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# Robotic Ornithopter

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## ABSTRACT

**The project work consists of designing and developing an ornithopter which can be controlled by a remote controller. The project aim at focusing on maximizing the efficiency of a UAV(Unmanned Aerial Vehicle ) sector where the predominant 'fixed wing UAV's' works in comparatively lower efficiency against 'flapping wing UAV's ' like an Ornithopter.The project consists of designing an Ornithopter and analyzing the feasibility of deploying of the same in law enforcement purposes ,jungle warfare scenario and civilian purposes like topological mapping & wildlife protection .Equipments like high definition and thermal cameras , stun-grenades are provided to give a technological and mission oriented approach to the ornithopter.**

**Keywords—**Ornithopter,UAV,flapping wings;

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## I. INTRODUCTION

The purpose of this project is to develop a remote piloted electric-powered ornithopter (flapping-wing aircraft).To study and adopt best possible wing design for higher efficiency and better flight. A detailed design study of drive - reduction systems for efficiently transmitting the electric power to the flapping wings. Further, to build an ornithopter with electric-powered transmission system and to demonstrate successful free flights.The development of flapping-wing flight can be dated back to the early days when Leonardo da Vinci designed his flapping-wing device around 1500 A.D. [4]. The first flapping-wing aircraft that had flown successfully was in 1870 when Gustave Trouve's ornithopter, powered by an internal combustion engine using gunpowder, flew 70 meters in a demonstration to the French Academy of Sciences. Simple ornithopters powered by rubber bands were soon developed. It has taken several hundred years of development in flapping-wing flight.Today there are competitions for indoor small ornithopters that are as light as paper to heavy outdoor ornithopters powered by gas combustion engines that have wingspan as large as 2 meters. All are fascinating to design and buildbecause of the endless possible variations. . This has proven to be more challenging because of the limitation of our knowledge of aerodynamics of flapping-wing flight for ornithopters of this size.

## II. LITERATURE REVIEW

Harijono Djojodihardjo et al (1999) have done research work on "Numerical Modelling, Simulation and Visualization of Flapping Wing Ornithopter": The state of the art of flapping wing Ornithopter MAV is reviewed to provide a comprehensive insight into the geometrical, kinematic and aerodynamic characteristics of flapping bio systems. Then a generic approach is carried out to model the kinematics and aerodynamics of Ornithopter to mimic flapping wing to produce lift and thrust for hovering and forward flight, by considering the motion of a three dimensional rigid thin wing in flapping and pitching motion, using simple approach, applied to a two and quad wing flapping Ornithopter, which are modelled and analyzed to mimic flapping wing bio system to produce lift and thrust for forward flight. Considering bird's scale Ornithopter, basic unsteady aerodynamic approach incorporating salient features of viscous effect and leading edge suction are utilized. Parametric study is carried out to reveal the aerodynamic characteristics of flapping quad wing

 

Ornithopter flight characteristics and for comparative analysis with various selected simple models in the literature, in an effort to develop a flapping wing Ornithopter model. Further, numerical and flow visualization studies are carried out to simulate the aerodynamics of generic rigid and flexible flapping Ornithopter wings. Two different solvers are utilized; FLUENT for fluid flow analysis and ABAQUS for structural analysis. The resulting coupled procedure retains second order temporal accuracy. The simulation of phenomena of aero elasticity is performed with a FSI method.

