CONSTRUCTION AND OPERATION OF ORNITHOPTER USIN RC

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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. This renewed interest has raised a host of new problems in vehicle dynamics and control to explore.

In order to better study the control of flapping wing flight we have developed a large scale ornithopter called the Phoenix. It can carry a heavy (400 gram) computer and sensor package and is designed specially for the application of controls research. The design takes special care to optimize payload capacity, crash survivability, and field repair abilities. This thesis covers the design process of both the mechanical and electrical systems of the ornithopter and initial control experiments. We also show that it is possible to stabilize the machine in pitch with a simple PD controller through experimental testing.

IndexTerms - Design process , flapping wing, flying vehicles, micro aerial vehicles,

I. INTRODUCTION

An ornithopter (from Greek ornithos "bird" and pteron "wing") is an aircraft that flies by flap plying its wings. Designers seek to imitate the flap plying-wing flight of birds, bats, and insects. Though machines may differ in form, they are usually built on the same scale as these flying creatures. Manned ornithopters have also been built, and some have been successful. The machines are of two general types: those with engines and those powered by the muscles of the pilot.

1.0 The Insectothopter The Insectothopter was a miniature unmanned aerial vehicle developed by the United States Central Intelligence Agency's research and development office in the 1970s. The Insectothopter was the size of a dragonfly, and was hand-painted to look like one. It was powered by a miniature fluidic oscillator to propel the wings up and down at the proper rate to provide both lift and thrust. A small amount of propellant produced gas to drive the oscillator, and extra thrust came from the excess gas vented out the rear.

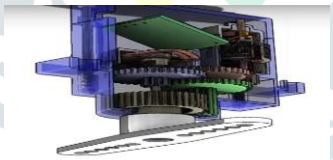
The project was abandoned when the Insectothopter was found to be too difficult to control in crosswinds.

Fig no: 1-Insectothopter

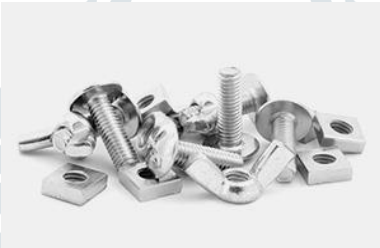
1.2 Micro Air Vehicle (MAV) Ornithopters Micro air vehicles, also known as MAVs, result from the US military's interest in miniature pying devices. The Defense Advanced Research Projects Agency (DARPA) has heavily funded some of these projects. Small radio-controlled ornithopters can carry a camera payload for spying inside buildings. The ultimate goal is to produce an ornithopter so small and lifelike that it can pass as a real insect or small bird, going unnoticed as it performs its deadly mission. With recent advances in hobby radio control products, now you can build your own micro-sized ornithopters and spy on your nabours.

I.Parts of Ornithopter

1.BLDC motor 3500kv	2. ESC controller	3. Servo motors	4. RC radio controller (Transmitter and Receiver)
5. Battery	6. Battery cells for RC Controller	7. Small black rods	8. FPV camera
9. Small bearings	10. Plastic Gears	11. Glass fiber sheet	12 Polythene cover
13. Double ball joint	14. Small nuts and foam	15. JST-XH Plugs	

Sl.no	Name	Figure	Specifications
1	BLDC motor 3500kv		Material: Composite Material Model Number: F23700
2	ESC Controller		resulting in more than 490 Hz response rate. 16KHz motor frequency Max cont. Current: 30A peak current: 40A (10s) Voltage: 2-3S LiPo, BEC: 5V / 3A
3	Servo motor		Weight: 9 g Stall torque: 1.8 kgf·cm Operating speed: 0.1 s/60 degree Operating voltage: 4.8 V (~5V) Temperature range: 0 ºC – 55 ºC
4	RC Controller Transmitter (FS-i6) Receiver (FS-iA6)		Channels 6 RF range 2.4055 - 2.475 GHz Bandwidth 500 KHz RF channel 142 RF power Less than 20 dBm 2.4GHz system AFHDS 2A Modulation type GFSK Stick resolution 4096 Low voltage alarm Yes (lower than 4.2V) PS2/USB Port Yes Power input 4.2V - 6.0V Weight 410g

