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Design a Multipurpose Ornithopter

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ABSTRACT: In recent years the subject of flying vehicle propelled by flapping wings, also known as ornithopter, has been an area of interest because of its application to various fields like (spying, aerial photography, for runway clearance on airport so that there is no bird strike and damage to aircraft) and various other purposes. These miniature vehicles seek to mimic small birds and insects to achieve never before seen agility in flight. Ornithopters are robotic flight vehicles that employ flapping wings to generate lift and thrust. Generally, nowadays when we see ornithopter mostly of them uses flapping mechanism and generate lift and thrust to fly but what we are doing is modifying the wing mechanism adding a little bit of forward and backward motion to the secondary wing of the ornithopter and thus making an ornithopter which uses flapping as well as forward and rearward motion just like a bird for flying as we have observed them.

Current knowledge of the aerodynamics of flapping flight is still very much in its infancy. As for experimental data, there are very limited since it is only in recent years that interest has begun in the study of flapping flight. Until now, even with advances in computational fluid mechanics theoretical calculations have been difficult because of the unsteady aerodynamics nature.

KEYWORDS: Ornithopter, wing mechanism, forward and rearward motion, multipurpose.

I. INTRODUCTION

With our desire to understand the capabilities of natural flyers such as birds, bats, and insects, and, lately, with increasing interest in developing the micro air vehicle technologies, substantial research efforts have been made on flapping flight. Flapping wing flight offers new possibilities in terms of actuation over conventional control surfaces such as elevons. With flapping, the main wings create both lift and thrust. Altering aerodynamic properties such as camber on each wing can vary the amount of thrust produced on either side of the vehicle analogous to actuation of the B-2 bomber drag rudder. Since the wings are hinged, it is also possible for an ornithopter to vary its flap angle on either wing, rotating the resulting lift vector of both wings differentially between the two sides. Further, a flapping wing vehicle inherits the ability to vary its dihedral angle in a glide by virtue of its hinged wings as well as its mean flap angle between both wings.

The objective of this project is to design a more versatile version of ornithopter that can be used to operate in various areas of operations. The major modifications that the project is concerned with is the belly of the machine or the fuselage in other words and the wing design. Birds generate the thrust and Lift force by flapping their wing up and down so-called Upstroke and down stroke. Downward stroke of the wing deflects the wing downward and backward which results in producing lift as well as thrust at the same time and during the time of upstroke the primary concern is to reduce the drag. Use of flapping wings offers even larger displaced air mass, moved at lower velocity, thus improving efficiency.

Some Practical Benefits of an ornithopter can be enlisted as follows:

- Flapping wings offer improved efficiency
- Better manoeuvrability
- Reduced noise compared with the rotary – driven airplanes and helicopter
- Resemblance to a real bird enables its use for intelligence and surveillance.

Ornithopter provides with a wide range of application in the field of military surveillances, local inspection of a particular area, communication network links or scouting disaster-struck areas of the world. This ornithopters applications were mainly due to rapid response or due to the harmful environment in the surveillance area. As we talk about future there are more and more possible ways in using ornithopter.

II. LITERATURE REVIEW

A. Basic wing moments of the bird:

The wing movement of an aircraft is basically divided into following parts:

1. Beating
2. Rotation
3. Twisting
4. Translational

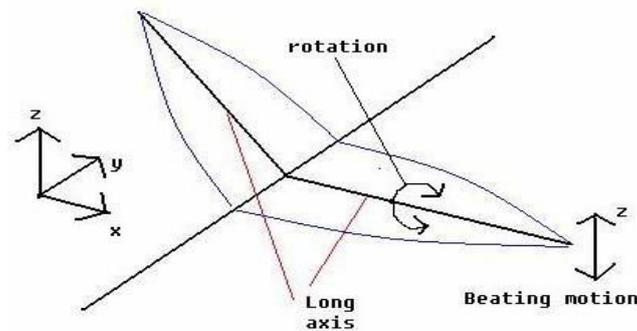


Figure.1: Diagram showing the different types of motions of the wings

In a beating movement, the long axis, which is the line extending from the base to the tip of the wing, together with the rest of the wing surface moves up and down, pivoting about the base. The rotational movement is about the long axis. The whole wing along its span rotates at the same angle. The insect wing combines the beating and rotational oscillations to produce a sort of winging motion.

