Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 4, Issue 4; July-September, 2017, pp. 179-182

http://www.krishisanskriti.org/Publication.html

Design of a Piezo-ceramic Biomimetic MAV

Dinesh Kumar G [1], Gowrishankar.D [2], Sidharth Satheesh Kumar [3], Sashank Babu [4] and Nivetha [5]

[1,2]School of Aeronautical Sciences, Hindustan Institute of Technology & Science, Chennai
[3,4,5]Students, School of Aeronautical Sciences, Hindustan Institute of Technology & Science, Chennai
E-mail: aerodinu@gmail.com

Abstract—*MAVs (Micro Aerial Vehicles) are one of the most captivating and anticipated areas in Research and Development. This paper is about the design and actuation of a flapping mechanism of a biomimetic flapping wing MAV. As fixed-wing MAVs are inefficient at low speeds, flapping wing system serves as an important substitute in such cases. Flapping wing MAVs doesn't need separate system for thrust and lift generation. The design is based on mimicking the Anisoptera commonly known as Dragonfly. The hovering, agility and three directional axis maneuverability is incorporated on the MAV as of the characteristics of the dragonfly. Based on the principle of piezoelectric effect the piezo-ceramic material is chosen. Piezoelectric actuators are used for actuating flapping mechanism for MAVs. This design is capable of performing pitch, yaw and roll motion as that of a rotary type air vehicle by varying the speeds of each wing.*

Keywords*: Micro Air Vehicles Dragonfly - Flapping wing - Piezoelectric actuators - Passive rotating system.*

1. INTRODUCTION

Recent years have shown a lot of development in the use of MAVs for numerous practical applications. Its most desired aspect is agility. Flapping wing is one of the most promising lift generation mechanisms due to the ineffectiveness of fixed wing at low speeds. The Reynolds number is an important aspect as it corresponds to the characteristic length, wing chord and flight speed. These MAVs would function only at low Reynolds number of less than 15,000.

As the crank or gear system used for the flapping mechanism for a conventional ornithopter, these systems results in the addition of weight and there by more power requirements and needs a more rigid structure.

Piezoelectric materials have high bandwidth depending upon the structural geometry of the system. As for the MAV the focus must be on the light weight composites that can be manufactured.

As the MAV has the capability to hover and move as its flapping wing is one of the most promising lift generation mechanisms. This could carry a small payload such a camera or sensors for defense and social purposes. Its size and its bio-mimetic characteristics make it undetectable to the human eye.

2. BASIC PIEZOELECTRICITY:

Piezoelectricity refers to the phenomenon of generation of vibrating motion or mechanical stress when electricity is applied or vice versa. Piezoelectricity is seen in crystals due to the shortage of symmetrical structure which results in polarization when mechanical stress is applied. Topaz, tourmaline, quartz etc. are some of the commonly available piezoelectric materials.

3. PASSIVE ROTATION:

The passive rotation is considered to be the rotation of the object along with the co- ordinate system. The actuators exert moment directly about the axis of rotation so the flapping can be consistently maintained as that of a dragonfly [1].

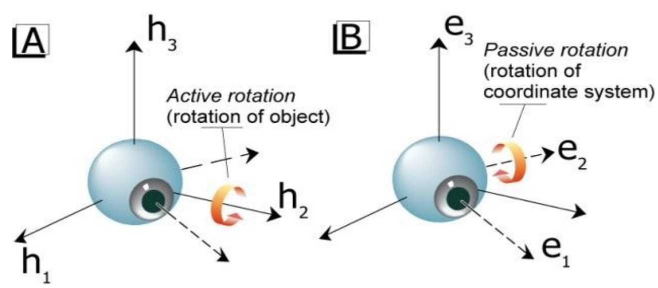


Fig. 3.1: Axis of Rotation

Passive-rotation flapping experiments with insect-scale mechanically driven artificial wings are conducted to simultaneously measure aerodynamic forces and three-degree-of- freedom kinematics (flapping, rotation and out-of-plane deviation), allowing a detailed evaluation of the blade-element model and the derived equations of motion. Variations in flapping kinematics, wing-beat frequency, stroke amplitude and torsional compliance are made to test the generality of the model. All experiments showed strong agreement with predicted forces and kinematics, without variation or fitting of model parameters. (J.P. Whitney and R.J. Wood 2010)