K. D. Jones et al (2003) have done research work on" Bio-inspired design of flapping-wing micro air vehicles". In this paper the development and flight testing of flapping-wing propelled, radio-controlled micro air vehicles are described. The unconventional vehicles consist of a low aspect ratio fixed-wing with a trailing pair of higher aspect ratio flapping wings which flap in counter phase. The symmetric flapping-wing pair provides a mechanically and aerodynamically balanced platform, increases efficiency by emulating flight in ground effect, and suppresses stall over the main wing by entraining flow. The models weigh as little as11g, with a 23cm span and 18cm length and will fly for about 20minutes on a rechargeable battery. Stable flight at speeds between 2 and 5ms –1 has been demonstrated, and the models are essentially stall-proof while under power. The static-thrust figure of merit for the device is 60% higher than propellers with a similar scale and disk loading With flying models in hand, we now went back to the wind-tunnel in order to gain a better understanding of the flow physics; hopefully allowing us to optimise the design. Since the pager motors used in the flying models had a relatively short lifespan, a model was built with the same fixed and flapping-wing geometry as the second radio controlled model, but with a larger fuselage to house a bigger motor and rotary encoder and with interchangeable parts. The new model, shown in Fig. 13, was attached to a two-component force balance to measure lift and thrust, and flow visualisation and unsteady LDV experiments were run. Streamlines were generated by a smoke wire which was constructed from 0·25mm diameter NiCr beaded wire, heated by passing a current through it, and using Rosco Fog Juice as the smoke agent. Imagery was recorded using either a digital still camera or a digital video camera with a high shutter speed to freeze the motion of the wings and streamlines. Details of the methods can be found in Jones and Platzer and Papadopoulos. Flow visualisation experiments were performed with the model mounted at a 15° angle of attack, at a flow speed of about 2ms –1 , approximating the low-speed flight conditions. Initially the flapping wings were at rest, and they were then quickly accelerated to a flapping frequency of about 30Hz. The results are shown in Fig. 14, viewing the model from the left rear corner forward; an angle which provides a good view of the flow over the upper surface of the left wing. In the upper image, without wing flapping, it is clearly seen that the flow separates at the leading edge, and the wing is fully stalled. In the upper image, after just four flapping strokes, the flow is already reattached. While the boundary layer appears to be very thick and unsteady, the outer flow remains parallel to the upper wing surface and reattaches at the trailing edge. Not only is the flow entrainment sufficient to reattach the flow, but it requires only about a tenth of a second to transition. The Reynolds number is about 2 × 104 for the main wing, and just 5 × 103 for the flapping wings. It is likely that birds have evolved to compensate for this imbalance. Their neck is highly articulated, such that their head is inertially stable for improved vision, and their body and tail most likely create additional thrust as they oscillate in opposition to the wing motion. However, it is doubtful that any man-made ornithopters benefit from fuselage oscillations, as this requires a level of sophistication beyond our current capabilities. Another aerodynamic phenomenon we wished to exploit was the ability to suppress flow separation using the flapping wings. Dynamic stall delay due to oscillatory pitching is a fairly well known phenomenon, of particular interest to rotary-wing engineers. However, a lesser known application is the use of a flapping wing downstream of a larger airfoil, using the favourable pressure gradient ahead of the flapping wing to suppress flow separation on the larger wing. Water-tunnel experiments demonstrated this phenomenon for flow over a backward-facing step and for separation control of flow over several blunt trailing edge airfoils. In the upper image the general experimental setup is shown, illustrating a large, stationary airfoil with a cylindrical leading edge and a rather abrupt cusped trailing edge. The airfoil thickens slightly along the chord to keep the boundary layer thin. Dye is emitted from a small hole just upstream of the cusped trailing edge region, where the flow is expected to be attached. Following the stationary wing is a small wing which may be flapped.

