Project Report

ORNITHOPTER (Flying Wing Mechanism)

Submitted in partial fulfillment of the award of the

Bachelor's of Science

In

Aeronautics(Mechanical)

By

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BONAFIDE CERTIFICATE

This is to certify that project report titled **“ORNITHROPTER (FLYING WINGS MECHANISM)"**, is a bonafide record of work carried out by **Mr. PRATHMESH EKNATH SHINDE** during the final semester from **February 2021** to **May 2021** under my guidance, in partial fulfillment of the requirements for the award of **Bachelor of Science** in **Aeronautics** (**Mechanical).**

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Prof. Dr. M Suresh Kumar | **Mr. Harshal Birari**

Principal | **Project Guide**

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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DIAGRAM

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Fig no 1 Ornithopter

ABSTRACT

In recent years the subject of flying vehicles propelled by flapping wings, also known as ornithopters, has been an area of interest because of its application to micro aerial vehicles (MAVs). These miniature vehicles seek to mimic small birds and insects to achieve never before seen agility in flight. In order to better study the control of flapping wing flight we have developed a large scale ornithopter called the Phoenix. This report focuses on the project objective to design a power unit for a basic ornithopter. The primary consideration during the design phase of the ornithopter was to minimize weight to enable sustained flight. The power unit consists of small electrical and mechanical components that all contribute to the flapping motion of the ornithopter.

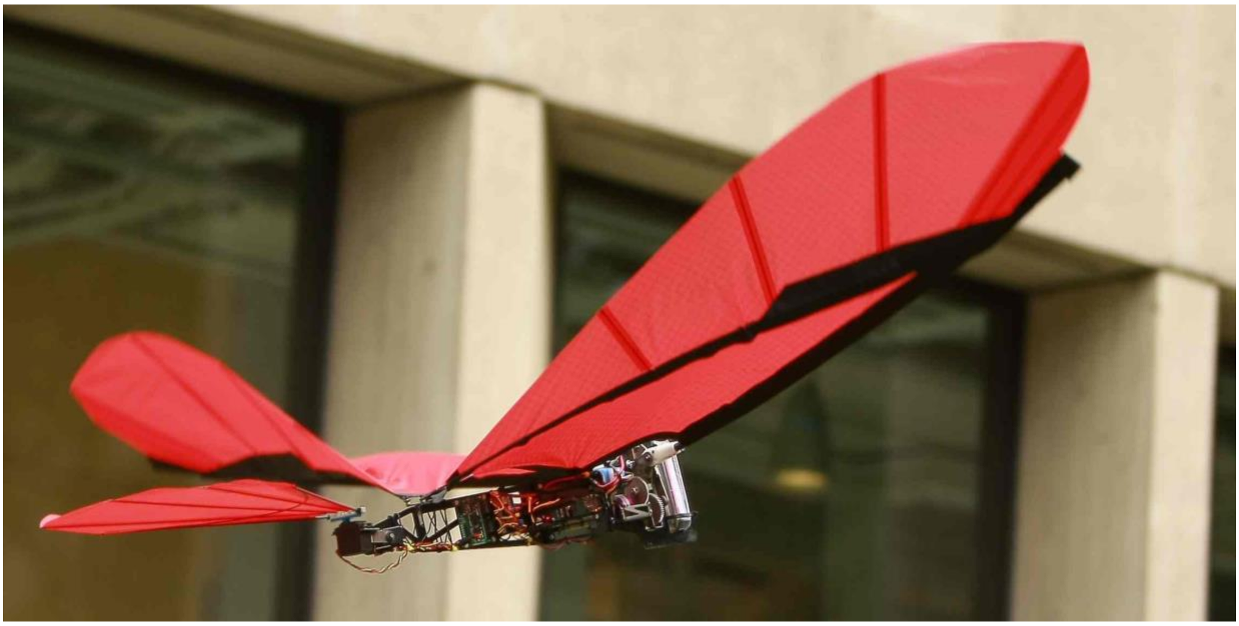

Fig. 2 **Flapping Wings Ornithopter**

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1. Introduction

The focus of this report is to detail how the design process was undertaken to reach the completion of making a physical model ornithopter. Despite the lack of development allocated to ornithopters compared to their fixed and rotary wing counterparts there is still a demand for flapping wing vehicles. Modern technologies and materials are gradually filtering their way down to the UAV branch of engineering thus re-invigorating experimentation with ornithopters. The predominant challenge in designing mechanical flapping wing air vehicles is emulating the natural muscular movement of birds and insects, designs must also consider the sensitivity of weight implications on such vehicles, as their stability is greatly decreased when subjected to uneven distributions of weight and forces. A primary asset of the ornithopter is the ability to sustain hovering flight like helicopters and hummingbirds whilst also being capable of gliding like aeroplanes and albatrosses. Perhaps the most exciting and rapidly growing aspect of ornithopters is their use in military and environmental applications where innovative uses include recognisant missions and bird population control respectively.

