

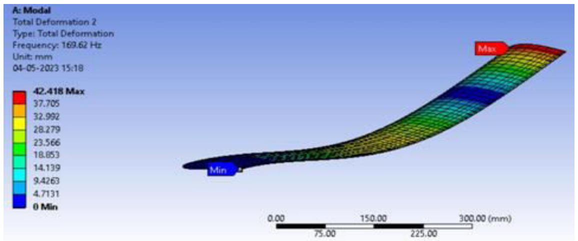


Fig. 21 Al-Zn-Mg Alloy Material Total Deformation at Mode 2

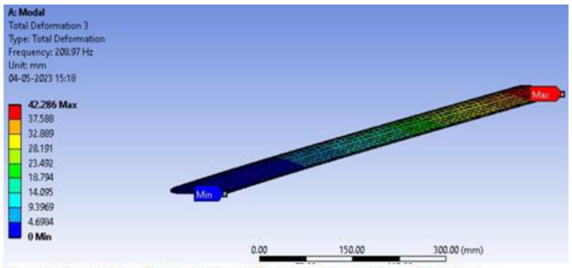


Fig. 22 Al-Zn-Mg Alloy Material Total Deformation at Mode 3

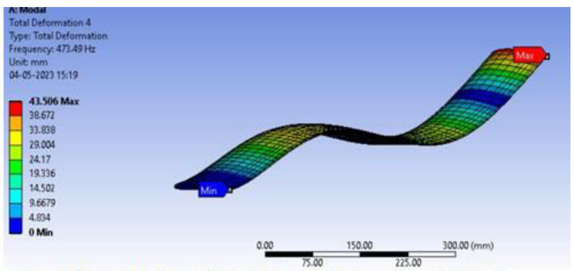


Fig. 23 Al-Zn-Mg Alloy Material Total Deformation at Mode 4

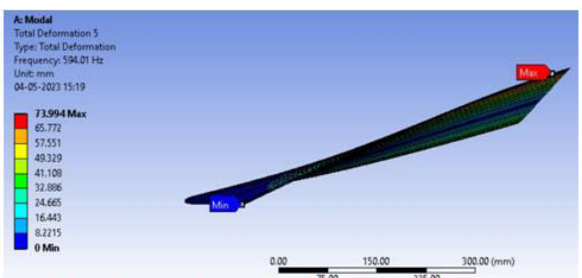


Fig.24 Al-Zn-Mg Alloy Material Total Deformation at Mode 5

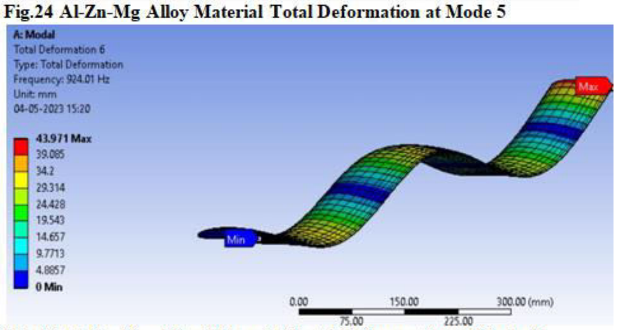
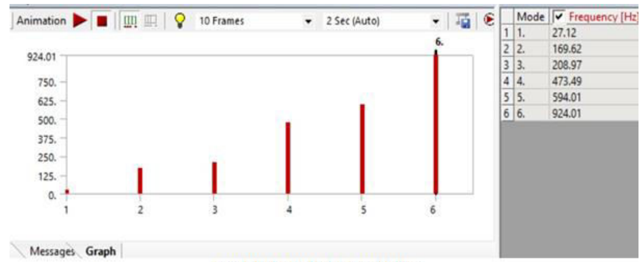


Fig.25 Al-Zn-Mg Alloy Material Total Deformation at Mode 6

The figures 20 to 25 show the distribution of equivalent stress, equivalent strain, total deformation on Al-Zn-Mg Alloy material under the load of 100N respectively. The maximum value is labeled in red color and minimum value is labeled is blue color.