The twisting axis is the same as the rotation's one. However, different parts of the wing along the span rotate at a different angle to produce the twisting effect. For the twisting action, it is found that there is no torsion in the outer two-thirds of the wing although it twists very strongly in the inner third. However, only the outer two-thirds of the wing are important aerodynamically. Thus, in designing a wing for flapping applications, it may be assumed that torsion does not have to be accounted for in the wing design itself or its flapping motions.

During flapping flight, the inner wing gives lift whilst the hand section provides Thrust. The inner part of a bird's wing remains relatively stationary and acts as an aerofoil, producing lift and drag. On the backstroke, which is the power stroke, the primary feathers are linked together to produce a near Perfect aerofoil. Since the outer part of the wing is more mobile, it can be twisted so that the wing points into the airstream; as with all aerofoil's, forces are generated and maximum thrust and minimum drag is obtained in addition to lift.

On the upstroke, the primary concern is to reduce drag. This is achieved through Different mechanisms for different species of birds. On the smaller birds, the Primary feathers are separated, allowing air to pass through and thus considerably Reducing drag. For the larger birds or small but long-winged birds their wings are typically either flexed or partially closed on the upstroke.

B. Wing Section:

The wing design greatly affects the amount of lift generation. Studies regarding various airfoil sections have been done to determine the optimal design to provide with maximum lift and minimum drag. The shows foil sections of some of the birds. According to Nathan Chronister, an ornithopter hobbyist, the area of the wing should be one-third to that of the wing area.



- The curvature of foil shape resulted from Bernoulli’s theorem gives rise to the required lift. Wing loading is defined weight per unit surface area of wing. Higher the wing loading, faster the bird must fly in order to overcome its self-weight.
- For testing purposes, the primitive models can be made from balsa wood and tissue paper. Polyethylene plastic film, water- resistant vinyl tarpaulin, etc can be used to build the wing membrane.
- Wingspan and design is selected on basis of biomimicry, while internal support structure is generally designed keeping that of a bat in mind.

Most of the lift is generated farther away from the wing root, where maximum deflections of the wings are observed i.e. at wingtips. Also, at higher AoA higher drag forces are observed. However, flexibility of wings leads to lagging in phase, of an average of 3 degrees, of the wingtip as compared to wing root.

III. MATERIAL SELECTION

- A variety of material is available in the market but we need the model to weigh less at the same time it should be strong enough to handle all the stresses that can generate on the body.
- To achieve the above objective a combination of various material can be used.
- The outer frame can be designed using a CAD software and later on can be printed using a 3-D printer and the material that can serve the purpose as mentioned above is carbon fibre as it weighs less and at the same possess good strength properties.
- For the gears we can simply use the plastic that we are very well familiar with in our daily life.
- For the wings that are related to the flapping motion a straight steel rod with very good stiffness properties can be used as we don’t want bending in the structure.
- For the main wings a nylon sheet or a polymer sheet can be used with frames and wires as support.

For mechanism	1)Brushless motor 2)Gear box (including gears and transmission shaft) 3)ESC(for controlling RPM) 4)Battery (to provide power to the motor)
For wing	1)For structural membrane we will use aluminum rod with thin diameter 2)For covering the membrane, we will use Nylon fabric material
For tail	1)Similar to wing for structural membrane aluminum rod with thin diameter 2)And Nylon fabric for covering 3) Servo motor to control tail.

IV. MECHANISM AND DESIGN OF COMPONENTS

A. MECHANISM

There are many types of ornithopter mechanism which convert rotary motion into flapping motion, for us the major concern was to come up with such type of mechanism in which we can make the wing A bit of forward and backward motion as well as retraction of wing is also possible.



