DESIGN, ANALYSIS AND LIFE ESTIMATION OF RADIO CONTROLLED NITRO AIRCRAFT WING

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ABSTRACT – *The project deals with designing a radio controlled aircraft by considering various parameters like taper ratio, aspect ratio and so on. A 3D CAD model is designed considering above parameters in solid edge. The quantitative and qualitative characterization of the aircraft wing will give helpful information in order to verify the selection and designing of the wing prior to fabrication of aircraft. Initially designing of wing geometry is carried out with the help of calculated values, then later analysis is carried out on designed wing for different boundary conditions. Linear and non linear analysis is done for different velocity and finally life estimation is carried out through fatigue life approach.*

Key Words: radio controlled aircraft, rc aircraft, linear analysis, non linear analysis, fatigue analysis, rc aircraft wing analysis.

1. INTRODUCTION

The aim of the project is to design and analyse a radio controlled nitro aircraft which involves in understanding various forces acting on an aircraft and choosing the right motors in order to make an aircraft fly. In order to achieve the described objective an extensive literature review is carried out in finding out various parameters to build a plane. Based on all literature survey and considering factors like lift coefficient, taper ratio, root cord etc we will be building a plane which will minimize the wing loading and to optimize the weight. Radio controlled aircraft is used in various fields as like spy planes, scientific experiments, target practice in military base.

1.1 BASIC FORCES ACTING ON PLANE

Weight of an aircraft pulls it in downward direction due to gravitational force. Lift is the amount of force required to pull an aircraft in upward direction which is generally achieved by aircraft wings and horizontal tail. Drag will pull the aircraft in backward direction due to the resistance offered by the air to the aircraft. Thrust will pull the aircraft in forward direction which is achieved by rotation of propeller because of the power generated by aircraft engine.

1.2 PLANE COMPONENTS

Figure 1.1 represents various components of rc aircraft.

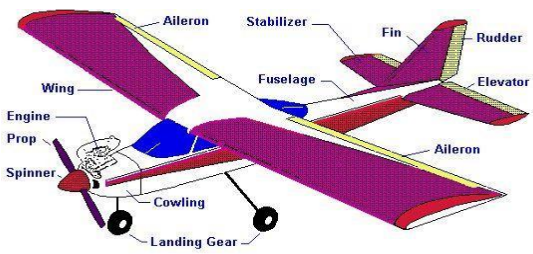

Figure 1: Plane components

Various parts of components like wings, horizontal tail, vertical tail, engine and its related components will be mounted to the fuselage. Engine bulk head is comparatively stronger than others as it need to sustain engine vibrations along with carrying weight of engine. The landing gear will be helpful in landing and take-off, along with that it absorbs impact load while load during landing. Here we will be using Dihedral wing which means angle between imaginary x-y axis and wing's centre cord and here we consider 5^0 as dihedral angle. Airfoil is a curved structure which will be helpful in piercing the air so that some air flows upside and some air flows down so we used TSAGI 12% airfoil. ASP nitro engine is used which utilize 10%to 40% of nitro methane mixed with methanol and this uses platinum iridium alloy coil for ignition and heated using batterie.

1.3 CONTROL SYSTEM OF THE PLANE

Figure 1.2 represents various parts used in controlling a plane.

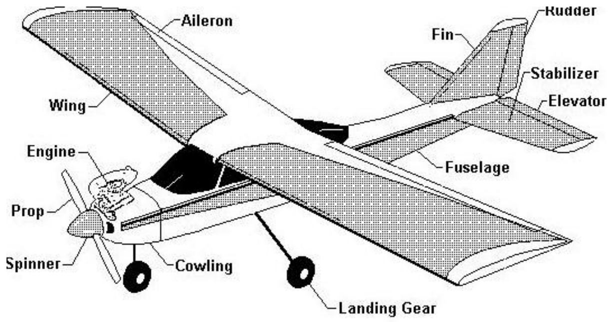

Figure 2: Control system of plane.

Elevators are the reason to make aircraft climb or dive. Elevators will be mounted on rear end of horizontal tail. Even elevators generate some of lift. Ailerons are placed at aircrafts wing and will be helpful in rolling action of aircraft. Ailerons on the either side of the wing will be moved in opposite direction hence the one which generates more lift will cause the aircraft to riseand the other will drop. Rudder will make plane either to take right or left turn, it will be mounted to vertical tail, it will steer aircraft in required direction. Lift generated by rudder will not affect lift generated by wing. Throttle is used in controlling speed of an aircraft i.e., it makes an aircraft to fly either speed or slow.

1.4 MATERIAL USED: BALSA WOOD

Balsa wood is lighter than other wood and its easier to cut but difficult to make a good-looking model. Since the wood is light in weight it deforms if applied pressure of cutting blade is more than required. It has an advantage of regrowth for every six to ten years which is pretty quick.

Low density balsa wood = 75 kg/m^3

Medium density balsa wood = 150 kg/m^3

High density balsa wood = 225 kg/m^3

Table -1: Properties of Balsa wood.

Compressive Strength	
Low density Balsa wood	4.71 Mpa
Medium density Balsa wood	12.12 Mpa
High density Balsa wood	19.49 Mpa
Tensile Strength	
Low density Balsa wood	7.63 Mpa
Medium density Balsa wood	19.89 Mpa
High density Balsa wood	32.24 Mpa
Yield strength	320 Mpa
Elastic Modulus for Compression	460 ± 70 Mpa
Elastic Modulus for Tension	1280 ± 455 Mpa

1.5 PARAMETERS TO DESIGN RC AIRCRAFT WING

Number of wings, Vertical position relative to the fuselage (low, mid, or high wing), Wing configuration (straight, tapered, delta etc), Span (b), Wing area (S_{wing}), Aspect ratio (AR), Taper ratio (TR), Tip chord (C_t), Root chord (Cr), Mean Aerodynamic Chord (MAC or C), Airfoil, Twist angle (TA), Aileron, Wing loading.