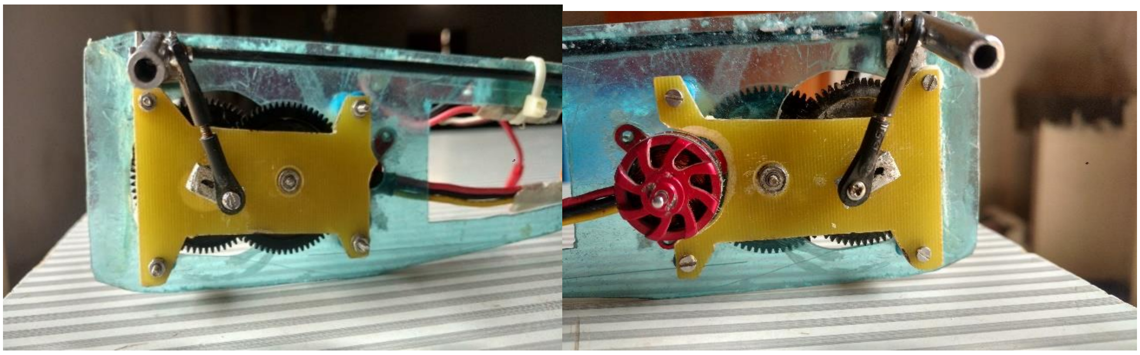
5	Battery for Drone		LiPo batteries are much lighter weight Maximum Operating time 45Min
6	Cells For Rc Controller		1.5 V Dry Battery
7	Small Rods		Plastic Rods for fitting in Drone to have swinging motion of rod and above cover will be places Less weight
8	FPV camera BV CAM App		Video Format: AVI Video Coding: M-JPEG Video Resolution Ratio: 640x480 VGA Network Transmission Resolution Ratio: 320x240 QVGA Video Frame Rate: 10fps±1fps Sensor: 1/3" CMOS Antenna: 2.4 G 802.11n WIFI Built-in Antennas Storage: Support TF Card, Max. to 32G Image Proportion: 4:3 Support System: Windows,ISO,Android Charging Voltage: DC 5V Interface Type: Mini 5Pin USB Save Support: Micro SD Card(TF Card) Battery Type: High Power Capacity Polymer Lithium Material: ABS Weight: 8g Automatic video recording when open the camera. Built-in rechargeable battery, about 45mins battery time
9	Bearings		A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between m oving parts

10	Plastic Gerars		A gear is rotating machine part having cut teeth which transmit motion form one gear to other gear
11	Fiber Sheet		Fiber sheets are used for supports
12	Polythene Cloth/Cover		Polyethylene is the most common plastic which is used for light weight
13	Ball Joint		These are used for eay motion of wings
14	Small Nuts and Foam	 	Small nuts and bolts are used for fitting rods and joints
15	JST-XH Plugs		JST connectors are commonly used by electronics hobbyists for rechargeable battery packs, battery balancers, battery eliminator circuits, and radio controlled servos

II. **WORKING PRINCIPLE**

2.0 GEAR BOX

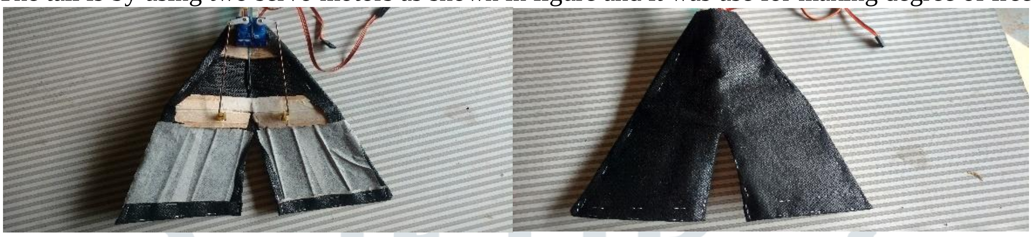
The most critical part of the ornithopter is the drive mechanism the converts theelectric power from the battery to the applying motion of the wings. This system is the most complex to design and fabricate because it must withstand very large forces which reverse direction several times a second while at the same time being extremely light and durable. Because of the loads it must be made from metal which makes it beneficial to perform careful analysis and trim as much weight as possible.



