Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Department of Mechanical and Aeronautical Engineering
MLV 420 – Aeronautics 420

Project Report:

Radio-Controlled Aircraft

Chown, M	(16343982)
Davis, JL	(16026129)
dos Santos Rocha, DFT	(14389585)
Mpolokeng, YM	(16352158)
Mathebula, V	(15207367)
Pascal, I	(17055459)

17/11/2020

Table of Contents

Table of Figures

1. Introduction

1.1. Background

Annually, there is an Aerospace Challenge, which is a flight competition that takes place between universities. This competition involves the formation of groups of students to conceptualize, design, construct and fly radio-controlled model aircraft designed by the students to meet both the competition's requirements and the design requirements established by the group. This is to be achieved by employing the skills and knowledge obtained from the MLV 420 (Aeronautics) module, as well as the engineering curriculum, inadvertently. The key features of the competition are to see which aircraft, able to take-off using its own power, can transport the most amount of tennis balls around the course within a five-minute period. A 'low-power' motor is provided to each group; therefore success (or good performance of the aircraft) is strongly dependent on a sound aerodynamic design.

1.2. Problem Statement

An aircraft must be designed with the ability to compete in the Aerospace Challenge and comply with all the requirements of the competition. In addition, the aircraft must be able to carry a payload of tennis balls along the entire length of the course; from Base A to Base B, situated at a distance of 150 meters apart. The aircraft must also be maneuverable, therefore able to turn predictably and in a stable fashion as the aircraft will have to change its heading by 180 degrees twice each flight, during which it travels a minimum of 300 metres. It must also be able to land.

1.3. Project Objectives

To complete the design project, there were a series of objectives that needed to be met. These objectives pertain to different aspects of the project and that, when put together, resulted in a final design taking shape. Several aspects were considered, and the objectives were separated into two groups; the first group were the regulatory objectives (complying with regulations, i.e. the framework of the design), and the second were the design and manufacturing objectives. These objectives are briefly listed below.

The regulatory objectives set out are as follows:

- The aircraft must takeoff using its own power
- The aircraft model must utilize an unmodified E-flight Park 450 brushless electric motor
- The power must be supplied by a 3 cell Lithium-Polymer (Li-Po) battery
- The aircraft must be designed and constructed without the use of pre-existing aerodynamic, or other (i.e. fuselage), parts; must be an original design
- The aircraft must have a fixed-wing configuration and rely solely on the wings and empennage for the needed aerodynamic forces

The aircraft must comply with the South African Model Aircraft Association (SAMAA) regulations (which regulate the use of model aircraft in South Africa) (SAMAA 2012)

1.4. Design Requirements

The strategy of the group is to carry a larger payload each flight, although it will result in a slower flight speed. In other words, more tennis balls per flight, and less flights to succeed. Therefore, the aircraft designed is geared to having wings with a high lift coefficient, while attempting to mitigate large induced drag which will have the effect of reducing aerodynamic efficiency.

The design objectives are briefly listed below:

- The aircraft wings must have a high lift coefficient (design for high load and slower flight speed)
- The induced drag that results must be minimized
- The aircraft mass must be minimized—light-weight foam board ideal
- The aircraft must be visible at a 200-meter distance
- The design must lend itself to simple manufacturing techniques; no special equipment should be needed (should be able to be done at home)
- The aircraft must be longitudinally and laterally stable
- The aircraft must be controllable remotely

2. Literature Review

2.1. General RC Aircraft Design

Fixed-wing aircraft have been designed and built for over decades and there is quite a significant amount of experience in the design and construction of scale models. It has been proven that the design of scale model aircraft is generally similarly to the design of full-scale aircraft (Terwilliger et al. 2017). In fact, scale designs have been successfully created over the years, and at these smaller scales it is possible to build aircraft able to fly at low subsonic speeds. Since numerous possibilities exist with Remote-Controlled (RC) aircraft, the emphasis is currently placed on the manufacturing techniques as it pertains to cost reduction (Keane et al. 2017), as seen from recently published literature.

Keane et al. (2017) firmly state in their work that the design process of RC (small scale) aircraft heavily involves "synthesis", whereby the choice of power source, features, material selection and manufacturing techniques, to name a few, play a prominent role right at the onset. Keane et al. (2017) go on to say that the design of RC aircraft rarely starts on "blank canvas". This particular point made this literature appear even more relevant to this design project. In a similar fashion, the motor, aircraft configuration and battery pack had already been prescribed at the onset of the project.

As a result, the first step in the design is to create the preliminary design. This is often done in separate development groups; each group typically has a different design task—creating wing concepts, structural and fuselage concepts, and so on. This is done in isolation bearing the fixed parameters (motor, aircraft configuration, etc.) in mind during this process. Though these ideas and designs are preliminary, they are tested and developed further as the next step is to consolidate all the ideas in the detail design phase (Keane et al. 2017).

The next phase of the design process is to finalize the designs, specifically by finalizing the interface between the components, as well as considering the effects each component has with respect to the other components. After the interfaces and detail designs are finalized, then manufacturing processes can be finalized, then the aircraft may be constructed (Keane et al. 2017).

2.2. Airfoil and Wing Design

Further insight and the effect of various wing parameters on aircraft performance are discussed below. These parameters need to be considered during the design process.

2.2.1. Airfoil

There are three types of airfoils: symmetrical, asymmetrical, and unsymmetrical. In the context of the flight competition, where high lift is required, an asymmetrical (or under-cambered) airfoil is desired. Symmetrical airfoils are generally used for acrobatic aircraft. The disadvantage of using an under-cambered airfoil is that they are more difficult to manufacture.

During the preliminary design stage, it is general practice to choose an airfoil whose geometric and aerodynamic characteristics are available in aeronautical literature.

Experimentally obtained characteristics of airfoils are usually displayed in plots. Fig. (1) is an example of such plots. The features of these are briefly discussed.

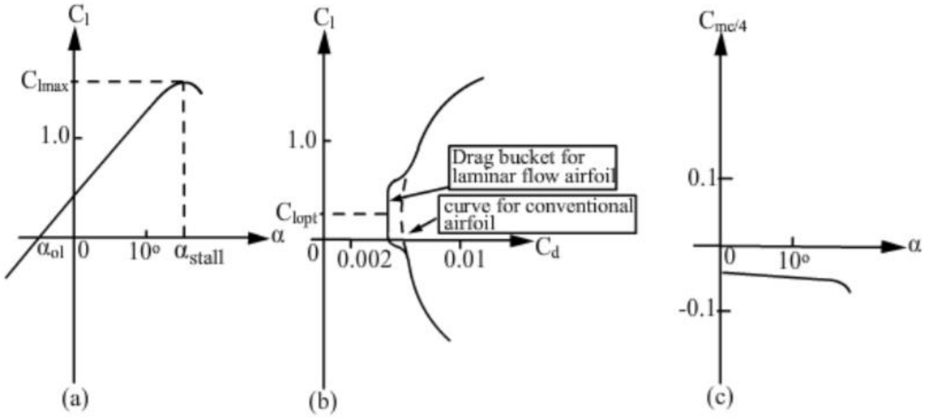


Figure 1: Airfoil aerodynamic characteristics

2.2.1.1. *Lift coefficient vs angle of attack*

The important features shown in this plot are the angle of zero lift, the lift curve slope, the maximum lift coefficient, and the angle of attack corresponding to the maximum lift coefficient.

