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DESIGN OF ORNITHOPTER

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ABSTRACT:

This report is about the construction of an Ornithopter which imitates the flapping motion of a bird's flight and the characteristics of lift and thrust generations of various wing designs are studied. This project focuses on the spar arrangement and the materials used for the wings that can achieve efficient performance. Different lift and thrust calculating methods are analyzed and evaluated. Different wing types of insects and birds were analyzed for understanding the production of lift created by the natural flyers by flapping the wings. Various experiments were conducted on different wing designs and materials and a design was developed for the Uri Bird. The prototype comprises of a length of 100 cm and a wing span of 104 cm and weighs around 170 g. The mechanism which was to be used for the flapping motion of the wing was designed and fabricated. This was achieved with the use of a brushless motor and a flexible and light wing structure. The tail of the Uri Bird has a design concept like the elevators of an aircraft. The tail is divided into two parts controlled by 2 servo motors which can move in opposite directions or the same directions at the same time.

KEYWORDS:

Aircraft, Artificial Intelligence, Bird, Flapping wing, Ornithopter, Unmanned Ariel Vehicle

Figure 1: Ornithopter

1. INTRODUCTION:

We notice a growth in the need of miniature flight vehicles with improved capabilities like the micro air vehicles for military and civilian surveillance. The flapping wing concept of birds gives an example of utilizing unsteady aerodynamics to mechanize the miniature flight structures at low Reynolds numbers. This project attempts to mimic the flapping wing concept of natural flyers and analyze how lift is generated through this mechanism. The results achieved will be used to investigate the flow characteristics to improve the designs of ornithopters. The flapping concept is the avian type which is the vertical motion of the wings.

In this project, a resonance type flapping wing model is developed. This type of flapping wing utilizes the resonance phenomenon of a two degree of freedom elastic system i.e. springs are used to support the wings for flapping and feathering motions, oscillating, at a resonance frequency of the system. The amplitude of flapping and feathering motions and the phase angles between them can be controlled by varying the amount of damping.

2. FLAPPING WING THEORY:

For years and years now, the natural creature's flight has been fascinating to man. It is like an unresolved mystery of nature. Many attempts have been done to imitate the natural bird's flight by scientists and engineers. For example, an aircraft should always maintain a velocity which is higher than the stall velocity to attempt a successful landing. But, where birds are concerned, birds can stall, and by the use of their tail and body, can attempt a soft and precise landing.

In order to understand the complexity of natural flight, it is important to understand the biomechanics of such creatures. It is necessary to analyze the wing configuration, and understand how a certain part of the wing contributes in producing lift. Simultaneously, the motive is to design and construct an air vehicle that can hover, and thereby, important information can be gained by studies of natural hoverers like the humming birds and insects.

Since the start, pioneers of aeronautics, researchers and experimenters like Casey, Lilienthal, and the Wright brothers were obliged by nature. The process or method where natural principles are applied to engineering and mechanical systems is known as bio mimicry. This ideology needs the biological and engineering research to be integrated.

2.1 Morphology of birds

A bird's body, wing dimensions and their correlation acts as an important factor for the flight performance of a bird. Since this is limited by the MAV constraints, this research is limited to small birds only. Even though the studies of humming birds are popular, the information obtained for these research are limited and it suggests a more general overview of birds. Studies conducted on birds should be able to cover the knowledge gap in the study of humming birds.

2.2 Wing's Shape:

The shape of a bird's wings varies according to their way of adapting to nature. The figure below shows the various types of wings and wing tips.

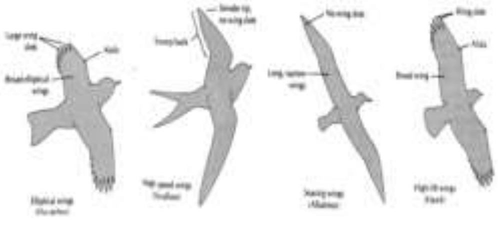


Figure 2: Various types of wings

The analysis of a wing geometry shows that a bird's flight varies in adaptation to its surroundings. Broad wings enable efficient power use for soaring. Long wings enable efficient lift required for gliding. Pointed wings decrease the drag induced and speedy flight.

3. DESIGN FOR ORNITROPTER:

In order to select the design for the Uri Bird, I carried out a parametric study where I compared a Cybird Ornithopter and I-fly Vamp Ornithopter with the design and features of the Uri Bird. I then finalized with the design of the Uri Bird where the length of the model will be about 100 cm and it will have a wingspan of 104 cm.

