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Review on Bio-Mimitic Robotic Bird

Mr. Sreedhar[1], B. Pavan[2], D. V. Anirudh[2], G. Shiva Krishna[2]

[1]Assistant Professor, [2]Student
[1,2]Department of Mechanical Engineering, Gurunanak institute of technology, Rangareddy, Telangana, India

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ABSTRACT

The present world has reached to a stage where most of the sophisticated and sensitive tasks are mostly done by artificial hands. This paper discuss about the details of artificial birds are also called as ornithopters which belongs to Micro Arial vehicle (MAV) category. Bio-mimicking robots have been replaced the place of human with their uncompromised accuracy and efficiencies. However the real challenges in developing MAVs is still unsolved and not interpreted as it flies in the transient and low Reynolds number flow. This paper investigated the aerodynamic factors of fly's which influence their flight, different kinematic mechanisms which drives the vehicle and different types of designs for wings and their performance. In line with this, both past and future of this innovative area were discussed. One other hand selection of material is also plays vital role in case of MAVs weight consideration . So, this paper explain the different material which suited for this kind of flying machine.

KEYWORDS: *Micro Arial vehicle (MAV), Angle of attack (AOA) and Reynolds number*

INTRODUCTION

Biomimetic or biomimicry is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems. Human have looked at nature for answering to many problems. Bio mimicking technology emphasizes scope in clear understanding of nature and reprinting the nature. One of the early examples of biomimicry was the study of birds to enable human flight. Leonardo da Vinci (1452–1519) was a keen observer of the anatomy and flight of birds, and made numerous notes and sketches on his observations as well as sketches of "flying machines". After number of unsuccessful attempts finally man made bird had taken flight in 1841which was made by ironsmith kalfa who is Serbian journey man. Along with the time the name of this bionic bird turns into ornithopter. Bird wings have a special feature of not only developing lift but also providing with the necessary thrust. It is a well-known fact that nature has been created with utmost perfection. Ornithopters try to imitate the way a bird flies, there by becoming a close to ideal flying machine. This imitation is termed as bio mimetics. The application of biomimetic principles to the development of small unmanned vehicles spans the scale of flight from insects to avian flyers.

There are two common types of ornithopters. The simplest models are powered by winding up a rubber band. These ornithopters are the least expensive to build, and they can be flown indoors. The rubber-band-powered ornithopters aregreat for a school competition to see who can get the longest flight time.

The second type of ornithopter is powered by an electric motor. Electric ornithopters are more difficult to design and build. These ornithopters range from 10 cm wingspan "micro air vehicles" to the size of an eagle. They are often radio controlled, and they can carry payloads such as cameras. The first challenge is constructing a reliable gearbox and flapping mechanism that will provide enough power for your ornithopter to fly. Once you have accomplished that, you will find that getting an ornithopter to steer and turn effectively can be equally difficult. As you overcome each of the challenges that your ornithopter can present, you will advance your knowledge of building techniques, electronics, and the principles of flight.

AERODYNAMICS OF FLAPPING WING

Flapping involves two strokes, which are upstroke and down stroke. During down stroke, the total aerodynamic force is adjusted to a tilt which generates lift and thrust. During upstroke, the angle of attack is positive near the root and can be either positive or negative at the tip depending on the pitching up of the wing. In upstroke, the upper part of the wing produces an aerodynamic force upward with a backwards tilt, producing positive lift and negative thrust. When the angle of attack is positive, the outer part of the wings produce positive lift and drag. Conversely, when the angle of attack is negative, the wings will produce negative lift and positive thrust

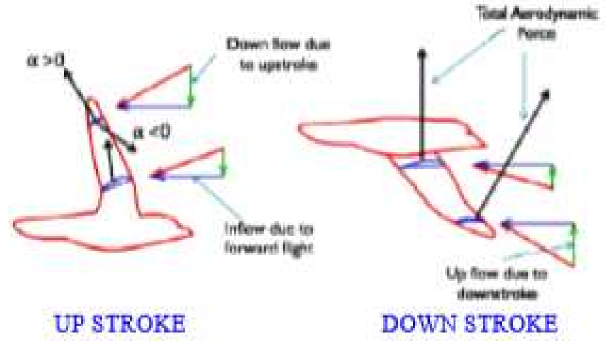

Fig.1. Force generation of flapping wing.