The variation of the lift coefficient with angle of attack near the stall is called the stall pattern. A gradual pattern as shown in Fig. (1a) is desirable, so the pilot gets adequate warning regarding forthcoming loss of lift. Airfoils with a thickness ratio (t/c) between 6% and 10% generally display abrupt stall patterns, whereas those with a thickness ratio greater than 14% display a gradual stall pattern.

2.2.1.2. *Drag coefficient vs lift coefficient*

This curve has two important features, namely: the minimum drag coefficient ($C_{d,min}$) and the corresponding lift coefficient (C_{lopt}).

The minimum drag coefficient of low-drag airfoils extends over a range of lift coefficients. This feature is called the 'Drag bucket' and is also a characteristic feature of the airfoil.

2.2.1.3. *Pitching moment coefficient about quarter chord vs angle of attack*

The location of the aerodynamic centre (a.c.) and the moment about it can be determined using this curve.

2.2.2. Wing area

It has been established that a wing design that can carry a higher payload is preferred. An aircraft with a large wing area relative to its mass (i.e. low wing loading) has a lower stalling speed. Thus, an aircraft with lower wing loading will be able to take off and land at a lower speed or take off with a greater payload. The wing area, S, is calculated using Eq. (1) where C is the wing cube loading and W is the mass estimation. The wing cube loading (WCL) is a comparative value which can be used for grouping radio-controlled aircraft by similar flight characteristics. Thus, a WCL can be selected based on the type of aircraft to be designed.

$$S = \sqrt[1.5]{\frac{W}{C}} \tag{1}$$

2.2.3. Aspect ratio

The aspect ratio of a wing is the ratio of the wing's span to its mean chord. Trainer RC airplanes have a moderate aspect ratio (AR) in the range of 5 to 8, while gliders have high an AR in the range of 8 to 18. The Aspect ratio can be used to predict the aerodynamic efficiency of a wing since the lift-to-drag ratio increases with aspect ratio.

2.2.4. Wing twist

Wing twist is introduced to prevent tip stall. The two types of twist are geometric twist (washout and wash-in) and aerodynamic twist. Washout twist is where the wing has negative twist. This means that the root has a higher angle of incidence than the tip. For wash-in twist, the wing has positive twist. Common wing twist angles range from 0° to -5°. Aerodynamic twist is when different airfoil sections are used for the root and tip of the wing.

2.2.5. Taper ratio

An elliptical lift distribution over the wing is desired to minimize induced drag. This can be achieved using an elliptical wing, but that would be difficult to manufacture. A tapered wing, however, can still achieve an elliptical lift distribution but is easier to manufacture. Thus, using a tapered wing is a good compromise.

2.2.6. Sweep angle

Swept wings are optimized for high flight speeds since thy reduce drag at high speed but increase at low speed. Since the sweep angle (Λ) of a wing operating at speeds less than M=0.65 is zero, the use of a swept wing in this context would be unnecessary. Swept wings are also more difficult to manufacture.

2.2.7. Dihedral

Dihedral is the upward angle of an aircraft's wings. the Dihedral has a strong influence on dihedral effect. The dihedral effect is the roll moment produced in proportion to the amount of sideslip. It is a critical factor in the stability of an aircraft about the roll axis.

2.3. Propeller and Motor

Propellers are essentially rotating wings whose lift is harnessed as forward thrust (propulsion). Efficient propulsion of aircraft operating at the low to medium subsonic speed ranges is possible through the use of propellers. Other means of propulsion do exist, such as jet engines, however, not all are suited for small-scale aircraft and their respective flight conditions. The benefits of propellers are their reliability, low weight, and cost (all of which are compared relative to the only main alternative—the jet engine). After many years of aircraft design, it has been established that the best means of propulsion for small aircraft operating at low flight velocities is the propeller (Nicolai et al.

2000). Therefore, a propeller is likely the best choice for propulsion for the aircraft to be designed.

Having a propeller chosen as the means of propulsion is one step, however, there are different types of propellers that exist, and propeller choice depends on the aircraft flight conditions. This is so as the flight velocity and propeller RPM determine the effective angle of attack of each propeller blade, and therefore the thrust (Anderson 2011).

In general, if you have a high-speed propeller (with low angle of attack blades) operating at a low flight velocity, it will result in each blade seeing a low angle of attack. Therefore, the propeller will generate low thrust. Conversely, a low-speed propeller operating at a high flight velocity will have its blades at a large angle of attack relative to the flow perceived by each blade section, therefore the propeller will begin to stall (at its tips first in the worst case), or at the very least be inefficient (Anderson 2011).

Therefore, to suit the design requirements of the aircraft, an APC slow-flyer, low-speed propeller was selected for the aircraft. This choice was in keeping with the design of the aircraft for low speed and high lift. This propeller is designed for low angles of attack seen by each blade section and is therefore twisted such that each blade section has a large angle of attack to maximize thrust generation at the desired flight velocity.

Propellers receive power from motors. Therefore, it is necessary to also select an appropriate motor to work in tandem with the propeller. There are various types of motors available that are mainly Internal Combustion (IC), or brushless electric, motors for small-scale RC aircraft (Keane et al. 2017).

Electric motors offer greater variety as compared to IC motors as they come in a wide range of sizes and ratings (from a few Watts up to about 15kW); it is possible to obtain an electric motor with an output much lower than that of the smallest IC motor. Brushless electric motors also have the benefit of being more reliable as they consist of fewer parts than their IC counterparts. The drawback, however, is the endurance of electric motors as they are limited by the battery cells (Keane et al. 2017).

Nevertheless, electric motors are well suited for small RC aircraft and have been selected for use on the aircraft in the competition. The motor to be used is an E-flite Park 450 890kV brushless outrunner motor, which is lightweight (a mass of about 72g). However, owing to its size, it does not offer a large surplus of power which poses the design challenge (horizonhobby 2020).

2.4. On-board systems

2.4.1. Receiver

The receiver, as the name suggests, is responsible for receiving the signals sent by the transmitter (or controller). The receiver then proceeds to send the signals to the individual channels through Pulse Position Modulation (PPM) commands. Pulse Position Modulation is a form of signal modulation in which M message bits are encoded by transmitting a single pulse in one of 2^M possible time shifts. This is operation repeated every T seconds, resulting in a transmitted bit rate of M/T bits per second.

