Design and Analysis of General Aviation Aircraft Wings Using Different Materials

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Abstract-An aircraft produces lift using its wings, while gliding through air. Through the geometry, wings have efficient cross-sections that are subjected to lift and drag forces and it act as an airfoil. In this thesis work, it is investigated how modelling and simulating softwares can be used in the early stages of an aircraft design process, especially for the design of an aircraft wing and its structural entities like wing spars and wing ribs. The domain of this research has been restricted to the engineering design of the wing and its analysis, as it plays a vital role in the generation of lift required by an aircraft. The main purpose of this project is to determine the material most suitable for wings structure. The wing is designed in CAD and the analysis is done ANSYS. Static structural analysis of the wing is done to find deformation, stress and FOS.

INTRODUCTION

To determine the most convenient material for aviation aircraft wing structure in every aspect, considering ergonomics, manufacturability, design feasibility, aesthetics.

The wings are crucial parts of any airplane like UAVs as they give the ability to fly high in the sky. The wing of an aircraft is comprised of several different elements that include spars, skin, and ribs, as well as control surfaces such as ailerons and flaps. Each of these components serves a specific purpose and must be designed to support different loads and should be able to tolerate high level of stresses and such as that of lift, weight, thrust and drag. Wings also need to be aerodynamically efficient. Thus, a right material needs to be selected for manufacturing a wing.

Aluminium, Steel, Titanium have customarily been used for the construction of an aircraft wing [1]. More recently, composite materials like Carbon fibre have become a substitute for construction of wings.

Structural Static analysis of an airplane wing with different materials become a critical aspect in the design of a useful and efficient wing.

Aircrafts like civil airplanes or UAVs has the ability to lift off from the ground and stay in the air by repulsing the gravitational force by the aerodynamic lift force generated by a flat horizontal wing having airfoil cross-section.

An airfoil shaped wing is generally used in airplanes and other aircrafts to generate lift when air flows over it.

The generation of lift force by an airfoil is governed by the Bernoulli's principle. As air flows over the curved upper surface of an airfoil, it moves faster than the air flowing over the flatter lower surface. This causes the air pressure on the upper surface to be lower than the pressure on the lower surface. The difference in air pressure creates an upward force on the airfoil, which is lift. The lift generated by an airfoil depends on factors such as its shape, size, and angle of attack relative to the incoming air flow.

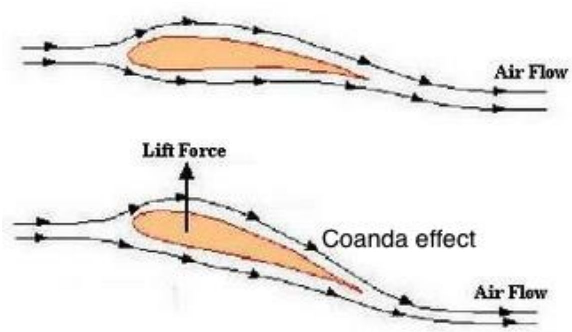

Figure 1: Airflow through Airfoil [2]

2. WING DESCRIPTION

The well-known seven standard aircraft wing configurations with each profile having different flight characteristics are listed below:

2.1 Wing Configurations

Low wing configuration, Mid-wing configuration, High-wing configuration, Dihedral wing configuration, Anhedral wing configuration, Gull-wing configuration and Inverted gull-wing configuration [3][4].

1. Low wing configuration – this wings configuration is common on modern passenger aircrafts and are

mounted on the lower half of the plane fuselage near the bottom.

2. Mid-wing configuration – this type of wing configuration offers more stable flight of an aircraft however control response and maneuverability of the aircraft becomes poor. In this wing configuration, aircraft wings are mounted at the centre of the fuselage.
3. High-wing configuration – is common on large cargo and military transport aircrafts. For better accessibility of the cabin, wings in this type of configuration are mounted on top of the fuselage.
4. Dihedral wing configuration – is a complex wing configuration on a fixed-wing aircraft where the wings are typically mounted on the lower part of fuselage having an upward angle from the fuselage.
5. Anhedral wing configuration – is similar to the dihedral wing configuration. The only difference is that the wings have a downwards angle from mounting base on the fuselage.
6. Gull-wing configuration – incorporated a dihedral wing design from the horizontal base, which is reduced or completely flattens after a short distance. This configuration ensures good pilot visibility.
7. Inverted gull-wing configuration – is the opposite of gull-wing configuration with the wing mounted at an anhedral angle.

Another configuration of airplane wings is based on their shape and design. These are: Rectangular Wing, Straight Tapered Wing, Elliptical Wing, Delta Wing, Trapezoidal Wing [4].

1. Rectangular Wing- this configuration of wings is usually found on low-subsonic aircrafts. These wings have equal length of root chord and tip chord.
2. Straight Tapered Wing – this configuration provides good aerodynamics and lift distribution profile to the aircraft wings. The wings are tapered having unequal length of the root chord and tip chord.
3. Elliptical Wing- this configuration has the wing planform in the shape of an ellipse and the edges of the wing turn inward to form a rounded tip.
4. Delta Wing- this wing planform is typically common on supersonic jet aircrafts. It has a triangular planform with a swept leading edge. It is aerodynamically efficient than a straight wing.

5. Trapezoidal Wing- this configuration provides good strength and stiffness to the wing and offers exceptionally low aerodynamics drag during high speeds. Military airplanes use the trapezoidal wing type because it provides excellent handling at supersonic speeds.

2.2 Airfoils types and design

An airfoil is the cross-sectional shape of an object whose motion through a gas is capable of generating significant lift. Airfoils can be designed with different geometries with each geometry providing different flight characteristics. For example, subsonic flight generally has a rounded leading-edge geometry is common for subsonic flight, while slimmer profile with a sharp leading edge is used for supersonic flight. All have a sharp trailing edge.

The lift on an airfoil is primarily the result of its angle of attack. When oriented at a suitable angle, the airfoil deflects the oncoming air, resulting in a force on the airfoil in the direction opposite to the deflection. This force is known as aerodynamic force and can be resolved into two components: lift and drag.

There are two main types of airfoils: symmetrical and non-symmetrical. Symmetrical airfoils have identical upper and lower surfaces, resulting in no lift at zero angle of attack. Non-symmetrical airfoils, also known as cambered airfoils, have different upper and lower surfaces and can generate lift at zero angle of attack. Airfoils can also be designed for use at different speeds by modifying their geometry. For example, airfoils for subsonic flight generally have a rounded leading edge, while those designed for supersonic flight tend to be slimmer with a sharp leading edge [5].

2.3 NACA Airfoils [6][7]

The NACA airfoils are airfoil shapes for aircraft wings developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA airfoils is described using a series of digits following the word "NACA". During the late 1920s and into the 1930s, the NACA developed a series of thoroughly tested airfoils and devised a numerical designation for each airfoil — a four-digit number that represented the airfoil section's critical geometric properties.

