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Design, Development and Aerodynamic Analysis of Ornithopter

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***Abstract:** In contrast to traditional fixed-wing aircraft, an ornithopter is essentially an aircraft that flies by flapping its wings. They have a wide range of uses, particularly in the military. Knowing what kind of wings to choose is essential for creating an ornithopter with the desired performance. Evidently, the kind of wing must be chosen by doing aerodynamic experiments on various wings and choosing the one with the desired properties. Based on an aerodynamic investigation, the wing is decided to be the ideal planform for this project.*

Keywords*:* Ornithopter, Flapping, Aerodynamics, and Ansys software

I. INTRODUCTION

Significant study has been done on flapping flight in order to better understand the abilities of natural flyers like birds, bats, and insects as well as with the growing interest in creating micro air vehicle technologies recently. Ornithopter, or flapping wing vehicles, have proven challenging to manage because of the erratic flow produced by the highly flapping surfaces. The majority of study to date has been on computational models that are used to optimize fixed flapping strokes. Then, in practice, these strokes are fixed, and the main control output for climb and descent is flapping speed. Current vehicles with flapping wings use moving surfaces modified from conventional airplane designs to maintain attitude. Pitch and directional control are usually provided by a single tail surface, and the main. Although at a controllable flapping frequency, wings are not actuated beyond their preset flapping stroke. Even though flapping flight has been effectively demonstrated, current Ornithopter designs lack the agility of fixed or rotary wing aircraft.

1.1 FLAPPING WINGS

Comparing flapping wing aircrafts to fixed wing and rotorcraft, flapping wing aircrafts have benefits of greater maneuverability, less noise, and better concealment. The essential component for achieving the optimal bionic performance of a flapping wing is the flapping mechanism. Mechanical, structural, aerodynamic, and bionic expertise are all needed to create an ideal flapping mechanism with multiple degrees of freedom (DOFs). Flapping motions with only one degree of freedom (DOF) are unable to accurately imitate prosthetic mechanisms.

Despite numerous studies on the flapping mechanism existing in the literature, these studies primarily concentrate on increasing the actuation amplitude. The planar four-bar flapping device is a widely used style for a model of a microbat. The aerodynamic force acting on the flapping wing as a consequence of the wing's passive deformation produces the twist. This makes it impossible for active actuation to coordinate the twist and flapping action.

1.2 MORPHOLOGY OF BIRDS

The relationship between the body and wing geometries and how well an avian performs while in flight is crucial. This study is restricted to small animals because of MAV limitations. Despite the popularity of hummingbird studies, a broader understanding of birds as flying species is suggested by the study of birds in general. The information gap in hummingbird research should be filled in with research on birds.

1.3 WING DESIGN

The development of the drive technology and the development of the flapping wing are the two primary tasks in the design of ornithopter models. In general, the drive systems and their components are of great importance. However, the flapping wings of such aircrafts are the primary development issue. In this area of design, desire and actuality diverge dramatically. Below, we make an effort to provide a general overview of the physical traits of well-known flapping wings. However, this collection makes no promise to be exhaustive.

II. LITERATURE SURVEY

Abbas Ibn Firnas, a 9th-century poet, and Malmesbury, a 12th-century poet, (recorded in the 17th century). Among the first to think about a technological method of flight was Roger Bacon, who wrote in 1260. The study of bird flight by Leonardo da Vinci started in 1485. He understood that using wings that are merely attached to the arms would not allow humans to fly because they are too heavy and weak.

