Design of Bio-Structural View on Micro Aerial Vehicle's of Practical Flyer

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ABSTRACT
We can learn many things by observing the biological flight of insects, birds and bats since they fly with higher aerodynamic efficiency i.e., their lift to drag ratio is much higher as compared to our airplanes. They produce thrust by a complex morpho-functional flapping phenomenon. The comparison of flight features of these three types of fliers gives us some useful clues on the nature of natural wing materials having special properties (like light weight and high flexibility) which have to be considered seriously for their usage in Micro aerial vehicle to enhance their aerodynamic efficiency. The evolutionary history of these fliers and flapping is a notable feature. Insects are miniature fliers having low mass, resilin, and membranous chitinous wings, with high flapping frequency of 500 Hz or more. To imitate them is difficult. Birds and bat wings are modified teteapod limbs for flight. Birds have thousands of keratin feathers which cannot be replicated easily. In birds, the finger bones are reduced. However in bats, the finger bones are highly elongated (delicately) and the whole body is covered by membrane. It may be easier to imitate bat model and not its echo location. Anti stalling devices (Alula in birds) need further study. Their effortless landing and takeoff is notable for micro aerial vehicle design. Comparative moment of inertia studies give better aerodynamic information on biological wings. These natural fliers have extraordinary sensory perception, integration, feedback mechanism and adaptive control of flight. The researchers are trying to suggest how to incorporate some of these features in micro aerial vehicle designs. In fact in the most advanced fighter aircrafts (like F – 22 Raptor of USA) some sensory features are incorporated. We can think of flexible materials for wings, like silk, thin graphite with latex support etc. The biological wings are elastic and they withstand bending and damp the vibrations.

I INTRODUCTION

Biological flight of insects, birds and bats has an evolutionary history of millions of years and phylogenetically they are different in origin, structure but develop similar aerodynamic forces during flight. Biological fliers have higher aerodynamic efficiency (L/D ratio) and possess flapping flexible wings which differ in their origin and morphological structure. The biological fliers in a way can be called as MAV's keeping in mind their weight limits which are shown in Table 1.

In biomimicking MAV's we have to introduce flapping flexible wings and the problems of takeoff and landing have remained unsolved. For the development of an MAV we need an interdisciplinary approach of aeronautic engineers, ornithologists and biologists. It is advisable to go for biomimicking MAV's based on insect model, bird model or a bat model. The bat model is little complex however, its elastic patagium supported by elongated delicate bones which is more ideal to copy.

The present paper aims in comparing basic aerodynamic features of an insect, bird and bat which can be the basis in detail understanding of biomimicking principles of natural fliers. All the biomimicking fliers should satisfy the conditions for hovering and successful horizontal flight.

II LITERATURE REVIEW

Deakin (1970, 2010) has derived an expression for wing beat frequency by considering the dimension analysis as the basis. He considered two dimensionless ratios by using 'Bukingham Pi Theorem', which states that equations can be reduced to a simpler relationship by using dimensionless products.

Hovering is a kind of continuous power on flight where forward velocity becomes zero and the wings act as propellers of high frequency. The body is held more or less vertical and stroke plane of the wings is approximately horizontal. The wingtip traces a figure '8' and the wings move back and forth. The rate of change of momentum supports the bird weight. Small and medium size fliers such as humming birds, kingfishers practice hovering mainly for getting food. During hovering, oxygen consumption increases five times as compared to resting state. The wing stroke angle may be larger than 120^0, therefore S_d (disc area) may be taken as 360^0. The S_d concept in mass flow (1977, 2011) is replaced by S_w (small wing swept area) in Crawford theory (1971). Birds in nature hover at one spot, and the transition to horizontal flight. The wing motion in hovering is sinusoidal. There is a marked drop in power as the bird converts its position from hovering to forward flight. Big birds are not able to hover because of high energy cost and for not developing sufficient lift.