The NACA four-digit wing sections define the profile by [6]:

1. First digit describing maximum camber as percentage of the chord.
2. Second digit describing the distance of maximum camber from the airfoil leading edge in tenths of the chord.
3. Last two digits describing maximum thickness of the airfoil as percent of the chord.

For example, the NACA 2412 airfoil has a maximum camber of 2% located 40% (0.4 chords) from the leading edge with a maximum thickness of 12% of the chord.

The NACA 0015 airfoil is symmetrical, the 00 indicating that it has no camber. The 15 indicates that the airfoil has a 15% thickness to chord length ratio: it is 15% as thick as it is long.

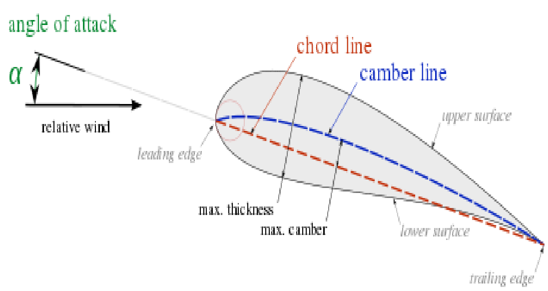

Figure 2: Airfoil Nomenclature [1]

3. GENERAL WING DESIGN [8]

The design of an aircraft wing is critical for its performance and safety. It should be light weight while not compromising on the structural rigidity. Here are mentioned some points on the basis of which the wing is to be designed.

3.1 Aerodynamics: The wing's shape is designed to generate lift, which keeps the aircraft in the air. The shape of the wing is typically a curved airfoil, which creates a pressure difference between the upper and lower surfaces of the wing, generating lift. For the current wing design NACA 4412 is selected. The 4412 airfoil has a camber of 4% and a thickness-to-chord ratio of 12%. It is symmetrical, which means that the shape of the upper surface is the same as the lower surface.

This airfoil is commonly used in the design of general aviation aircraft wings and has been found to provide good lift characteristics and low drag at a range of angles of attack.

The designation "4412" refers to the specific series of airfoils developed by NACA. The first digit "4" indicates that the airfoil has a maximum camber of 4% of the chord length, while the second and third digits "4" and "12" respectively indicate the position of the maximum camber and the thickness-to-chord ratio, both as percentages of the chord length [6].

Overall, the NACA 4412 airfoil is a well-established and widely used airfoil shape that has proven to be effective in a variety of aircraft designs. Also discussed in the paper [6] which describes about different characteristics of NACA 4412.

3.2 Wing span: The distance from the tip of one wing to the other is called the wing span. A longer wing span typically generates more lift, but also creates more drag. Shorter wingspans are more manoeuvrable but may generate less lift. So, settling between the two we have to design. For the common practice of the prototypes total wing span is created between 2 to 3 meters. For design feasibility we took in consideration of 2.4m as total wing span and for simulation and design we created half wing span, that is, of 1.2m [9].

3.3 Wing area: The surface area of the wing is also important for generating lift. A larger wing area can generate more lift, but may also create more drag. A smaller wing area may create less lift, but will also have less drag. Hence, we have selected tapered wing configuration instead of constant chord wing as it has more advantages [9].

Improves lift to drag ratio: A tapered wing can provide a better lift-to-drag ratio than a constant chord wing. This means that the wing can generate more lift for the same amount of drag, leading to better overall performance and efficiency.

Improved stability: Tapered wings can provide better stability and control over a wider range of angles of attack than constant chord wings.

Reduced weight: Tapered wings can be lighter than constant chord wings, as they can be designed to have less material in the outer sections where the chord is smaller.

3.4 Wing loading: This is the amount of weight that the wing supports per unit of wing area. Higher wing loading requires a larger wing area to generate the required lift. Higher wing loading can make the aircraft faster, but it can also reduce its manoeuvrability.

3.5 Wing sweep: The angle at which the wing is attached to the fuselage, known as the sweep angle, affects the aircraft's performance. A swept-back wing reduces drag at high speeds, but it can reduce stability and increase drag at low speeds.

3.6 Wing dihedral: The angle between the wings, known as the dihedral angle, affects the aircraft's stability. Positive dihedral (wings angled upward) improves stability in turns and reduces the risk of rolling over. Negative dihedral (wings angled downward) can make the aircraft more manoeuvrable but less stable.

3.7 Flaps and slats: These are movable sections of the wing that can be extended or retracted to increase lift or decrease drag. Flaps and slats are used during take-off and landing to allow the aircraft to fly at slower speeds. Overall, a good wing design balances the trade-offs between lift, drag, stability, and maneuverability to achieve optimal performance for the specific mission and operating conditions of the aircraft.

4. MATERIAL SELECTION AND DESIGN PARAMETERS

S.No.	Parameters	Values
1	Tip Chord	302.87mm
2	Root Chord	605.73mm
3	Half Wing Area	1.11m2
4	Half Wing Span	1200mm
5	Airfoil	NACA 4412
6	Spar	Hollow Square Section 15mm x 1mm
7	Ribs	Thickness: 2mm

Table 1: Design Parameters [8][9]

The choice of wing material for aircraft depends on various factors, including the type of aircraft, performance requirements, cost, and availability of materials. Here are some commonly used materials for aircraft wings [1][10] [11]:

1. Aluminium alloys: These are lightweight and strong materials that have been used in aircraft construction for many years. Aluminium alloys are easy to work with, and they can be shaped into various forms, making them suitable for use in the wings and other parts of an aircraft [1].
2. Composite materials: Composites are made up of two or more materials with different physical and chemical properties. They can be lightweight, strong, and resistant to corrosion. The most commonly used composites for aircraft wings are carbon fibre reinforced polymer (CFRP), glass fibre reinforced polymer (GFRP), and aramid fibre reinforced polymer (AFRP) [11].
3. Titanium alloys: These are lightweight and strong materials that are highly resistant to corrosion. Titanium alloys are used in aircraft construction for their high strength-to-weight ratio, which allows them to withstand the stresses of flight [1].
4. Steel: Steel is a strong and durable material that is commonly used in the construction of commercial and military aircraft. However, it is heavier than other materials, which makes it less suitable for high-performance aircraft.
5. Magnesium alloys: Magnesium alloys are lightweight and have excellent strength-to-weight ratio. They are commonly used in aircraft wings and other components because of their high resistance to corrosion and good machinability.

For our prototype we will be choosing Al 6061, Composite structure with Carbon fibre and Balsa Wood [3] and Titanium.

Aluminium alloy 6061 is a commonly used material in aircraft manufacturing due to its high strength-to-weight ratio, good corrosion resistance, and excellent machinability. It has a relatively low density compared to other metals, making it a lightweight option for aircraft structures.