2.4.2. Electronic Speed Controller

The Electronic Speed Controller (ESC) is an electronic circuit that controls and regulates the speed of an electric motor. To achieve this, the ESC uses a signal from the throttle lever and varies the switching rate of a network of field effect transistors (FETs). The speed of the motor is changed by adjusting the switching frequency of the transistors.

Different types of speed controllers are required for brushed and brushless DC motors. A brushed motor can have its speed controlled by varying the voltage on its armature, whereas the speed of a brushless motor is varied by adjusting the timing of pulses of current delivered to the windings within the motor. ESC's also have a voltage output through the signal wire, which is often used to power the receiver.

2.4.3. Servomotors

A servomotor, usually abbreviated to "servo", is a rotary actuator that allows precise control of angular position, velocity, and acceleration. It generally consists of a motor coupled to a sensor which is used for position feedback. Servos are usually capable of 180° of rotation but only 90° are required for RC control.

In this context they take the commands given by the receiver and rotate to a set position. The servo will also hold its position if a force is applied to it. Servomotors are classified by a weight and torque rating, usually given in Kg.

2.4.4. Motors

The motor is the power plant of the plane. There are two main variants of motors, namely: brushed motors and brushless motors. Brushed motors have small brushes that switch the power through the coils, while brushless motors need an external controller. Brushless motors are preferred for RC aircraft because they are more efficient, can handle higher speeds and torques, and last longer since they do not have brushes that can wear out.

The two types of brushless DC motors are out-runner types and in-runner types. Outrunners have the permanent magnets on the outside, and their housing spins with the axle. In-runners have the permanent magnets on the inside and the housing does not rotate. Although outrunners have more torque than in-runners, they have less speed. They are usually used with larger propellers. This makes them suitable for this application. Motors generally have a KV rating which means rotations per minute per volt. Motor with lower KV ratings have more torque but less speed.

2.4.5. Battery

The two most common battery types for RC applications are NiMH or NiCd and Lithium polymer batteries. A lithium polymer (LiPo) battery is a rechargeable battery that makes use of a polymer electrolyte instead of a liquid electrolyte. They provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, such as in RC aircraft. NiMH (Nickel metal hydride) and NiCd (Nickel-Cadmium) batteries are heavier than LiPo batteries and are outdated. Although, Benefits of using them are that they are more affordable and less sensitive to shock, and vibration.

Batteries have several different ratings. The mAh (milliamp hour) rating is the capacity of the battery. For example, a 1000mAh battery can supply one amp (or 1000 mA) for one hour. The S and P ratings represent for number of Series cells and number of parallel cells in the battery. the number of cells in series determines battery voltage, while the number of parallel cells determines capacity of the battery. Finally, The C rating communicates the amount of current the battery can provide.

3. Design

3.1. Design Parameters

Below are the initial design parameters:

Airfoil	NACA 6412
Wing area (S)	0.39
Wing span (b)	1.5
Root chord	0.3
Tip chord	0.225
Taper ratio	0.75
Aspect ratio	5.77
Sweep	0
Twist	4
Volume tail ratio	0.523

3.2. Structural Design and Manufacturing

3.2.1. Material Selection

3.2.1.1. Wing and Tail

The selection of material for the wing and tail components of the RC aircraft was highly important as a reliable material had to be selected for the components that would experience the highest loading and stress values. Factors such as structural strength, weight, ease of manufacturing, cost and availability were taken into consideration in the selection.

For the wing and tail, two potential materials were considered: Balsa wood and polystyrene. Both materials lightweight and are known to be reliable in terms of strength. But with these advantages, both materials differ in the other factors that were considered in the selection process.

3.2.1.2. Polystyrene Foam

For the case polystyrene, it is denser compared to balsa wood. Incorporating this material in the wing design would allow for a solid wing design. This feature would fare well with wing loads as the loads would be distributed more evenly. The polystyrene wing could also allow for a hollow design as well. This would assist in decreasing the weight of the wing and additionally, freeing up space in the aircraft. This space can be filled with additional electronic and control system required to assist the aircraft during flight.

With the above advantages that polystyrene offers, polystyrene known to be difficult to manufacture as complex processes are required to produce a full wing and tail design. A more complex manufacturing process would make it more difficult to accurately construct the airfoil shape for the wing. This would also add to the overall manufacturing time of the aircraft, thus limiting the time needed to run important simulations and manufacturing of other aircraft components. This factor also doesn’t allow for a redundant wing design to be readily available in case the primary wing design suffers structural damage.

3.2.1.3. Balsa Wood

In terms of weight, balsa wood is lighter compared to polystyrene. This would assist in decreasing the overall weight of the RC aircraft as a whole.

Balsa wood also readily available and easy to manufacturing, allowing for easier correction during manufacturing resulting in higher accuracy of airfoil shape along the wing.

In most cases, balsa wood is produced as thin planks that range in thickness. This gives designers and manufactures variation in which the wing can be design and manufactured. Most wing designs follow a rib-spar layout, where the ribs are shaped in the selected airfoil and can be altered in terms of airfoil thickness, camber and chord length. With the lightweight nature of balsa wood, internal space is increased and overall weight f the wing is decreased. This allows for more space for electronic systems to placed ideally. The additional space and decreased weight provide a chance for designers to adjust the location of the electronic components to compensate for the centre of gravity location.

With balsa wood allowing for a lightweight design, this makes the wing susceptible to damage. This can be countered by covering the wing structure with thermoplastic that can be heated and moulded to the shape of the wing, thus protecting the inner wing structure and the components in the wing.

3.2.1.4. Selection

In the best interest of the project and taking into account the above factor stated, balsa wood is this best option due to its ease of manufacturing and lightweight properties.

3.2.1.5. Fuselage

For the fuselage, strong and lightweight material is required as the bending moments and external forces experienced during flight and landings needs to be managed.