- After researching and studying our basic research paper “*Dynamic and control of flapping wing* “ by “*Tay Wee Beng*” from “*National university of Singapore* ” we came up with above mechanism which will be helpful in making both right and left wing in synchronisation.
- After that we have tried to make Styrofoam mechanism of one part of the wing in which we have accumulated flapping, a bit of forward and backward motion and retraction motion, which is shown on next page

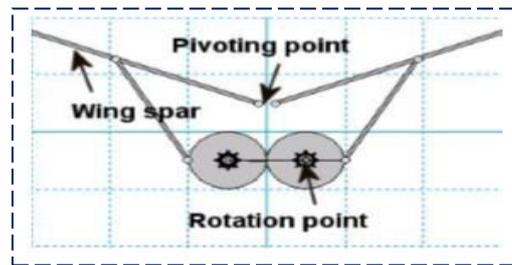
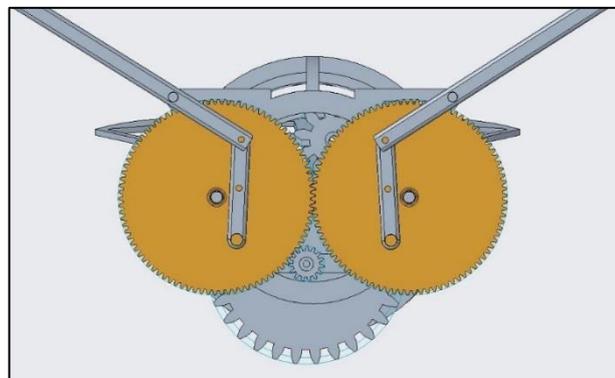


Figure.2: Representation of two front gears that are responsible for moving the links to and fro.

B. GEARS

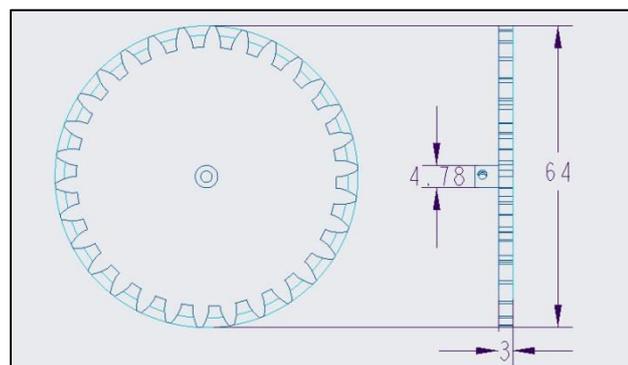
a. Gear Dimension(in mm): -After calculation below were the Dimension for gear which were used in mechanism
Gear1:

Module(m)	2.00mm
No. of Teeth(z1)	10
Ref. Pressure Angle(α)	20°
Pitch	6.28mm
Diametrical Pitch(DP)	12.7mm
Pitch Circle Diameter(d)	20mm
Tip Diameter(da)	25mm
Root Diameter(dr)	17.5mm
Tooth Depth(dt)	4.5mm
Addendum Height(ha)	2mm
Dedendum Height(hf)	2.5mm
Tooth Thickness(t)	3.14mm
Tip&Root Clearance(c)	0.5mm



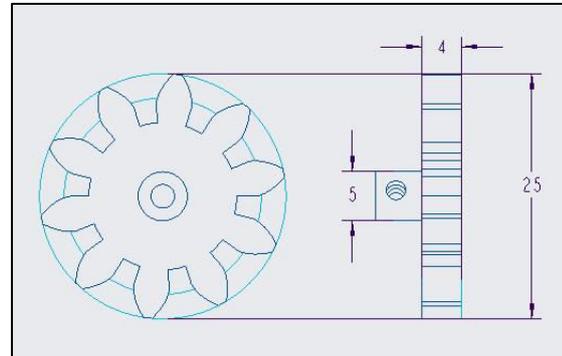
Gear2

Module(m)	2.00mm
No. of Teeth(z2)	30
Ref. Pressure Angle(α)	20°
Pitch	6.28mm
Diametrical Pitch (DP)	12.7mm
Pitch Circle Diameter(d)	60mm
Tip Diameter(da)	64mm
Root Diameter(dr)	57.5mm