6061 aluminium alloy is typically used in the construction of aircraft wing spars, fuselage frames, and other structural components due to its excellent machinability. Also it costs less than Aluminium 7000 series and is readily available.

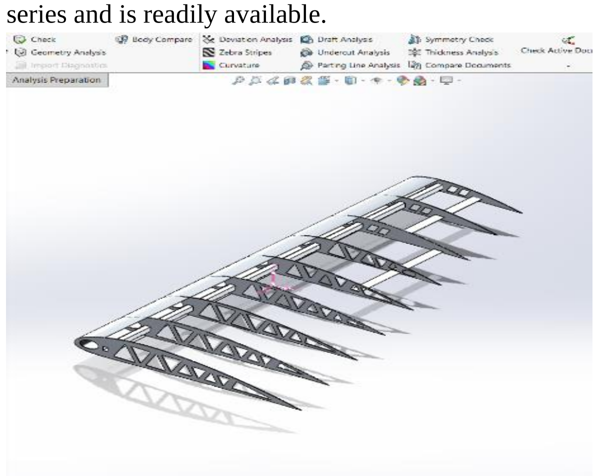

Figure 3: Wing with material Aluminium 6061[1]

Mechanical Properties for Aluminium. 6061		
S.No.	Parameters	Values
1	Tensile Strength	310MPa
2	Yield Strength	276MPa
3	% Elongation	12%
4	Modulus of Elasticity	68.9GPa
5	Density	2.7 g/cm3
6	Wing Weight	1100 grams

Table 2: Mechanical Properties for Aluminium 6061[1]

Composite structures are most commonly used in aircraft structures. **Carbon fibre** is a high-performance material made from thin, strong fibres of carbon. It has a high strength-to-weight ratio, excellent fatigue resistance, and good stiffness. These properties make it an ideal material for use in high-performance applications such as aerospace, automotive, and sports equipment [11].

In aerospace applications, carbon fibre is commonly used in the construction of aircraft wings, fuselages, and other structural components. It is often used in combination with other materials such as epoxy resins and honeycomb structures to create lightweight, strong, and stiff composite structures that can withstand the high stresses of flight. Due to its mechanical properties we can use it in spar as well as slits which holds or bears the load of the wing.

Balsa wood is a lightweight, yet strong and versatile material that has a number of advantages in various applications. Balsa wood [3] is one of the lightest commercial woods available, with a density of only 8-14 pounds per cubic foot. This makes it an ideal material for use in applications where weight is a concern, such as in aircraft, boats, and model making.

Despite its lightweight, balsa wood has excellent strength-to-weight ratio, making it strong enough to be used in various applications. This is due to its cellular structure, which gives it high strength and stiffness.

Balsa wood is easy to cut, sand, and shape, making it a popular material for hobbyists and model makers. It can also be easily painted and finished to achieve desired aesthetics.

Combination of Carbon fibre for spar and slits and balsa wood for ribs can create a light weight and durable structure.

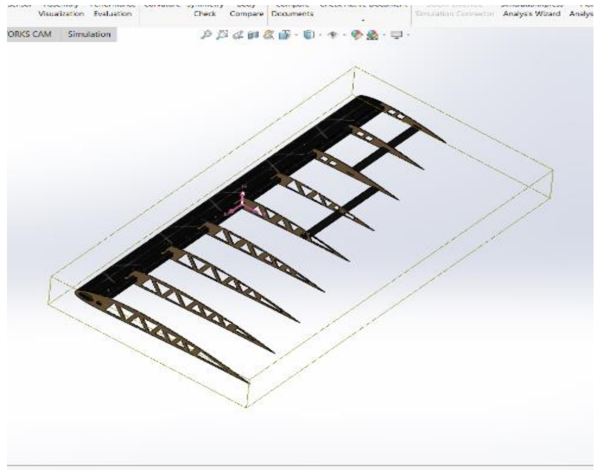

Figure 4: Wing with material Carbon Fibre (3000 filament) and Balsa wood [3] [11]

Mechanical Properties for Carbon Fibre		
S.No.	Parameters	Values
1	Tensile Strength	2410MPa
2	Yield Strength	-
3	% Elongation	1%
4	Modulus of Elasticity	228GPa
5	Density	1.6g/cm3
6	Wing Weight	367.30 grams

Table 3: Mechanical Properties for Carbon Fibre [11]

Mechanical Properties for Balsa wood		
S.No.	Parameters	Values
1	Tensile Strength	52MPa
2	Yield Strength	21MPa
3	% Elongation	-
4	Modulus of Elasticity	11 - 21GPa
5	Density	0.26g/cm3
6	Wing Weight	367.30 grams

Table 4: Mechanical Properties for Balsa Wood [3]

Several titanium alloys are used in aircraft, but two of the most commonly used titanium alloys are Ti-6Al-4V (also known as Ti-64) and Ti-6Al-2Sn-4Zr-2Mo (also known as Ti-6242) [1] [11].

Ti-6Al-4V is an alpha-beta titanium alloy that contains 6% aluminium and 4% vanadium. It is a high-strength alloy that has excellent corrosion resistance, good fatigue resistance, and good weld ability. These properties make it a popular choice for use in aircraft applications such as engine components, landing gear, and structural parts.

Ti-6Al-2Sn-4Zr-2Mo is a near-alpha titanium alloy that contains 6% aluminium, 2% tin, 4% zirconium, and 2% molybdenum. It has excellent high-temperature strength, good toughness, and good corrosion resistance. These properties make it a suitable material for use in aircraft engine components, such as compressor blades, where high-temperature strength is critical.

Both of these titanium alloys offer a high strength-to-weight ratio, making them attractive materials for aircraft applications where weight savings are important. Additionally, titanium alloys have a lower density than steel and other metals, which helps to reduce the overall weight of the aircraft.

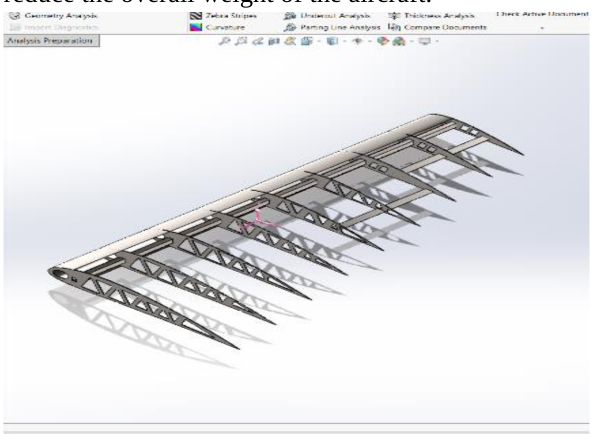

Figure 5: Wing with material Titanium alloy [1]

Mechanical Properties for Titanium alloy		
S.No	Parameters	Values
1	Tensile Strength	895MPa
2	Yield Strength	-
3	% Elongation	10%
4	Modulus of Elasticity	125GPa
5	Density	4.51g/cm3
6	Wing Weight	1874 grams

Table 5: Mechanical Properties for Titanium Alloy Grade 5 [1]

5. ANALYSIS OF WING DESIGN

Static analysis of a wing is an essential step in the design and development process of an aircraft. It involves analyzing the wing's behaviour under static loading conditions, which includes the weight of the aircraft, payload, and other external loads [12] [13] [14].