1.6 LITERATURE SURVEY

As Daniel P Raymer and Nicolai [1] point out, airplane design is an art of compromise between various components like aerodynamics, structure and economy. When it comes to aerodynamics, stability and maneuverability do not go hand in hand. When both are meet, efficiently vastly reduces.

Mamla and Galinski [2] suggests that positively staggered and jointed wings are aerodynamically more efficient when compared with negatively staggered and jointed wings. Positively staggered refers to high wing in front of lower aft wing where as negatively staggered refers to the lower wing in front of higher aft wing. They claim that positively staggered jointed wings have greater aerodynamic efficiency compared to negatively staggered wings.

Abzug and Larrabee [3] talk about an ingenious way to overcome the problem with “relaxed stability”. In order to initiate maneuvering in less steady aircraft small control in deflection is sufficient. But these characteristics will be very difficult to control by the pilot hence it can be achieved using computers, which is used in modern aircrafts.

Schiktanz et al [4] explains that in order to achieve intrinsic stability in an aircraft model, the fore and the aft wing’s lift coefficient ratio is increased in the favor of fore wing. They also explain the conflict of aerodynamic efficiency with respect to the stability of the fixed wing of an aircraft.

Kaan Taha and Ilyas [5] in the fabrication of UAV’s, light-weight structure which is able to withstand the possible loadings in vertical, horizontal and transition flight modes is essential. They also describes that high strength of composite material permits designing of higher aspect ratio wings in the airfoil sections.

Mr. Daniel Odido and Dr. Diana Madara [6] highlighted the emerging technologies in the use of Unmanned Aerial Systems (UAS) for the integration of various systems in the realization of Vision 2030 goals in the counties in Kenya. The UAS technology has numerous applications in mechatronics, aeronautics and robotics. Several sectors like Agriculture, Energy, fishery, forestry, remote sensing, earth observation and others have seen increased usage of UAS.

Omkar Bhosle et al [7] encourage the students to learn the field of aerodynamics by creating the model. In this research paper they have include all the essential data required to build a flying model which will help students as the guide to complete their model. Initially the radio-controlled airplane was developed for research purpose and the miniature planes were constructed as a study model of the full-scale airplanes and will be studied the forces acting on the newly designed models and later the design was modified to get the required results. He designed RC plane with electric motor which is useful for beginners.

Shreyas S Hegde et al [8] is development of a Canard type aircraft with the mission of aerial reconnaissance and surveillance. It was designed to have optimum lift and drag characteristics. This was accomplished by selecting the best values of fuselage length, wing-span, elevator, rudder which are determined by series of iterative analysis. Based on all those factors systematically design and analysis is made and an RC plane is built. This project provides the basics of aircraft design, engineering, building and testing.

Karan S. Patel et al. [9] studies the Computational Fluid Dynamic analysis or CFD analysis of the flow of air over TSAGI 12% airfoil and comes to a conclusion that at zero degree of analysis, there is no lift generated. Along with that the amount of drag force and co-efficient of drag also increased but increment in the amount of drag force and co-efficient of drag is quite lower compared to lift force.

1.7 PROBLEM DEFINATION

Designing the wing of Radio controlled nitro aircraft, conducting simulation of designed wing and life estimation of the wing using Fatigue analysis.

1.8 OBJECTIVE

To develop the plan by selecting appropriate geometry of RC aircraft. To develop 3D model and to select appropriate materials, engine, propeller based on aircraft geometry. Finally, to perform linear, non-linear analysis and fatigue analysis.

2. METHODOLOGY

Methodology of the project is as follows: 1. Geometric modelling is created with solid edge. 2. Meshing is done with Ansys workbench. 3. Applying loads and boundary conditions on wings. 4. Finite element model is solved using Ansys solver. 5. Linear and non linear analysis is carried out on wings. 6. Results Validated.

3. DESIGNING AIRCRAFT WING

The designing of wing begins with calculation part, minimum data required is aircraft weight and wing span. Therefore, the aircraft weight is 1340gm, wing span is 121.92 cm (48'') and aspect ratio (AR) is 6.

Table 2: Aspect Ratios for Various Aircrafts

SL NO	AIRCRAFT TYPE	ASPECT RATIO
1	Hang glider	4-8
2	Glider (sailplane)	20-40
3	Homebuilt	4-7
4	General Aviation	5-9
5	Jet Trainer	4-8
6	Low subsonic transport	6-9
7	High subsonic transport	8-12
8	Supersonic fighter	2-4
9	Tactical missile	0.3-1
10	Hypersonic aircraft	1-3

Since we are designing a homebuilt aircraft, aspect ratio is selected as 6 from the available standards.

Step 1: Calculation of Wing Area (S_{wing});

$AR = b^2 / S_{wing}$

$S_{wing} = b^2 / AR$

$S_{wing} = 121.92^2 / 6 = 2477.41\ cm^2$

Step 2: Selection of wing loading;

With respect to structural constraints it should be less than 0.6 gm/cm^2.

Wing loading = Mass of the aircraft / S_{wing}

Wing loading = 1340 / 2477.41 = 0.54 gm/cm^2

Step 3: Taper ratio (TR) = 1 (Since we are considering straight wing).
Step 4: $C_{root} = 2 * S_{wing} / (b * (1 + TR))$

$C_{root} = 2 * 2477.41 / (121.92 * 2)$

$C_{root} = 20.32$ cm

Step 5: $C_{tip} = (TR * C_{root}) = (1 * 20.32)$

$C_{tip} = 20.32$ cm

Step 6: Calculation of mean aerodynamic chord (C);

It is the point on width of wing at which overall weight is assumed to act.