Figure 7: Design for Uri Bird (Right View)

4. COMPUTATIONAL FLUID DYNAMICS:

Initially, the flight dynamics and flow characteristics over the flapping wings were examined with the help of Computational Fluid Dynamics. Birds usually flap their wings about their body axis with a change in twist. Therefore, chord wise flapping has been applied to analyze the model.

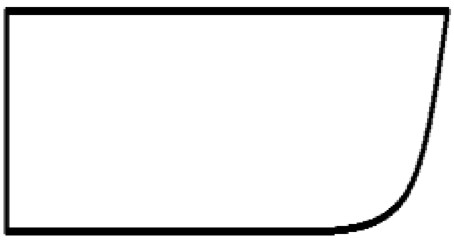


Figure 12: Dimension of the wing

ANSYS software was used to simulate the flow around the wing. The wing has a wingspan of 104 cm, mean wing chord length of 10.5 cm. The computing domain extended to 50-chord lengths in all directions around the full model wing, and that, there were about 107 meshes of the tetrahedral type. The flow condition was unsteady transient flow.

The wing geometry of the wing selected is shown in the figure above which has a wingspan of 104 cm and a wing area of 0.175 m^2. The wing is initially set at rest. The initial frequency for flapping is about 0.5 rad/s, corresponding to the reduced frequency 'k' of 0.0025. The estimated velocity of the Uri Bird is 5 m/s. Using this value gives the Reynolds number to be around 61340.45. The wing is set to flap down and up about the axis of its body, imitating the start of the flapping motion and returning to its starting position. The flapping angle is varied from + 30° to – 30° during down stroke motion and from – 30° to + 30° during upstroke motion. The downward stroke during the first half of the cycle is the lift generation stroke while the upward stroke during the second half of the cycle is the recovery stroke.

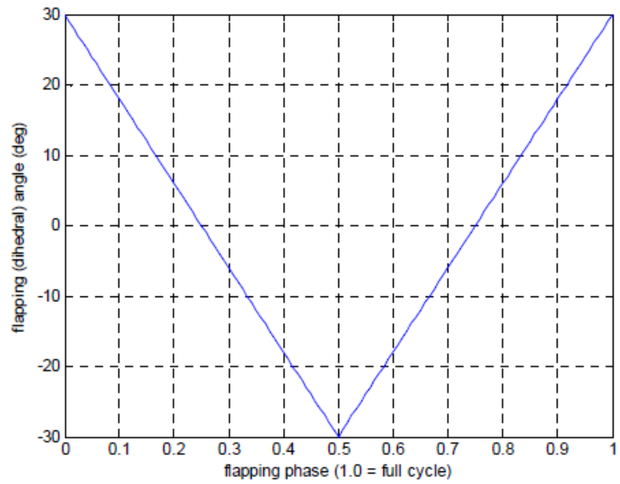


Figure 13: Flapping Pattern

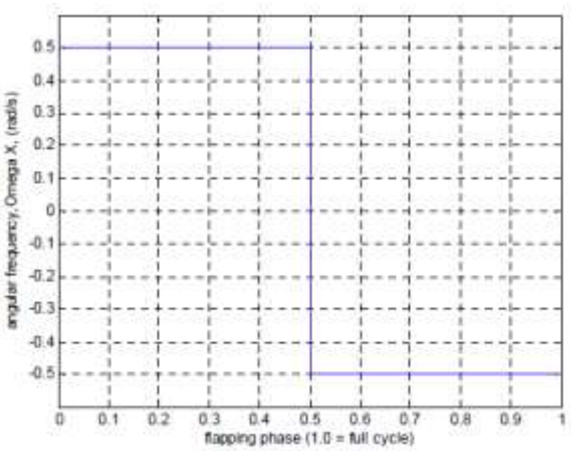


Figure 14: Angular Velocity for Flapping angle

At the start, the position of the wing was kept at + 30º degree dihedral angle. When the wings began to flap, the wing flapped downwards about its chord. At the outer half of the wing the flow separated from the wing, which causes a vortex to form which is visible at the top. There is a flow separation at the trailing edge, near the root at the area close to the scapula. This results in the formation of strong leading edge vortex producing high lift at the initial start of the down stroke motion.

