International Journal of Pure and Applied Mathematics
Volume 119 No. 16 2018, 3623-3634
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

DEVELOPMENT OF BIOLOGICAL INSPIRED ORNITHOPTER MICRO AIR VEHICLE (MAV)

KG.Thirugnanasambantham[1], B.A.Sarath Manohar[2], Rajasekar Rangasamy[3],T.Pearson[2], G.Chaithanya Naidu[1]

[1] *Department of Mechanical Engineering, St. Peter's Engineering College, Hyderabad, Telangana, India.*

[2] *Department of Electronics and Communication Engineering, St. Peter's Engineering College, Hyderabad, Telangana, India.*

[3] *Department of Computer Science and Engineering, St. Peter's Engineering College, Hyderabad, Telangana, India.*

corresponding author:universalthiru@rediffmail.com

ABSTRACT

Technological progress in number of areas to include aerodynamics, micro-electronics, sensors, micro-electromechanical systems (MEMS), micro-manufacturing, and more, is ushering in the possibility for the affordable development and acquisition of a new class of military systems known as Micro-Air Vehicles (MAV). MAVs are a subset of Uninhabited Air Vehicles (UAV) that are up to two orders of magnitude smaller than the manned systems that permeate our contemporary life. Recent advances in miniaturization may make possible vehicles that can carry out important military missions. These missions can be possible if MAVs can fulfill their potential to attain certain attributes to include: low cost, low weight, range, endurance and precision. So the present work concentrates on development of MAV with ornithopter (flapping wing) concept. The development of flapping wing utilizes a combination of two things, biologically inspired design and incorporation of composite material. The MAV has imitate the wing structure as a basic concept of aerodynamics and kinematics. Hence in this paper work, study and analysis of aerodynamics of bird and insect has been carried out. The main objectives of this project are, to create an ornithopter with best available flapping using kinematic arrangement and to attain crash resistance power by building the MAV with carbon fiber composite rod.

Keywords: Micro air vehicle, ornithopter (flapping wing), carbon fiber composite, kinematics, aerodynamics

1. Introduction

MAVs are the aircraft with a maximum size wing span 150 mm, and are capable of operating at speeds of 15 m/s or less. The concept is for a small, inexpensive and expendable (if required) platform to be used for missions of surveillance and measurements in situations where larger vehicles are not practical and too expensive. Such missions can include low-altitude operations in battlefield, urban, or wildlife applications. Payloads may consist of video cameras, chemical sensors and communication devices. There are numerous technical challenges associated with designing and creating very small flying vehicles including a precipitous reduction in aerodynamic efficiency as the Reynolds number drops below 100,000—the typical flight regime for MAVs. Other critical areas are the guidance, navigation and control (GNC), the design of efficient and reliable propulsion systems. Typically table 1 shows specification and requirement of our MAV:

2. Methodology of project

The methodology of project integrates various areas for developing the biological inspired ornithopter MAV. The Figure 1 shows the methodology for this paper. The specification of MAV shown in Table 1:

Specifications	Requirements
Size	100-150 mm
Mass	35-50 g
Endurance	5 min
Payload	2-5g

Table 1: specification of our MAV

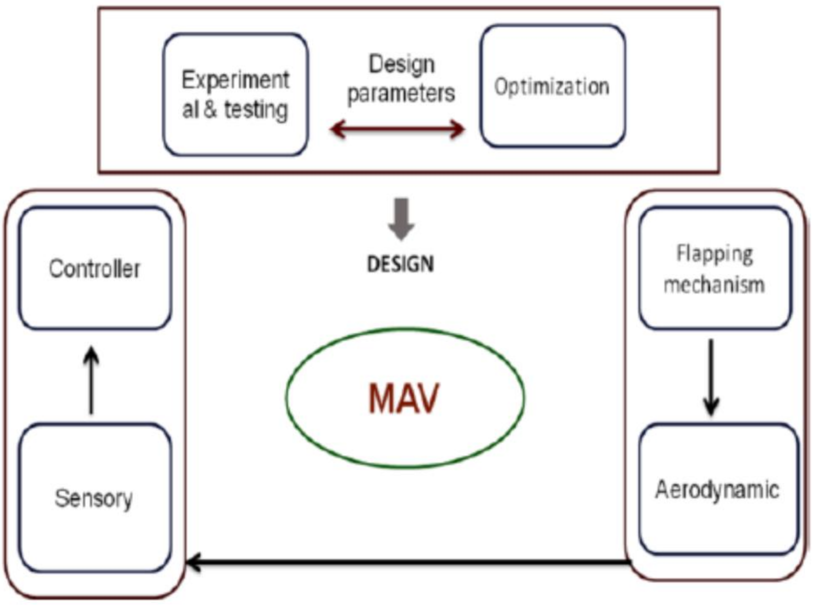

Figure 1: Methodology of project

3. Flapping mechanism design

Ornithopter (ornithos - bird‖, pteron -wing) is an aircraft that flies by flapping its wing. One of the most difficult and challenging task is to design and develop a highly efficient wing that has unsteady-aerodynamics.