4. KINEMATICS OF PASSIVE ROTATION:

In line to its changing parameters, kinematics is strongly connected to the mechanism of the passive rotation wing through which the lift and drag is produced. Here the motion of the wing is denoted in two simple motions that are stroke (upstroke or down stroke) and pitch as axis motion of the hinges are constrained to X and Y plane.

Where, α=90-ψ

Ψ=pitch

Φ=stroke

5. MATERIAL SELECTION:

The selection of materials will play a major role as the weight, resistivity and durability are important aspects. The actuator material should exhibit good piezoelectric effect when electricity is given. The body of the MAV should be able to absorb the vibration and direct it only to the parts required. The wing should be made of light weight fabrics and not compromising structural adjustments. After further research the materials selected are as follows:

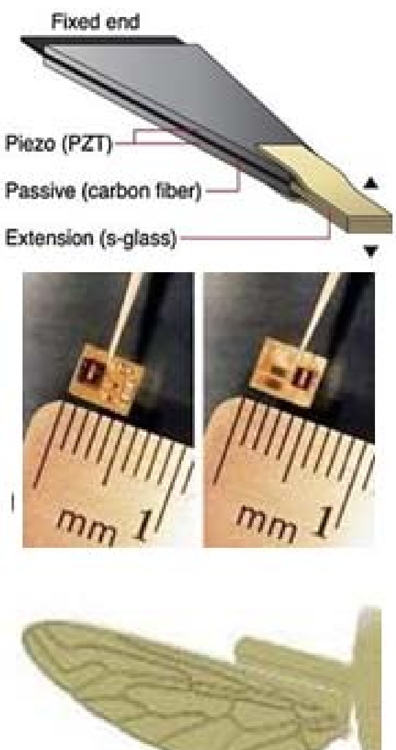
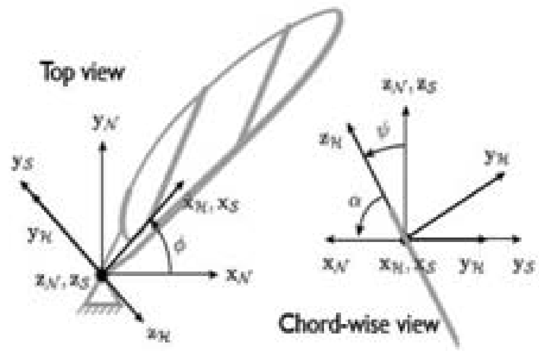


Fig. 3.2: Actuator, electronics and wing



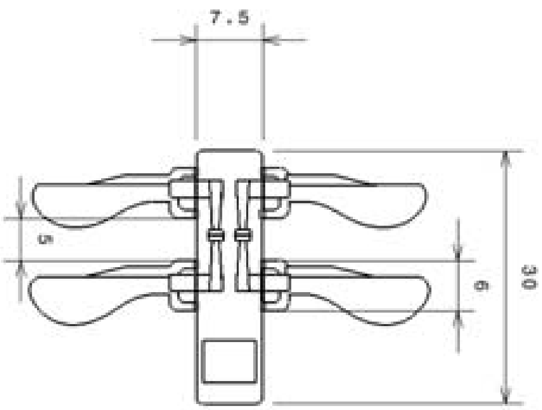


Fig:- 3.3 Schematic Diagram

6. VI SIGN EVOLUTION

The design of this bio-mimetic dragonfly has four PZT actuators, wings, rotational hinges, body and electronics. The design was developed as per the figure given below after rectifying the flaws in its prior design. The final design also has four actuators but here the MAV can achieve multi axis maneuverability by changing the stroke speed of each wing individually. The weight was calculated and then a portion was set for the electronics in such a way the body of the MAV would remain balanced in flight conditions.