2.0. Gear box

(a) TAIL

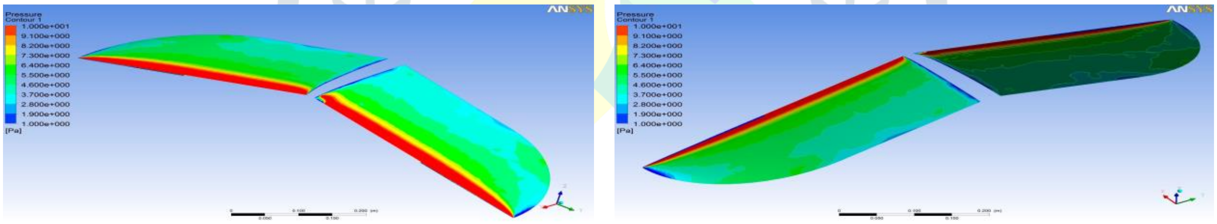
The tail section of the ornithopter is responsible for both of the controllable degreesof freedom aside from the ability to throttle the drive motor. The tail is by using two servo motors as shown in figure and it was use for making degree of freedom angles.



2.0a): Tail

(**b)Wing design**

In our ornithopter the wings is not only use for giving power but also thrust, this made ornithopter easy to fly by flapping its wings.



2.0 (b): The showing wings are in -15 angles, and we use rods for wing design and cloth.

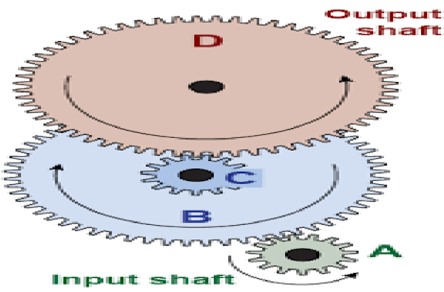
(c) BODY

We made ornithopter by usng fiber glass , the frame on gear box is by using fiber only and the body was built by glass and all cutting processes are done by hand made.

(d) Gears

In ornithopter we use three gears.

1) Pinion gear(A).
2) spur gear(B) with pinion(C).
3) Driven gear(D).

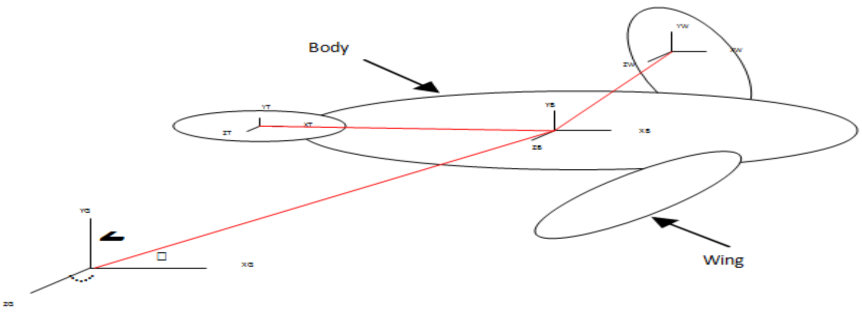


2.0 (d): Gears

2.1 .OPERATION

The ornithopter work in the principle of transverse gear mechanisum, the gears are placed as Compound gear train , motor have 10 teeth gear attachement and that gear was attache with 70 teeth spur gear that spur gear has pinion gear attachement , that pinion gear have attache with main gear. The frame well design by placing gear box.