Project Aims

- To design an electrically powered ornithopter
- Capable of self-sustained flight
- Develop concept sketches into a physical model through a design process
- Identify appropriate components

Project Objectives

- Investigate all forms of the components possibly required
- Investigate the characteristics of ornithopter UAVs

2. Subject Review

Introduction

The following literature reviews outline the various sources of information gathered during the research phase at the beginning of the project, The research focused on, but was not limited to, tie fundamental aspects of omithopter mechanics and the basic principles of electric motors, servos, speed controllers, batteries and radio transmitters/receivers. The relatively niche market for ornithopters consequently means that information and documentation is confined to the internet as opposed to being published in books or journals. having said that, it was possible to combine information from a variety Of wider sources, not obviously associated with ornithopters, to gain a substantial understanding of the flapping flight discipline.
Initial research swiftly ruled out two options for sustaining power to an omithopter during flight, the first being an elastic band and the second being a combustion engine. The elastic band method relies on the potential energy stored in the winding of the band; once the whole of this energy has been exerted the Ornithopter can no Imger sustain flight. Alternatively the combustion engine should be capable of sustaining flight for a substantial period of time, however the ancillary parts required for the engine to function, such as a fuel tank, would violate weight restriction imposed by wing size and flapping frequency. Therefore the electrical DC motor. drawing power from a is the most suitable application for sustaining an Ornithopter in flight due to its lightweight characteristics and reliability.

Literature Review

Origin of the Ornithopter

Leonardo da Vinci and Otto Lilienthal are two of the most notable names associated with the primitive stages of human developed and human powered flapping wing flight. Ornithopters can be traced back even further than da Vinci and Lilienthal to Greek mythology where Homer's Daedalus constructed bird like wings from goose feathers and beeswax to escape imprisonment enforced by King Minos, the word 'ornithopter' actually derives from Greek where 'ornithos' translates to 'bird' and 'pteron' to wing' '', however da Vinci and Lilienthal were pioneers of progressing ornithopters into useful vehicles by studying the natural flight of birds and wing shapes. Consequently for orithopters the development of aeroplanes and helicopters gradually diminished the interest, and indeed requirement, for flapping wing flight. Yet, as the development of aircraft in use today begins to peak and environmental awareness grows ever more poignant interest in flapping wing flight has been re-kindled.

Flapping Wing Flight

Similarly to avian vertebrates, ornithopters can only produce the thrust required to fly through the flapping of wings, a unique motion that does without the requirement of a propeller or rotating wing installed on more traditional aircraft. The complexity of bird wings have occupied scientists and engineers for decades; the shape, size, angle of attack, flap frequency, layering of feathers and muscular construction of a bird's wing have been the subject of numerous studies.

Flapping Wing Science

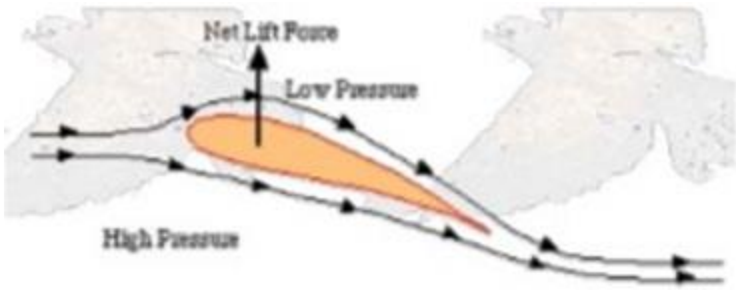

Figure 3 – Bird Wing Aerofoil [2]

Much like an aeroplanes aerofoil a bird's wing creates high-pressure regions around the lower surface and low-pressure regions along the upper surface thus allowing the bird to glide . In order to gain height the bird increases the flapping frequency of its wings, which forces larger deflections of air downwards resulting in the reactive force of lift.

The complex nature of a bird's wing occurs during the transition from a downstroke, to produce lift, to an up-stroke, where the cycle restarts. A common misconception is that the up-stroke

should produce a force similar to that of the down-stroke, thus equalling the forces. YouTube video maker Smarter EveryDay uses slow motionfilm to illustrate how bird wings function and do not conform to the misconceptions. He explains that during the upstroke feathers separate to allow air to flow through the wing, additionally the bird is capable of altering the angle of their wing to form the most streamline and aerodynamically efficient shape, both of these actions therefore enable the bird to 'provide downward thrust on a backward stroke 131. Current technology does not have the capability to replicate birds' wings in such delicate detail; instead ornithopters are resigned to mirroring bird wing shapes, sizes and flapping frequencies. The forces acting on a flapping wing can be quantified and calculated when using a simpler aerofoil as opposed to attempting to replicate the complicated natural mechanics of a real avian wing, for example, the extensive research that has already been conducted on aeroplane aerofoils can be implemented for the theoretical reckoning of flapping wing dynamics.