- The wing must be light & strong.
- The wing able to withstand flapping frequency without breaking and is capable of generating enough lifts and thrust to fly the vehicles.

So potentially justifies significant effort which necessary to understand ornithopter concept with the help of biological inspirisation of natural flyers and to develop ornithopter for small air vehicles. For that our first work started with studying the flight characteristics of birds, insects and tried to mechanically duplicate to operate efficiency at their range of Reynolds's number.

From the analysis of natural MAV flyers, it is found that the MAV size falls within the range of small birds, hummingbirds, and large insects. Figure shows some samples of natural flyers. We estimate that these flyers of MAV size mass about 10- 50 grams and we believe our ornithopter should weight about the same from the figure 2.

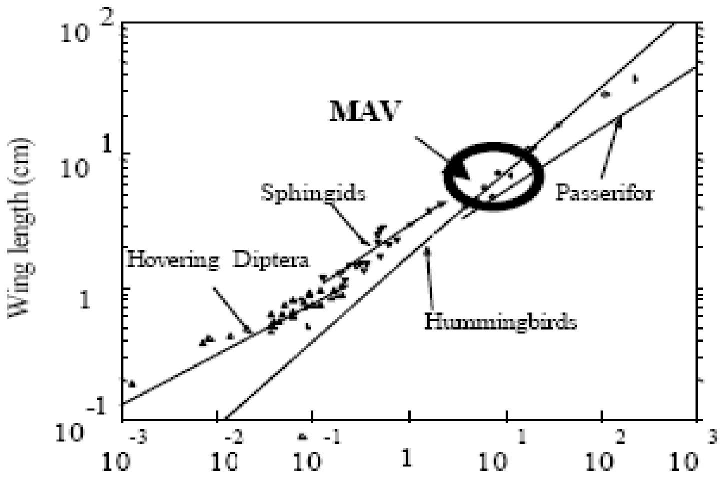

Figure 2: Size of natural flyers

3.1 Flight characteristics of natural flyer-humming bird

The reason for studying the hummingbird characteristics it has extraordinary flight capability. No other bird can hover as long or as steady as the hummingbird, although, a lot of energy is expended to stay aloft in this hovering attitude. The disadvantage of hovering is the excessive energy required for its success. The excessive energy requires the hummingbird to consume a lot of food. If a plot of wing-length to weight was made of all natural flying creatures, one would get a graph as shown in Figure 3. The figure displays the relationship between wing and total length for the whole range of flying animals. The slope is approximately 3, which means that the body-weight is proportional to the cube of the wing length. Of course, it is expected that all points will not lie on the average line. In fact, the hummingbird characteristics lie close to the end of the bird region and are on the verge of the insect region.

Also, Figure 4 shows the relation between the wing beat rate and the wing length. In this figure, we see that the insect or bird to be modeled in the appropriate size range should have a wing beat close to a hummingbird. From our above analysis flight characteristics of natural flyers birds and insects fly by flapping their range wings respect to their size at very high frequencies & control the motion precisely to create the lift forces. Bird flap up and down with small variation in angle of incidence. This angle of incidence allows generating the thrust while maintaining the small angle of variance.

Birds can need some initial airspeed to take off. This can obtain by jumping or running. In ornithopter vehicle, it can apply wing shape morphing (multi hinged skeleton and achieve flow control).To increase their flight range with high gliding ratio and it can be utilize for thermal atmospheric streams.