It also ensures:

1. Structural integrity: A wing must be able to withstand the loads and stresses it will experience during flight, including those caused by static loads. Static analysis helps to ensure that the wing structure is strong enough to resist these loads and maintain its structural integrity [14].
2. Safety: Static analysis helps to identify any potential failure modes or stress concentrations that may occur in the wing structure. This information is crucial in ensuring the safety of the aircraft and its occupants.
3. Weight optimization: Static analysis helps to identify areas of the wing structure that are overdesigned or have excess material. This information can be used to optimize the wing's weight and reduce the overall weight of the aircraft.
4. Performance optimization: Static analysis can also be used to optimize the wing's aerodynamic performance by analyzing the wing's lift and drag characteristics under static loading conditions. This information can be used to refine the wing's design and improve its overall performance.

As described in the material selection section we will be testing on Aluminium 6061, composite of carbon fibre and balsa wood, titanium alloy.

As this paper concerns about structural rigidity of the wing we will be analysing the wing on the basis of:

1. Modal Analysis: The wing is tested under a frequency which ensures that the wing can withstand engine vibrations, air turbulences etc. [12].
2. Cantilever Analysis: The weight of the wing is applied on the ribs according to its own weight distribution [13].
3. Pressure Analysis: When the wing generates lift it experiences some amount of pressure of its surface.

Keeping mesh size of 5mm because larger than that may cause accuracy error and lower than that may affect computational speed. Depending upon the skewness value and other meshing parameters mesh doesn’t seems to be distorted or broken, hence 5mm is finalised.

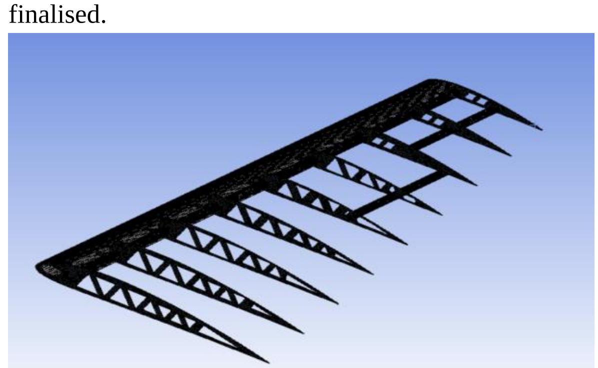

Figure 6: Meshed Image of the Wing [10]

5.1 Analysis for Al 6061

Modal, Cantilever, Pressure, Analysis is done for the Al 6061 material :

5.1.1 Modal Analysis

Fixing the root rib as it will get attached to the main body of the aircraft we will see the deformation of the wing when a certain amount of frequency (Default - 10,00,000Hz) is acting on it [10].

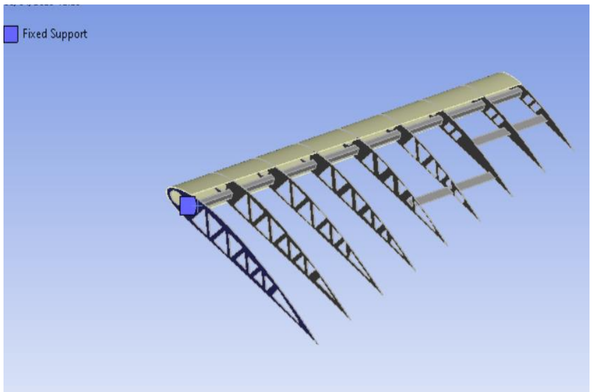

Figure 7: Fixed Support of the Wing [10]

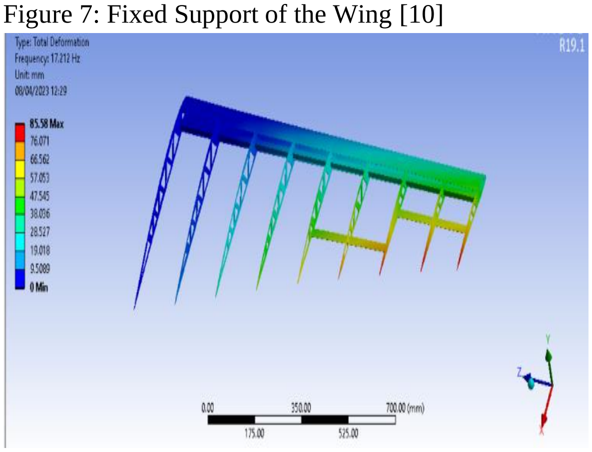

Figure 8: Deformation of wing in Modal Analysis (Material Aluminium 6061) [11]

Deformation of 85.58mm is observed in longitudinal direction. It is reasonable as the tip of the wing is free from any support with the main body directly in contact.

5.1.2 Cantilever Analysis

Fixed Support: Root Rib

Force is applied to each rib in the order 1.67N, 3.34N, 5.01N, 6.68N, 8.361N, 10.03N, 11.70N, 13.2N, starting from root to tip respectively.

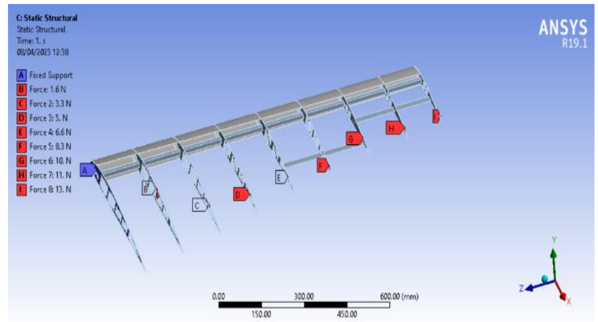

Figure 9: Boundary Conditions [13]

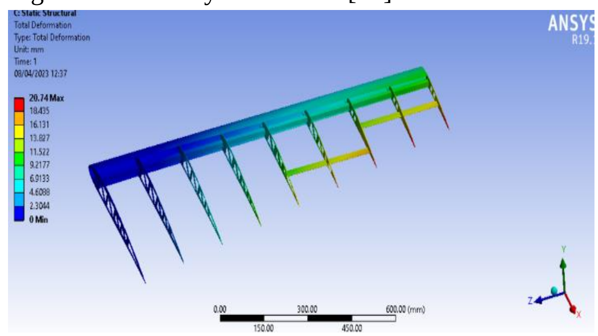

Figure 10: Deformation of wing in Cantilever Analysis (Material Al.6061) [13]

Total Deformation of 20.74 mm is observed.