In France, the first ornithopters with wings were built. In 1871, Jobert used a rubber band to propel a miniature avian model. Rubber-powered ornithopters were also produced in the 1870s by Victor Tatin, Alphonse Penaud, and Abel Hureau de Villeneuve. Tatin's ornithopter was reportedly the inspiration for a commercial device made available by Pichancourt around 1889, and it was possibly the first to use active torsion of the wings. The first internal combustion engine was created by Gustave Trouvé in 1890, and during a display for the French Academy of Sciences, a model of his aircraft flew 80 meters. A Bourdon tube activated by gunpowder charges caused the wings to move. From 1884 on, Lawrence Hargrave constructed a large number of ornithopters that were propelled by springs, elastic bands, steam, or compressed air. He pioneered the use of tiny flapping wings to power a larger fixed wing, doing away with the need for gear reduction and streamlining the building. (William L. Hosch)

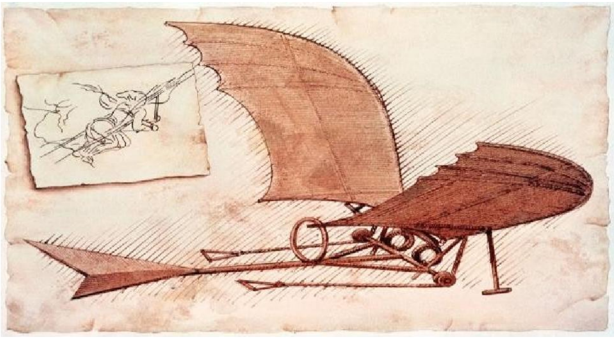


Figure: Leonardo da Vinci, ornithopter

The FAI presented Yves Rousseau with the Paul Tissandier Diploma in 2005 for his services to the aviation industry. In 1995, Rousseau made his first try at a flapping flight propelled by human muscles. He managed to fly 64 metres (210 feet) on April 20, 2006, on his 212th try, as witnessed by representatives of the Aero Club de France. On his 213rd effort to fly, a gust of wind caused a wing to break up, severely injuring the pilot and leaving him paralysed. An engine-powered, piloted ornithopter was the focus of several years of study by a group at the University of Toronto Institute for Aerospace Studies, led by Professor James DeLaurier. Professor DeLaurier visited the Bombardier Airfield at Downs View Park in Toronto. Professor DeLaurier's UTIAS Ornithopter No. 1 successfully completed a jet-assisted launch and 14- second flight in July 2006 at the Bombardier Airfield at Downs View Park in Toronto. DeLaurier claimed that while the jet was required for long-distance flight, the majority of the effort was done by the flapping wings. (Jada Walters)

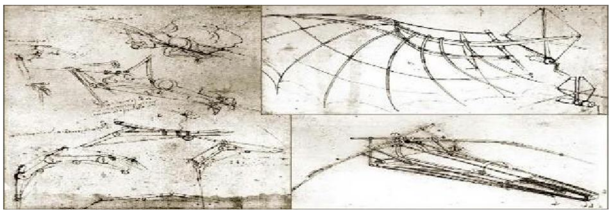


Figure: Leonardo da Vinci, ornithopter wing design.

III. OBJECTIVES

- To design and fabricate ornithopter which works on mechatronics concept.
- To check the performance of ornithopter.
- To Analyze the Aerodynamic analysis of wing using ANSYS software.

PRINCIPLE

Similar to an airplane, an Ornithopter operates on the same basic principle: by moving forward through the air, the wings can direct air downward to produce lift. Instead of a spinning propeller, there are flapping wings.

The ornithopter in its operational state is being influenced by three forces.

- Weight force (mg)
- Buoyancy force ($\rho g v f d$)
- Drag force ($\rho A v^2$)

Total force = weight force + Buoyancy force + Drag force.

F = mg+ $\rho gvfd$+ ρAv^2

= **ρ**(gv+ gvfd+Av^2)

CALCULATIONS

GEAR RATIO

- 6/26=0.230
- 26/38=0.684
- 38/38=1
- 38/26=1.5

GEAR ROTATIONS

- 60(rev/min)/3 = 20 (rev/min)
- 60(rev/min)/1 = 60 (rev/min)