Custom remote controlled vehicle kit US 8579671 B2 :A method, apparatus, and computer software to provide a kit which allows an operator to construct a variety of vehicles such as cars, boats, hovercraft, airplanes, etc. The operator can use software to select characteristics of the vehicles, and then print out sheets of paper or other thin material that can then be folded into a vehicle. Motors can be inserted into each vehicle in order to propel the vehicle. The kit can also comprise special tools which allow for forming the paper or other material into particular three dimensional shapes. The kit can also comprise a remote control transmitter and receiver so that the vehicles can be controlled remotely. In one embodiment, computer drafting software is incorporated in the kit which allows for the manipulation of models in two dimensional and three dimensional forms on a computer output device. Users have the ability to modify dimensions, colours and shapes of the vehicles. The software can be included inside the kit itself or be accessible remotely, e.g., using a computer communications network such as the Internet to access a remote server where the software can be downloaded or run remotely. The kit as described herein would include such remotely accessed software even if such software is not physically supplied with the kit itself. The kit can further comprise a remote control transmitter receiver, foldable fabrication material, interchangeable control and drive controllers to allow a user to create multiple vehicle configurations. The kit can also include various tools to help shape the original construction material (e.g., paper) into desired three dimensional shapes. The kit can be used to create toy land vehicles and toy air vehicles. Land vehicles are vehicles that cannot directly be controlled to rise off the ground, such as cars, trucks, etc. Air vehicles are vehicles that can travel on the ground but can also be controlled to rise above the ground for a substantial period of time (e.g., more than 10 seconds).

J. Wojciechowski et al (1998) have done research work on ,"Experimental investigation of aerodynamic forces generated on Ornithopter model in wind tunnel "The measurement of lift and drag forces on the Ornithopter model with flapping wings was carried out in the wind tunnel. The wing movement had two degrees of freedom: flapping (around the longitudinal axis of the model) and feathering (around the wing axis). Forces were measured in static case - as averaged values during many cycles of movement, and in dynamic case - as unsteady forces captured in function of the flapping phase. The magnitudes of the aerodynamic coefficients of lift and drag were calculated.

James D. DeLaurier et al (1994) have done research work on "An Ornithopter Wing Design" : A simulated Ornithopter was modelled using the multi-body dynamics software, MSC.ADAMS, where the flexible parts can be included by importing a finite element model built in the finite element analysis software, ANSYS. To model the complex aerodynamics of flapping-wing, an improved version of modified strip theory was chosen

Michael H. Dickinson et al (2004) have done research work on," Designing a Bio mimetic Ornithopter Capable of Sustained and Controlled Flight":The controllability and power supply are two major considerations, so this project compares the efficiency and characteristics between different types of subsystems such as gearbox and tail shape. The ornithopter is radio-controlled with inbuilt visual sensing and capable of take-off and landing. It also concentrate on its wing efficiency based on design inspired by a real insect wing and consider that aspects of insect flight such as delayed stall and wake capture are essential at such small size.

## III. FLAPPING WING PROPERTIES DURING FLIGHT

At the wing upstroke the aerodynamic forces along the wing can be adjusted by suitable wing twisting so that the torsional moments round the wing hinge balanced themselves . Here, the wing area close to the fuselage acting as a wind turbine directly powers the outboard wing area acting as a propeller. This is the 1st possibility to use the wind turbine energy.

There is no energy consumption or transfer at this upstroke configuration. The wing can virtually be flapped up by the drive without effort(as referred to fig 1). Propeller and wind turbine effects cancel out each other. The overall effect of the upstroke in the thrust direction is thus equal to zero.

Due to the lever action of the wing at this upstroke setting the positive lift close to the fuselage must be bigger than the negative lift at the wing tip. In total, there still remains some positive upstroke lift ( Otto Lilienthal 1889). The wing down stroke with its generally strong generation of lift and thrust can ensure the balance of the remaining forces during the whole flapping cycle