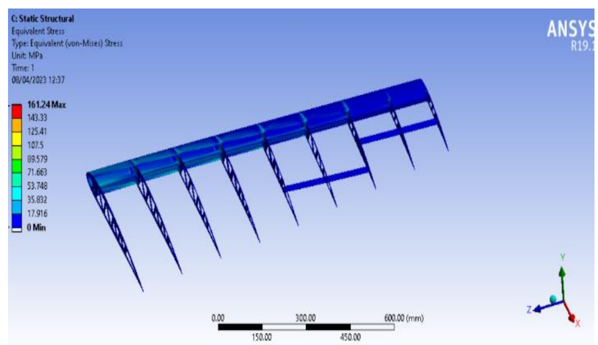

Figure 11: Stress of wing in Cantilever Analysis (Material Al.6061) [13]

Total Stress of 161.24 MPa is observed.

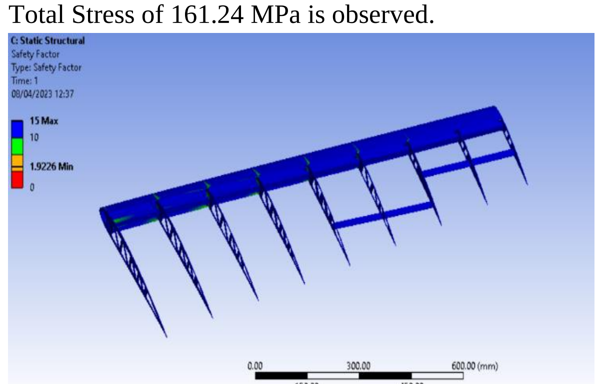

Figure 12: FOS of wing in Cantilever Analysis (Material Al.6061) [13]

Factor of Safety: 1.92

5.1.3 Pressure Analysis: Pressure of 500Pa is applied to the bottom side of the wing and root of the wing is fixed [1].

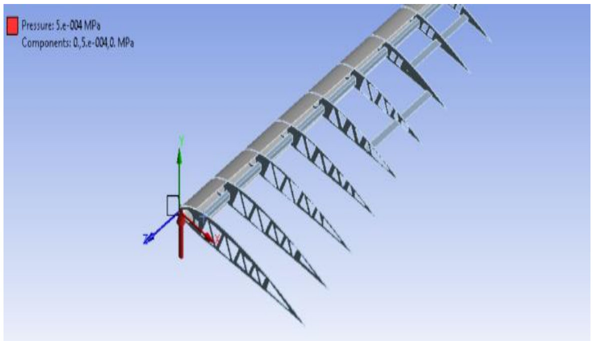

Figure 13: Boundary Condition: Pressure Applied [1]

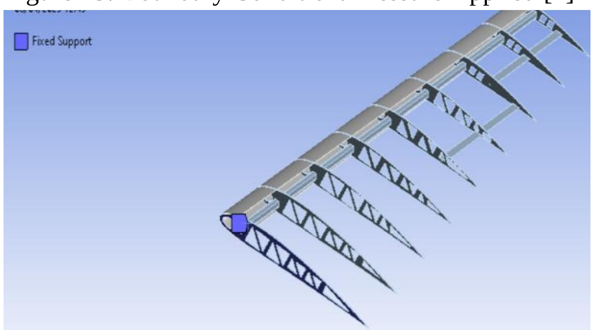

Figure 14: Boundary Condition showing fixed Support [1]

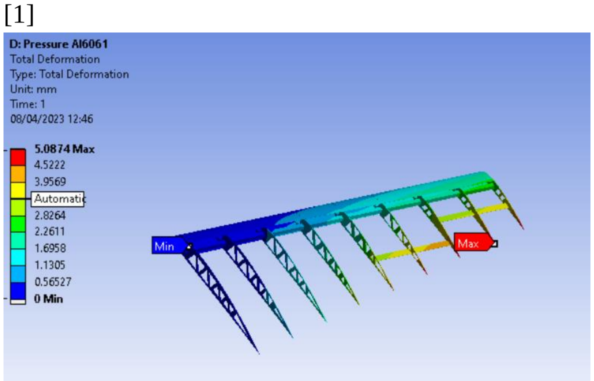

Figure 15: Deformation of wing in Pressure Analysis (Material Al.6061) [1]

Total Deformation of 5.08 mm is observed.

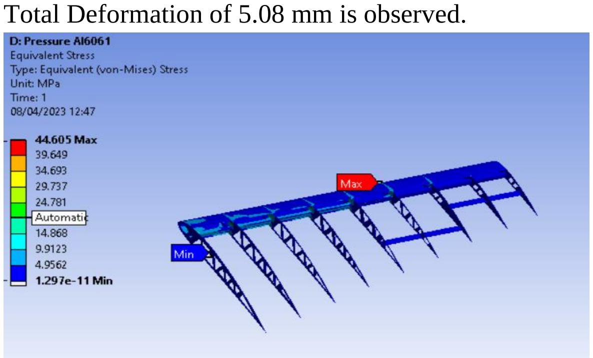

Figure 16: Stress of wing in Pressure Analysis (Material Al.6061) [1]

Total Stress of 44.605 MPa is observed.

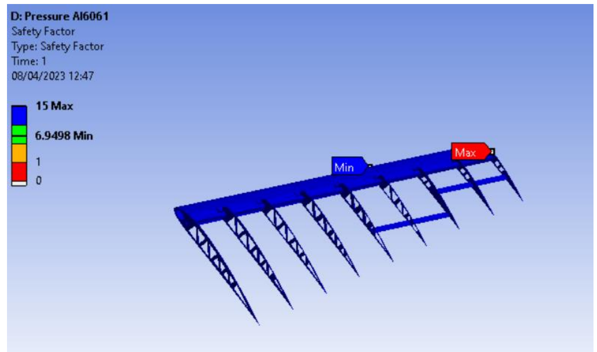

Figure 17: FOS of wing in Pressure Analysis (Material Al.6061) [1]

Factor of Safety: 6.94

5.2 Analysis for Carbon Fibre and Balsa Wood (Carbon Fibre + Balsa Wood)

Modal, Cantilever, Pressure, Analysis is done for the (Carbon Fibre + Balsa Wood) :

5.2.1 Modal Analysis

Fixing the root rib as it will get attached to the main body of the aircraft we will see the deformation of the wing when a certain amount of frequency (Default - 10,00,000Hz) is acting on it.