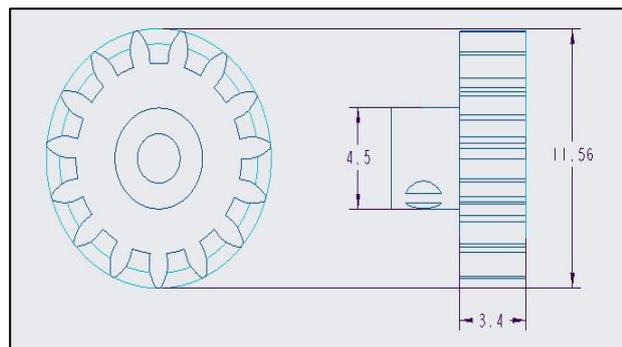


Tooth Depth(dt)	4.5mm
Addendum Height(ha)	2mm
Dedendum Height(hf)	2.5mm
Tooth Thickness(t)	3.14mm
Tip&Root Clearance(c)	0.5mm



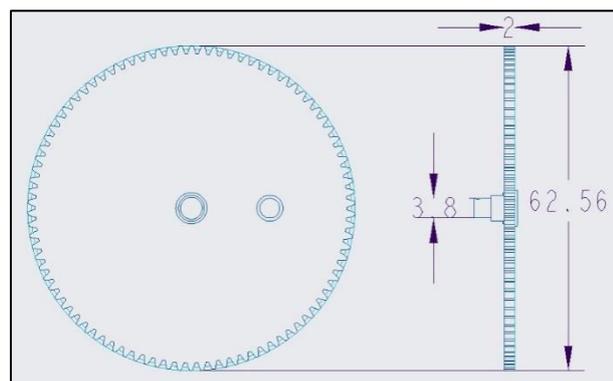
Gear3

Module(m)	0.68mm
No. of Teeth(z3)	15
Ref. Pressure Angle(α)	20°
Pitch	2.1352mm
Diametrical Pitch (DP)	37.35mm
Pitch Circle Diameter(d)	10.2mm
Tip Diameter(da)	12.2mm
Root Diameter(dr)	7.7mm
Tooth Depth(dt)	1.53mm
Addendum Height(ha)	0.68mm
Dedendum Height(hf)	0.85mm
Tooth Thickness(t)	1.0676mm
Tip&Root Clearance(c)	0.17mm



Gear 4&5

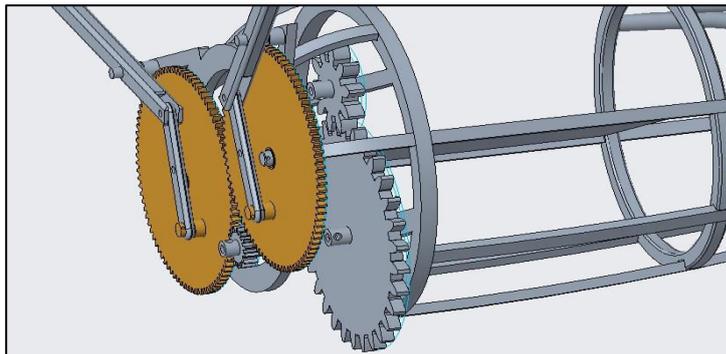
Module(m)	0.68mm
No. of Teeth(z4&5)	90
Ref. Pressure Angle(α)	20°
Pitch	2.1352mm
Diametrical Pitch (DP)	37.35mm
Pitch Circle Diameter(d)	61.2mm
Tip Diameter(da)	62.5mm
Root Diameter(dr)	58.7mm
Tooth Depth(dt)	1.53mm
Addendum Height(ha)	0.68mm
Dedendum Height(hf)	0.85mm
Tooth Thickness(t)	1.0676mm
Tip&Root Clearance(c)	0.17mm



b. Gears Arrangement

- Gear1 will be driven by a brushless DC motor
- Gear2 and Gear3 will be connected via a transmission shaft.
- Gear3 will transfer power to Gear4
- Gear4 and Gear5 which are of same dimension are meshed together and will rotate counter to each other making the motion possible.