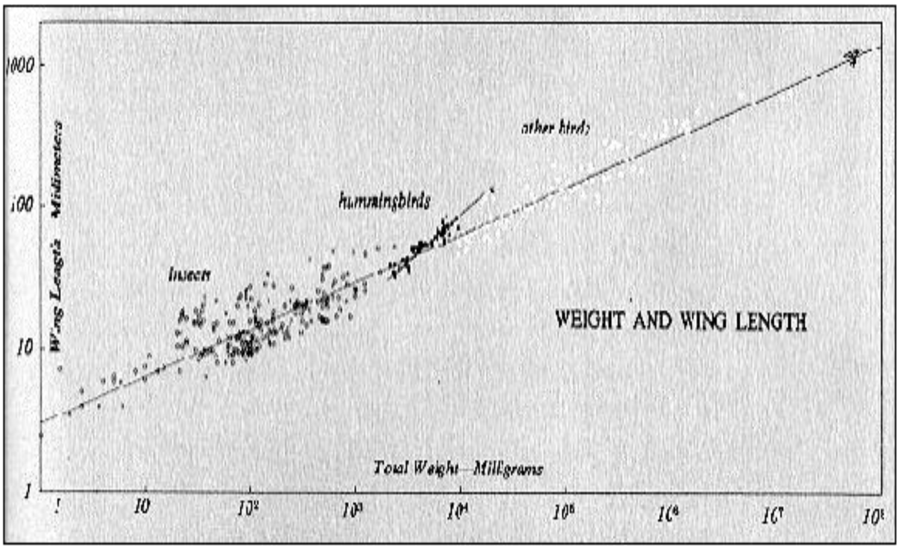

Figure 3: wing length versus weight (Flying birds)

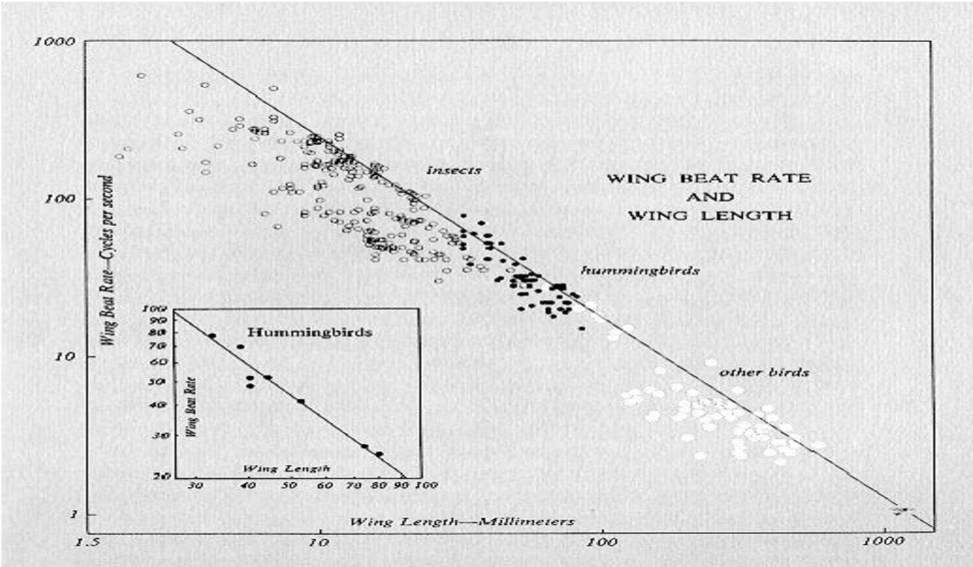

Figure 4: Wing beat rate versus wing length (Flying animals)

4. Statistical data for flight characteristics of birds from the above analysis:

Humming bird :

Generally the humming bird can flap their wing 12 – 90 times/second and speed of 15 m/s for different species.

Mass	2.2 to 20 grams
Wing span	8.9 cm
Wing flapping rate	12 to 90 times/seconds
Speed	15 m/s

Table 2: specification of humming bird

Butterfly :

Mass	5-9 grams
Wing flapping	5 to 12 times/seconds
Speed	6 m/s

Table 3: specification of butterfly

Advantages of flapping mechanism:

- Flapping mechanism benefit for unsteady aerodynamics at insect scale to generate greater lift than the steady state aerodynamics.
- Higher maneuverability and agility as seen in insects & humming birds.
- Ornithopter vehicle can take off and land vertically at very short distances but fixed, rotary wing vehicle cannot have such a performance.

5. Flapping mechanism design concept

Flapping wing designs can be more desirable, enabling the MAV to fly at air velocities approaching 0 (i.e., hovering), much like rotorcraft structure. However, the flapping motion associated with these wing designs can produce thrust and lift forces that are more unsteady than fixed wing MAVs, which requires suitable kinematic arrangement for assessing flight characteristics of bird and insect

5.1 The mechanism (ornithopter) has the following features:

- Simplest kinematic arrangement
- It can with stand shocks and loads from the propulsive system. The number of parts and joints should Minimum for eliminating complexity and reduces the losses
- The mechanism can generate more lift and support wing flapping for the vehicles

We are design the flapping mechanism from the basic principle of four bar mechanism with compound gear train as shown in Figure 5.Flapping mechanism is the driving systems which run by motor with help of battery (propulsive system).