The motor wires well need to connect with ESC controller , that ESC controller has two phases one was with motor and second phase is got two connections one was with batter And another was connected with RX(reciver) , two servo motors well used in it that well connected with RX and work by TX(transmiter).

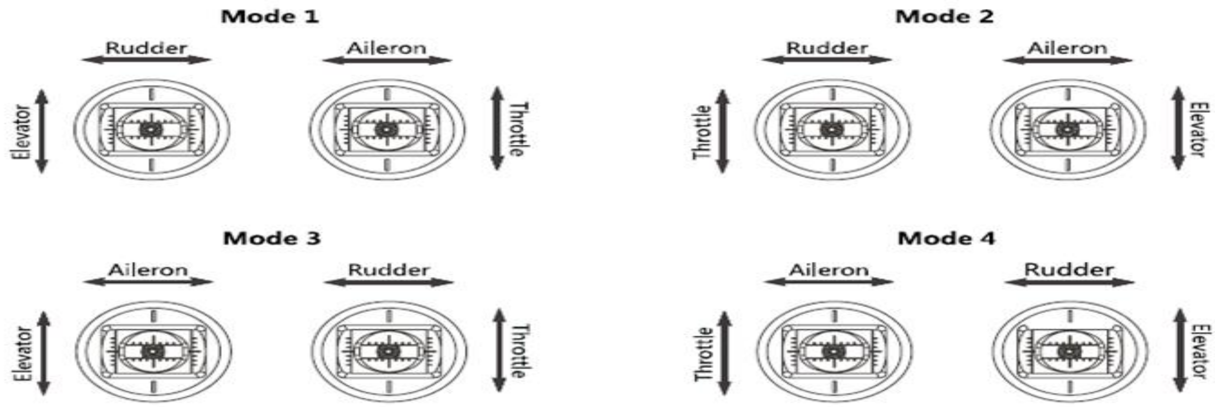


2.1.flying angles

2.2 RC MODES and Working

2.2.1. Stick modes

Usually the stick with the self centering feature on both axes be mapped to the elevator, while the other to the throttle.
The functions of the sticks in respective modes are shown below