Lift and drag of flapping wing is influenced by the incident angle and forward speed and it is considerably affected by flapping frequency also. However, thrust is concerned with the flapping frequency and forward speed but not on incident angle[1]

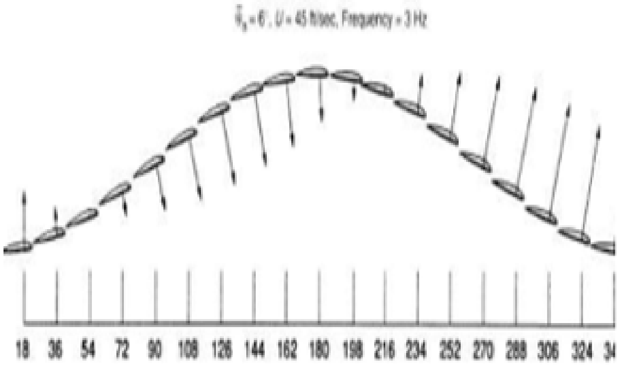

Fig. 2 Thrust and lift generation of flapping wing

This type of MAVs operate under the low Reynolds number ranging from 10^4 to 10^6 , so there is significant shift in fundamental behavior of flapping wing[2]. Designing and developing of controls and power system becomes difficult due its unsteady effect. Lift and thrust generation of Mavs is not same as the fixed wing aircrafts. Mavs operated under the transient state and has following aerodynamic effects.

A clear understanding of flapping flight aerodynamics has been obtained by dynamically scaled models of insect wings that can reproduce the same aerodynamics mechanisms present in insect flight by Dickinson et al (1999). These experiments have unveiled three main aerodynamic mechanisms involved with flapping flight: delayed stall, rotational lift and wake capture.

The delayed stall appears at the onset of motion of the wing as shown in fig. As the wing starts moving a small vortex appears behind the leading edge and an asymmetric, opposite swirl appears in the fluid close to the original resting position of the wing as illustrated in Figure. The presence of two vortices moving in opposite directions but with identical strength is the equivalent principle of conservation of momentum for fluids. The vortex above the wing creates a lower pressure on its back surface, thus producing a net aerodynamic force perpendicular to the wing surface. As the wing moves, the vortex behind the leading edge increases along with the aerodynamic force. However, after a certain distance a new vortex starts appearing behind the trailing edge to keep the total fluid momentum constant this vortex has a rotation direction opposite to that of the leading edge vortex and in turn decreases the force production. Moreover, the vortex on the leading edge keeps on increasing till it reaches a critical size at which point it detaches from the wing and is shed into the fluid, thus it is decreased the force production even further as shon in fig. As soon as the leading edge vortex detaches, a new vortex starts appearing behind the leading edge and this process of the vortex building and detaching repeats itself endlessly.

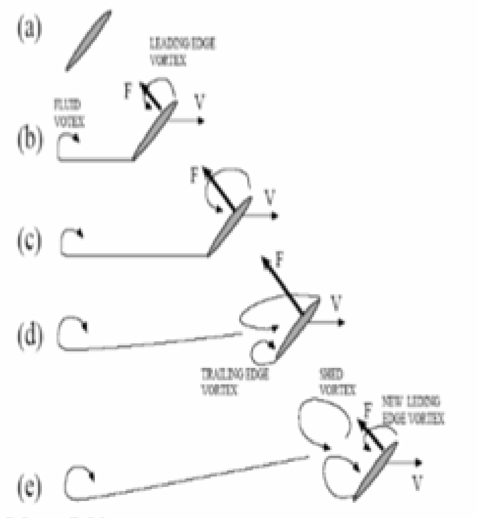

Fig.3 Delay stall mechanism.

Another very important characteristic of flapping flight is that the wings do not translate but rather rotate about their wing hinges. The rotational lift mechanism is the result of a combination of the translation and rotation of the wing. This mechanism is analogous to the one that allows a ball to curve when it is thrown with some spin, as commonly seen in baseball or tennis. In fact, an aerodynamic force perpendicular to the translational velocity appears if the ball has a backspin as shown in Figure. The magnitude of the aerodynamic force generated by the rotational lift is approximately proportional to the product of the angular velocity and translational velocity.

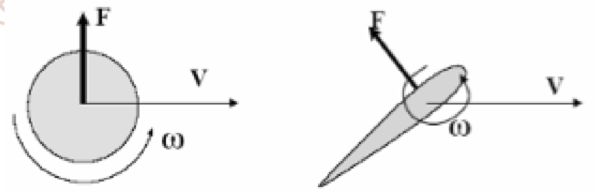

Fig.4 Rotational lift for spinning ball and spinning wing.

The last mechanism present in flapping flight is the wake capture. It is present at the beginning of each half-stroke after the wing has inverted its motion and started to move. The wake capture appears when the wing interacts with the effects of past strokes on the ambient fluid environment. The fluid behind the wing is dragged along with the motion of the wing. As the wing slows down and inverts the direction of motion, it hits the fluid, which is still moving because of its momentum. Therefore, the velocity of the wing relative to the fluid is larger than the velocity of the wing alone, and therefore results in the generation of a larger force. This is a simplified explanation of the principle behind the phenomenon of wake capture. The contribution of each of these three aerodynamic mechanisms has been measured using a dynamically scaled model of a wing [3].