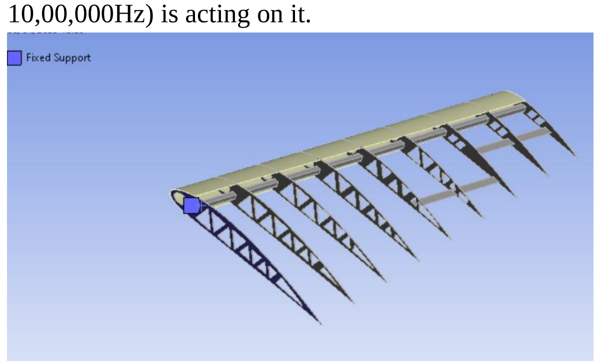

Figure 18: Fixed Support of the Wing [12]

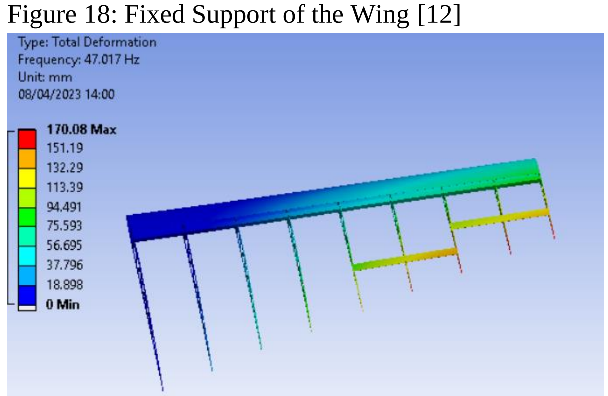

Figure 19: Deformation of wing in Modal Analysis (Material Carbon Fibre + Balsa Wood) [12]

Deformation of 170.08mm is observed in longitudinal direction. It is reasonable as the tip of the wing is free from any support with the main body directly in contact.

5.2.2 Cantilever Analysis

Fixed Support: Root Rib

Force is applied to each rib in the order 0.55N, 1.11N, 1.67N, 2.22N, 2.78N, 3.34N, 3.9N, 4.4N, starting from root to tip respectively.

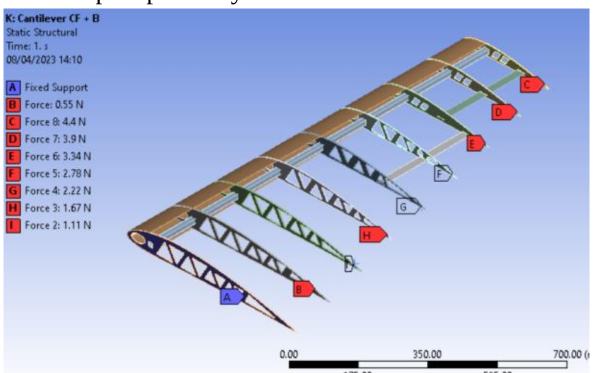

Figure 20: Boundary Conditions [13]

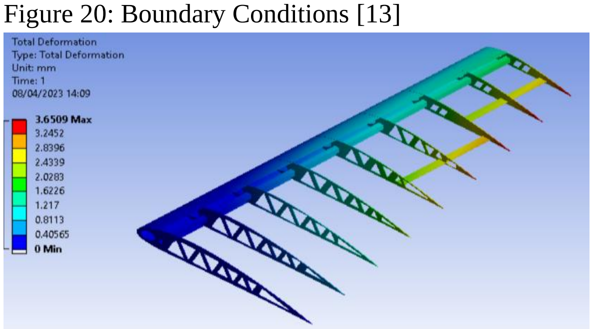

Figure 21: Deformation of wing in Cantilever Analysis (Material Carbon Fibre + Balsa Wood) [13]

Total Deformation of 3.65 mm is observed.

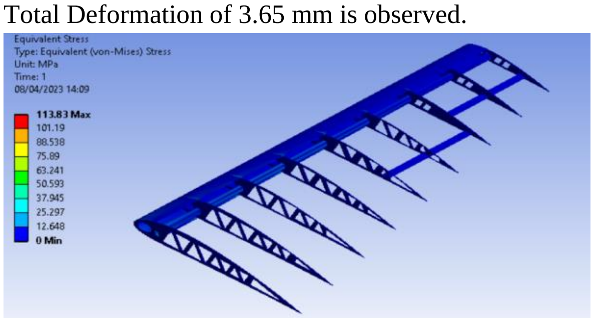

Figure 22: Stress of wing in Cantilever Analysis (Material Carbon Fibre + Balsa Wood) [13]

Total Stress of 113.83 MPa is observed

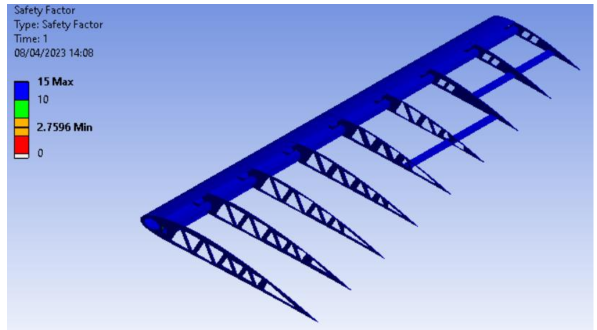

Figure 23: FOS of wing in Cantilever Analysis (Material Carbon Fibre + Balsa Wood) [13]

Factor of Safety: 2.75.

5.2.3 Pressure Analysis:

Pressure of 500Pa is applied to the bottom side of the wing and root of the wing is fixed.

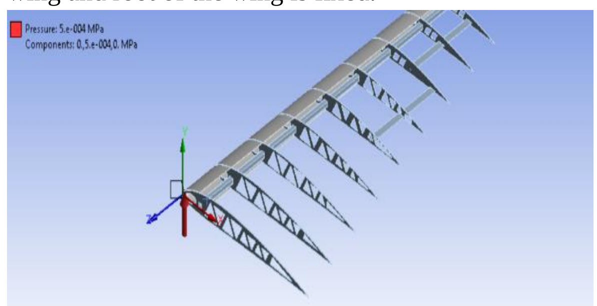

Figure 24: Boundary Condition: Pressure Applied [1]

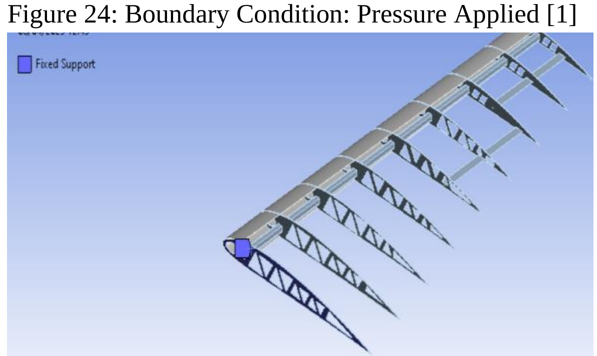

Figure 25: Boundary Condition showing fixed Support [1]