$C = 2 * C_{root} (1 + TR + TR^2) / (3 * (1 + TR))$

$C = 2 * 20.32(1 + 1 + 1) / (3 * (1 + 1))$

Therefore C = 20.32 cm

Step 7: Calculation of aerodynamic center (X);

It is the point on width of wing at which overall weight is assumed to act.

$X = (C_{root} - C) + C / 4$

$X= (20.32 – 20.32) + 20.32 / 4$

$X = 0 + 5.08$

Therefore X = 5.08 cm

Step 8: Calculation for designing Airfoil;
$L = W * 0.5 * \rho * V^2 * CL * S_{wing} = M * g$

Where,

ρ = density of air = 1.225 kg/m^3 = 1.225 * 10^{-3} g/cm^3

g = acceleration due to gravity = 9.81 m/s^2 = 9.81 * 10^{2}cm/s^2

V = the cruise speed = 12m/s = 12 * 10^{2}cm/s

C_L = The Co-efficient of lift

S_{wing} = 2477.41cm^2

M = 1340g

Co-efficient of lift = 0.6015

Usually aircraft is designed for Angle of attack (α) of 3^0 to 5^0. Here angle of attack is assumed as α = 5^0 so as to overcome stall angle and for safer flight. Symmetrical airfoil is used i.e., "TSAGI 12%".

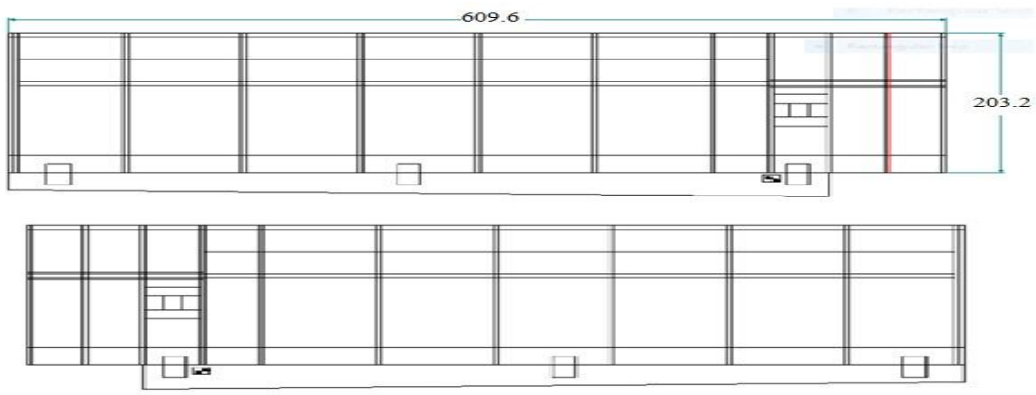

Figure 3: 2D view of wing

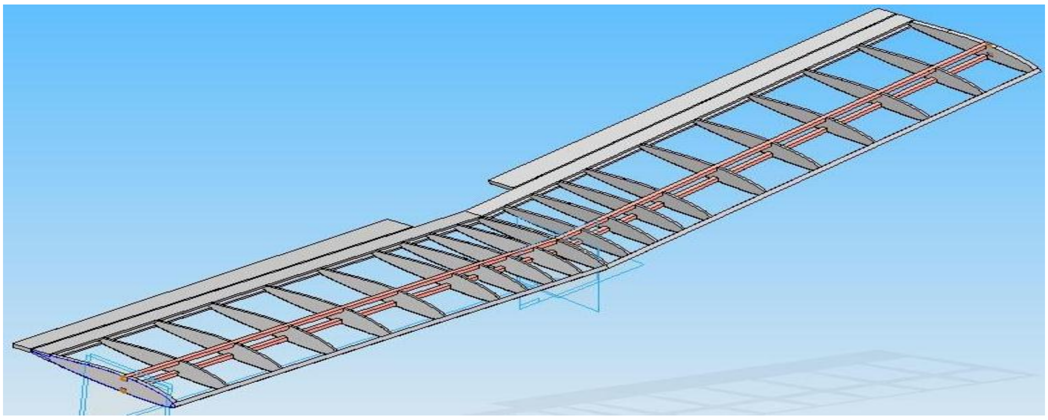

Figure 4: 3D view of wing

4. RESULTS AND DISCUSSION

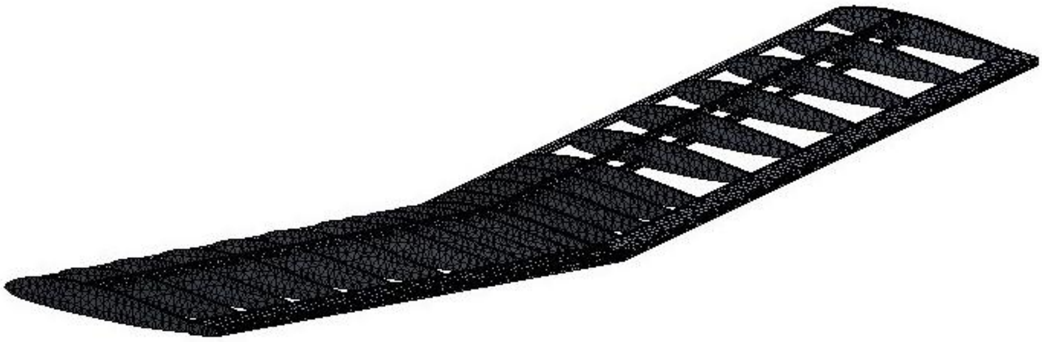

Figure 5: Wing meshed with tetrahedral elements.