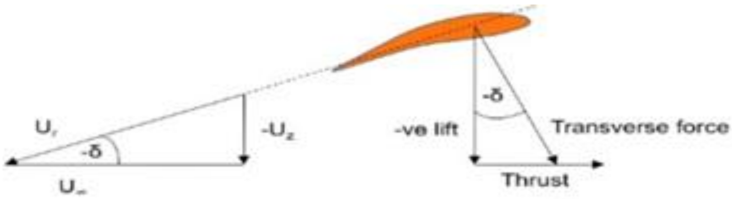

Figure 4 – Upstroke with negative lift [4]

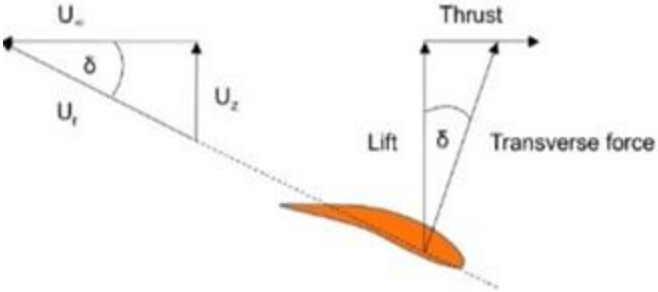

Figure 5 – Downstroke [4]

Figures 2 and 3 illustrate how the thrust of a flapping wing can be related to vectors of resultant forces where U. is the airflow due to forward motion, Uz is the airflow due to the flapping motion and Ur is the relative airflow. demonstrates in further detail how the downstoke of a birds' wing produces lift and thrust in the same movement. it becomes apparent that the aerodynamic force (K) is almost perpendicular to the track of the birds' wing, furthermore the downstroke generates lift (L) and thrust (T), this concept has also been explored by Henk Tennekes who concluded that 'the thrust to lift ratio is equal to the ratio of the downward speed of the wing and the forward speed of the bird (w/V)' Ha). As well as identifying speed and force vectors for a flapping wing it is also possible to distinguish physical deformations that are imposed on the wing during flight. In particular, bending and twisting forces can be detrimental to any wing, especially man-made ones that are constructed from material that eventually fatigues and fails. The flapping motion make the wing susceptible to bending forces at the root where the power of the motor is being transferred and converted to thrust. In addition to the fore mentioned forces, vibration can also cause distress to an ornithopter in the shape of a force that will gradually lessen the rigidity of the structure. Vibration forces can form from asymmetric wing flapping, where the wings are not flapping in sync (symmetrically), but the most common source of vibration is from the motor and gearing system that will be rotating at high speeds. Such vibration can be controlled by balancing the rotation, problems occur when an unbalanced object is rapidly rotated and eventually 'shakes' itself apart.

Wing Shape and Size

As mentioned in section 2.2.3 scientific research has diligently explored the reasons behind the differing shapes and sizes of avian vertebrates wings. The behaviour and lifestyle of birds dictates the type of wing they have evolved to bear. Research has revealed that predatory birds, like Hawks and Eagles, have developed wings capable of enabling them to fly quickly and change direction rapidly, whereas birds that traverse large distances over landmass and oceans typically have wings suited to gliding, resulting in energy efficient flight. Ornithopters tend to adopt wing shapes that provide the most stable platform for stable flight and as previously mentioned the intricate detail of a bird's wing is not directly mirrored but instead the outline shape and span is more closely observed. As well as endeavouring to provide stability for the omithopter the wing design also considers the required lift generation to sustain it in flight. Heavier ornithopters require larger wings or more frequent wing beats, but because the stresses of rapid wing flapping can be problematic a larger wing is usually preferred. Consequently larger wings require more powerful motors to provide enough leverage for the downward and upward strokes. Martin Simons discusses model aerodynamics in his book Model Aircraft Aerodynamics and explains that a semi-elliptical wing has been mathematically proven to be the most stable because at all speeds it provides constant downwash, equal load distribution along the wing and stalls simultaneously at each point 151.
Stability is an imperative attribute to make the omithopters handling characteristics more forgiving for the pilot.

2.2.5.Practical Applications

This section will diverge slightly from the scientific analysis of omithopters and focus on the reasons for their use and the environment in which they are deployed. Military interest in ornithopters has re-focused the interest on flapping wing UAVs, particularly where there is an opportunity for companies to gain capital from developing and delivering ornithopters for practical uses. The United States Darpa department (the Pentagon's advanced research unit) is an exceptional example.
Darpa were commissioned to manufacture a micro-ornithopter, capable of hovering and carrying its own power source, with the intention of using it for covert indoor missions such as bugging a room with hidden listening devices or transmitting audio and video to locations up to one kilometre away. Darpa claim that the micro- ornithopter is more aerodynamically efficient than remote control helicopters/aeroplanes, a claim measured by the low Reynolds Number (airborne efficiency) [6]. Moreover, military interest extends beyond small-scale ornithopters, they also intend to capitalise on the ornithopters resemblance to birds and insects for inconspicuous recognisance missions. Natural environmentalists are also beginning to understand the advantages of ornithopters, for example, the Colorado Division of Wildlife has used ornithopters to aid the survival of an endangered bird

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species, the Gunnison Sage Grouse. Further commercial uses extend to the protection of commercial aircraft from bird strikes at takeoff and landing, Schiphol Airport in Holland has seen success with this method.