Graph 3 Mode Vs Frequency

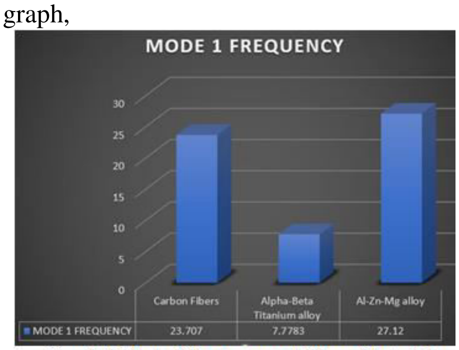
MODE	FREQUENCY
1.	27.12
2.	169.62
3.	208.97
4.	473.49
5.	594.01
6.	924.01

Table 4 Mode Vs Frequency for Al-Zn-Mg Alloy

GRAPHS:

MODE 1 FREQUENCY:

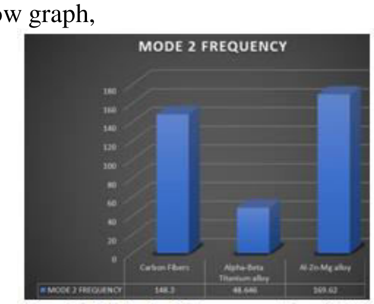
The frequency of mode 1 modal shapes are illustrated in below graph with having maximum frequency obtained by Al-Zn-Mg alloy of 27.12 and lesser frequency obtained by 7.7783 are shown in the below graph,



Graph 4 Mode 1 Frequency of Three Materials

MODE 2 FREQUENCY:

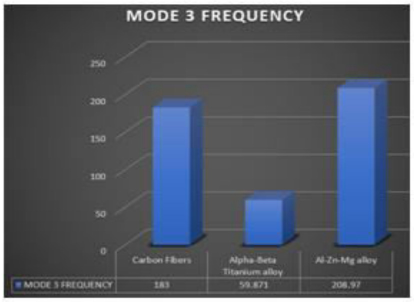
The frequency of mode 2 modal shapes are illustrated in below graph with having maximum frequency obtained by Al-Zn-Mg alloy of 169.62 and lesser frequency obtained by 48.646 are shown in the below graph,



Graph 5 Mode 2 Frequencies of Three Materials

MODE 3 FREQUENCY:

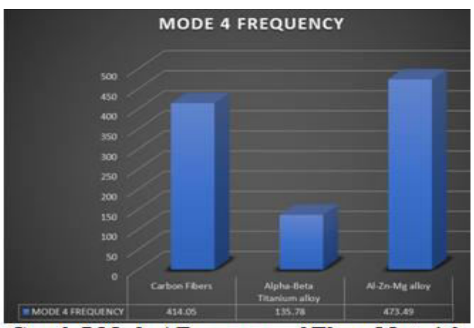
The frequency of mode 3 modal shapes are illustrated in below graph with having maximum frequency obtained by Al-Zn-Mg alloy of 208.97 and lesser frequency obtained by 59.871 are shown in the below graph,



Graph 6 Mode 3 Frequencies of Three Materials

MODE 4 FREQUENCY:

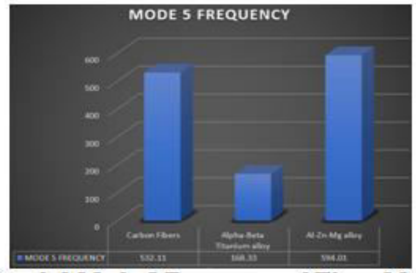
The frequency of mode 4 modal shapes are illustrated in below graph with havingmaximum frequency obtained by Al-Zn-Mg alloy of 473.49 and lesser frequency obtained by 135.78 are shown in the below graph,