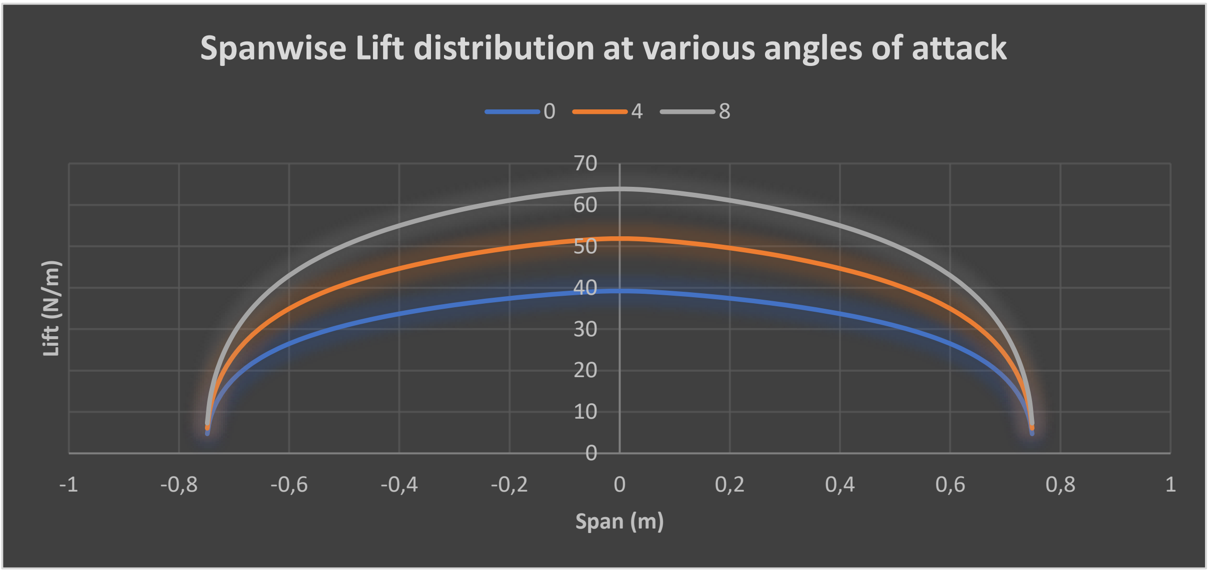
A single steel rod will be used as the main fuselage. This is ideal as minimal manufacturing is required. A single rod layout also allows for a solid structural connection between the various components of the RC aircraft.

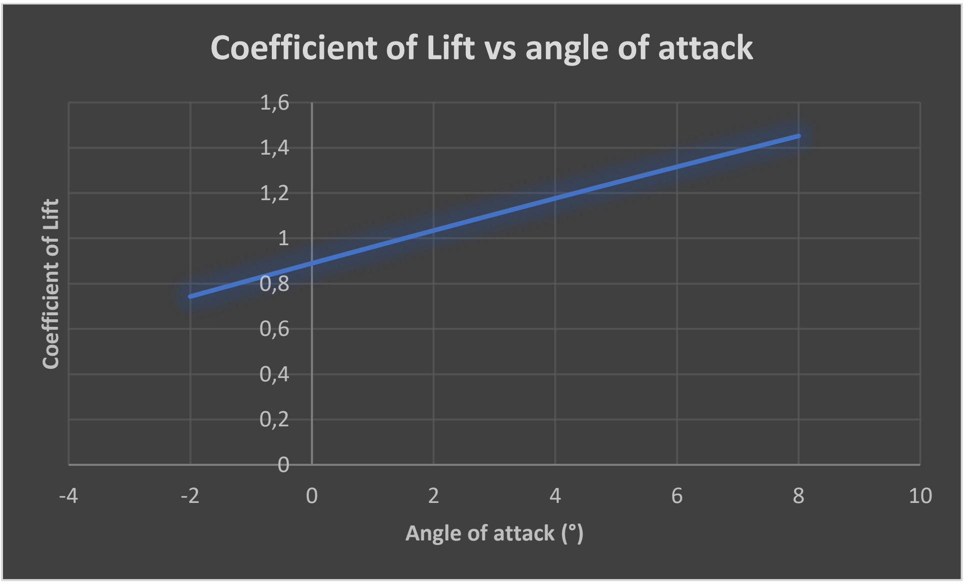
3.2.2. Flight Performance and Simulations

3.2.2.1. Simulation Calculations

3.2.2.1.1. Coefficient of lift calculations

The performance of the wing discussed in section 2.1 was analyzed in XFLR. The spanwise distribution of coefficient of lift at varying angles of attack and the graph of coefficient of lift vs angle of attack are shown below:



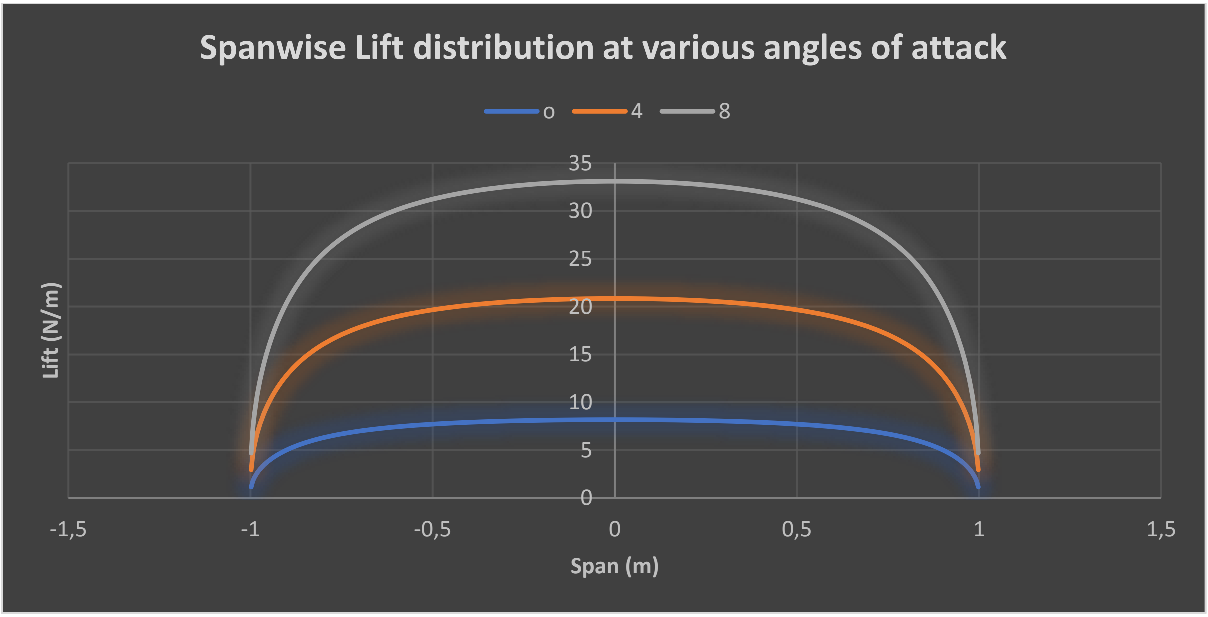


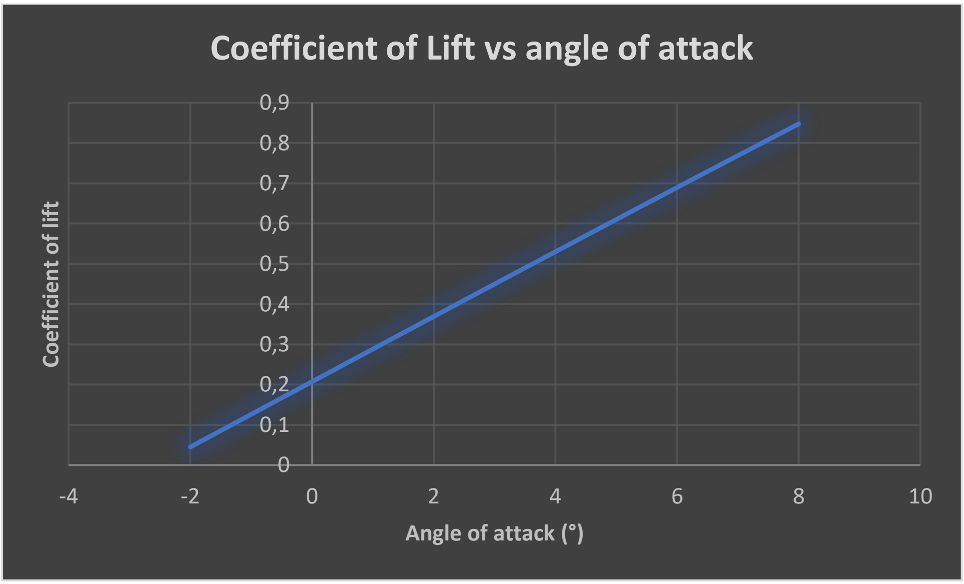
As can be seen from these graphs, the first iteration design of the wing was would've sufficed for the task as it produces high lift coefficients and has a near elliptical lift distribution.

However, the manufacturing process of this wing was deemed as being too difficult. Therefore, a rectangular wing was manufactured with the following parameters

Airfoil	Eppler e598
Wing area (S)	0.5
Wing span (b)	2
Root chord	0.25
Tip chord	0.25
Taper ratio	1
Aspect ratio	8
Sweep	0
Twist	4
Volume tail ratio	0.397

The spanwise lift distribution and graph of coefficient of lift vs angle of attack is given for the new wing





The wing produces less lift than the original wing however, this wing has the advantage of being easy to manufacture.

3.2.2.2. *Stability Analysis*

Using the Original parameters specified in section 2.1, a stability analysis was performed for the plane.

3.2.2.2.1. Tail design

The equation of tail volume ratio is given as:

$$\boldsymbol{V_H = \frac{l_t S_t}{cS}}$$

Where l_t is the distance from the centre of gravity to the centre of gravity and S_t is the area of the tail. For the RC aircraft a tail volume ratio >0.4 was desired. This is because a good tail volume ratio results in the plane being able to achieve a good pitching angle and longitudinal static stability. During the manufacturing of the plane, it was discovered that the rod on which the tail would be fitted to had fixed l_t to being 670 mm. This meant that the tail design was based purely on S_t. The designed of the tail was made with the following design criteria:

- The tail volume ratio must be equal to or larger than 0.4.
- The span of the tail must not exceed 1/3 of wing span
- Plane must be able to achieve longitudinal static stability at positive angle of attack.

This resulted in the tail design with the following elevator parameters:

Horizontal stabiliser:

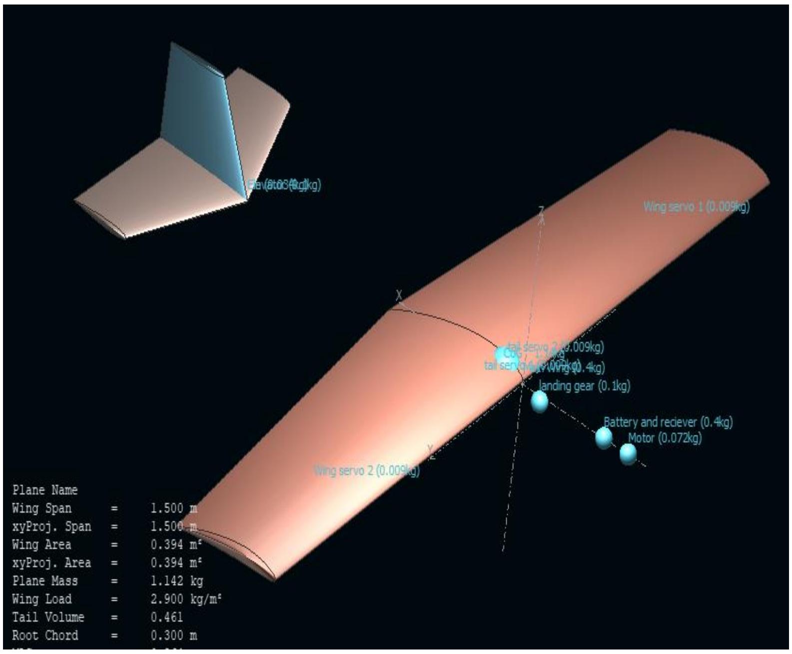
- Airfoil: NACA 0012
- Span: 0.5m
- Root chord: 0.2m
- Tip chord: 0.12m
- Leading edge taper ratio: 0.6
- Area=0.08 m^2
- Elevator flap is 25% of the horizontal stabilizer
- Tail volume ratio: 0.523
- With a tail angle setting of -3°

Vertical stabiliser

- Airfoil: NACA 0012
- Span: 0.17m
- Root chord: 0.2m
- Tip chord: 0.12m

- Leading edge taper ratio: 0.6
- Area=0.0272 m^2
- Rudder flap is 25% of the horizontal stabilizer
- Vertical tail volume ratio: 0.08

The stability analysis of the plane with the tail is then performed. The analysis was completed using XFLR 5. The figure below shows the plane being analysed.



The plane had the following characteristics:

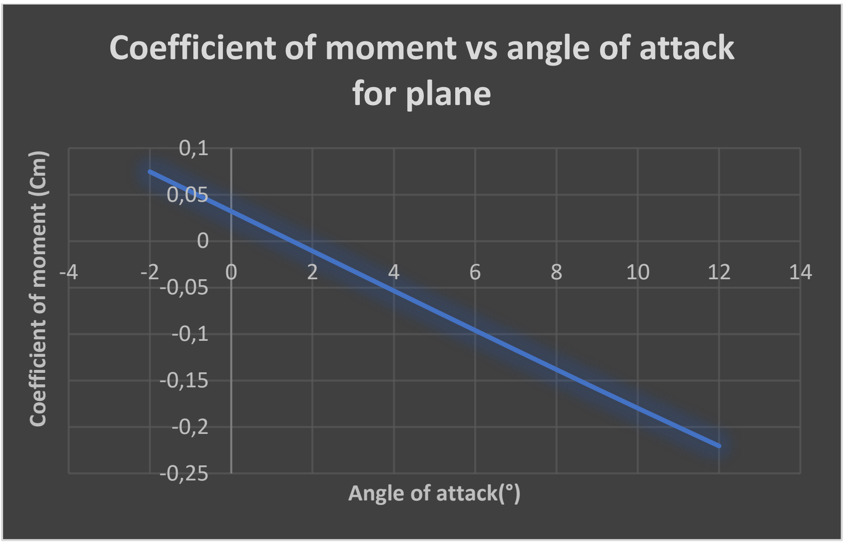
- Centre of gravity: 0.045m from leading edge.
- Weight of 1.154kg