Table 6.1: Material Properties

S. NO.	PART	MATERIAL	PROPERTIES
1	Actuator	Lead Zirconate Titanate (PZT)	-High Piezoelectric effect -High Bandwidth
2	Body	Acrylonitrile Butadiene Styrene + Polycarbonate Alloy (ABS+PC)	-Light weight -Good process ability
3	Wing	Elastane + Polymide	Light weight fabrics
4	Electronics	Nano Tech circuit boards	Smaller in size

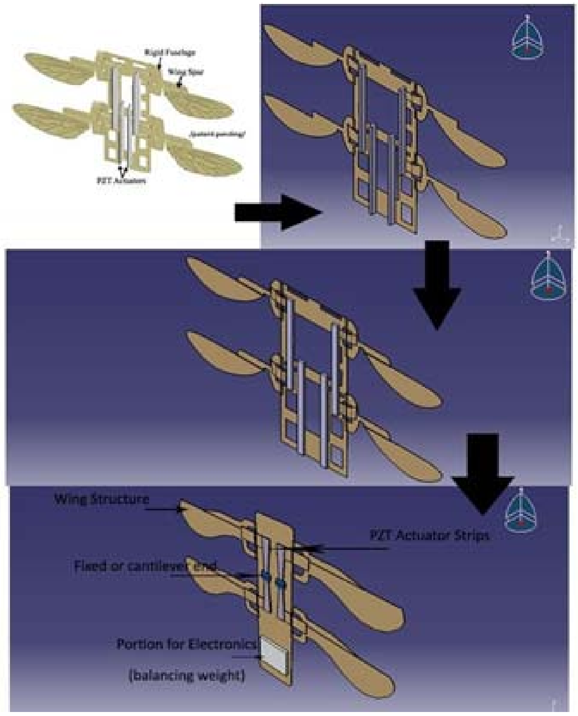


Fig. 6.2-Design structure of Dragon fly

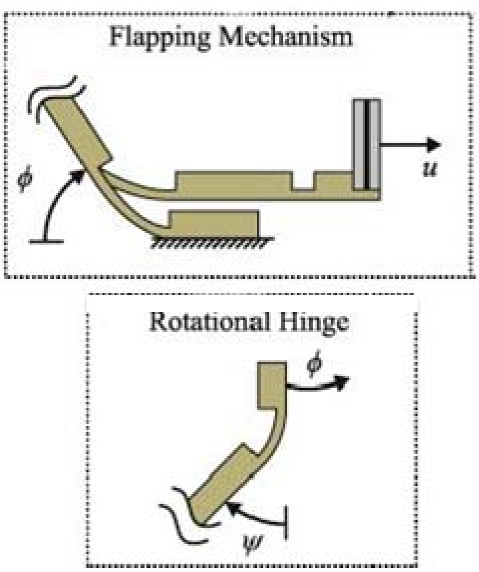


Fig. 6.3 Flapping Mechanism

7. DESIGN AND WORKING OF THE MAV:

The wing flapping's angular displacement of the actuator tip is converted from linear displacement because of the presence of the flexure based transmission and piezoelectric actuator. Here there are four individual piezoelectric actuator strips present to actuate each wing of a Dragonfly separately. This increases the resonance frequency of the wing-piezo system higher grants for a similar consistent relationship between voltage and stroke and produces a flap rate of approximately 120Hz. The four flapping wings that allow passive rotation are connected to the transmission by a flexural hinge.

Piezoelectric actuators are used for actuating flapping mechanism for MAVs. This design is capable of performing pitch, yaw and roll motion as that of a rotary type air vehicle by varying the speeds of each wing.