❖ Construction of Our Ornithopter:

1. Main frame
2. Electronics
3. Wings
4. Gear Box
5. Tail

1.**Main Frame:**

For construction of main frame the material selection was an important thing. As the weight of material and its strength are very important factor for this project. It is liable to use Carbon Fiber in order to obtain light weight structure. BT it is rarely available and the cost is also high. So we started finding the alternatives of Carbon Fiber. This disadvantage of Carbon fiber is been dismissed by Balsa wood. It a type of wood with very light weight, can be comparable with Thermocole but strength is good. so we decided to use Balsa wood for our structure.

Comparison between balsawood and Carbon Fiber:

Constraints	Balsa Wood	Carbon fiber
Density	0.13gm/cm3	1.4gm/cm3
Dielectric Strength	4.5kv/mm	30kv/mm
Elastic Modulus	3Gpa	10Gpa
Elongation	1.2%	1.4%
Strength to Weight	110kNm/kg	150KNm/kg
Thermal Expansion	16.5 *10^-6m/mk	0.4*10^-6m/mK

- **BALSAWOOD**:

Fig 6. Balsa wood

Common Name(s):Balsa

Scientific Name: Ochroma pyramidale

Distribution: Tropical regions of the Americas; also grown on plantations

Tree Size: 60-90 ft (18-28 m) tall, 3-4 ft (11.2 m) trunk diameter

Average Dried Weight: 9 lbs/ft3 (150 kg/m3)

Specific Gravity (Basic, 12% MC): .12, . 15

Modulus of Rupture: 2,840 lb,/in2 (19.6 MPa)

Elastic Modulus: 538,000 lb/in2 (3-71 GPa)

Crushing Strength: 1,690 lb,/in2 (11.6 MPa)

Shrinkage; Radial: 2.3%, Tangential:

%, Volumetric: 8.5%, T/R Ratio: 2.6

Color/Appearance: Heartwood tends to be a pale reddish brown color, though it is not commonly seen in commercial lumber.

Grain/Texture: Balsa has a straight grain with a medium to coarse texture and low natural luster.

Rot Resistance: Sapwood is rated as perishable, and is also susceptible to insect attack.

Sustainability: This wood species is not listed in the CITES Appendices or on the IUCN Red List of Threatened Species.

Common Uses: Rafts, surfboards, model airplanes, musical instruments, packing/transport cases, core stock in sandwich laminations, and fishing lures.

Comments: Balsa is a wood that is famous worldwide. And while its density and mechanical values can vary significantly depending on the growing conditions of

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any particular tree, it is generally the lightest and softest of all commercial woods, ranging from 8 to 14 pounds per cubic foot. Yet despite its softness, Balsa is technically classified as a hardwood, rather than a softwood, since it has broad leaves and is not a conifer.

❖ Electronics:

While the electronics on the ornithopter are not a critical system as far as the mechanical functions of the machine performs they do make up the one of the most important specifications for the project, the minimum payload capacity. Because the rest of the sizing and designing of the ornithopter depends on this and the weight of the computer, interface equipment, sensors, and battery must be determined first.

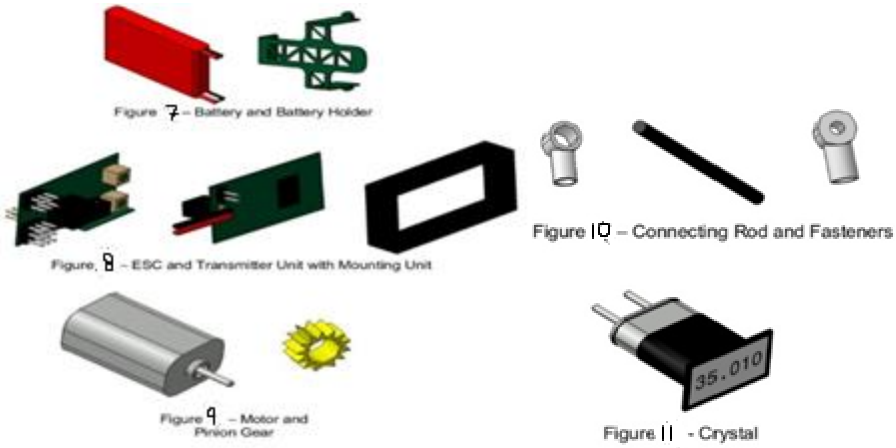

Figure 7 – Battery and Battery Holder

Figure. 8 – ESC and Transmitter Unit with Mounting Unit

Figure 10 – Connecting Rod and Fasteners

Figure 9 – Motor and Pinion Gear

Figure 11 - Crystal

❖ Batteries

Lightweight batteries suitable for omithopters are identified as the lithium polymer (lipo) variety. Lipo batteries are the most recent addition to the battery family and benefit from a steady discharge of voltage and a higher average voltage when compared to older nickel-metal hydride and nickel cadmium batteries. Batteries are required to be sized to the voltage consumption of motors and their charge capacity can be measured in milliamp hours (mAh). A particular safety concern regarding a battery mounted to an omithopter is the possibility for damage to occur from a crash landing, battery instruction manuals clearly stress that puncturing battery cells will release toxic chemicals and create a viable fire hazard. Manuals also state that the voltages applied to the battery during re-charging cycles should be monitored and voltage overcharging or discharging will impair the lifespan of the battery.