C. RPM Calculation and final wing beat frequency



For RPM :-As we know Gear tooth number,

$z_1=10$

$z_2=30$

$z_3=15$

$z_4=90$

Therefore;

$$\begin{aligned}
 RPM\ Reducing\ Factor\ (R) &= (z_2 \div z_1) \times (z_4 \div z_3) \\
 &= \frac{30}{10} \times \frac{90}{15} \\
 R &= 18
 \end{aligned}$$

Thus, RPM will be reduced by **18th times** of the given RRM, which will be very helpful in bringing the flapping frequency in to considerable range (which is 6~9 Hz wingbeats) for our ornithopter.

V. FUSELAGE / FRAME

The fuselage was modified and was given the shape of a hot air balloon this was done to serve the purpose of multifunctionality.

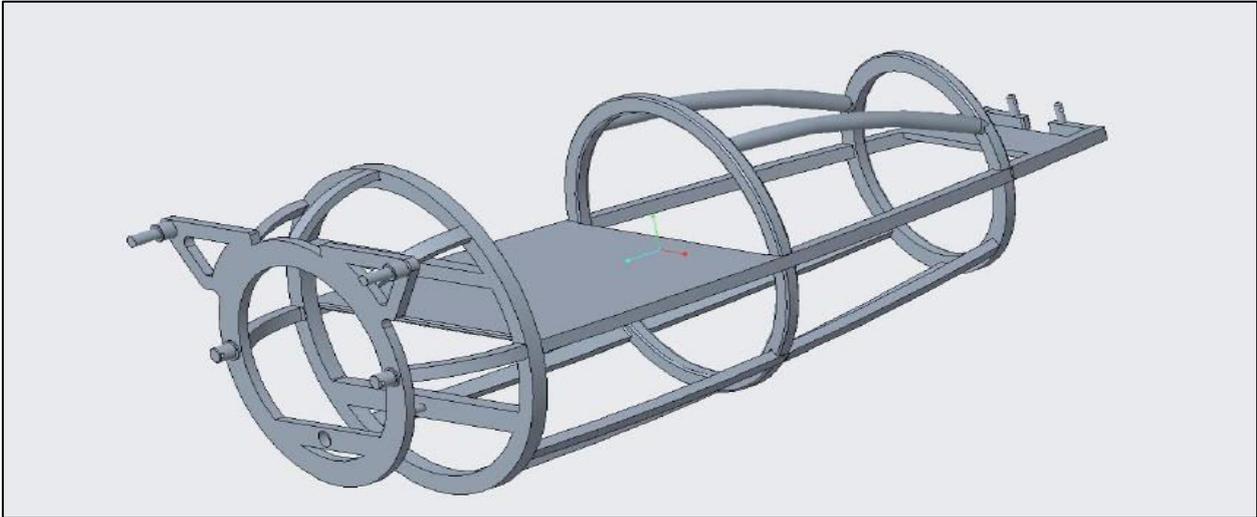
1.The fuselage was provided with enough space to be used to store small package.

2.Since not every time the mission will be to deliver a package so during other missions it can be filled with some light gas. By doing so we can provide more stability plus when we want the mechanical bird to glide it will increase the glide purpose in addition also it will also reduce the weight of the entire body and at the end will increase the operation time.

