



Flapping Wing over fixed wing – A review

Saiyed Moinuddin S¹., Kevat Mitesh M¹., Avdhiya Darsan A¹., Vasava Vasanti K¹, Meet Jayesh Shukla¹

¹Department of Mechanical Engineering, Valia Institute of Technology, Valia -

Abstract: *The concept of flapping wing has served as a deep field of interest for aerodynamics engineers. It is based on the argument that flapping wing flight, is more efficient than traditional fixed wing at small scale and rotary flight. It is recognized that the flexible nature of membrane type wings can quantitatively increase aerodynamic stability by absorbing unsteady forces/moments which store elastic potential energy. Study of this type of wings at various flapping parameters like frequencies and airflow pattern will aid future researches in building a flapping wing with more beneficial effects to design UAV(unmanned aerial vehicle)by using flexible membrane wings.*

Keywords : *Flapping Wing , Flexible Membrane Wing , Aerodynamic Stability , Elastic Potential Energy*

I. INTRODUCTION

1.1 Flying on Flapping Wings

- Over the past twenty-five years, interest in small unmanned aerial vehicles (UAVs) has greatly increased.
- Most of the UAVs in production and use today are fixed wing airplanes, which mean that these aeroplanes employ traditional methods of lift and thrust: a propeller for thrust and rigidly attached wings relying heavily on the free stream velocity for lift.

1.2 Ornithopter

- An ornithopter (from Greek ornithos means "bird" and pteron means "wing") is an aircraft that flies by flapping its wings. Designers tend to imitated by the flapping- wing flight of birds, bats, and insects. Through machines may differ in form, they are usually built on the same scale as these flying creatures. Manned ornithopter have also been, and some have successful. An ornithopter is an aircraft that flies by flapping its wings. Inspired by nature, we intend to design our own ornithopters by studying the kinematics and dynamics of flapping wing. Also, to fabricate the remote controlled flapping wing MAV. A gear box is needed to be constructed to bring down the rpm to a reasonable value so that the wing flapping frequency becomes 2-4 Hz. Next we need harness the vertical velocity of the rotating gear using the simple concept of simple harmonic motion. In aircraft, tail is used for the pitch and yaw motion whereas in ornithopter tail is used for pitch motion. The ornithopter can be used for various kind of spying and surveillance by fabricating better construction material and gears. Ornithopter can be used for military application, such as aerial reconnaissance without alerting the enemies that they are under surveillance as they can be resembled into birds or insects.



Figure 1. Manned aerial vehicle

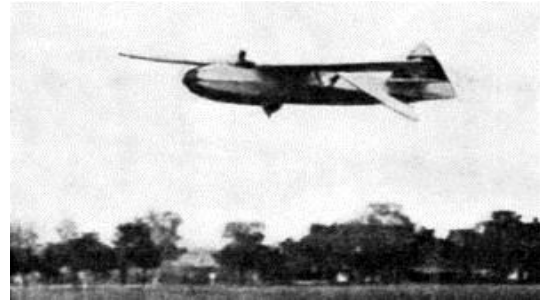


Figure 2. Ornithopter

Alphonse Penaud, in 1870's performed a mechanical flapping wing rubber powered model ornithopter in France, which was documented and witnessed. Alexander Lippisch also worked on ornithopters [1]. During 1990's The Project Ornithopter engine powered piloted aircraft was which is based on the technology of the Harris/De Laurier model. One of the first successful attempts to develop bird- like flapping flight was by De Laurier [2].

The first MAVs were developed as early as WW-I in the form of guided munitions later expanding their roles into radio controlled target drones, reconnaissance aircraft and glide bombs of the modern day cruise missile [3]. The first radio controlled (RC) aircraft flight in Germany 1936 led the way to further refinement of small UAVs in post war era. The air flow field in flapping wings can not be assumed as steady. A large angle of attack would lead to flow separation and turbulences too. Obviously, there must be phenomena producing extra lift. As was discovered with the development of MEMS technology, the physics of the small are different from that of the large (for example, friction is more important than gravity) [4]. For MEMS technology to progress, researchers had to develop a new understanding of these physics, and develop new techniques for overcoming and capitalizing on them. This is the case with small scale, or low Re aerodynamics today.