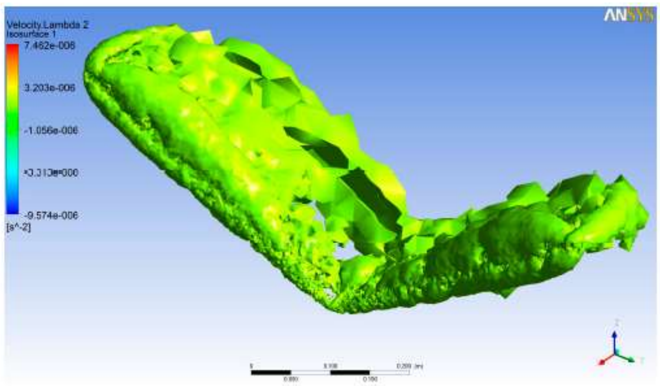


Figure 15: Structure of Vortex on the wing

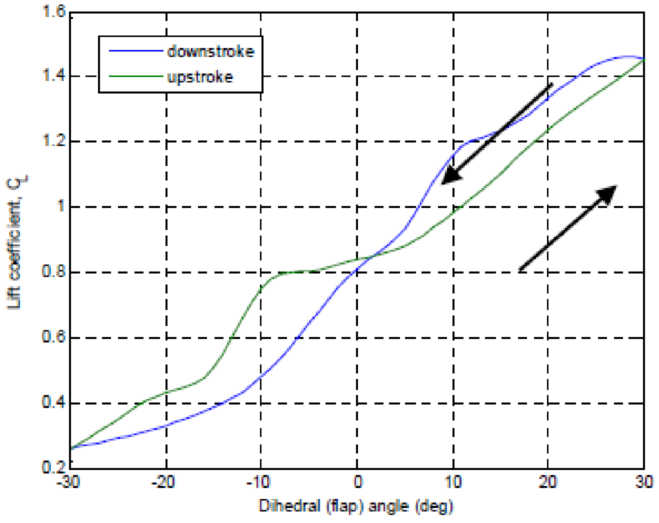


Figure 16: Lift co-efficient for down stroke and upstroke of the wing

With time, the flow keeps separating across the wing, which forms the strong leading-edge vortex over the wing. At the inboard area close to the trailing edge and scapula, the wake is more dominant. There is more lift generated through the push down motion of the wing. Post midpoint, the vortex tends to increase, and the flow separates from the entire wing at the leading edge close to the alula. ailing edge of the wing also separates into outer and.

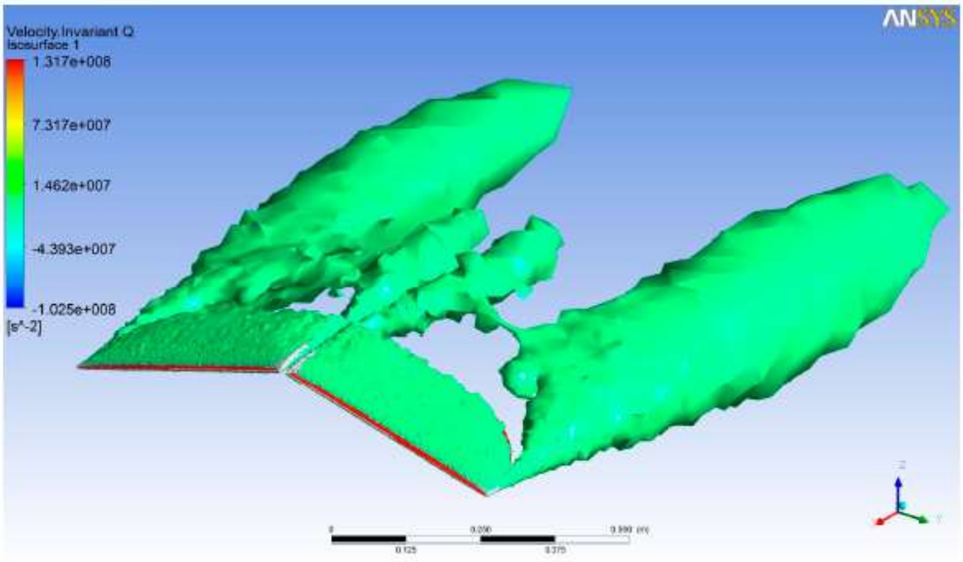
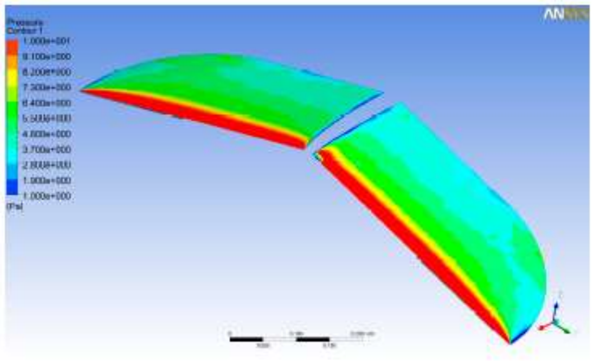


Figure 18: Vorticity over the wing

The figure above determines the structure of the vortex when the wings are at an angle of – 15°. The vortex on the leading edge appears to be more dominant as it covers the wing entirely. The wingtip vortices can be seen clearly with the wake present behind the wing.



