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Design of a 3D Printed Ornithopter

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Abstract:- The paper deals with design of basic mechanism of wing movement in ornithopters and development of ornithopter. Flapping wing systems can fill the void left by traditional fixed and rotary wing drones for defence ,agriculture, civilian and research purpose mostly in university level projects . These systems are also known as ornithopters, seek to replicate bird flying . This rising interest has raised a series of problems like kinematics of machinery, design and development of mechanisms and the stability, guidance, control, and navigation of birds, aerodynamics and control to explore. In this work we have designed few wing working mechanisms and designed an ornithopter. The ornithopter has imitated the bird structure with wings developed using kinematics of machinery.

Literature Survey:- A group of students at MIT university developed Smart Bird in early 2010s ,it is one of the first working examples of biologically inspired flapping bird like systems. Smart Bird developed by Festo in 2012 by a German company had a wingspan of around 2 meters and weighed just 500 grams. In MIT university Phoenix developed an ornithopter in 2009 which can carry load of 400 grams. In 2016 group from COEP, Pune built an ornithopter of 1.3 kg and tested it on a load cell beam setup.

Keywords:- *Ornithopter , Fuselage ,Tail Wing ,Rudder ,Dual Gear Crank Mechanism ,Transverse Gear Crank Mechanism.*

I. INTRODUCTION

There are various mechanisms to build an ornithopter which are dual gear crank mechanism ,transverse gear mechanism ,single gear mechanism. The mechanisms are developed with basic and sound knowledge of kinematics of machinery ,design of machine elements .The various mechanisms of ornithopter are designed along with final model using transverse gear mechanism in this seminar .

II. CONCEPT OF AN ORNITHOPTER

These are bird like drones called ornithopters which fly with the help of gears ,motor ,battery and electronic speed controller and the motion is transferred to wings . Over the years there has been a growing interest in ornithopters by universities in USA, Europe, India which include research students ,professors ,aerospace enthusiasts ,defense sectors ,agriculture , which has led to a variety of innovative ornithopter designs. There are many aeromodelling events where ornithopter competition take place. The principle of operation of the ornithopter is like aero plane, the motion through the air allows the wings to deflect air downward, producing lifting. The propeller of aero plane is replaced by flapping motion of wings.

➢ *Problem Statement*

To design and explore various mechanisms of an ornithopter, with study in field of kinematics of machinery, Computer aided design software's like SolidWorks ,Fusion 360, and manufacture its few parts using technologies like 3D printing .

III. DESIGN OF MECHANISMS OF ORNITHOPTER

➢ *Dual Gear Crank Mechanism –*

This design model features two gears of same module that control each wing separately . The support for the gears is fixed. The Wing is articulated type wing .In this type of wings symmetry of flapping can be achieved. The gears are of the same module and pitch circle diameter .The wing rods are provided with hinges for movement .

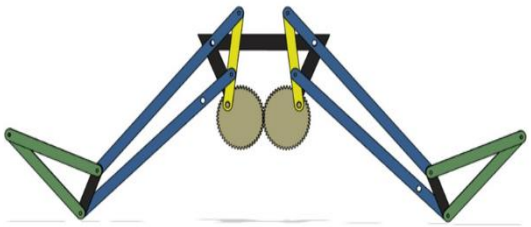

Fig.1 CAD model 1 of dual gear crank mechanism

Fig 2 . CAD Model 2 of dual gear crank mechanism

➢ *Difference between model 1 and 2*

In model 1 the fixed support is attached at back side of gears. In model 2 the fixed support is attached at front side of gears .The working mechanism is similar, but wingspan is different.

➢ *Three gear mechanism -*

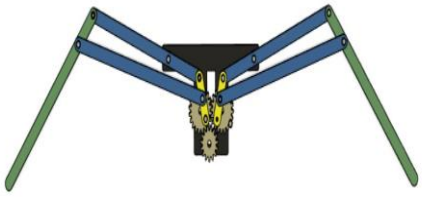

Fig.3 CAD model of 3 gear mechanism

The model consists of the addition of one more gear compared to dual gear crank mechanism .The gears are supported on the T frame. The wings are based on articulated mechanism.

➢ *Transverse Gear mechanism –*

It is heaviest and most complicated design .As the rotating gears and flapping wings are not on the same plane it is difficult to construct and work. Number of gears in this design are more than any other mechanisms.

IV. DESIGNED COMPONENTS OF AN ORNITHOPTER USING TRANSVERSE GEAR MECHANISM -

a)**Fuselage -** It is the main part of ornithopter where all mountings take place. It is completely 3D printed and designed in SolidWorks software. The material used for manufacturing is ABS (Acrylonitrile butadiene styrene)
b)**Gears-** the gears are of plastic .Gear ratio is 27:1.The gear train is compound gear train.
c)**wings** – The wing consists of Carbon fiber rods of 3mm diameter and wing fabric is PU Coated fabric. The size of the wingspan is 800 mm.
d)**Tail wing** – The Tail wing consist of horizontal and vertical rudder .It consists of hinge .The Tail is completely 3D Printed in PLA (Polylactic acid).The tail wing can be attached to servo motors for direction and stability .The rudders are helpful in tail movement .
e)**Gear casing** – It is mounted along with fuselage and is 3D printed like fuselage .It consists of gear of module.
It is 3 stage gearbox.
f)**Wing junction -** It is a junction where carbon fibre rods will meet .The Inner diameter of this junction is 3.2mm .The wing junction is 3D printed with PLA material. The Carbon fiber rods of 3 mm will be inserted into the hole.
g)**Linkages** – The wing and gears are connected with linkages .They are 3D printed using PLA material .