Puranik and Chari (1986) reviewed wing beat frequency in a chronological order. Pennycuick (1975) has suggested a formula for wing beat frequency of birds in steady flight. Sane (2003) has reviewed the aerodynamics of insect flight with emphasis on flapping flight. Wong (2005) has reviewed recent experimental, computational and theoretical approach to study the forces and flows around flapping wings of insects.

For the design and development of a MAV, necessary basic (Chari 2011) and derived parameters are listed in table 2.

III MECHANISM OF FLIGHT

Birds fly not only by flapping their wings, but by gliding with their wings outstretched for long distances. The work on a buoyancy principle.

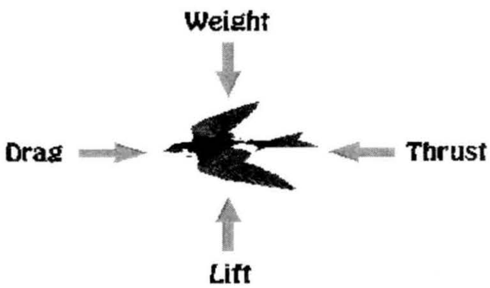

Fig.1

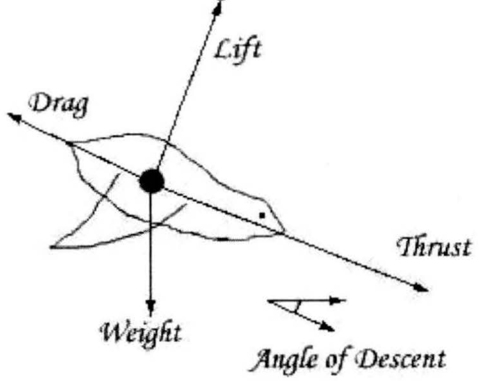

Fig.2

IV FORMULATION OF GLIDING FLIGHT

The actual wing span B of the bird could be determined, since

$$B = b1\frac{R1}{f}$$

where

b1= was the wing span of the image of the bird on this negative.

f= is the focal length of the camera lens.
R1= pre-set on the rangefinder.
If *bi* was the span of the image on the i'th negative, then the range R_i at which it was taken is given by

$$R_i = f.\frac{B}{bi}$$

An estimate of range was thus obtained for each negative in a series, separated by a constant time interval. A regression of range on time was then calculated, and the regression coefficient was taken as an estimate of the bird's speed relative to the glider, i.e. the closing speed *Vx*.

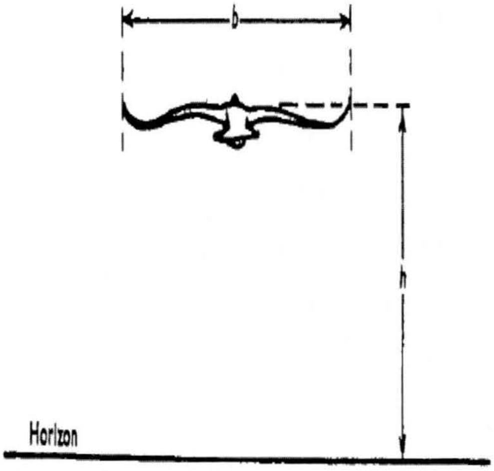

Fig. 3

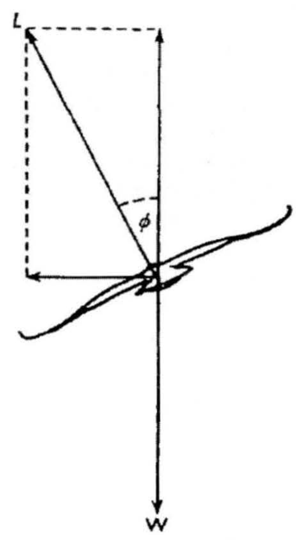

Fig. 4

V DISCUSSION AND SUGGESTIONS

The mass range as suggested for MAV's is from 0.1 to 0.2 Kg. The above mentioned fliers in Table 2 and their species specific, aerodynamic features have been very well tested in nature for millions of years under genetic control. Each flier as suggested in the Table 2 has definite environmental adaptation for flight. Our knowledge of airplane aerodynamic parameters is hardly 110 years old where we have separated lift and thrust. Therefore, scaling of biological features of insect, bird and bat flapping wing along with their body morphology might help in the design of better biomimicking MAV's. These prototypes have to be studied theoretically and experimentally.