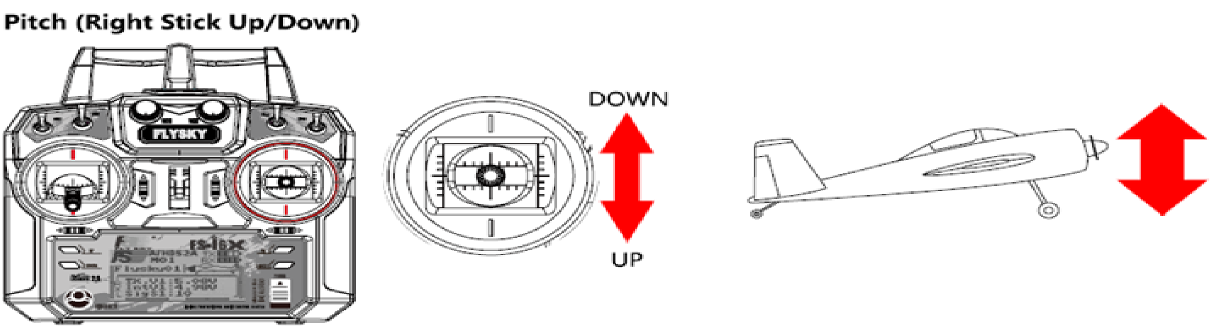


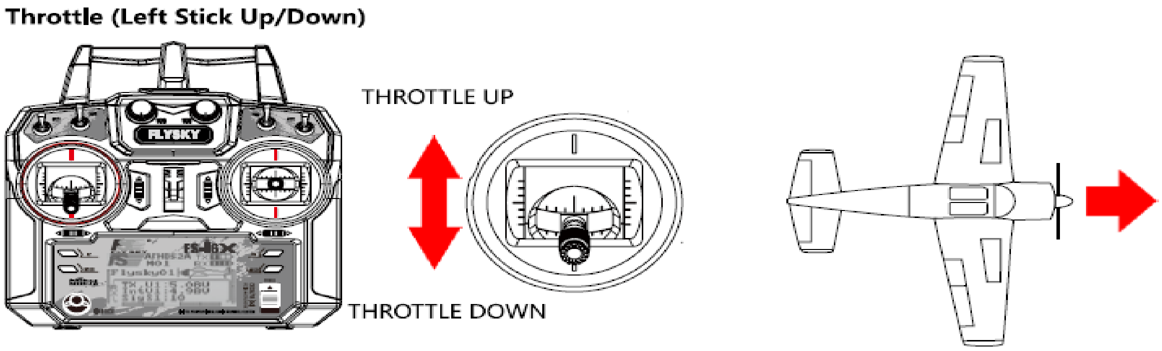
2.2.1. RC actions

2.2.2. Function descriptions

Flight controls (Default mode 2)

The sticks are used for controlling the aircraft, each stick has 2 functions. The right stick controls pitch and roll, the left stick controls throttle and yaw





2.2.2. Controlling actions

2.3. Testing

Many test flights were conducted with the finished Phoenix ornithopter, first with an equivalent weight and distribution payload under manual control to determine whether the machine would actually be able to fly. Initial tests showed that sustained flight was possible but the robot was exceedingly difficult to control and quickly crashed. Later tests with a PD control on the elevator to stabilize pitch qualitatively showed promise but difficulties with gearbox and wing spar reliability plagued the testing process.

This process of breaking things during testing is an essential part of the design process and leaps of progress were made during this time in tracking down problems and implementing design solutions to them. Parts of the gearbox like the connection between the final rocker link and the shoulder were a common point of failure and received stopgap design revisions until enough changes accumulated for a full design iteration of the machine. Changes were incorporated into the gearbox design, the electronics package switched over to the much lighter Gumstix based system, and the frame was reconfigured to balance the new weight distribution properly.

This second revision Phoenix took its first successful semi-autonomous flight on August 18, 2008 by traveling about 30 yards in steady, level flight before being shut down manually to avoid hitting MIT’s Building 18. A PD control stabilizing pitch was applied to the elevator with the throttle set at a fixed point by a remote control operator. The throttle setting was taken from a successful manual flight. The controller gains and pitch set point were initially set to a response that seemed to mimic a human pilot and tuned over the course of several tests. At the end of the flight flapping power is shut off and the wings passively enter a high dihedral which causes it to quickly glide to the ground while maintaining roll and pitch stability.

Steady state flight data from one of the successful test is shown below, note that the length of time is only about two seconds because the section containing initial conditions is excluded and the area used for testing is small. Longer tests are planned but have not been conducted yet. The data shown covers nine wing beats.

The graph of orientation shows pitch maintained with small variations, most likely caused by environmental conditions and the action of the wings flapping. Both roll and yaw are uncontrolled but are expected to be somewhat passively stable. The trend in roll shown in the data seems likely to be caused by a difference between the wings such as a weakened spar or out of trim tail.

set at about 70% of maximum for the steady level flight. Two factors complicate measurement above this point. First is the speed controller is only rated for 30 amperes so going above this level results in the speed controller shutting down. Second is that throttle settings near maximum excite a second mode in the motion of the wing spars and sets up a standing wave instead the desired flapping motion. Both of these problems will be subject of further invesigation.

Because both current and voltage are measured it is simple to look at the power it takes for the ornithopter to fly. While efficiency isn’t an immediate goal it’s obvious that the current realization of the ornithopter and its controller is an extremely inefficient way to fly. An estimated forward velocity of about based on total time of flight and distance covered combined with a vehicle weight of 1.2Kg shows a very rough unitless cost of transport of about 30.