Fig.12 Li-po Battery

- **Wings:** Here the wings are made up of Balsa material. They are 540mm in length and 150 mm in height and 6mm in thickness. They are connected from front end of frame to rear end so as to covered whole body in order to create high lift force.

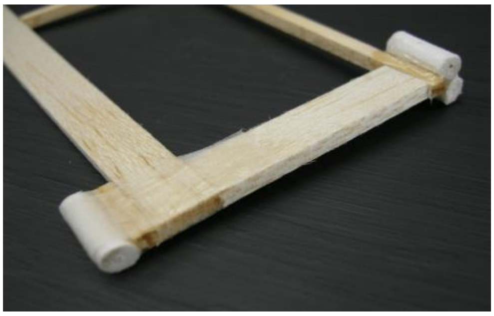

Fig. 13 Prototype ornithopterFrame

- **Gearbox:**

Many types of gears are available in market in order to reduce or increase the speed. The types of gear that can be used are as follows

- Bevel Gear
- Spur Gear
- Helical Gear
- Herringbone Gear

Fig.14 Gearbox

The most favorable gear in this case is Bevel Gear

Selection of bevel gear is good due to its good power transmitting capacity and availability of manufacturer. But we faced some problems relating to its speed control and manufacturing. We wanted very small size of gear for mechanism .With bevel gear we were using quick return mechanism so that rotary motion will get transmitted to reciprocating motion. By using reciprocating motion we are trying to control both wings so that due to both driving wings more lift force will get created and ornithopter might take flight.

❖ ESC(Electronic speed control):

Electronic speed controls are a vital safeguard against damaging electrical motors by regulating motor rotation speeds. ESCs are often defined as standalone units or are married to the remote control receiver. Brushless motors use the back EMF to sense rotary position whereas brushed motors tend to rely on Hall Effect or optical sensors. ESCs are programmed by the user to define required voltage cut-off values, acceleration rates and rotational direction. In order to provide voltage to an ESC a battery is required, this supply of voltage is regulated by the ESC and passes through to the motor.

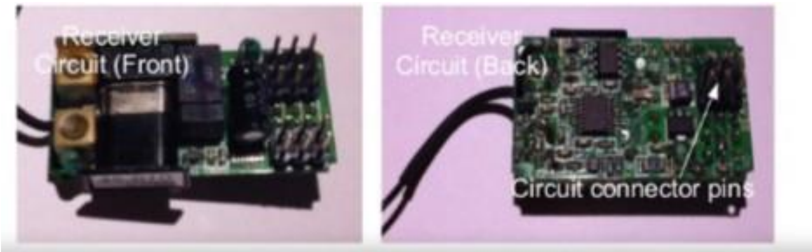

Fig.15 Electronic speed control

❖ Servos:

A servo is basically a small electric motor that responds to control inputs by applying torque to a shaft connected to an output arm in order to rotate it in a very calculated manner. Servos are constructed from four main components gears, a motor, a feedback potentiometer and an amplifier . Firstly, gears are fabricated form plastic or metal depending on their intended use. Plastic gears are suitable for smaller models requiring less powerful servos to manipulate control surfaces under less stress whereas metal gears are suited to servos mounted on models weighing over 2.5kg. Secondly, brushed motors make a re-appearance for use in servos as they are robust and can be obtained at low costs. The iron armature at the core of the motor can be problematic when a servo with extremely fast responses to control inputs are required because of the inertial/momentum forces of a heavy material.

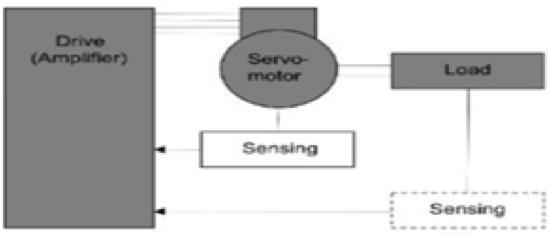

Figure 16 – Basic Servo System [10]

The feedback potentiometer is an ingenious component mounted to a small circuit board in the servo casing that can determine the position of the output arm by using a variable resistor to create a voltage determining its precise location. This is an important so that the user can manipulate the output arm in the desired manner during all phases of the operation. Finally, amplifiers are digital microcontrollers that control the torque, speed and accuracy of the servo. A. W. Richmond characterizes servo schematics in his book Servos and Steppers that illustrate how servo motors are connected to their loads, among other components.

Fig 17. Transmitter

Observing above Figure it can be seen that the hand held control transmission unit consists of joysticks to dictate the movement of the ornithopter, trim tabs to govern the continued position or power settings of certain components and a crystal on the same frequency as the crystal found in the receiver unit.

•**Theoretical Calculations**

.Motor RPM

The RPM of the motor can be calculated using the following equation: Motor RPM =

Motor Kv x Battery Voltage - Equation 1

Using the known values from the components acquired for installation Equation 1 can

be calculated as:

Motor RPM = 2500Kv x 7.4V = 18500RPM - Equation 2

•**Output RPM**

The output RPM is a measure of the RPM left after the motor shaft rotation has been transferred through the gear mechanism.