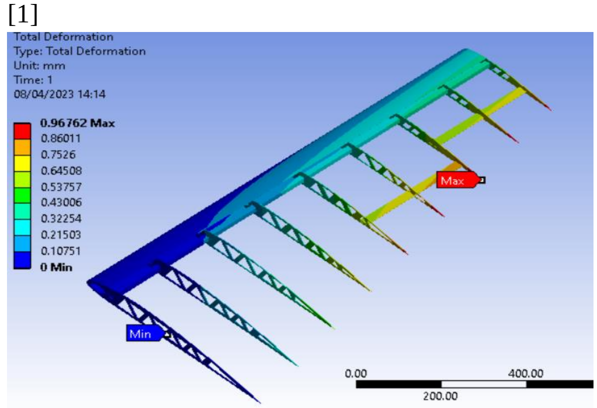

Figure 26: Deformation of wing in Pressure Analysis (Material Carbon Fibre + Balsa Wood) [1]

Total Deformation of 0.96 mm is observed.

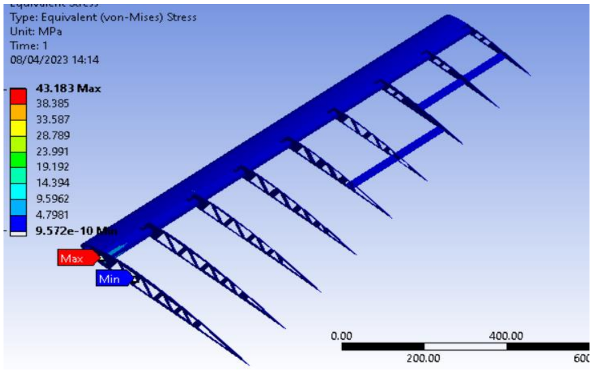

Figure 27: Stress of wing in Pressure Analysis (Material Carbon Fibre + Balsa Wood) [1]

Total Stress of 43.183 MPa is observed.

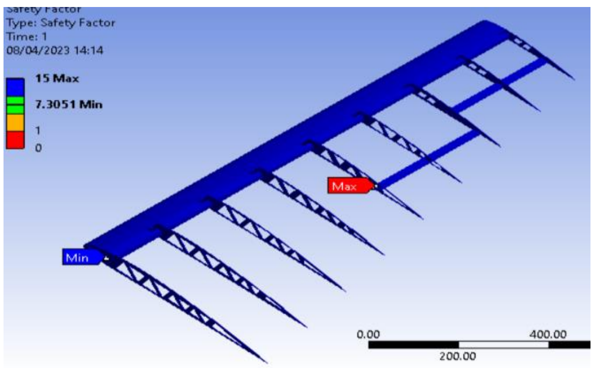

Figure 28: FOS of wing in Pressure Analysis (Material Carbon Fibre + Balsa Wood) [1]

Factor of Safety: 7.3

5.3 Analysis for Titanium Alloy

Modal, Cantilever, Pressure, Analysis is done for the Titanium Alloy :

5.3.1 Modal Analysis

Fixing the root rib as it will get attached to the main body of the aircraft we will see the deformation of the wing when a certain amount of frequency (Default - 10,00,000Hz) is acting on it [12].

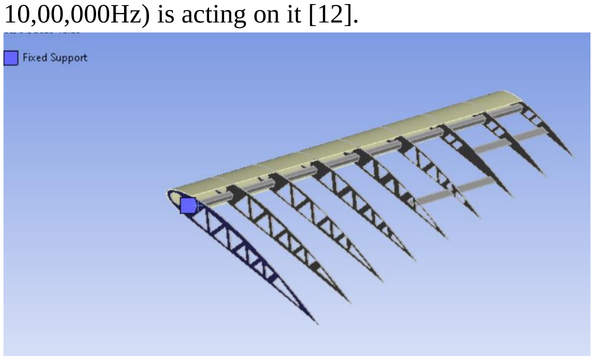

Figure 29: Fixed Support of the Wing [12]

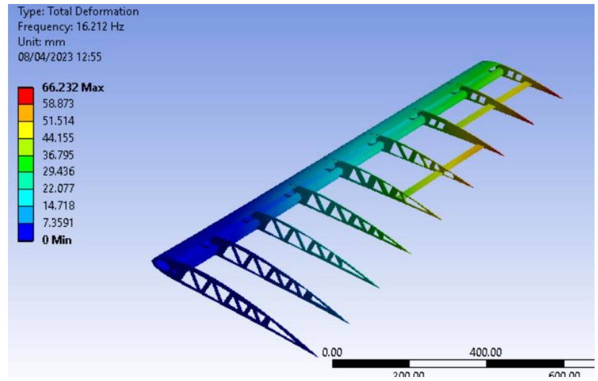

Figure 30: Deformation of wing in Modal Analysis (Material Titanium Alloy) [12]

Deformation of 66.23mm is observed in longitudinal direction. It is reasonable as the tip of the wing is free from any support with the main body directly in contact.

5.3.2 Cantilever Analysis

Fixed Support: Root Rib

Force is applied to each rib in the order 2.84N, 5.68N, 8.57N, 11.36N, 14.2N, 17.05N, 19.8N, 22.4N, starting from root to tip respectively [13].

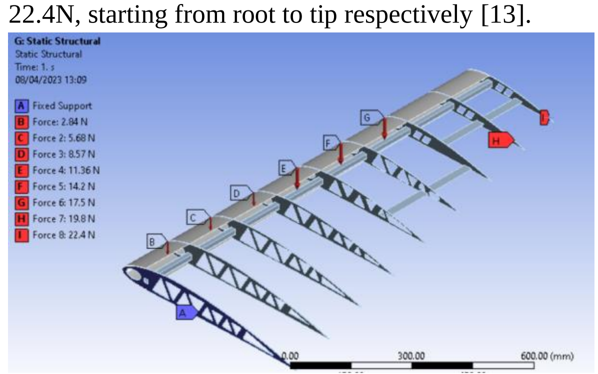

Figure 31: Boundary Conditions [13]

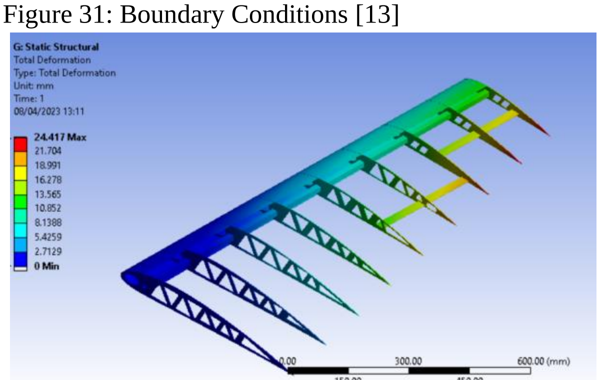

Figure 32: Deformation of wing in Cantilever Analysis (Material Titanium Alloy) [13]

Total Deformation of 24.417 mm is observed.