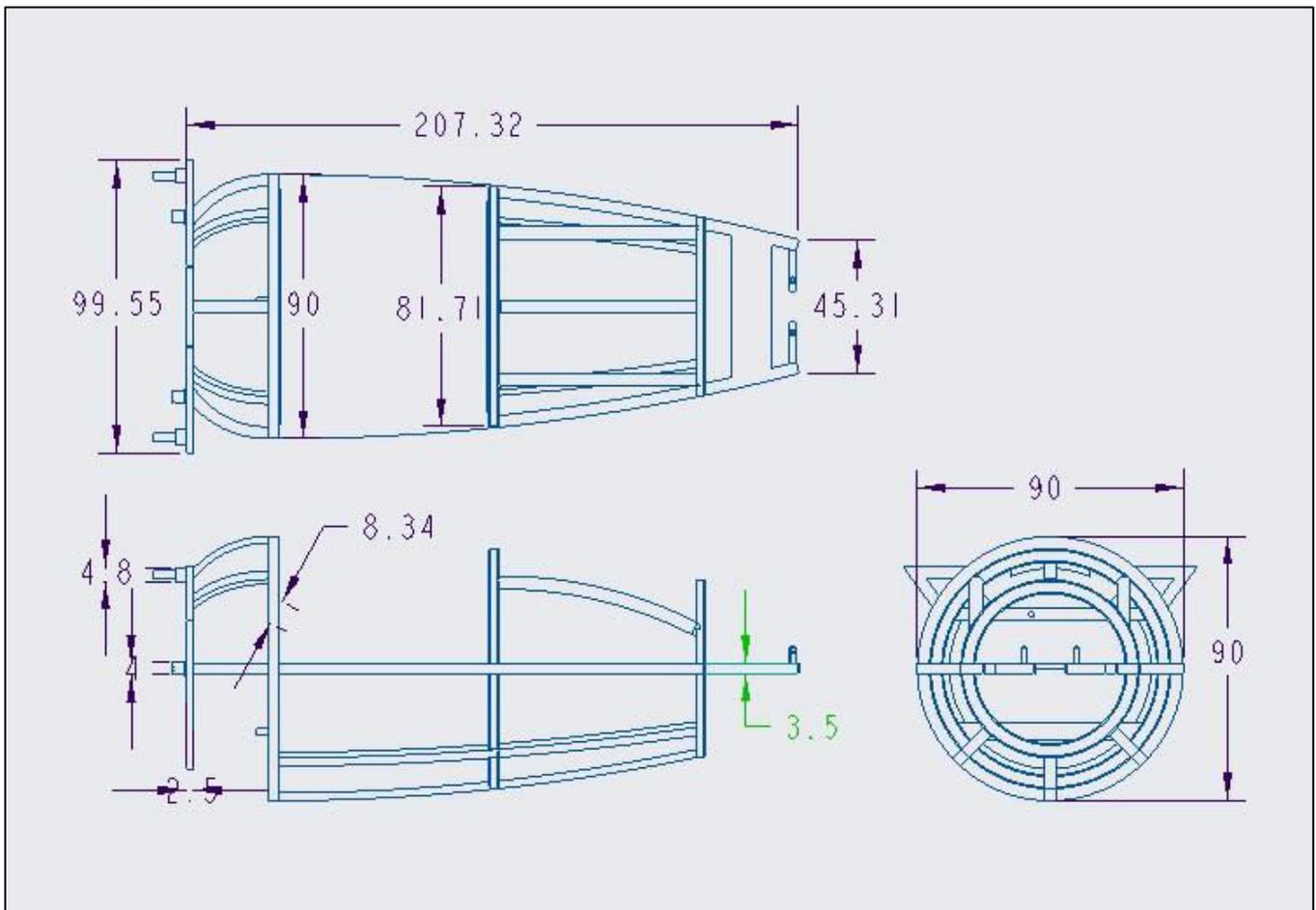
- It is less bulky which will incorporate in reducing the weight of overall body.
- It also incorporate very well with gear assembly and mechanism easily
- It also provide enough space inside so that we can use helium gas pockets to make the body light weight.