To calculate the Coefficient of moment of an entire aircraft the following equation is used (ignoring downwash effects in this case):

$$\boldsymbol{C_{m,cg} = C_{m,ac} + C_{L,ac}\left[h - h_{ac} - V_h\left[\frac{a_t}{a_{wb}}\right]\right] + V_H(i_t)}$$

However in this design, it is important to note that the coefficient of moment values were obtained using XFLR 5

An inviscid analysis was performed for the RC aircraft and the figure below shows the results of the analysis



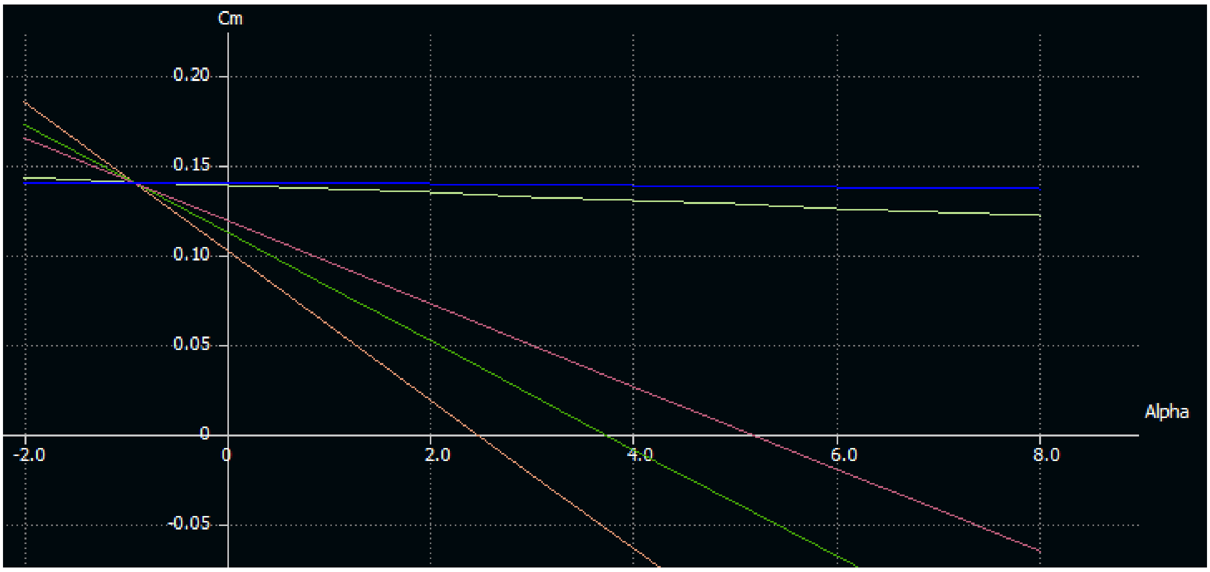
The plane had achieved longitudinal static stability and had a trim angle of approximately 1.6°.

Neutral point and static margin

The neutral point can be seen as the aerodynamic centre of the aircraft and is calculated using the following equation:

$$h_n = h_{ac} + V_H \left[\frac{a_t}{awb}\right]$$

For this design, the neutral point was determined using XFLR5. This is done by iteratively moving the centre of gravity back until the graph of the coefficient of moment vs angle of attack remains at a constant value for the angle of attack an example of this is shown in the figure below



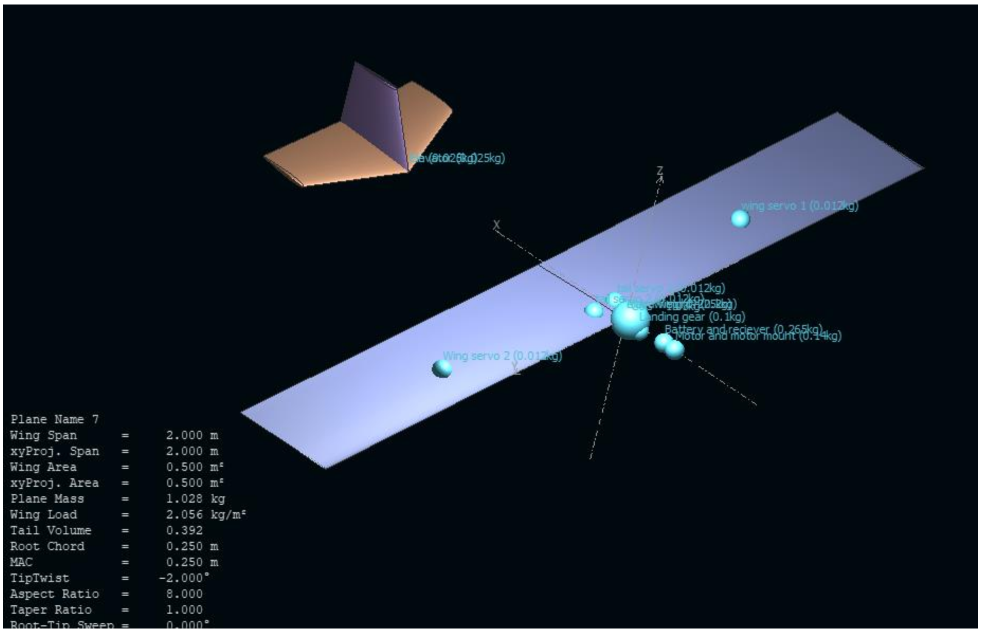
For the this plane the neutral point (in metres) of the aircraft was determined to be approximately 0.116m from the leading edge.

The static margin is the distance from the centre of gravity to the neutral point. It can be seen as a measure of how far the centre of gravity can be moved back before the plane is no longer able to achieve longitudinal static stability. It is given by the following equation:

$$Static\ margin = c(h_n - h) = x_n - x_{cg} = 0.116 - (-0.045) = 0.161m$$

A stability analysis of the plane used in the flight test was also performed. For this plane the tail was kept the same. However, the new configuration was resulted in the centre of gravity of the aircraft being pushed back. This resulted in a l_t of 0.621. For the new wing configuration, the tail volume ratio is calculated as 0.397 which is deemed close enough to the desired tail volume ratio.