4.1 LINEAR STATIC ANALYSIS: Velocity 100 m/s

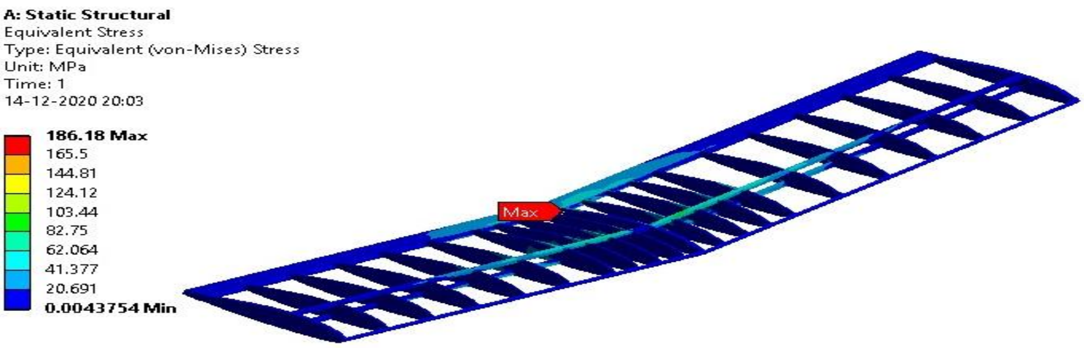

Figure 6: Equivalent or Von mises Stress on wing at 100 m/s.

Maximum von mises stress is 186.18 Mpa and minimum von mises is 0.0043754 Mpa. Yield stress of balsa wood is 320Mpa and maximum equivalent stress is less than yield strength of material, hence safer to design.

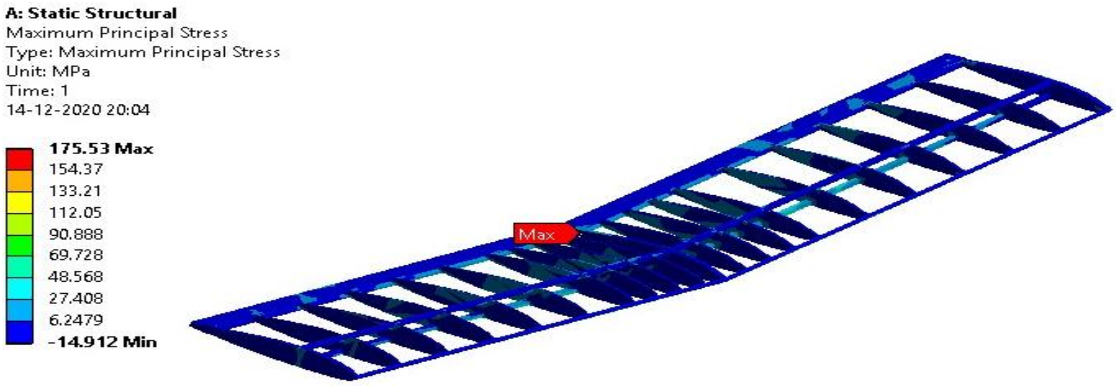

Figure 7: Maximum principal Stress on wing at 100 m/s

Maximum principal stress is 175.53 Mpa and minimum principal is -14.912 Mpa. Yield stress of balsa wood is 320Mpa and maximum principal stress is less than yield strength of material, hence safer to design.

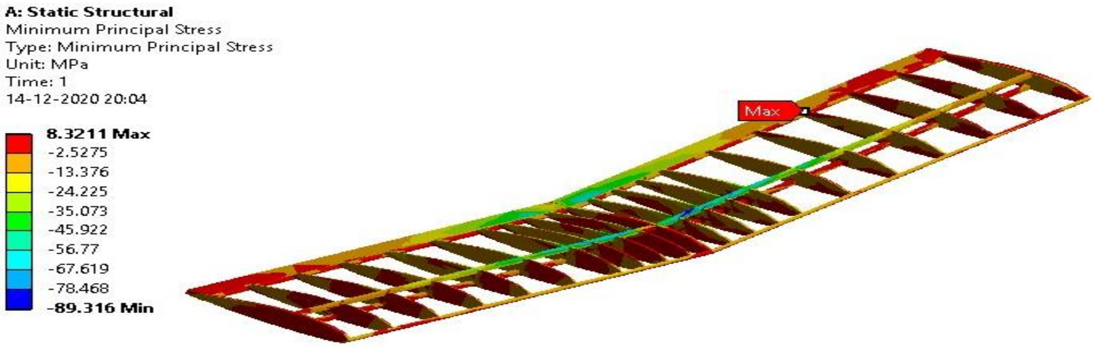

Figure 8: Minimum principal stress in wing at 100 m/s.

Minimum principal stress on the wing where maximum of 8.3211 Mpa and minimum stress of -89.316 Mpa.

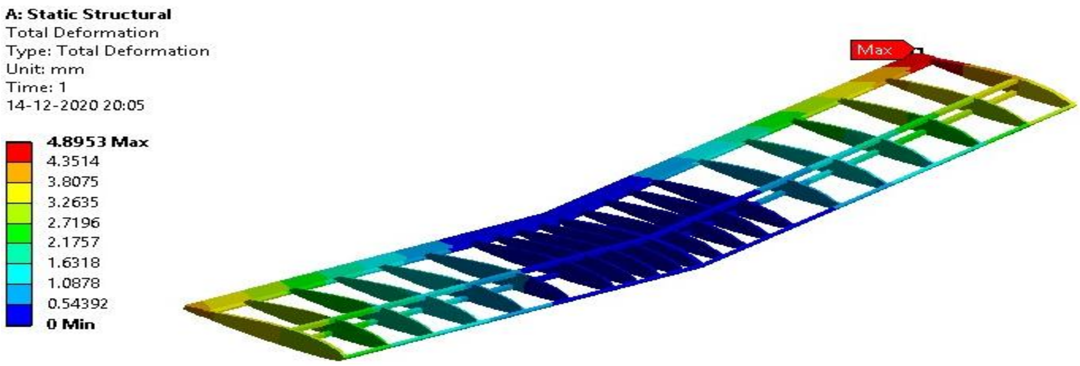

Figure 9: Total Deformation of the wing at 100 m/s.