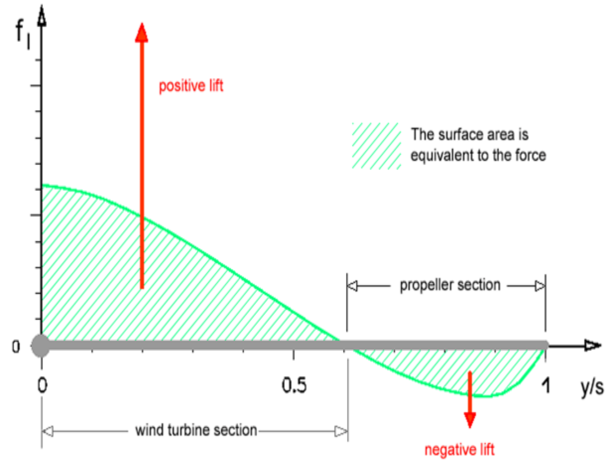


Fig 1: Lift Force Distribution

## IV. STRONG INCLINED CLIMB AND HOVERING FLIGHT

Precedingly, flight situations are described during which lift is directed upward and thrust forward. The all up weight is thereby carried by the wing lift. In short, this can be called Flying with lift.

But similar to a helicopter, during flapping flight the weight force can be balanced by a slipstream directed downward or by a thrust force directed upward. This is Flying with thrust. Thereby, the wing upstroke practically affected only with the drive. At least in steady flight, the thrust force is always perpendicular to the wing-stroke plane and can be adjusted according to their inclination.

If the thrust force points exactly in flight direction, there is either pure flying with thrust (perpendicular climb flight) or pure flying with lift (horizontal flight). In settings between these extremes and during a horizontal motion not too slow, the balance of all up weight is affected both by thrust and by lift directly generated at the wing(fig. 2).

A good way to decrease the wind turbine effect in spite of strong lift generation is the pulling or the dragging of the outboard wing section during the upstroke of the inboard wing section. Thereby the outboard section of the wing becomes a winglet to the inboard section of the wing.

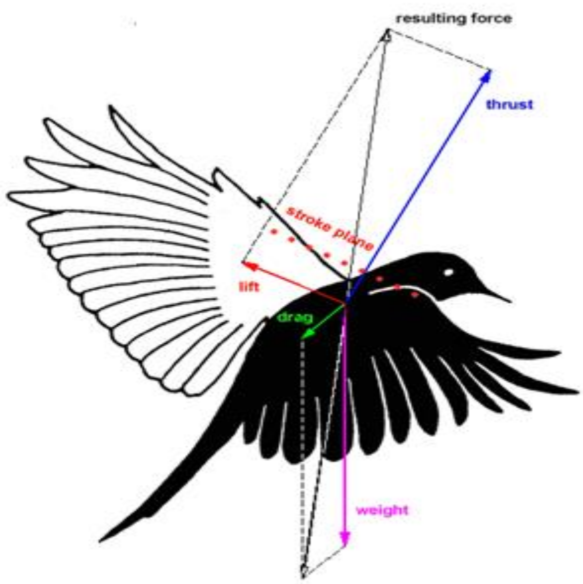


Fig 2: Inclined Climb and Hovering Flight

 

These mixed configurations are also assigned to flying with thrust. The taking off of an ornithopter, hovering on the spot, strong inclined climbing flight and slow horizontal flight are only possible according to the method flying with thrust

## V. CRUISING FLIGHT

Starting from the previously described flight scenario for the horizontal cruising flight it is more advantageous to increase the total lift during the upstroke and shift it a little more towards the wing tip.

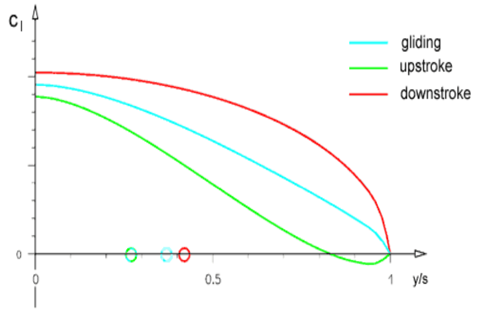


Fig 3:Lift Distribution of a Flapping wing

There, only a little bit of negative lift is generated - if any at all (Please look at the force vectors of the following picture). But by this way, the wind turbine effect and its working drag are increased .That this should be beneficial is amazing at first. The wind turbine effect now can no longer be used for generating thrust in the area of the wing tip.
A good way to decrease the wind turbine effect in spite of strong lift generation is the pulling or the dragging of the outboard wing section during the upstroke of the inboard wing section(Fig.3). Thereby the outboard section of the wing becomes a winglet to the inboard section of the wing.