Graph 7 Mode 4 Frequency of Three Materials

MODE 5 FREQUENCY:

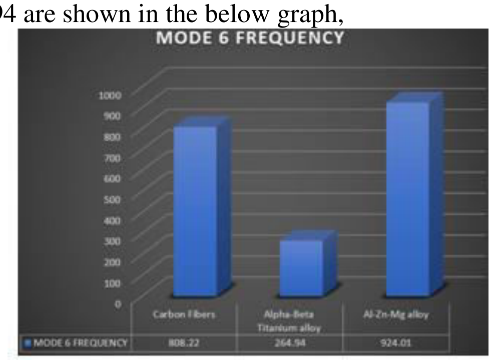
The frequency of mode 5 modal shapes are illustrated in below graph with having maximum frequency obtained by Al-Zn-Mg alloy of 594.01 and lesser frequency obtained by 168.33 are shown in the below graph,



Graph 8 Mode 5 Frequency of Three Materials

MODE 6 FREQUENCY:

The frequency of mode 6 modal shapes are illustrated in below graph with havingmaximum frequency obtained by Al-Zn-Mg alloy of 924.01 and lesser frequency obtained by 264.94 are shown in the below graph,



Graph 9 Mode 6 Frequency of Three Materials

V. CONCLUSION

Modeling of NACA 4412 is done using SOILDWORKS and is imported into ANSYS Software for conducting modal analysis to check the modal frequencies and quality of materials such as Al-Zn-Mg alloy along with carbon fiber and advanced alpha-beta titanium alloy. From the obtained modal frequencies at six different modes of frequencies is captured using modal analysis on three materials respectively. Compared these materials with Alpha-beta titanium alloy material posses have less frequency values proven through graphical representation. Finally, among the Al-Zn-Mg alloy, carbon fiber and alpha-beta titanium alloy analysis, basedon results it is concluded that Alpha-Beta Titanium Alloy material is more suitable material forNACA 4412 Aerofoil model.

REFERENCES

[1] PRABHAKAR A. AND OHRI A., (2013) "Modal Analysis on MAV NACA 2412 Wing in High Lift Take-Off Configuration for Enhanced Lift Generation", J Aeronaut Aerospace Eng., 2: 125.

doi:10.4172/2168-9792.1000125.

[2] NATHAN LOGSDON, “a procedure for numerically analyzing airfoils and Wing sections”

, The Faculty of the Department of Mechanical &Aerospace Engineering University of Missouri – Columbia, December 2006.

[3] P. THIEDE, (2001) Aerodynamic Drag Reduction Technologies: Proceedings of the CEAS/Dragnet European Drag Reduction Conference, 19-21 June 2000, Potsdam, Germany vol. 76: Springer Verag.

[4] W. SHYY, H. AONO, C. KANG, H. LIU, (2013) “An Introduction to Flapping Wing Aerodynamics”, Cambridge University Press, pp. 42.

[5] NGUYEN MINH TRIET, NGUYEN NGOC VIET, AND PHAM MANH THANG (2015) “Aerodynamic Analysis of Aircraft Wing” VNU Journal of Science: Mathematics – Physics, Vol. 31, No. 2, 68-75.

[6] S. KANDWAL, DR. S. SINGH, “Computational Fluid Dynamics Study of Fluid Flow and Aerodynamic Forces on an Airfoil”, IJERT, Vol. 1 Issue 7, September– 2012.

[7] MR. MONIRCHANDRALA, PROF. ABHISHEK CHOUBEY, “PROF. BHARAT GUPTA Aerodynamic Analysis of Horizontal Axis Wind Turbine Blade”,IJERA, Vol. 2, Issue6, November-December 2012.

[8] SUDHIR REDDY KONAYAPALLI AND Y SUJATHA (2015) “Design and Analysis of Aircraft Wing” International Journal and Magazine of Engineering, Technology, Managementand Research. Volume No: 2, Issue No: 9.