III.CALCULATION

3.0 Ornithopter design

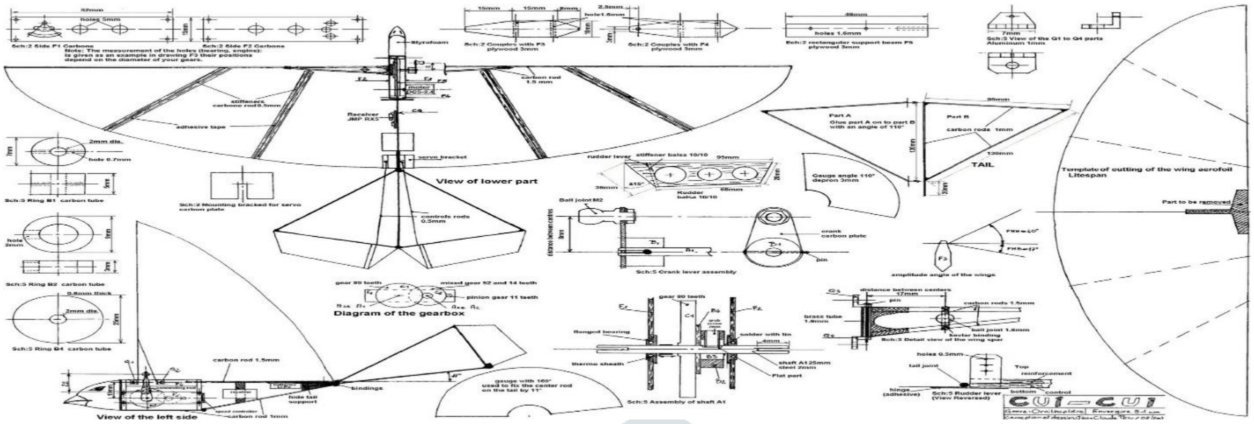


Fig.3.0 ornithopter design

3.1 wing actions

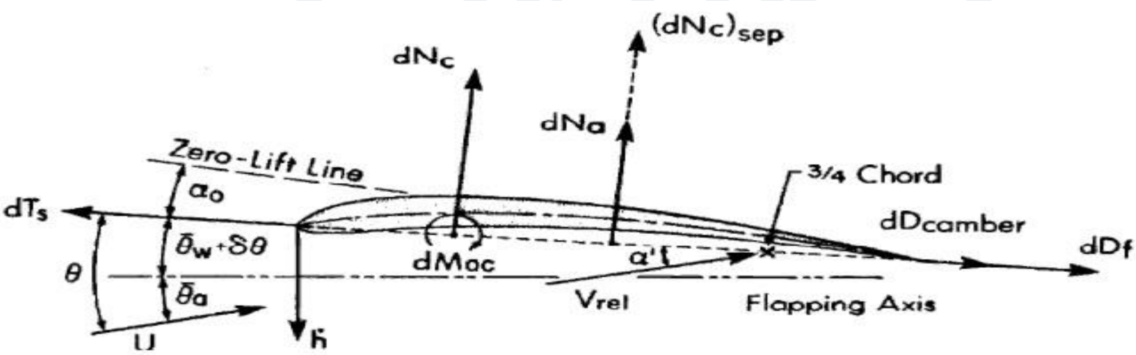


Fig.3.1.wing actions

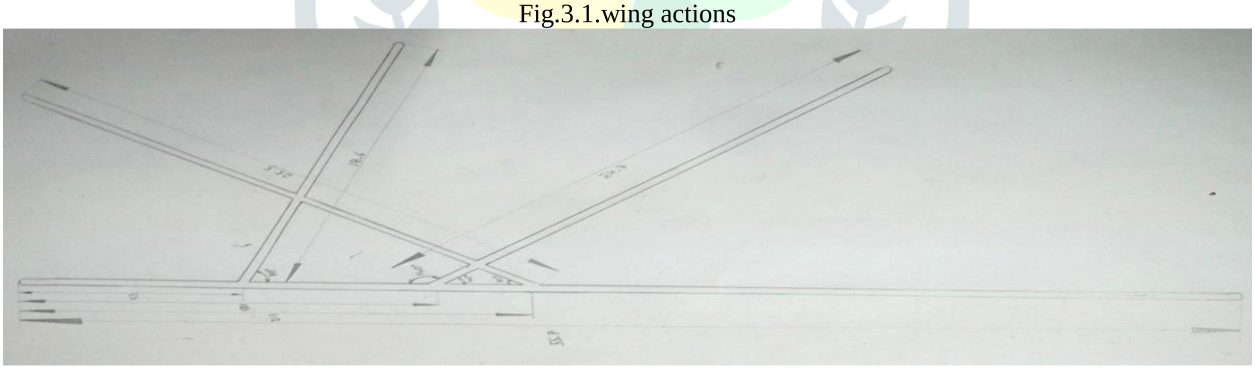


Fig.3.1.1.wind rod dimensions

Three Forces are acting on the ornithopter in its working condition

1. WeightForce(mg)
2. BuoyancyForce(ρgvfd)
3. DragForce($\rho A v^2$)

Total Force=weight+Buoyancy+DragForceForceForce

$F = mg+\rho g v f d+ \rho A v^2$

$=\rho g V+\rho g v f d+ \rho A v^2$

$=\rho(gV+gvfd+ Av^2)$

Where ρ=Density Of Air

V=Volume OfOrnithopter

v=Relative Velocity

fd= coefficient of drag force

5.2 Condition for safe design

σ<= syt/n syt= yield strength of material

n= factor of safety

f/A<= syt/n

f= Total Force

A= Area of Ornithopter

(VSTOL)Very Short Take Off and Landing

3.2. Aspect Ratio

The aspect ratio of a wing is the ratio of its length to the breadth (chord)

- A high aspect ratio indicates long narrow wings
- A low aspect ratio indicates short stubby wings

Aspect ratio = wingspan2/Area of wing = (51)2/860 = 3.0244

3.2.1. Design of high aspect ratio

- has lower induced drag
- produces more lift than low aspect ratio of wing

3.2.2. Applications

- gliders require high lift to drag ratio
- aircraft requiring long range
- aircraft requiring high endurance

3.3. Design of low aspect ratio

- greater maneuverability
- less drag at high speeds
- higher roll rate

3.3.1Applications