•This mainly has a bisecting effect on the effective wind turbine span.

•At the same time, it reduces with its winglet effect the induced drag
of the inboard wing section.

•Furthermore, it reduces problems of wing inertia especially in the area
of the upper final wing position.

•To enable at the upstroke strong lift at the inboard wing section it will be equipped with large airfoil

## VI. CONCLUSION

Ornithopter have the potential and scope to achieve what the present generation fixed wing aircrafts and UAV's have never been able to achieve so far like flying in ground level or sea skimming capabilities and high manoeuvrability on close quarter flights.

The Ornithopter flies up and glides through the skies by mimicking the birds or rather its commonly called bio-mimicking. Preceding, flight situations are described during which lift is directed upward and thrust forward. The all up weight is thereby carried by the wing lift. In short, this can be called Flying with lift. But similar to a helicopter, during flapping flight the weight force can be balanced by a slipstream directed downward or by a thrust force directed upward. This is Flying with thrust. Thereby, the wing upstroke practically affected only with the drive. At least in steady flight, the thrust force is always perpendicular to the wing-stroke plane and can be adjusted according to their inclination.

Practical applications capitalize on the resemblance to birds or insects. The Colorado Division of Wildlife has used these machines to help save the endangered Gunnison Sage Grouse. An artificial hawk under the control of an operator causes the grouse to remain on the ground so they can be captured for study.

The controllability and power supply are two major considerations, so this project compares the efficiency and characteristics between different types of subsystems such as gearbox and tail shape. The ornithopter is radio-controlled with inbuilt visual sensing and capable of take-off and landing. It also concentrate on its wing efficiency based on design inspired by a real insect wing and consider that aspects of insect flight such as delayed stall and wake capture are essential at such small size.

Added to that bird like feature enables it to disguise itself and can be used for counter terrorist operations and surveillance purposes. Equipments like high definition and thermal cameras , stun-grenades are provided to give a technological and mission oriented approach to the Ornithopter

## REFRENCES

[1] J.D. DELAURIE ,"Development of an efficient Ornithopter wing" Institute for aerospace studies, University of Toronto, Vol. 20, No. 5, pp. 48-67. March 2001.machine intelligence, vol. 24, no. 7, July 2002

[2] James D. DeLaurier, “An Ornithopter Wing Design”, Canadian Aeronautics and Space Journal, Vol. 40, No. 1, pp. 10-l 8, March 1994.

[3]K. D. Jones, "Bio-inspired design of flapping-wing micro air vehicles".2003.

[4]Jeffery Dickinson, "Designing a Bio mimetic Ornithopter Capable of Sustained and Controlled Flight",2004

[5] Lippisch Alexander, "Theoretische Grundlagen des Schwingenfluges", Flugsport, issue 11/1925 page 246-253, Publishing house Flugsport, 10 March 1978

[6] Thomas Jacobs, "Ornithopter a Practical and Theoretical analysis " 2000 .

[7] Räbiger Horst ,"Arrangements of wing tip vortices on flapping wings". externer Link Flapping Wings, newsletter, issues autumn 2014 and winter 2015

[8]Rashid, Tahir, “The Flight Dynamics of a Full-Scale Ornithopter”, M.A.Sc. Thesis, University of Toronto Institute for Aerospace Studies, 1995. Jones Robert T

[9] Moffett Field California ,"Wing flapping with minimum energy",Ames Research Center, NASA, January 1980

[10] Michael H. Dickinson, Fritz-Olaf Lehmann, and Sanjay P. Sane. "Wing rotation and the aerodynamic basis of insect flight". Science journal, 284;10, June 1999.

 