II. EFFECT OF VARIOUS PARAMETERS

2.1 Kinematics of Wing

The flapping wing motion ornithopters and entomopters can have three basic motion with respect to axis based on the kinematics motion of wing and mechanism of force generation a) Flapping, which is up and down plunging motion of the wing. Flapping produces the majority of the birds or insect's power and has the largest degree of freedom. b) Feathering is the pitching motion of wing and can vary along the span. c) Lead-Lag, which is in-plane lateral movement of wing [5].

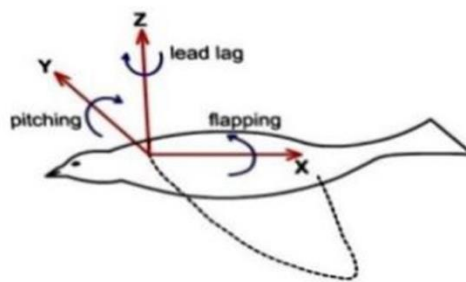


Figure 3. Representation of axis

2.2 Flapping Wing Forces

Flapping motion involves two stage: the Down Stoke, which provide the majority of the thrust and the Up stoke which can also (depending on the birds wing) provide some thrust. At some thrust at each up-stroke the wing is slightly folded inwards to reduce the energetic cost of flapping with flight. Birds change the angle between the up stroke and the down stroke of their wing. During the down stroke of their wing. During the down stroke the angle of attack is increased and is decreased during the up stroke.

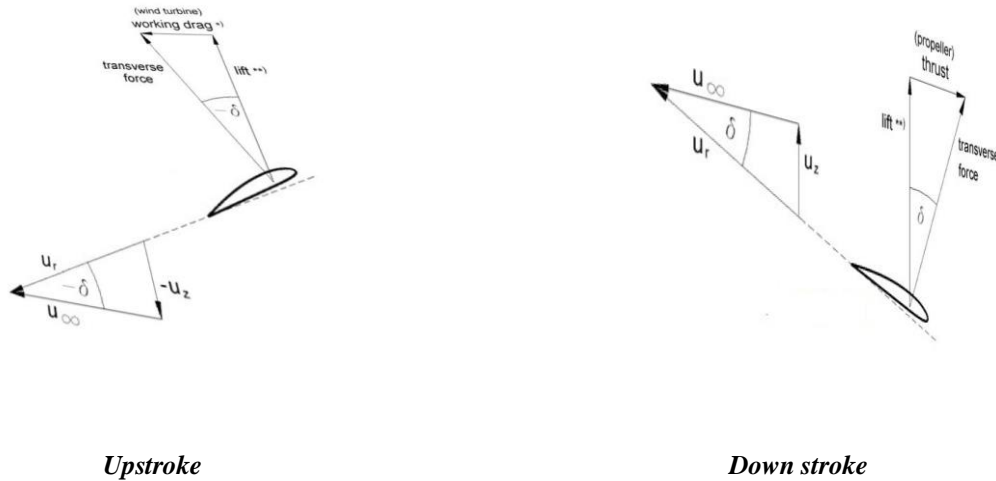


Figure 4. Forces acting on Flapping Wing

During the down stroke the total aerodynamic force is tilted forward and has two components, lift and thrust. During up stroke, the Angle of attack (AOA) is always positive near the root but at the tip it can be positive or negative depending on the amount of pitching up of wing. Therefore, during up stroke the inner part of wing produces aerodynamic force which is upward but tilted backwards producing lift and negative thrust. The outer region of the wings would produce positive lift and drag if the AOA is positive. But if AOA is negative then it will produce negative lift but positive thrust [5]. Both cases are depicted in the fig. 3.1.2.

2.3 Flapping Frequency

Pennycuik et al. has made some observations in the flapping frequency which has been considered. His found out multiple regression and dimensional analysis by conducting an experimental studies on 32 morphologically diverse bird species, representing 18 families, and ranging mass from 20g to 5kg. The wing beat frequency is correlated by the following formula:

$$F = 1.08 (m^{1/3} g^{1/2} b^{-1} s^{-1/4} \rho^{-1/3})$$

Where m is the bird's body mass, g is the acceleration due to gravity, b is the wing span, S is the wing area and ρ is the air density [8]. The relationship between flight speed & the mass of the bird can be given by from Pennycuik

III. PROTOTYPE OF DESIGN AND MODEL

3.1 Basic Flapping Wing Theory

Flapping flight is more complicated than flight with fixed wings but still the basic concept of aerodynamics of fixed wing can be applied. The thin membrane of flexible material can be stuck on the leading edge and root chord of the wing. The thin membrane are used for the wing is non-woven fibre and celloso plastic.