There are three types of interaction of the harmonically oscillating wing, used as a thrust generator, namely

- Optimal interaction of the oncoming vortices with those shed by the wing, resulting in the generation of still more powerful vortices in the wake in the form of a reverse Karman vortex street.
- Destructive interaction of oncoming vortices with those shed by the wing, resulting in the generation of weaker vortices in the wake in the form of the reverse Karman street.
- Formation of a vortex pair with vortices of opposite sign shed from the wing, this effect leads to the generation of a wide wake composed of vortex pairs which are shed at an angle to the free stream [4]

TYPES OF FLAPPING WING MECHNAISMS

An efficient flapping wing mechanism is necessary for producing required lift and thrust forces. For avian ornithopter which has more than 0.8 meter wing span, motorized Four-bar crank rocker mechanism is highly adequate to make the ornithopter airborn. This mechanism has only one degree of freedom for their flapping wing[5].

STAGGER CRANK

Connecting rods are positioned in a measured distance and two connecting rods are placed at two different angles such that wings can flap symmetrically. These types of ornithopters can be built at home with household things [6].

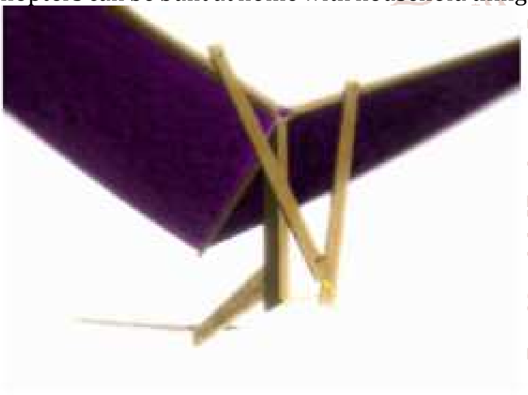

Fig 5. Staggered crank

SINGLE GEAR CRANK

This mechanism may look simpler and light but constructing this mechanism is complicated. It has a single connecting rod pinned on single gear it is connected at center point of two wing arms. The center point where the connector rod and the wing hinges are connected to each other has to expand and contract as the mechanism flaps [7].

Fig. 6 Single gear crank mechanism

DOUBLE CRANK ROCKER MECHANISM

This mechanism consists of specially designed gear box two gears are mounted at front to which two connecting rods are connected. These two gears are driven by a pinion which is driven by motor. Two connecting rods are connected to two wing arms. This design is much simpler and reduce wing symmetry miss alignment [8].

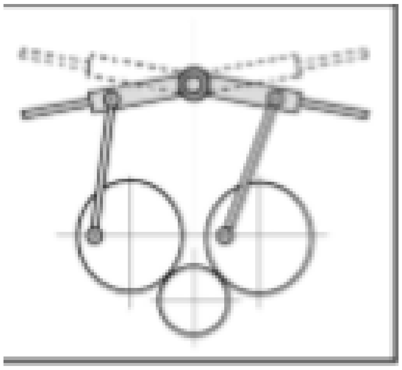

Fig7. Double crank rocker mechanism

TRANSVERSE SHAFT MECHANISM

The transverse shaft design is the other variation of flapping mechanism which allows for the most symmetrical flap, however, it is the heaviest and the most complicated design. The rotating gears and the flapping wings are not in the same plane thus the connector rod has to be able to rotate. The connector rod has a ball bearing inside and this adds weight to just the component itself. The number of gears used in this design is more than any other design. The transverse shaft design is usually used for a bigger MAV design where weight could be overcome by large wings [9].

Fig 8. Transverse shaft mechanism

SLIDER-CRANK MECHANISM

When dealing with micro Ariel vehicles which has wing span less than 100cm like insects or butter flies, smaller more compact than four bar crank rocker mechanism is required. In smaller ornithopters slider crank mechanism is employed. This type of vehicles has X-type flapping wings [10].

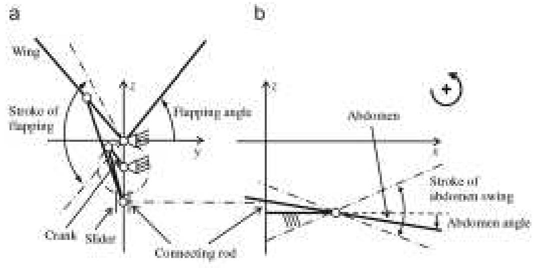

Fig.9 slider crank

MODIFIED SLIDER CRANK MECHANISM

Ornithopter which has to replicate dragon flies and other wasp required even more reliable mechanism in order to make it more agile and efficient maneuver. These kinds of manmade birds uses modified slider crank mechanism as shown in fig.8 [11].