FORMULA

OUTPUT ROTATIONAL SPEED = INPUT
ROTATION SPEED OF GEAR * GEAR RATIO

GEAR RPM

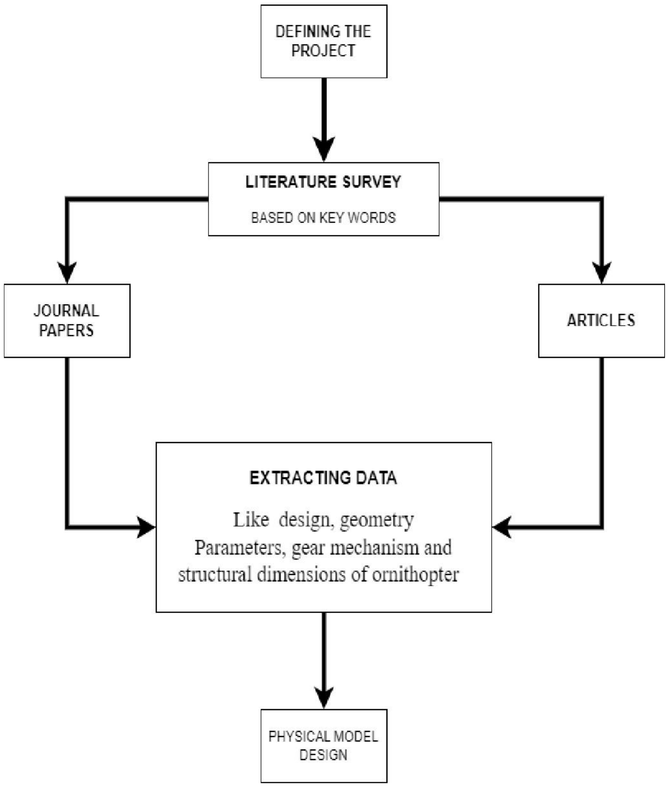
- Na = 120rpm
- Nb = 120rpm
- Nc = 120rpm
- Nd = ?
- G.R = N(input) / N(output)
- 1.5 = 120 / N(output)
- Nd = 80rpm

TORQUE

Input Torque = 2*pi*N/60 = 2*pi*120/60 Torque = 13Nm

IV. METHODOLOGY

The mechanical bird's fluttering mechanism is distinguished by the fact that it is primarily composed of the beating system, torsion system, and oscillation system; the described beating system includes a support gear motor; the motor is by gear engaged transmission is patted motion synchronously through crank rocking bar mechanism; and; The described torsion system consists of a cylindrical holder, a semicircle band of column, and a ring gear motor; the motor powers the synchronous twisting motion of the left and right wings flapping through the transmission; The oscillation device is described as having a pedestal, cylinder, ring, gear, gear support, and a motor that drives left and right wings flapping in the proper directions as they move through the gears of the transmission.



SELECTION OF AIRFOIL

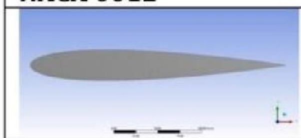
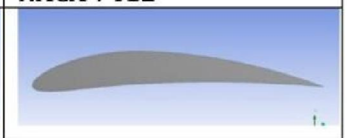
NACA 0012	NACA 7412
	
Drag – 0.7286 N	Drag – 1.1667 N
Lift – 0.0014 N	Lift – 0.1557 N

Figure: NACA 0012 & NACA 7412 Airfoil

After comparing the lift generated by sNACA7412 and NACA0012, it can be seen that the NACA7412 airfoil produces more lift than the NACA0012 airfoil series.According to the Bernoulli's theory, pressure decreases as velocity increases. As a result, the pressure at the top of the airfoil surface will always be higher than the pressure at the bottom.The number of airfoils on the wing also affects several other variables, such as the amount of air that is trapped between the airfoils. However, fewer airfoils result in more air being trapped in open space, and more airfoils result in a heavier ornithopter. As a result, 16 airfoils in total are mounted across the 120 cm wingspan.