According to the Ornithopter Design Manual (Chronister, 1996) and Micah O'Halloran (1998), membrane wings generate positive lift and thrust during the down stroke. However, during upstroke, the lift becomes negative although thrust is still positive. The material of the membrane is flexible. Hence during down stroke, as shown in Fig. 4.1, air is displaced downward and backward, causing the membrane to be pushed upward and forward. The direction of this force will produce lift and thrust. Although the front of the membrane is glued to the leading edge, the trailing end is allowed to swivel within the limits of the flexible material. This will cause the trailing edge to always lag behind the leading edge. As a result, the membrane will become positively cambered. From fixed wing aerodynamics, the camber shape will provide some additional lift as well.

During the upstroke, as shown in Fig. 4.2, the reverse happens and the trailing edge is always lower than the leading edge. The new direction of force will provide thrust but negative lift.

Throughout the whole flapping cycle, the net force will only be the thrust because the positive and negative lift cancel each other out. In order to obtain lift, the forces must be redirected by increasing the pitch of the wing. In ornithopter's design, this is usually achieved using the tail. The tail is tilted slightly upwards and this will cause the wing to pitch up during flight.

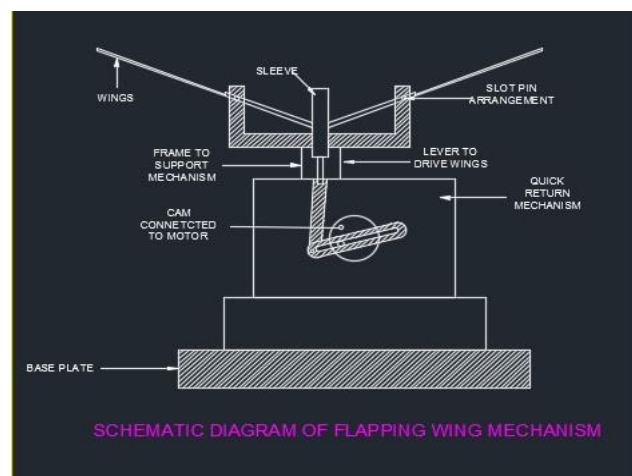


Figure 5. Schematic diagram of flapping wing

The main objective of flapping mechanism is to convert the motor's rotary motion into flapping motion. It is the most important component of the MAV thus much research was done to assess the many different designs available.

Generally the mechanism design is about the same to each other with only slight modifications.

3.2 Wing Design of Model

One of important process of this project is wing design and its development. The wing has semi-span of 20cm having an half elliptical shape. The length of wing is 51cm. The wing has an area of 765 sq.cm. The leading edge and root of wing structure is been fabricated by using plastic sheet of 2mm thickness.