The maximum deformation of wing is 4.89 mm which is indicated by red color in fringe pattern.

4.2 LINEAR STATIC ANALYSIS: Velocity 150 m/s

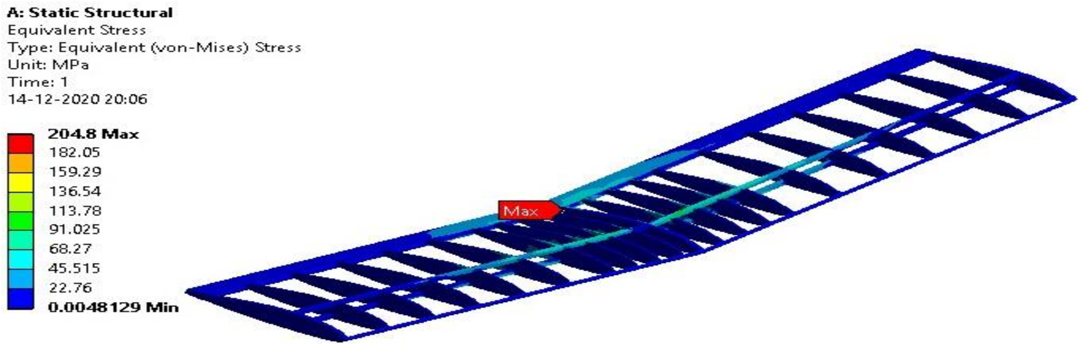

Figure 10: Equivalent or Von mises Stress on wing at 150 m/s.

Maximum von mises stress is 204.8 Mpa and minimum von mises is 0.0048129 Mpa. Yield stress of balsa wood is 320Mpa and maximum equivalent stress is less than yield strength of material, hence safer to design.

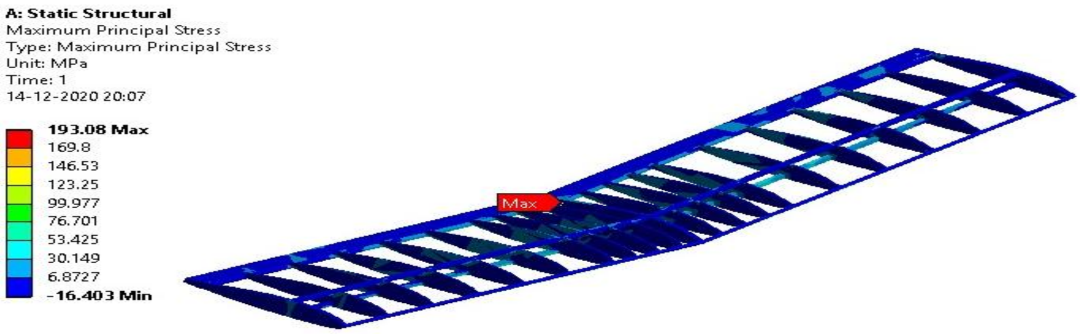

Figure 11: Maximum principal Stress on wing at 150 m/s

Maximum principal stress is 193.08 Mpa and minimum principal is -16.403 Mpa. Yield stress of balsa wood is 320Mpa and maximum principal stress is less than yield strength of material, hence safer to design.

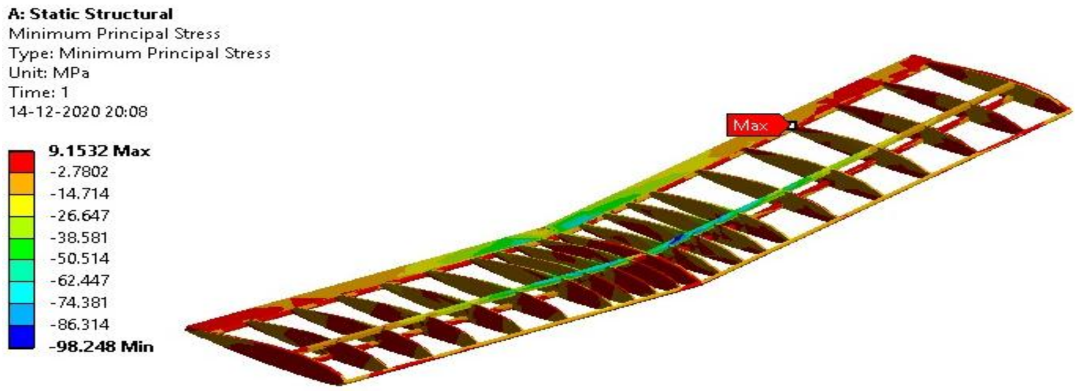

Figure 12: Minimum principal stress in wing at 150 m/s.

Minimum principal stress on the wing where maximum of 9.153 Mpa and minimum stress of -98.248 Mpa.

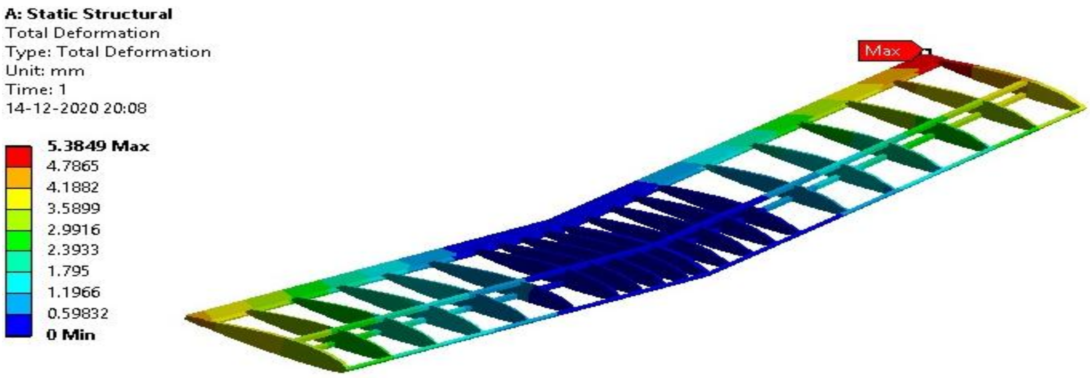

Figure 13: Total Deformation of the wing at 150 m/s.