- flighter aircraft
- stun planes

An airplane wing produces lift by moving forward through the air. This force, called lift, is what keeps the airplane from falling to the ground. The special shape of the wing, combined with the slight upward angle of the wing, causes air to be deflected downward. There is more pressure on the bottom of the wing than there is on the top. This differencein pressure produces lift.

Fig.3.3.1.Airplane wing in forward flight produces lift

3.4. Newton's Laws

Newton's Third Law of Motion states that for every action, there is an equal and opposite Reaction. This is another way of saying you can't exert a force without something to push Against. The concept is easily demonstrated with a simple latex balloon. Blow air into the Balloon, but don't tie it off. Then release the balloon. The balloon is made of elastic Material and it wants to contract. Therefore air is forced backward through the nozzle of The balloon. Pushing this air backward also causes the balloon to be pushed forward and it May travel very rapidly across the room.

IV.RESULT AND CONCLUSSION

4.0 RESULTS

After collecting results and using the necessary information. The team was able to use Bernoulli's Lift Equation to calculate the velocity necessary to achieve lift.

$$L=Cl*\rho*A*v2/2$$

Bernoulli's Lift Equation
L = Lift (N)
Cl= Coefficient of Lift (1.6, unit less)
ρ = Density of Air (1.2041 kg/m^3)
A = Area (.4032 m^2)
V = Velocity (m/s)