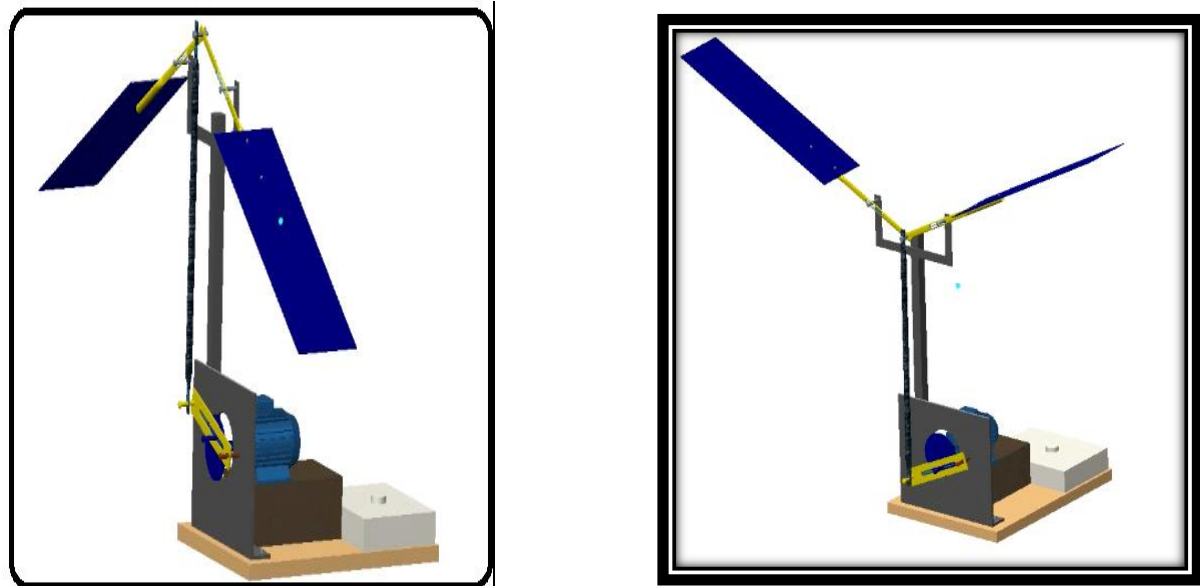


Figure 6. CRIO Images of model



Figure 6. Actual image of our model

3.3 Aerodynamic of flapping wing

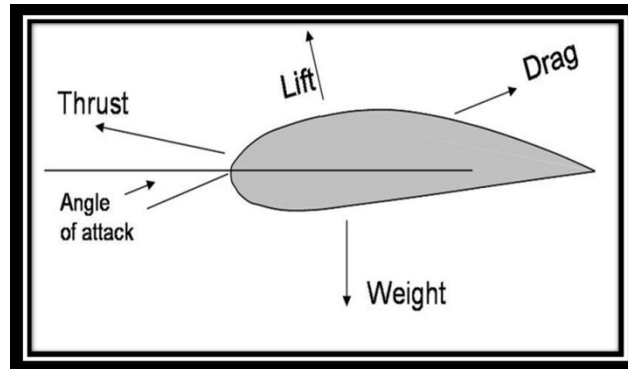


Figure 7. Representation of various forces/reactions

3.3.1 Lift (L)

- When the flapping the wings, the airflow is highly turbulent and producing more lift compare to wing flight.
- The lift that is produced by applying the wings is characterized by highly non-stationary aerodynamic effect.

$$L = \frac{C_L \times \rho \times v \times A}{2}$$

Where,

ρ = the air density, v = Air Speed

A = Platform area, C_L = The lift coefficient for a specific angle of attack.

3.2.2 Weight (W)

- The weight acts vertically downward from the centre of gravity (CG) of the airplane.

3.2.3 Drag (D)

- Drag is the force which oppose the forward direction pushing or pulling force by aircraft engine.

$$D = \frac{C_d \times d \times v^2 \times A}{2}$$

Where, C_d = Drag Coefficient

d = Density of Air and

v^2 =Velocity of Air

3.3.4 Thrust (F)

- Thrust is defined as the forward direction pushing or pulling force by aircraft engine.

Parameter	Fixed wing	Flapping wing
α (Angle of Attack)	15°-20°	>(15°-20°)
C_L (Co-efficient of lift)	$CL \propto \alpha$	$CL \propto \alpha$
L (Lift)	$L \propto \alpha$ ($L = (CL.p.v^2.A)/2$)	$L \propto \alpha$ ($L = (CL.p.v^2.A)/2$)

Table 1.

CONCLUSION

The goal of this study was to develop a flapping wing mechanism to improve the quality of MAV. The focus was also in the improvement in wing design and controllability. These goals were fully reached. The chosen mechanism for turning rotation of the DC motors into a flapping movement of the wings is accurate and leads to error free functioning. The wings were optimized in angle and chord length that yield to enough lift generation for hover flight. In order to achieve more lift generation the search space for finding the optimal wing and mechanical configuration can be extended by a smoother discretization and including also the wing shape. There were no improvements on the motors so far. Many suppliers have the same size of DC-Motors but with different parameters, such as velocity constant. Also there should be a betterment in the controllability by calibrating the motors and reducing play in the structure. The gained knowledge can be used for further improvements and opens the way toward an autonomous flapping wing.

Thus this paper serves to uncover the advantages of flapping wing over fixed wing. And this paper would help researchers to develop the model of flapping wing as discussed above.

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