The maximum deformation of wing is 5.38 mm which is indicated by red color in fringe pattern.

4.3 NON LINEAR STATIC ANALYSIS: Velocity 200 m/s

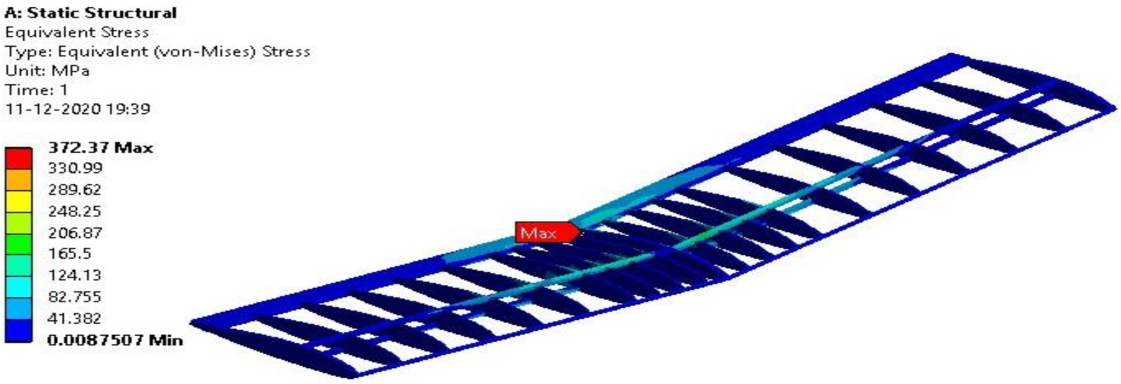

Figure 14: Equivalent or Von mises Stress on wing at 200 m/s.

Maximum von mises stress is 372.379 Mpa and minimum von mises is 0.0087507 Mpa. Yield stress of balsa wood is 320Mpa and maximum equivalent stress is more than yield strength of material and enters plastic region, hence not safer to design.

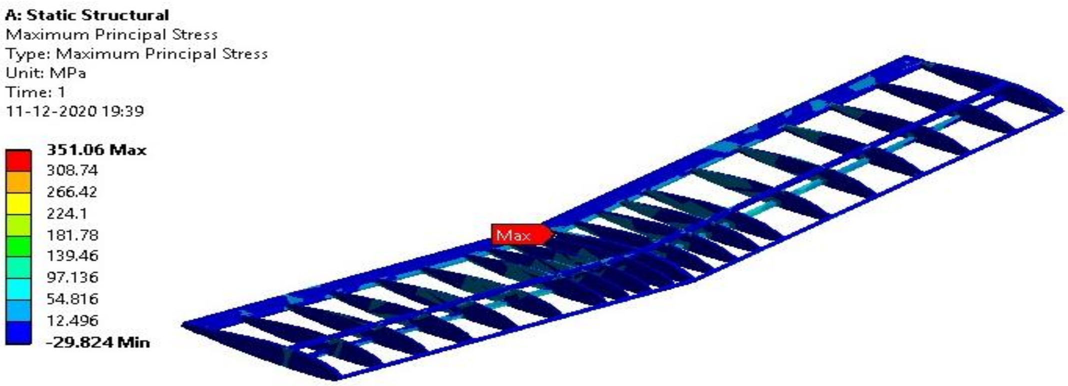

Figure 15: Maximum principal Stress on wing at 200 m/s

Maximum principal stress is 351.06 Mpa and minimum principal is -29.824 Mpa. Yield stress of balsa wood is 320Mpa and maximum principal stress is more than yield strength of material and enters plastic region, hence not safer to design.

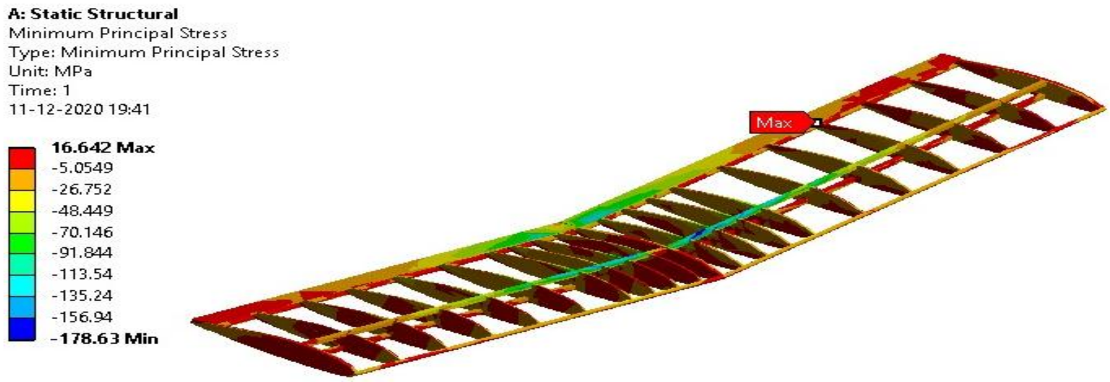

Figure 16: Minimum principal stress in wing at 200 m/s.

Minimum principal stress on the wing where maximum of 16.64 Mpa and minimum stress of -178.63Mpa.