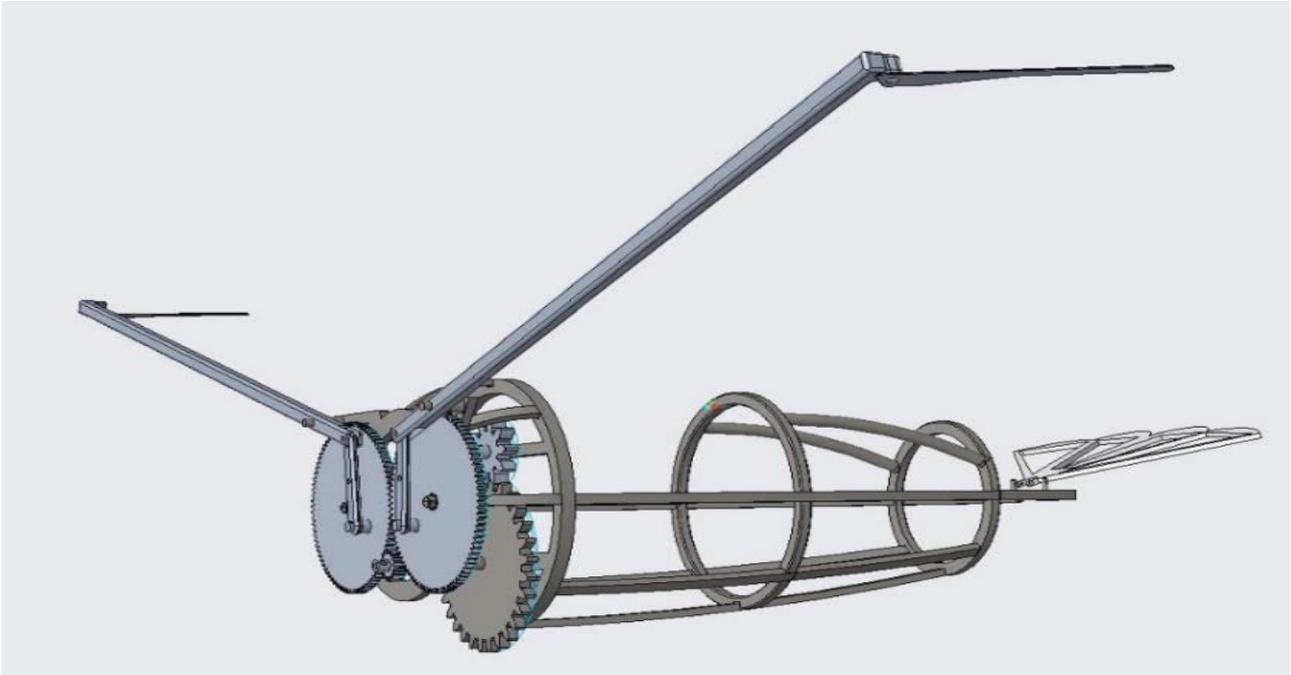
- The outer covering can be covered by light weight Styrofoam .



a. Fuselage dimensions (in mm)



VI. FINAL ASSEMBLY



VII. CONCLUSION

The following conclusions can be drawn:

The design can be helpful to serve the purpose of multifunctionality with the minor modifications inside the fuselage in no time. The main purpose that it can serve with the modifications are:

1. Delivery: The design can be extensively used to deliver small packages fitted inside its belly to severe locations especially when we don't want anyone to suspect or to deliver the package secretly.
2. Spying: The belly can be used to store micro camera that can take images of the ground without coming into the eye of enemy as drones are very vulnerable are easily identified but it is hard to believe on the statement that a bird flying above your head is taking images: making it stealthy.
3. To counterbirds : As very less known but the project is in pilot basis to keep stray birds away from runways thus avoiding bird strikes during take-offs and Landings by giving it a design of a predator generally that fears other birds and help in keeping the runway clear.

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