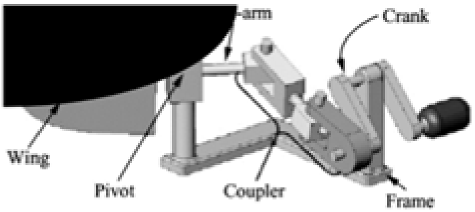

Fig10. Modified slider crank mechanism.

EFFECT OF WING DESIGN ON THE FLIGHT PERFORMANCE

Wing design influences the flight condition of ornithopter. Experimentation is done by taking three different cross sections of wings which are PET cambered thin section wing, Orcon cambered thick wing and Orcon flat wing are shown in fig 9.

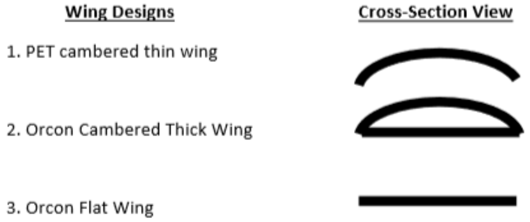

Fig11. Cross-section view of different wings

It was observed that in both PET cambered thin wing and Orcon cambered thick wing are generating negative lift thus they are generating no lift. Only in orcon flat wing can able to produce positive lift. Graphs are plotted for lift and thrust for various flapping frequency.

Firstly, graph is plotted thrust of each wing design against the time at single flapping frequency [12].

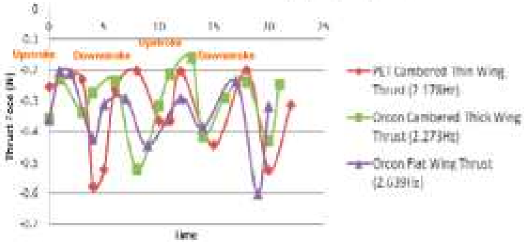

Fig.12. Thrust vs time.

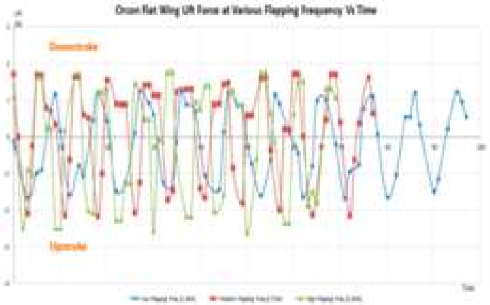

Fig13. Lift vs time at three different frequencies for Orcon flat wing

Type	Low Speed (N)	Medium Speed (N)	High Speed (N)
PET Cambered Thin Wing	−0.196	−0.140	−0.218
Orcon Cambered Thick Wing	−0.225	−0.256	−0.305
Orcon Flat Wing	−0.075	0.264	−0.142

Table1. Lift comparison for various wing designs

Gary Parker and JohnyBorbone tried to construct a ornithopter which replicate the great albatross which also ideal bird in this design. They have designed a successful model which deduct the friction losses during up stroke by making wing folding mechanism and generate lift in down stroke with full expansion of wing. They studied optimal gliding and dynamics of ornithopter using three different types of wing membranes namely firm felt, membrane plastic and Styrofoam [13].

Fig.14 Ornithopter with firm fel

Fig.15 Ornithopter with mebrane plstic wing

Fig.16 Ornithopter with Styrofoam wing

MATERIAL

Material used for wing should possess elasticity, stiffness, strength, higher resistance of wear and tear, and extremely light weight. Some of the material which are often used for ornithopter are carbon fiber, Mylar foil, polyurethane- foam Polyurethane foam, polyester films, Titanium alloys and balsa wood also [14].

In Delfly1, 6 micron Mylar foil along with 2 stiffeners was used to control the increased flexibility, but still due to such high flexibility higher lift was not obtained [15]. Instead, carbon fiber rods wings and body is compound with polyurethane. This will help in reduction of length to weight ratio and strength and stiffness of wing [16]. Harvard robo Bee wings are made of polyester material as wing membrane and carbon fiber rods as stiffener[17].

CONCLUSION

In last one and half decade advancements in this area significantly increased and its ability to mimic the natural flies makes it more appealing for surveillance applications. Still it has to overcome many challenges. Due to fast and continuous motion there will be chance of fatigue failure of components. With this investigation one can say upward stroke generate negative thrust which is undesirable in flight. So the wing should have ability to fold, change camber and reduce its wing span during upstroke, which in turn reduce drag and negative lift production. However, there should be much more progress in development of ornithopters with autonomy in their flight. There should be much more improvement in case of payload capacity of ornithopters. Present ornithopters did not have much pay load capacity, which restrict installing the on board camera feed and other electronics. Ornithopter with back fly is more advantageous, because in tunnels or in narrow space there won't be enough space to turn. In that case back flying ornithopters can have ease of fly.

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