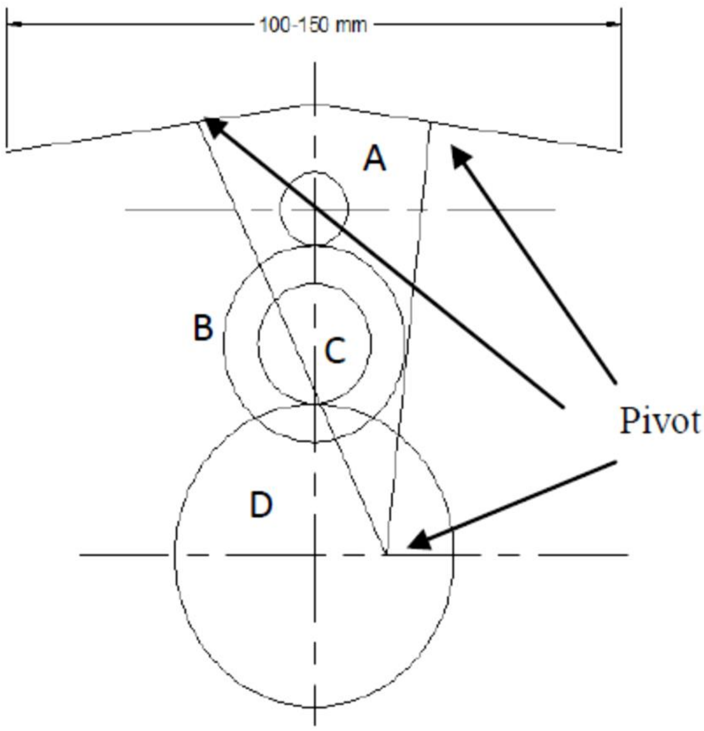

Figure 5: Design sketch for flapping mechanism

6. Input parameters of Compound gear train:

Number of gears used, n = 4

Number of teeth in each gear, $T_A = 12$, $T_B = 50$, $T_C = 10$, $T_D = 42$

Input speed which is given by motor, its run around 10,000 rpm. So we are calculating output rpm with the help of gear ratio formula,

Mass	5-9 grams
Wing flapping	5 to 12 times/seconds
Speed	6 m/s

Table 4: Gear mechanism output

7. Motor specifications:

The motor specifications influence the diving system (flapping mechanism) as shown in figure 6.The motor that has been selected for mechanism has the following specifications.

Motor type : DC high speed servo motor

Motor Mass : 12 g
Motor speed : 10000 RPM
Input voltage : 3.7 V

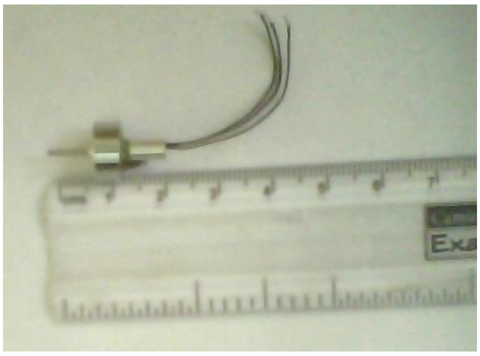

Figure 6: Motor

8. Battery specifications

Batteries are extremely reliable, inexpensive, and quiet. However there are tradeoffs among different battery chemistries. Nickel – Cadmium (NiCd) and Nickel – Metal – Hydride (NiMH) batteries have very high power densities, but very low energy densities. Lithium (Li) batteries are generally designed to have high energy densities, but relatively low power densities. We choose to use Li batteries for full filling the requirements and the picture of the battery shown in Figure 7.

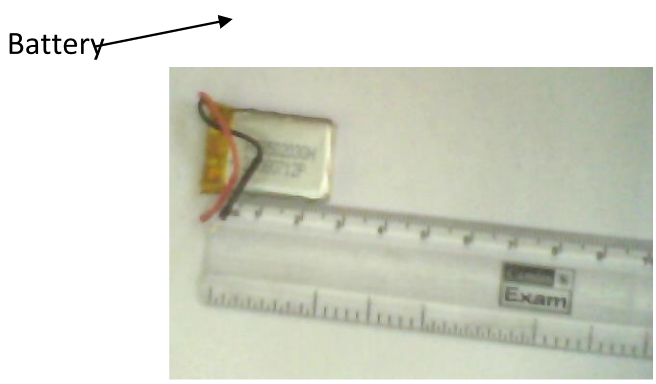

Figure 7: Battery

Battery type : Lithium polymer

Battery Mass : 4.5 g

Endurance : 3 min

9. Mass Estimation

Traditional method was used to estimate the take-off weight, considering an empirical equation derived from gathered MAV information and also shown in Table 5.