Main

Pinion Gear

Pinion Teeth Main Gear

Teeth Equation 3

The tooth ratio of both gears, 2/18, can be inserted into Equation 3 to make: 18500Kv X 2/18

= 2055RPM - Equation 4

Equation 4 indicates that the total RPM after taking the gears into account equates to 2055 RPM. It is important to note that although the RPM is high for a small-scale ornithopter the motor power can be reduced via the hand held transmitter.

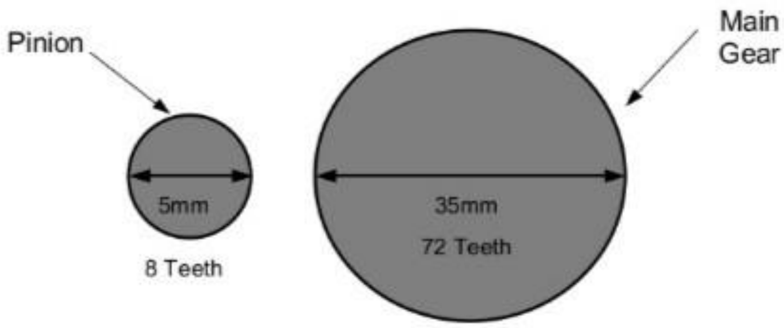

Fig18. RPM of gear

- **Tail :**

The tail section of the ornithopter is responsible for both of the controllable degrees of freedom as well as from the ability to throttle the drive motor. The tail can provide aerodynamic shape to the structure. Its function is to change the direction while flying. The tail of Aero plane has also the same function to perform.

But here in this case as the Ornithopter is not able to take flight due to the above discussed reasons here the tail section is clamped just in order to give it a shape of bird.

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❖ PRESENT WORK

ABOUT OUR PROJECT

In our model there is one crank and connecting rods. Wings are attached to connecting rods and the wings are hinged to two different slots. When rotate the crank, the second connecting rod oscillates. The oscillatory motion of connecting rod leads to flapping of wings. Quick Return Mechanism is used here. The wings travel faster during the downward stroke as compared to the upward stroke. This gives more power during the downward stroke and hence gives lift.

□ DIMENSION

S Crank radius= 4.5 cm

Length of connecting rod 1= 20 cm

Length of wing rod= 25 cm Length of Wings= 27 cm

Height= 21 cm

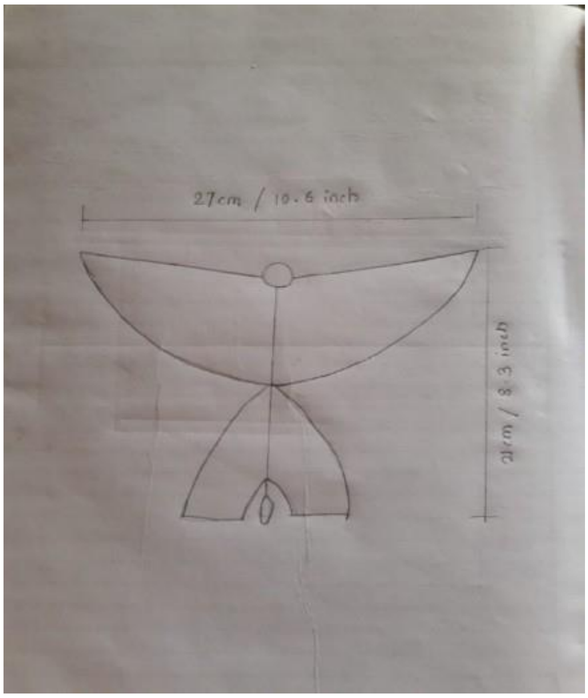

Fig no. 19 Dimensions

□ Components used :

- Connecting rods
- Vinyl sheets (wings)
- Gearbox (Flapping Mechanism)
- Foam sheet(Nose shape).
- Servo motor (for high torque)
- Balsa square sticks (forbody)
- 2.4ghz Transmitter and receiver (for controlling)
- LED (for nightvision)
- Camera (for capturing aerial activities)
- Feathers (We are using real feathers to cover the body and wings of the model to give an real touch, so that when it is being used by the police men's or military the enemies couldn't get alert that they are under surveillance.)

- **Innovation :**

We are using an raspberry Pi camera in this ornithopter. As the primary application of such ornithopter is to capture all the aerial activities going into the surrounding. This camera can be fitted in different positions, but to get an easy and good visual we have fitted it into the belly of the model.

There are four applications provided: raspistill, raspivid, raspiyuv and raspividyuv. raspistill and raspiyuv are very similar and are intended for capturing images; raspivid and raspvidyuv are for capturing video.All the applications are driven from the command line, and written to take advantage of the MMAL API which runs over OpenMAX. The MMAL API provides an easier to use system than that presented by OpenMAX. Note that MMAL is a Broadcom-specific API used only on VideoCore 4 systems.