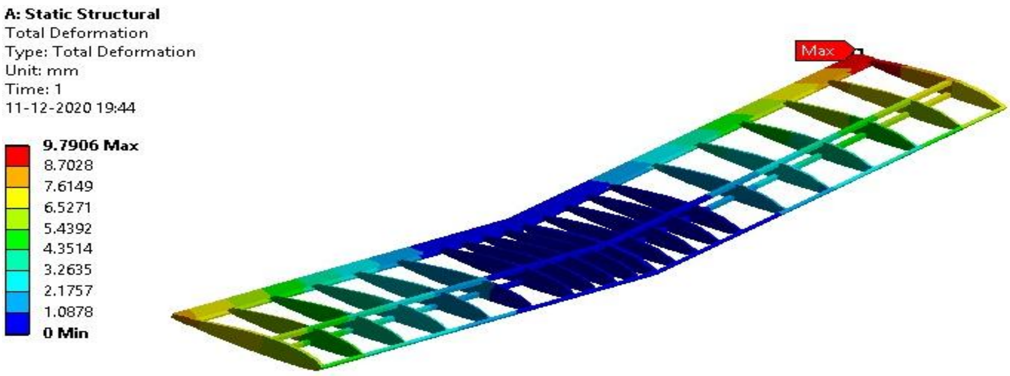

Figure 17: Total Deformation of the wing at 200 m/s.

The maximum deformation of wing is 9.79 mm which is indicated by red color in fringe pattern.

4.4 NON LINEAR STATIC ANALYSIS: Velocity 250 m/s

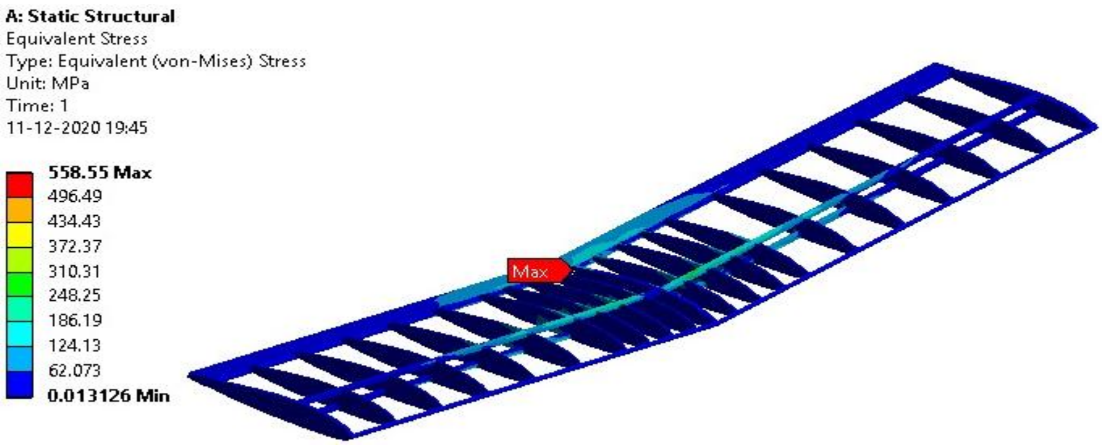

Figure 18: Equivalent or Von mises Stress on wing at 250 m/s.

Maximum von mises stress is 558.55 Mpa and minimum von mises is 0.013126Mpa. Yield stress of balsa wood is 320Mpa and maximum equivalent stress is more than yield strength of material and enters plastic region, hence not safer to design.

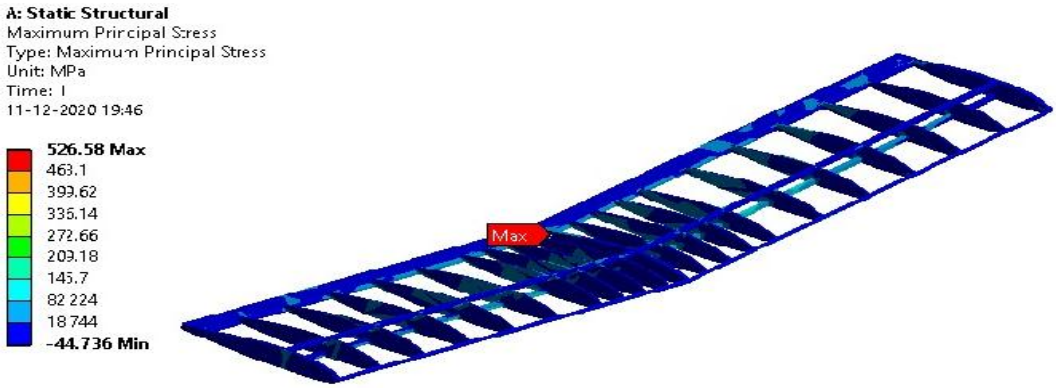

Figure 19: Maximum principal Stress on wing at 250 m/s

Maximum principal stress is 526.58 Mpa and minimum principal is -44.74 Mpa. Yield stress of balsa wood is 320Mpa and maximum principal stress is more than yield strength of material and enters plastic region, hence not safer to design.

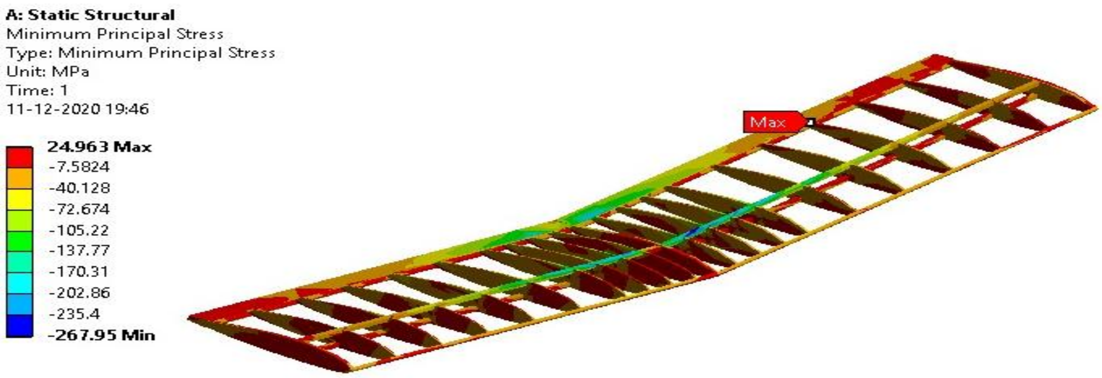

Figure 20: Minimum principal stress in wing at 250 m/s.