M P = M motor + M battery

M airframe = M fuselage + M wing + M tail

M payload = M servos + M control + M subsystem

10. Flight testing and controlling

Most of our test flying is done using conventional RC equipment at close range, keeping the vehicle in continuous visual contact. Because of the small size of the vehicles, flying at distances greater than about 100 feet can quickly cause loss of orientation unless the pilot is flying by monitoring the video output from an on-board camera. The RC transmitter produces a radio frequency signal that causes the RC receiver carried in the vehicle to develop a series of pulses of varying pulse widths (pulse width modulated or PWM) that are delivered to the control surface servos as the command signals for the desired positions of these surfaces.

Micro Air Vehicle (MAV) Components	Mass(g)
Propulsion Motor Battery	12 4.5
Control Servos(2 items)	4
Mechanism Main support with gears	15
Fuselage, tail, wing, glue, etc	15
Total	50.5

Table 5 Mass summary of Micro Air Vehicle (MAV)

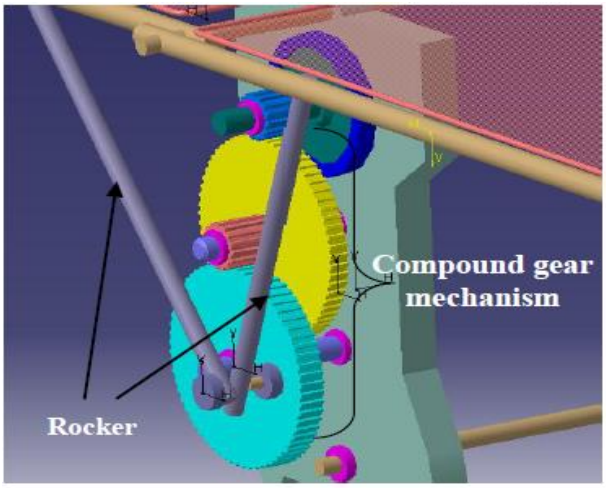

Figure 8: Fabricated Model of Flapping mechanism

LIST OF NOMENCLATURE

N_1 Input Speed, RPM
N_4 Output speed, RPM
i Gear Ratio
M Mass, g
n No of gears
T No of teeth on each gear

Conclusion

The primary objective of our project design and development of ornithopter micro air vehicle (as shown in figure 8) and attain the crash resistance power by constructing the MAV with modern materials successfully done and also experimental and testing work was carried out in GOOD RICH Aerospace laboratory, Bangalore. And also finally the MAVs offers an excellent opportunity to integrate the original research in multi disciplinary platform and meaningful for us.

Further progress we are implementing visible light camera (image capturing), optical sensor in our Micro Air Vehicle (MAV), it is expected to take place rapidly.

REFERENCES

[1] Ellington C.P (1999), ―The novel aerodynamics of insect flight: applications to micro air vehicles‖, The Journal of Experimental Biology, Vol.202, pp.3439-3448

[2] Grasmeyer,J.M.and Keennon, M.T (2001), ―Development of the Black Widow Micro Air Vehicle,‖ AIAA, 2001-0127

[3] Peter G.Ifju, David A. Jenkins, ―Flexible – wing based micro air vehicles‖,American Institute of Aeronautics and Astronautics (AIAA), 2002-0705

[4] Mukherjee .S and sanghi .S (2004), ―Design of a six link mechanism for a micro air vehicle‖,Defence Science Journal", Vol.54, pp.271-276

[5] William R. Davis, Jr. (1996), ‗ micro air vehicles for optical surveillance, the Lincoln Laboratory Journal", Vol.9, pp.197-212

[6] Albertani R, Stanford J.P (2007) ‗Aerodynamic coefficients an deformation measurements of flexible micro air vehicle wings", Society for Experimental MechanicsVol.47, pp.625-635

[7] Caspar T. Bolsman and Hans F.L. Goosen (2007) ―The Use of Resonant Structures for Miniaturizing FMAVs", *3rd US-European* Competition and Workshop on Micro Air Vehicle Systems (MAV07) & European Micro Air Vehicle Conference and Flight Competition (EMAV2007), pp 17-21