Fig 4.0: Total Assembly Component with wings

Component	Weight(g)	Parameter	Value
BLDC Motor	12	Flapping amplitude (degree)	40
Radio receiver	6.4	Flapping frequency (Hz)	5.2
Servo motor	9.8	Lift coefficient	1.6
battery	30	Air density (kg/m3)	1.22
ESC controller	25	Chord length (m)	0.051
MAV design	15	Wing span (m)	0.051
Total weight	98.2	Lift (N)	83

Table 4.0: Lift and weight Comparison

4.1 Conclusion

Ornithopters have been a relatively obscure area of research in comparison to fixed wing aircraft and field of ornithopter design is sparsely populated. Much of the research done has been performed by hobbyists such as Sean Kinkade. In this report the case for the construction of a large scale ornithopter suitable for control systems research and surveillance application is motivated. Performance and weight constraints imposed by the computers and sensors desired onboard make it difficult to work with the smaller platforms currently available, let alone micro UAVs currently in development. The ornithopter was designed from the ground up with the needs of research in mind. All components have been designed to be as lightweight and high performance as possible so as to maximize payload capacity and are intended to fail in predictable and repairable ways. Examples of this are the screw in wing spars and replaceable face plates. In addition to this all parts of the ornithopter are simple and inexpensive to fabricate and assemble. Manual and initial autonomous flight tests have been conducted and show that the ornithopter is capable of sustained flight with a full load of electronics and can be stabilized by simple controllers. At the base is the mechanical ornithopter system which has the main requirement of flying acceptably. Acceptable in this most preliminary case is to sustain weight of the sensors and computer. Branching out from this base requirement are several secondary requirements. Because this is a controls research platform it can be expected that the ornithopter will end most of its beginning stages, this makes crash survivability of great importance in addition to it being a reliable machine in less severe conditions. An emphasis is placed on designed points of failure to isolate damage to parts easily replaced in the field. In addition to this all of the systems need to be easy to tie into the computer controller.

V.FEATURE SCOPE AND REFERANCES

5.0 Feature Scope

5.1 Reynolds Ornithopter: In the 1990s, Francis Reynolds developed an incredible mechanism for driving ornithopter wings. The advance ratio can be adjusted for different flying speeds, allowing a full range of flight from hover to high speed dives. Wing twist can be used for aileron and flap functions. All of this would be done with an efficient airfoiled wing. Reynolds never finished his ornithopter, but you have the opportunity to bring this amazing project to completion. One qualified applicant will be able to work with Reynolds' original machine and either make it fly or build your own version.

Fig 5.1: Reynolds Ornithopter

5.2 Mobile App Development: Develop a smart phone app that uses the phone camera to measure the flapping rate of any ornithopter or bird. Or, create a mobile version of the Flap Design software on this web site. These apps would be very useful for developing ornithopters and for studying bird behavior.

Fig 5.2: Mobile App Development

REFERENCES

1. Chronister, Nathan. (1999). The Ornithopter Design Manual. Published by The Ornithopter Zone.
2. Mueller, Thomas J. (2001). "Fixed and flapping wing aerodynamics for micro air vehicle applications". Virginia: American Inst. of Aeronautics and Astronautics. ISBN 1-56347-517-0
3. Azuma, Akira (2006). "The Biokinetics of Flying and Swimming". Virginia: American Institute of Aeronautics and Astronautics 2nd Edition. ISBN 1-56347-781-5.
4. DeLaurier, James D. "The Development and Testing of a Full-Scale Piloted Ornithopter." Canadian Aeronautics and Space Journal. 45. 2 (1999), 72–82. (accessed November 30, 2010).
5. Warrick, Douglas, Bret Tobalske, Donald Powers, and Michael Dickinson. "The Aerodynamics of Hummingbird Flight." American Institute of Aeronautics and Astronautics 1–5. Web. 30 Nov 2010.
6. Crouch, Tom D. Aircraft of the National Air and Space Museum. Fourth ed. Lilienthal Standard Glider. Smithsonian Institution, 1991.