Minimum principal stress on the wing where maximum of 24.96 Mpa and minimum stress of -267.95 Mpa.

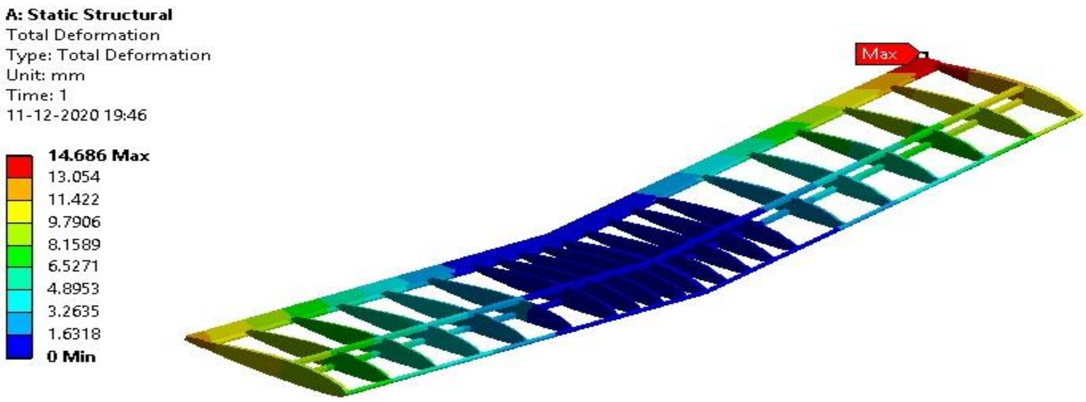

Figure 21: Total Deformation of the wing at 250 m/s.

The maximum deformation of wing is 14.68 mm which is indicated by red color in fringe pattern.

4.5 LIFE ESTIMATION: FATIGUE ANALYSIS

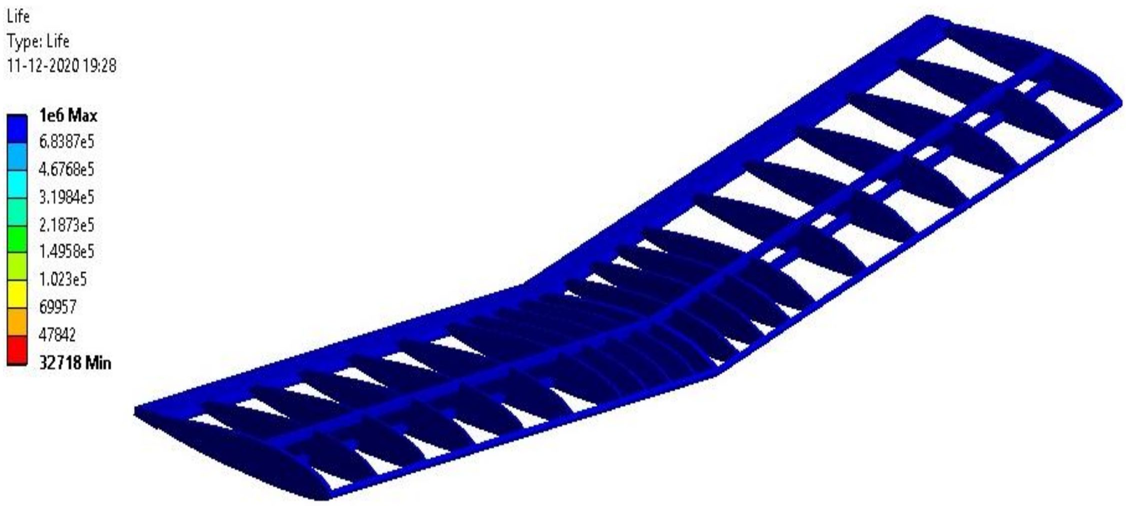

Figure 22: Fatigue analysis of wing.

The failure of aircraft wing occurs when it is subjected to cyclic loading i.e., rapidly changing stress will be acting on wing. When it is subjected to continuously loading and unloading stress, microscopic flaws will be generated over the surface of the structure, gradually as the crack will reach a critical stage, it will propagate rapidly which leads to the failure of the structure. The life estimation is carried out for safer design and it can sustain minimum of 32718 cycles and can maximum of ten lakh cycles.

Table 3: Results

Boundary Condition (Velocity in m/s)	Yield stress of Balsa wood (Mpa)	Equivalent (Von-Mises) Stress in (Mpa)	Maximum Principal Stress (MPa)	Minimum Principal Stress (MPa)	Total deformation (mm)
100	320	186.18	175.53	8.32	4.89
150		204.8	193.08	9.153	5.38
200		372.37	351.06	16.64	9.79
250		558.55	526.58	24.963	14.686

5. CONCLUSION

The project deals with Design, analysis and life estimation of radio controlled nitro aircraft. The 2D drawings were drafted and 3D model in solid edge. The total payload of aircraft is determined to be 1340gms. TSAGI airfoil is considered. Lift and coefficient of drag were found to be 0.6 and 0.45 respectively. Linear static and non linear static analysis is carried out on wing for different velocity i.e., from 100 m/s to 250 m/s. From all the study we can conclude that analysis which is done for 150 m/s boundary condition holds a safer design for balsa wood material. Life estimation of wing using fatigue life approach is observed that it can sustain minimum of 32718 cycles.

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