MATERIALS USED

Electrical Components	Structure Components	Mechanical Components
Brushless Motor	EPE Foam	4 Spur Gears
ESC (30 amps)	Carbon Fiber Rods	1 Worm Gear
Servos	Foam Sheet	5mm Carbon Rods
Transmitter and Receiver		

COMPONENTS	SPECIFICATIONS
Brushless Motor	1000kv
ESC	30amp
Servos	4.8v -6.0v
Transmitter and Receiver	FSIA 6-B
Battery	850mah,2s(Li-polymer battery)
EPE Foam	2mm
Carbon Fiber Rods	4mm*1000mm
Foam Sheet	3mm
4 Spur Gear	60mm & 40mm(dia)
1 Worm Gear	32mm (dia)

V. CONCEPTUAL DESIGN

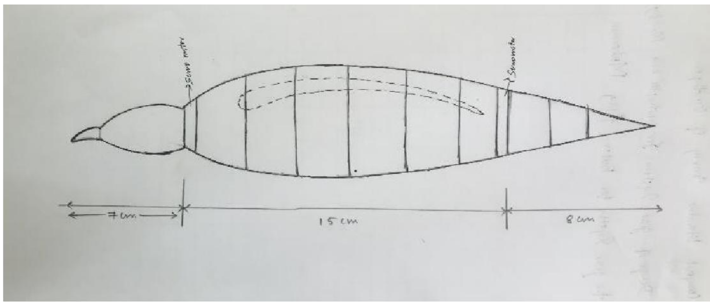
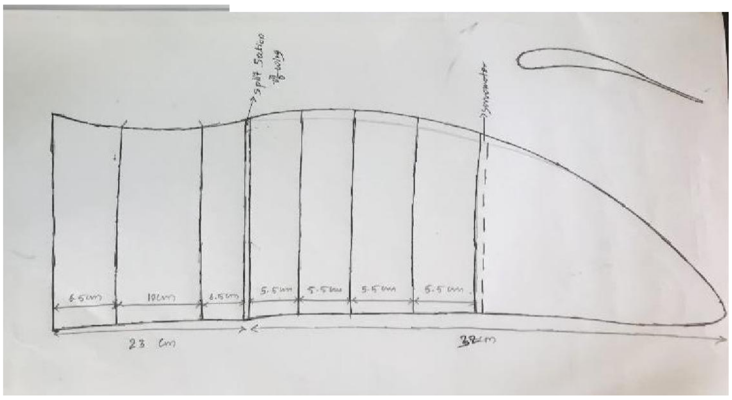


Figure: Fuselage Body of Ornithopter



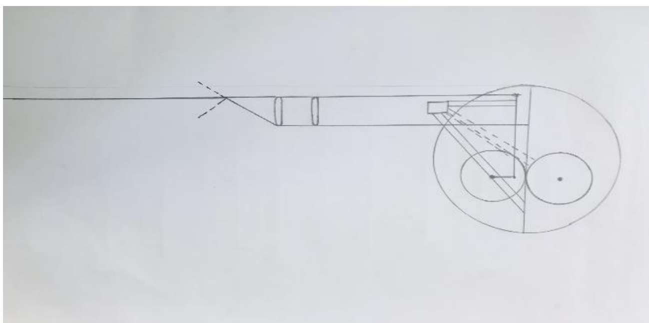


Figure: Gear Mechanism of Ornithopter

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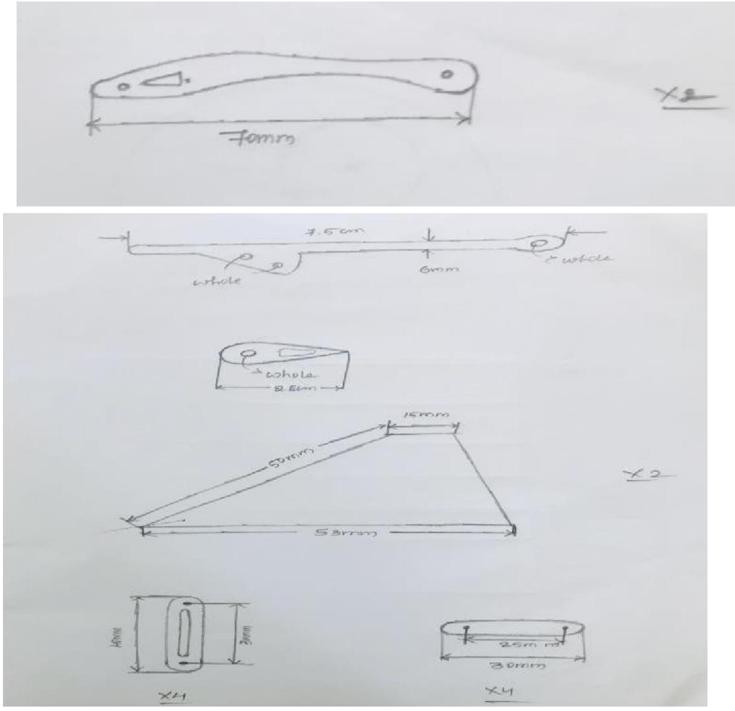