Here each figure shows the different types maneuverability where in considering if the lifted wing sections indicate to be flapping in a faster rate and if the flatter wings are flapping slower. Then roll left, roll right, forward motion and backward motion (from top to bottom) are indicated in the below figures

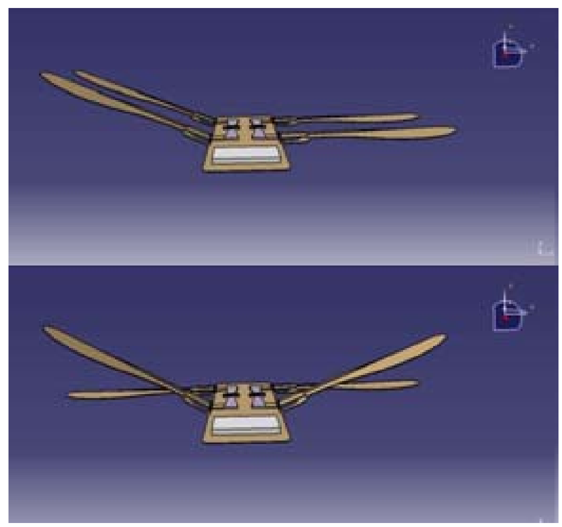


Fig. 7.1 Flapping Upstroke

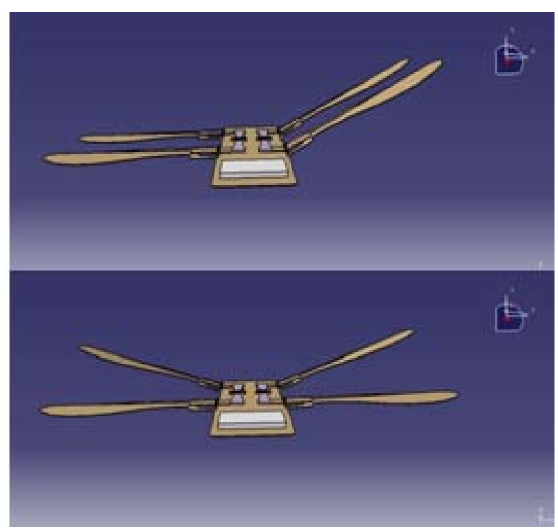


Fig. 7.2 Flapping Down stroke

8. CONCLUSION & FUTURE WORKS:

We showed in this work that we have used four piezoelectric actuators used for actuating individual wings of the dragonfly. By using four control actuators, considerably more payload can be lifted. A design structure of a dragonfly has been developed to actuate all the piezoelectric actuators connected to the flapping mechanism of the wing. As the hinges location is set down from the leading edge the aerodynamic performance improves. Further developments will be made to make the MAV autonomous. However there will be differences between in the kinematic model and experimental performance.

REFERENCES

[1] Challenges for 100 Milligram Flapping flight, by Robert J. Wood and Ronald S.Fearing, 2011.

[2] Basic Piezoelectricity, by John Potter Shields, 1966.

[3] A Flapping-Wing Micro robot with a Differential Angle-of-Attack Mechanism, by Z. E. Teoh and R. J. Wood

[4] Modelling piezoelectric PVDF sheets with conductive polymer electrodes, by Laura Marie Lediaev, April 2006.

[5] Hovering Hinge-Connected Flapping Plate with Passive Deflection, by Hui Wan, Haibo Dong and George P. Huang

[6] Aeromechanics of passive rotation in flapping flight" by J. P. WHITNEY, July 2010

[7] Aeromechanics of passive rotation in flapping flight, by J. P. Whitney and R. J. Wood

[8] Design of Flapping wing mechanisms, by Rohan Tariq, National University of Singapore, 2010.

[9] Material development for a dragonfly inspired composite wing and PVDF sensor, by Sampada Bodkhe, IIT Kanpur, May 2012.

[10] Passive torque regulation in an under-actuated flapping wing robotic insect, by P.S. Sreetharan and R.J. Wood, July 2011.