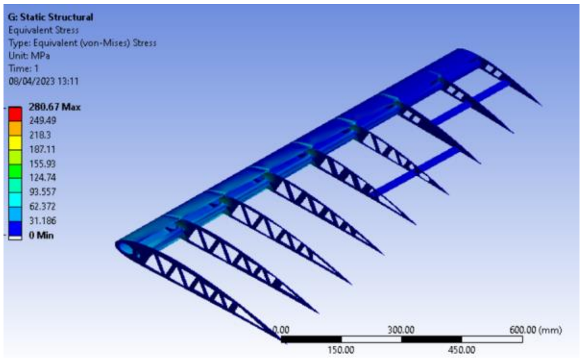

Figure 33: Stress of wing in Cantilever Analysis (Material Titanium Alloy) [13]

Total Stress of 280.67 MPa is observed.

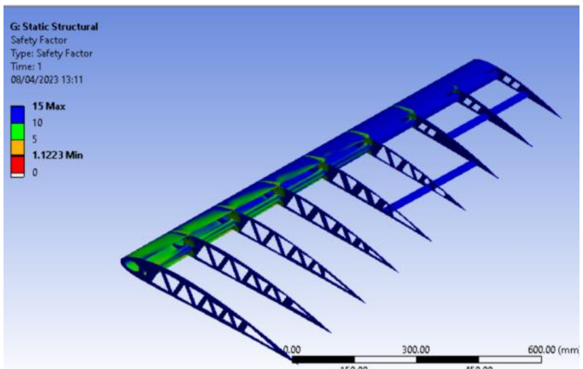

Figure 34: FOS of wing in Cantilever Analysis (Material Titanium Alloy) [13]

Factor of Safety: 1.12

5.3.3 **Pressure Analysis**: Pressure of 500Pa is applied to the bottom side of the wing and root of the wing is fixed [1].

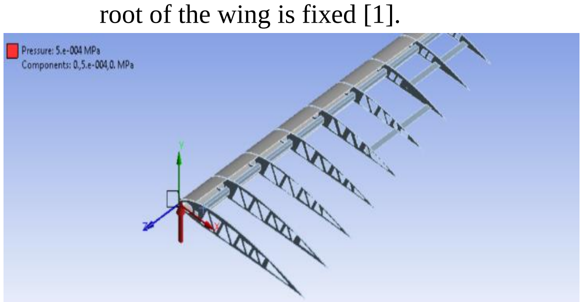

Figure 35: Boundary Condition: Pressure Applied [1]

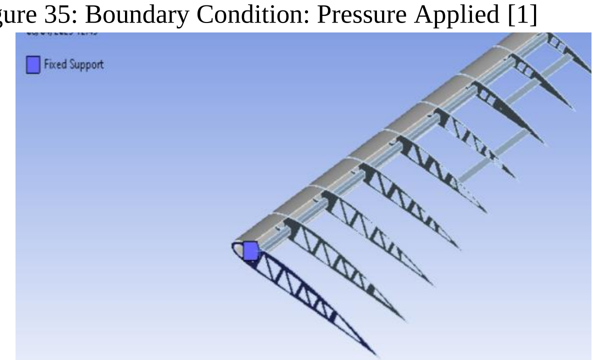

Figure 36: Boundary Condition showing fixed Support [1]

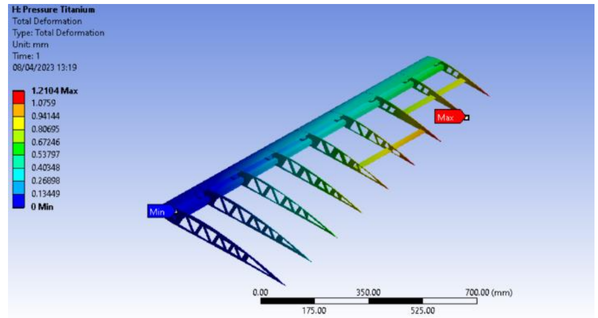

Figure 37: Deformation of wing in Pressure Analysis (Material Titanium Alloy) [1]

Total Deformation of 1.21 mm is observed.

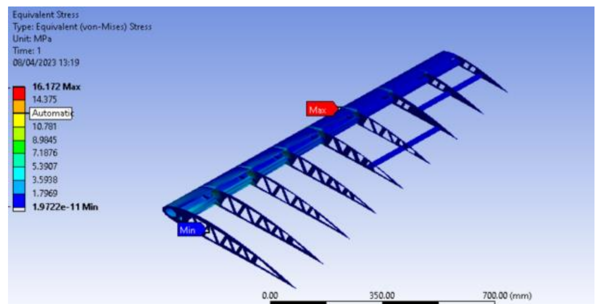

Figure 38: Stress of wing in Pressure Analysis (Material Titanium Alloy) [1]

Total Stress of 16.172 MPa is observed.

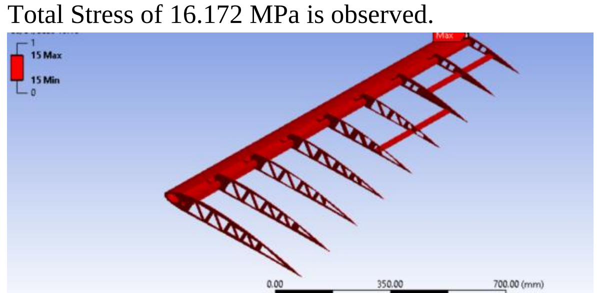

Figure 39: FOS of wing in Pressure Analysis (Material Titanium Alloy) [1]

Factor of Safety: 15

6.CONCLUSION

With reference to all the materials present above we have chosen the final one on the basis of usage, availability, weight, strength and many more considerations. From these three materials we further concluded by doing analysis on the wing with the material.

The composite of Carbon Fibre and balsa performs the best. With a weight of just 360 grams it shows remarkable factor of safety of 2.75 with minimal deformation of 3.65mm.

When consider to jerk loading for an aircraft the maximum load comes on the tip of wing because of their own weight, with minimal deformation the structure can show minimal flex and can show maximum flexural rigidity so it will be an advantage to use the composite.

When it comes to design a wing, weight plays very important role in every aspect covering manoeuvrability, fuel economy, requires less engine power to drive, maintaining structural integrity and many more.

Since spar supports the main load of the wing we decide to create it with carbon fibre including the slits which holds the ribs in place. Ribs are made up of Balsa Wood as it will be easy to fabricate, laser cut and putting to place.

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