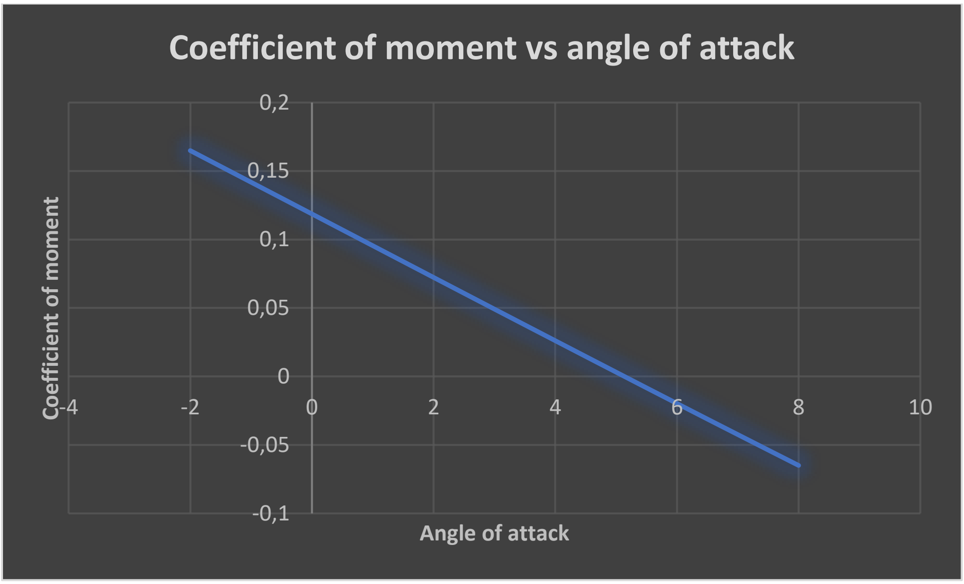
The stability analysis is performed for the plane with the new configuration as shown in the figure below:



The plane had the following characteristics:

- Weight: 1.028kg
- Centre of gravity: 0.04m behind leading edge.

The coefficient of moment vs angle of attack for the plane is shown in the figure below



From the graph it is evident that the aircraft has achieved longitudinal static stability and has a trim angle of approximately 5.146°.

To calculate the neutral point and static margin, the same process for the original plane is followed. It is determined that the neutral point of the aircraft is approximately 0.105m from the leading edge of the wing. The static margin of the aircraft is calculated to be 0.101m

This plane has a higher trim angle than the original design and a lower static margin. However, the aircraft is still able to achieve longitudinal static stability and has a large enough static margin for it to still have static stability when the plane must carry the tennis balls.

3.2.3. Manufacturing Process

3.2.3.1. Landing gear and fuselage

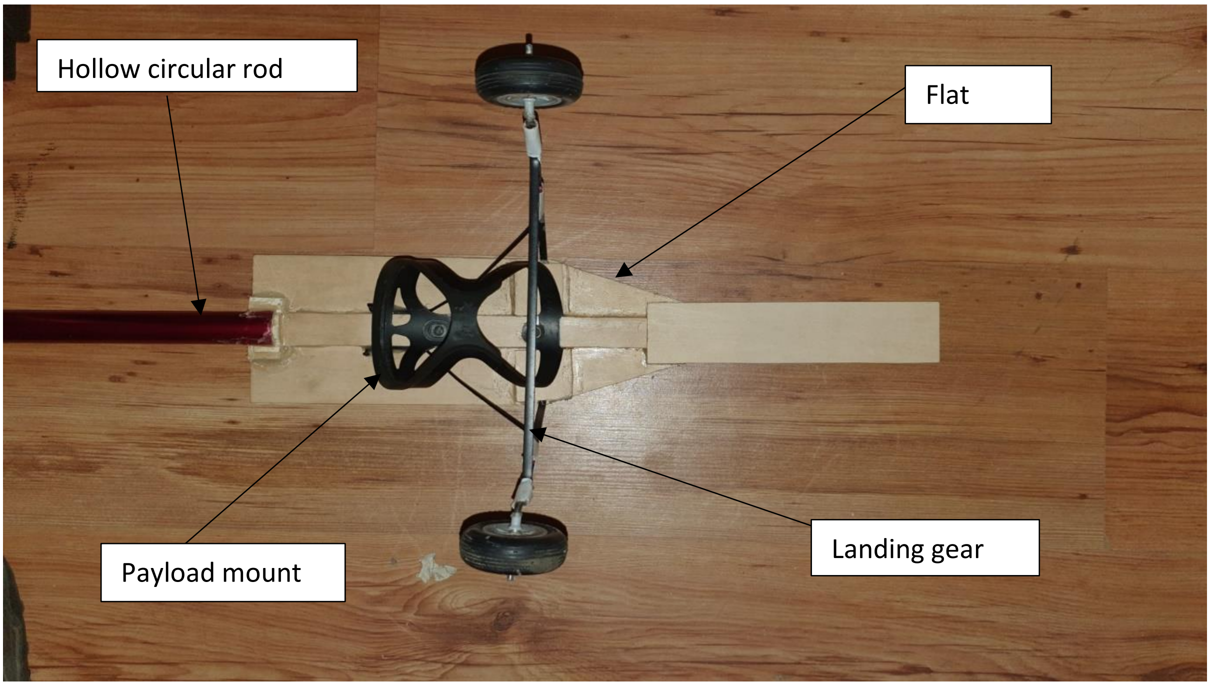


Figure 2:Bottom view of assembled landing gear and fuselage

Flat Base:

The flat base was manufactured by cutting a sheet of plywood into the desired shape. An extra layer of plywood was added to the places where holes were drilled for the purpose of attaching the payload mount and the wing

Hollow circular rod:

An aluminium circular rod was purchased with a pre-existing slit through the diameter of the rod. This slit was used to connect the flat base to the rod. The flat base was slid into the slit and glue was applied to strengthen and secure the connection

Landing Gear

the landing gear was manufactured from bicycle spokes. The spokes were bent into the desired shapes then joined together by tape

Payload mount

The payload mount is a purchased harness that was bolted to the flat base at two points