The mass of the flier is carried on the flapping wings by developing lift and thrust at a particular frequency.

VI CONCLUSION

(a) For the biomimicking wing structure, pigeon (dove) or eagle (hawk) can be considered to start with. The materials should be less dense and stronger. Dragon fly or locust are the other easier insect models to mimick. Scaling is the most essential factor in biomimicking.

(b) The experimental work in wind tunnels is needed to obtain the aerodynamic parameters and to validate CFD studies. Since the experimental work is tedious, CFD analysis can be carried out on much geometry after their due validation. The experimental model needs a robust flapping mechanism, for the study of unsteady aerodynamics.

(c) If the flapping wing is not able to produce sufficient thrust, a stand by propeller can be thought of to generate the deficit thrust.

(d) For biological fliers, the landing and takeoff are not a problem either for terrestrial, aquatic or arboreal environment. Similar one can be thought of for the terrestrial MAV's. Since present MAV's do not have adequate landing and takeoff provisions.

Table1
Minimum and Maximum Weight of Biological Fliers

Parameter	Insect	Bird	Bat
Minimum Weight	$5 * 10^{-9}$	0.005	0.008
Maximum Weight	0.01	12	1.2

(All units are in SI system)

Table2

Species Specific Features of Insect, Bird and Bat

Parameters	Insect	Bird	Bat
Mass (M)	0.0008	0.168	0.0075
Wing Length (l)	0.0217	0.256	0.127
Wing Span (L)	0.0564	0.542	0.283
Wing Area (2A)	0.0004	0.0579	0.0114
Effective Wing Breadth, B_{eff}	0.015	0.113	0.041
Wing Loading (M/ 2A)	1.96	2.98	0.65
Wing Span Loading, (M/L^2)	0.269	0.572	0.0936
Frequency, (ν_h)	49	11	5
Induced Power (P_i)	1.19	363.6	30.65
Time (T)	0.01	0.09	0.22
Wing Hinge	Point fulcrum	Ball and Socket joint	Ball and socket joint patagium attached to body

Insect – T. Javanica (Soap nut bug), Bird – S. d, decacto (Ring dove), Bat- H. spereosis (leaf nosed bat), (All units are in SI system)

REFERENCES

[1] Deakin, M. A. B., 1970. "The Physics and Physiology of Insect Flight", American Journal of Physics 38:1003-1005.

[2] Crawford Frank S., 1972. Comments on "The Physics and Physiology of Insect Flight", American journal of physiology 39: 584.

[3] Puranik, P.G., Gopal Krishna G, Adeel Ahmed and Chari N. 1977. "Wing Beat Frequency of a Flier – Mass Flow Theory", Proc. Ind. Acad. SciSoc. A., 85, 327-329

[4] Puranik, P. G., and Chari N. 1986 "Bio-Aerodynamics of Fliers." National Book Enterprises, Hyderabad, A.P. India.

[5] Pennycuick, C. J., 1972. "Mechanics of Flight in Avian Biology", Vol. 5 (ed. D. S. Farner and J. R. King), pp. 1-75. Newyork: Academic press.

[6] Pennycuick, C. J., 1996. "Wing Beat Frequency of Birds in Steady Cruising Flight: New data and Improved Preditions", Journal of Experimental Biology, Vol. 199: 1613-1618.

[7] Sane, S. P., 2003. "The Aerodynamics of Insect Flight", Journal of Experimental Biology, Vol. 209: 4191-4208.

[8] Wang, Z. J., 2005. "Dissecting of Insect Flight", Annu. Rev. Fluid Mech, Vol. 37: 183-210.

[9] Chari N., 2011 "Bio-Aerodynamics of Bird Flight." Vistar Graphics, Hyderabad, A.P. India, V edition.