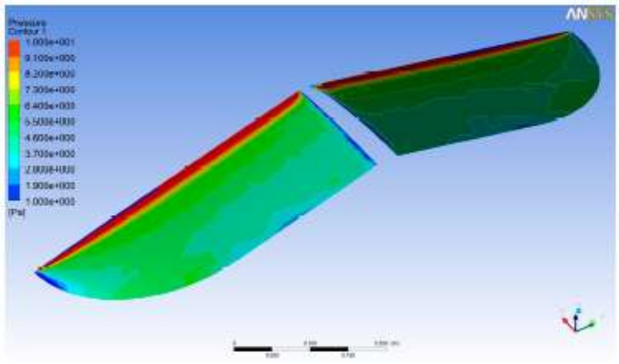


Figure 19: Surface pressure (TOP) *Figure 20: Surface pressure (BOTTOM)*

The two figures above show the pressure on the surface of the Uri Bird's wing when the angle of the wings are – 15º. A region of low pressure can be seen at the tip which can be seen colored in blue. Therefore, we can say that the Uri Bird maneuvers through flapping whole wingspan at varied amplitudes instead of using its wing tip only.

These results that show unsteady flow determines that the Uri Bird produces lift on the wings through vortex lift mechanism. Lift is produced through flapping the entire wings at varied amplitudes instead of using the wing tip only. Addition of span wise flapping may tune the position inflight.

5. MATERIAL USED:

The material that I'll be using for the frame of the Uri Bird is fiberglass. The reason I'm using fiberglass is because it has high physical strength, high specific toughness, and good strength to weight ratio and all this will make the frame durable and strong increasing the life of the Uri Bird and at the same time makes it lighter in weight.

Figure 21: Fiberglass

6. COMPONENTS USED:

1) Motor:

The motor that will be used for the wings of the Uri Bird is a brushless DC motor 2020 which has a speed of 3500 rpm / V. The motor weighs 11 grams with a diameter of 20.2 mm and length of 20 mm. I found this motor to be essential for the Uri Bird as it provides the required speed to the wings and with its light weight also contributes in making the Uri Bird lighter.

Figure 22: Brushless DC Motor

2) Synthetic Nylon cover:

Synthetic Nylon is the material that will be used as a cover on the wings as this cover won’t add much load on the wings allowing the wings to flap easily and this will also ensure proper air flow around the wings improving the aerodynamics of the ornithopter.

Figure 23: Synthetic Nylon

3) Spur gear:

Spur gear is the most common type of gear used. It is used for transmitting power between two parallel shafts. Spur gears are helpful in increasing or decreasing the torque or power. The Spur gear that will be used for the wings of the Uri Bird will consist of 70 teeth and will have a diameter of 35 mm.

Figure 24: Spur gear

4) Pinion gear:

A pinion gear is usually a smaller gear that is driving a larger gear in a gear train intended to decrease speed while increasing torque. A pinion gear will also be used in the gear mechanism to drive the main gear for the flapping of the wings.

Figure 25: Pinion gear

5) Battery:

The battery I'll be using for the Uri Bird is a 7.4 V 500 mAh battery.

Figure 26: Li-Po Battery

6) Servo motor:

I'll be using two 9 g servo motors for the tail of the model. As shown in the design, the model will have elevators like tail. Both the parts of the tail will be connected to the servo motor through rods and both the parts of the tail can then be moved in one direction or different directions as per the requirement.

Figure 27: Servo Motor

CONCLUSION:Understanding the operation of a flapping wing UAV. Calculations are required to be done in order to find the lift that will be produced by the wings and to see if the lift will be enough to overcome the drag that will be experienced by the UAV.

- Designing the body, tail and the gear mechanism of the UAV with the help of software's like AutoCAD. Constructing the frame, the wing and the gear mechanism of the UAV.
- Calculating the weight distribution throughout the frame of the UAV with the help of formulas for forces acting on a body. Connecting the servo motors to the gear mechanism and the tail of the UAV and then connecting the motors to the receiver of the UAV.
- Once the construction is completed, the motors are connected to the tail and the wing mechanism, testing the performance of the UAV and the efficiency of the flapping of the wings.
- Finally, evaluating the performance of the UAV by testing all the important components of the UAV and analyzing the lift being created by the wings.

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