Wing

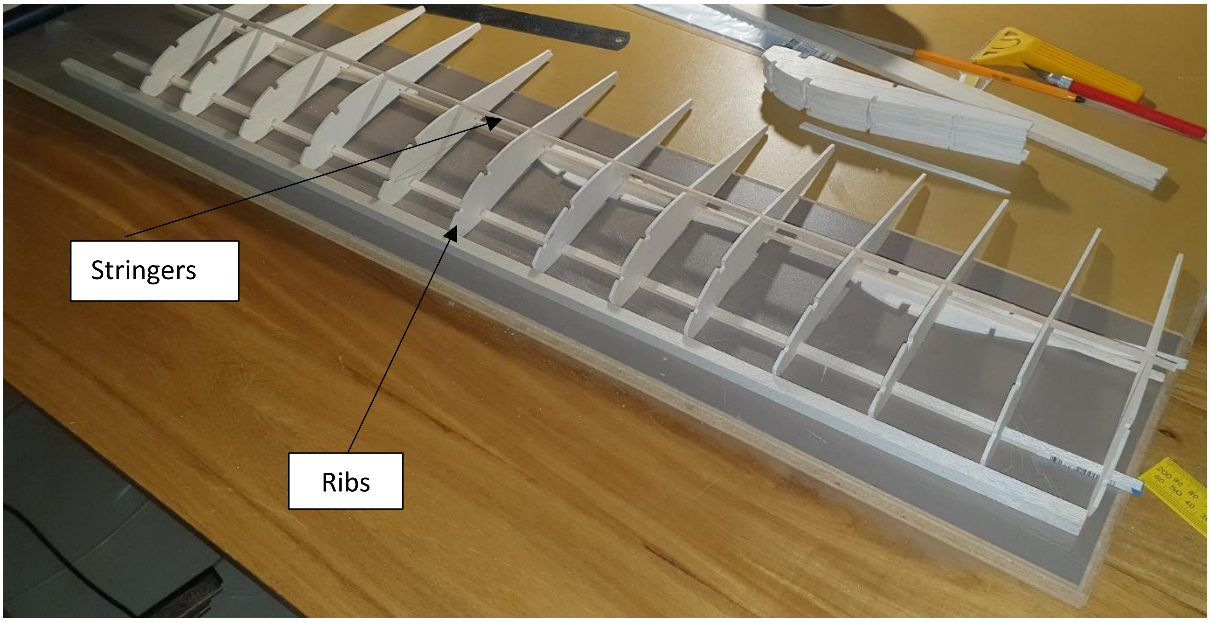


Figure 3: Internal wing structure

Ribs:

In total 26 ribs were manufactured and equally spaced across the wingspan. The airfoil modified with groves for the stringers was traced on to a sheet of balsa wood then carefully cut out using a knife, this was repeated for all the ribs. Finally, the ribs were stacked together, a knife and sandpaper were used to ensure uniformity across all the ribs

Stringers

The stringers were also cut from a sheet of balsa wood to fit the grooves cut out in the ribs; glue was used to join the stringers to the ribs. A total of five stringers were joined to each rib; three on the top surface and two on the bottom surface

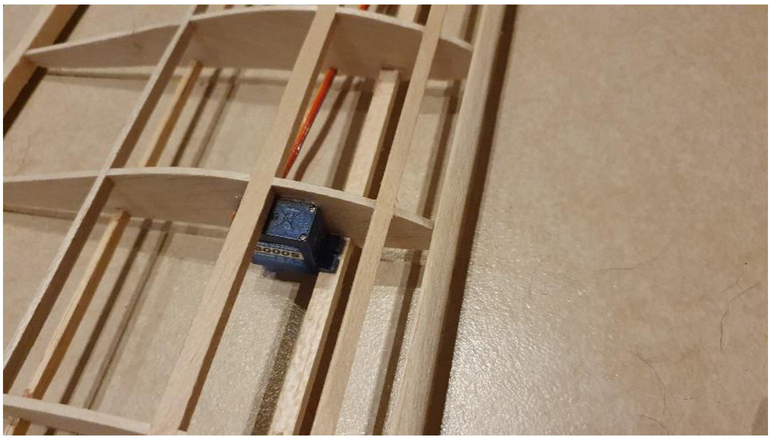


Figure 4: Aileron Servos

The aileron servos were stuck to both the ribs and stringers in a section of the wing closest to the centre respective aileron. The ailerons were attached to the wing through two hinge joints for each aileron; the hinge joints were stuck on using glue and also typed using fibre type.

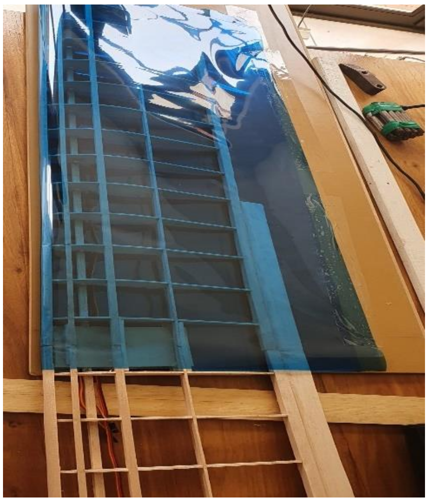


Figure 5: WIng with plastic surface

The wing was then completed with a plastic surface stuck on as an outer cover to the wing

Empennage

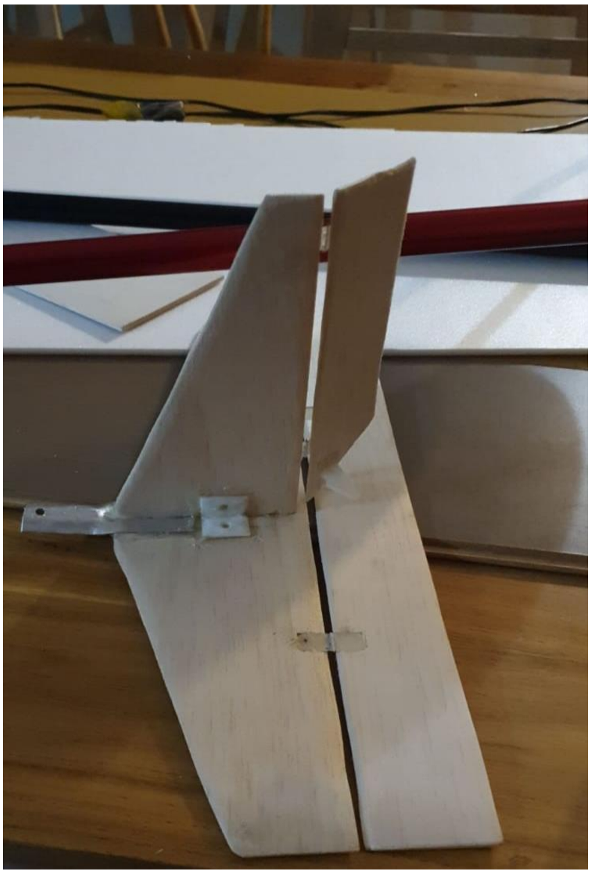


Figure 6: Tail section

The vertical and horizontal tails were cut out and shaped using a knife and sandpaper they were then joined together using glue and a corner joint. A metal plate with a screwed hole was stuck in-between the vertical and horizontal tail as a mounting plate for the empennage and aluminum rod. Both the rudder and elevator were joined to the empennage using two hinge joints each

4. Test Flight Summary

Figure 7: Image of test flight in progress

Two test flights were conducted on 07/11/20 at the Corsair Airfield

Test Flight 1:

The objectives of the first flight were to obtain:

- If controlled flight could be achieved with the prototype
- If the hinges connected to the control surface were robust enough to perform basic manoeuvres without failure
- If the joint between the circular rod and flat base would be able to withstand the stresses associated with the bending moments during landing

Test Flight 2:

The second test included a payload of a go pro and release pod loaded with an empty can. During the test, the prototype was pitched up and the can was dropped. The objectives of the second test were:

- To see how the prototype would perform with a payload especially during take-off and landing
- To see how sensitive the longitudinal static stability was to a slight shift in CG mid-flight

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