The applications use up to four OpenMAX (MMAL) components: camera,preview, encoder, and null sink. All applications use the camera component; raspistill uses the Image Encode component; raspivid uses the Video Encode component; and raspiyuv and raspividyuv don't use an encoder, and sends their YUV or RGB output directly from the camera component to file.

The preview display is optional, but can be used full-screen or directed to a specific rectangular area on the display. If preview is disabled, the null sink component is used to 'absorb' the preview frames. The camera must produce preview frames even if these aren't required for display, as they're used for calculating exposure and white balance settings.

In addition, it's possible to omit the filename option (in which case the preview is displayed but no file is written), or to redirect all output to stdout. Command line help is available by typing just the application name in the command line.

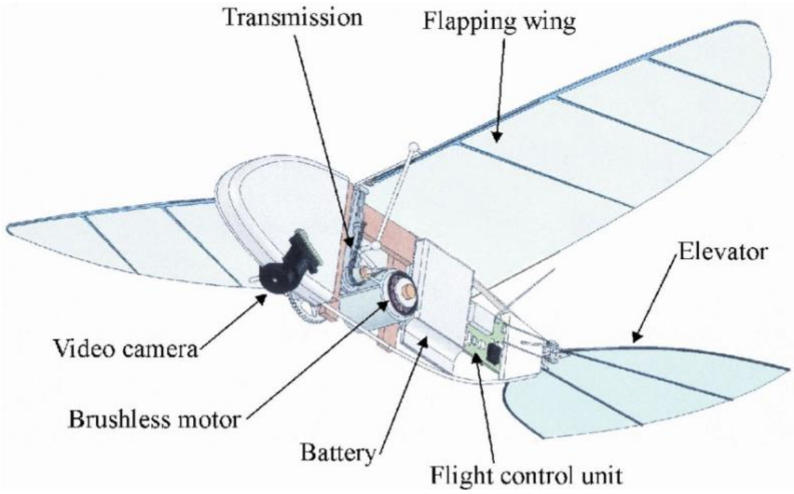

Fig. 20 Ornithopter components position

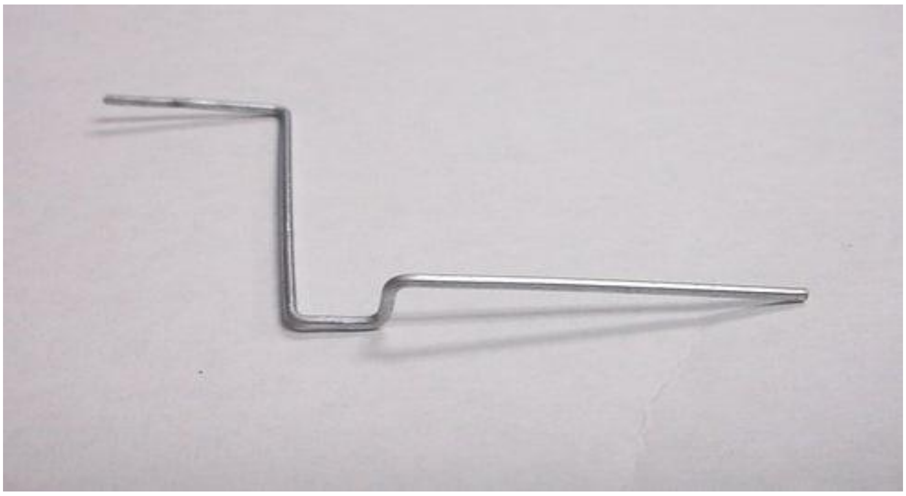

Fig21. Wire bending

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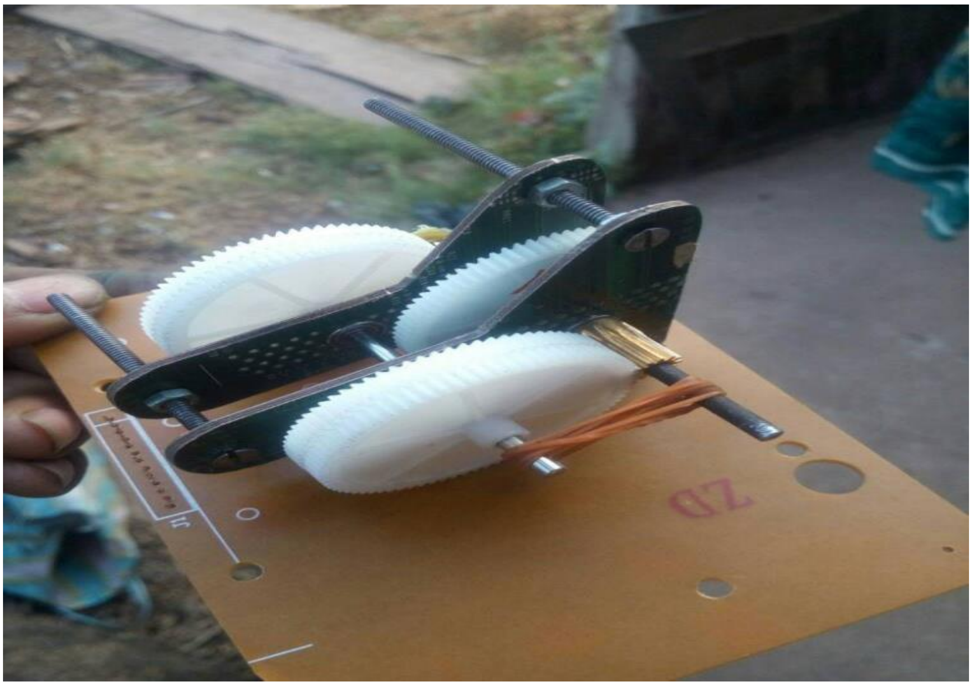