Figure: Connecting Rod of Ornithopter

VI. ORNITHOPTER DATA

For the flow analysis we have designed the ornithopter. The details of the Ornithopter is show below.

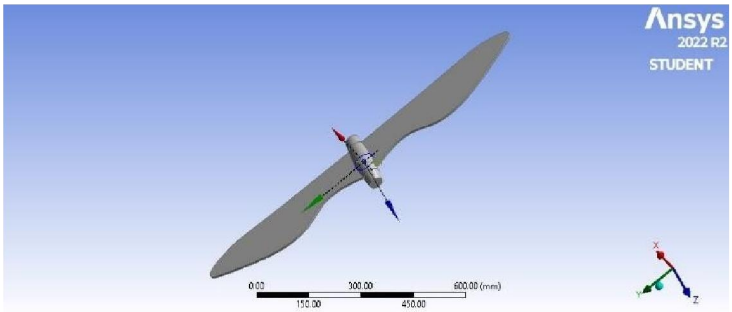

Figure: Geometrical Model of the Ornithopter

Wing span	110cm
Fuselage Diameter 1	120mm
Fuselage Diameter 2	100mm
Fuselage Diameter 3	80mm
Plane 2	70mm
Plane 3	70mm

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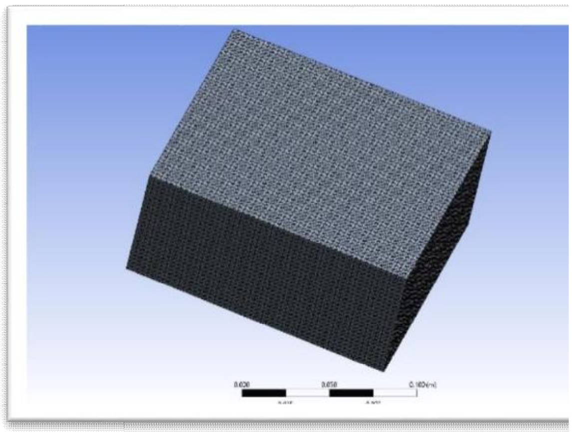

Figure: Mesh created for the Ornithopter

Physical preference	CFD
Solver Preference	Fluent
Relevance	90
Element order	Linear
Size Function	Adaptive
Relevance center	Fine

No. Of nodes	No. of elements
183024	858500

Table: General Meshing Details

Simulation

The numerical simulation was carried out on an aerofoil wing model at static conditions where we only considered the wing section. The methodology for the simulation are as follows-