Fig22 .mini gearbox

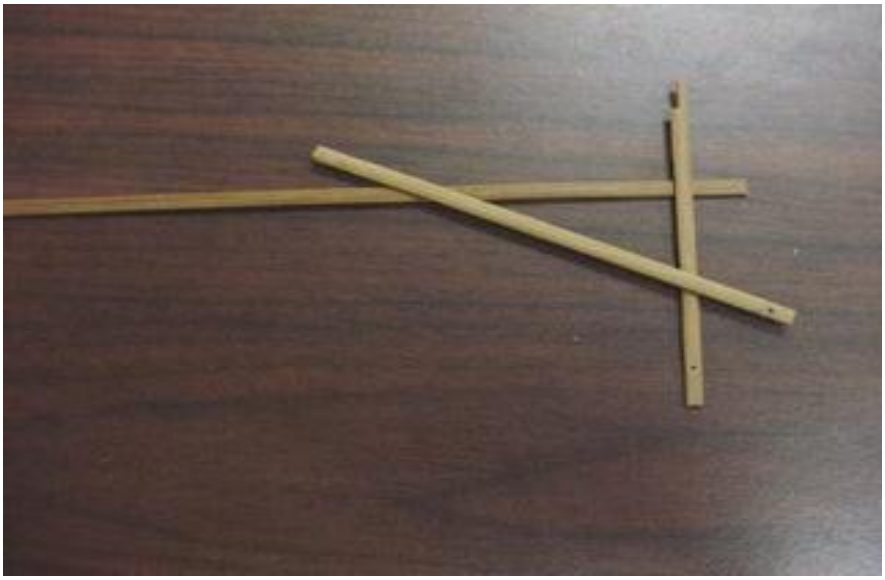

Fig23. Connecting Rod

Fig 24. Full body frame

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❖ APPLICATION :

Because ornithopters can be made to resemble birds or insects, they could be used for military applications, such as aerial reconnaissance without alerting the enemies that they are under surveillance. Several ornithopters have been flown with video cameras on board, some of which can hover and maneuver in small spaces. In 2011, AeroVironment, Inc. announced a remotely piloted ornithopter resembling a large hummingbird for possible spy missions.

Practical applications capitalize on the resemblance to birds or insects. The Colorado Division of Wildlife has used these machinesto help save the endangered Gunnison Sage Grouse. An artificial hawk under the control of an operator causes the grouse to remain on the ground so they can be captured for study.

Some applications of this model -

- The primary application is to capture the aerial activities it can also be used in followingthings
- For the police departments to have all the required information about their suspects andcriminals.
- It can also be used in lots of the places like banks, malls etc. as an moving/flying CCTV camera. It can also be used as an still CCTV as required.
- They could be used for military applications such as aerial reconnaissance without altering the enemies that they are under surveillance.
- It can also be used during the pandemic's such as floods, earthquake, cyclone etc. to detect the people's they had got stuck there. ETC Many more suchapplications

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- **Advantages** :

Flapping wings offer potential advantages in maneuverability and energy savings compared with fixed-wing aircraft, as well as potentially vertical take-off and landing. It has been suggested that these advantages are greatest at small sizes and low flying speeds.

Unlike airplanes and helicopters, the driving airfoils of the ornithopter have a flapping or oscillating motion, instead of rotary. As with helicopters, the wings usually have a combined function of providing both lift and thrust. Theoretically, the flapping wing can be set to zero angle of attack on the upstroke, so it passes easily through the air. Since typically the flapping airfoils produce both lift and thrust, drag inducing structures are minimized. These two advantages potentially allow a high degree of efficiency.

Fig 25. Aerovironment Ornithopter

❖ Conclusion :

Sooner or later, maybe - in the nearest future, manned motor ornithopters will cease to be "exotic", imaginary, unreal aircraft and start to service for humans as a junior member of aircraft family. Necessary high aviation technology already exists.
Designers and engineers will be forced to solve not only, for example, wing design problem, but all problems peculiar to any safe and reliable aircraft of any type. Parts of them, such as stability, controllability, durability etc. are inherent to all aircraft with no exemption.

The second part - In order to take flight the lift force should be greater than weight force which is not happening here due to following alternate arrangements. Weight is the major constraint here. Due to high weight of flapping wing mechanism the Ornithopter is not able to take flight. Also Balsa wood is used in placed of Carbon Fiber, which is not a replacement. In this case it is used in order to reduce weight only. The motor used here can be replaced by another high torque motor so that it can produce high torque and can produce enough amount of lift force. If all this replacement could be done then Ornithopter might take flight.

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