- Geometry
- Meshing
- Boundary Conditions
- Result

Results and Contours

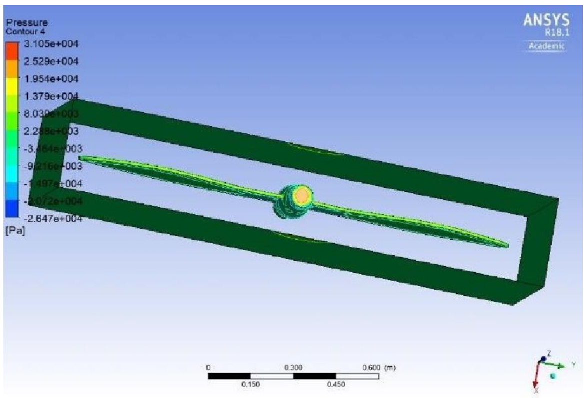

Figure: Contour of Static Pressure

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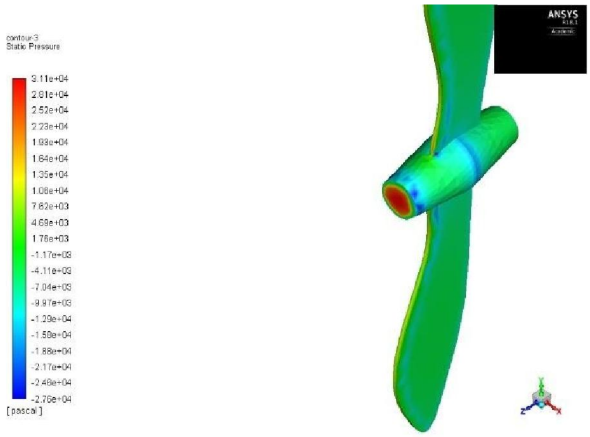

Figure: Contour of Static Pressure.

The above fig shows the contour results of static pressure According to the contour results, the pressure at the inlet of wing and fuselage is more this is because of the face that the velocity will be more at the inlet of pressure than the outlet. At the inlet velocity of 40 m/s. It lies in the safe state as per the scale of contours.

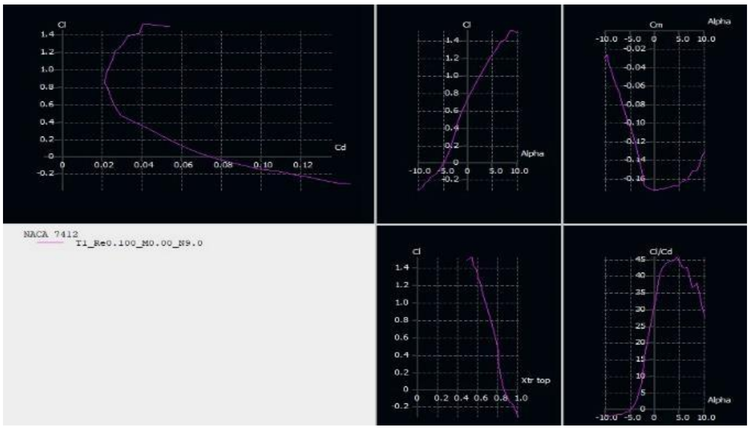

Figure: Cl, Cm, Cp v/s Alpha graph for NACA 7412

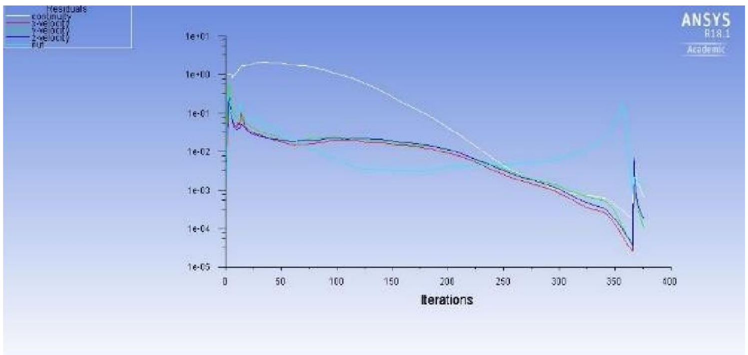

Figure: Resudial v/s irritation Graph for Ornithopter

VII. ADVANTAGES

- As Ornithopter resembles Bird, & its appearance is attractive and it's impossible to detect the model / UAV Ornithopter.
- It is very much useful in agriculture applications to monitor the crop health and Growth.
- It is very much useful in military applications.
- such as Surveillance, as spy in missions

- Aerial reconnaissance without alerting the enemies.
- Some mechanical birds have been flown with video cameras on board, some of which can hover and maneuver in small spaces.

VIII. CONCLUSION

- Aerodynamic analysis was conducted by using ANSYS FLUENT for flow analysis and gave the results which has been
- Geometry has been don e to ANSYS FLUENT(software)
- Fine meshing of Ornithopter has been done.
- Aerodynamic analysis with result contourshas been obtained.

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