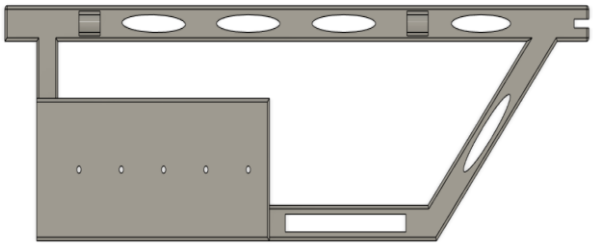

Fig 4 Fuselage with gear casing designed in Solidworks

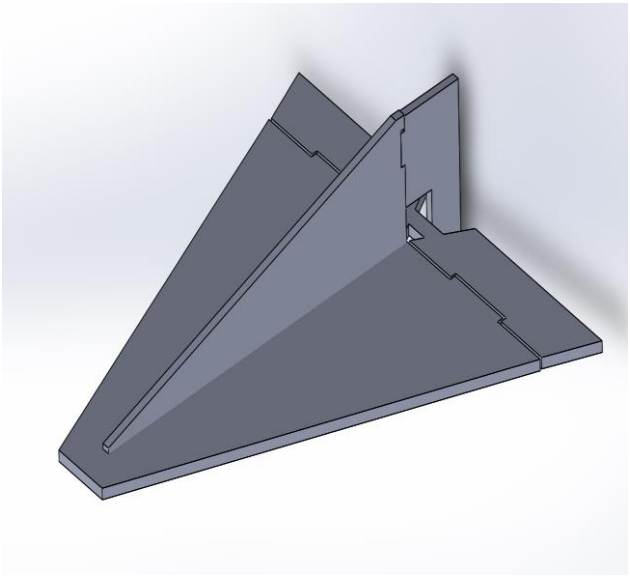

Fig.5 Tail wing designed in Solidworks

Fig 6 .Wing junction designed in Solidworks

V. CALCULATIONS

Gear box calculations =

Na / Nf = teeth of driven gear / teeth of driver gear

Na/Nf = (30/10) *(30/10)* (30/10)

Na/Nf = 27/1

Gear ratio = 27 **:** 1

RPM of Brushless Motor (N) = 10000 rpm

X = flaps per minute

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X = 10000/27 = 370.37

370.37 /60 = 6 flaps per second

VI. BODY DESIGN

The ornithopter consists of fuselage , gear casing ,motor mounting slot on gear casing , tail wing slot at the end of fuselage for tail wing mounting .The tail wing is also designed for stability and direction purpose .The wing is made with carbon fibre rods of 3 mm diameter and consist of wing junction for joining the carbon fibre rods. The wing fabric used is PU coated fabric .The fuselage will also consist of battery and servo motor mounting along with electronic speed controller and receiver.

VII. STUDY OF ELECTRONIC COMPONENTS

1)**Motor** – Ornithopter requires motor of high torque .The motor can vary according to weight and speed required for ornithopter. It can be coreless motor ,BLDC motor ,Servo motor. The motor used is the coreless motor in the prototype.
2)**Battery** – The battery widely used is Lithium Polymer battery. The voltage and current rating depend on the use. The specification of battery is 1250 mAh and 3.7V
3)**Electronic speed controller** – The Electronic Speed Controller accepts standard Remote control signal as input and offers functions such as reverse ,forward and braking. El
4)**connectors** -Relimate connectors are connectors which normally consist of female and male connectors .They are soldered to PCB and the female connector consists of wires at one end and other end can be open or can consist of female part on another end .
5)**Fly Sky Transmitter and Receiver** – It is suitable for controlling quadcopters ,drones ,multirotor.

VIII. FLAPPING MECHANISM

Here, rotary motion of motor is converted to oscillatory motion .The mechanism should be simple and logical .The basic mechanism is kind of four bar mechanism .There is rotating crank shaft driven by the coreless motor .As the crank goes around the connecting rods get pushed and give up and down working .The flapping motion requires great study of kinematics of machinery .The mechanism should be properly designed .

IX. ASSEMBLED CAD MODEL

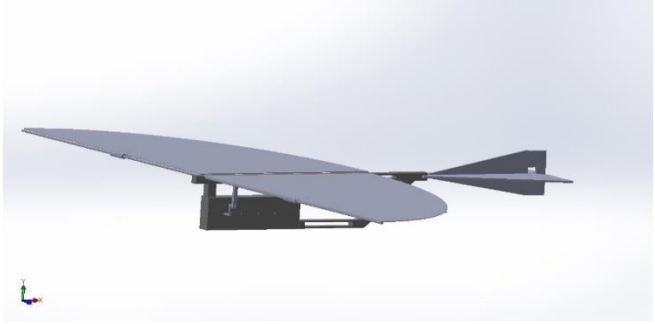

Fig. 7 CAD assembly of Ornithopter designed in SolidWorks and Fusion 360

X. USE OF 3D PRINTING

To manufacture the parts of ornithopter we decided to print parts using ABS(Acrylonitrile Butadiene Styrene) and PLA(Polylactic Acid) material .The Fuselage was printed in ABS and tail wing and wing junction , crank connecting rod were printed in PLA .The observations were as follows –

Table 1 USE OF 3D PRINTING

ABS	PLA
It is very strong and impactful material .	PLA is stronger than ABS ,easy to 3D print , and has higher stiffness than ABS.
ABS has superior mechanical properties compared to PLA while being light and more durable.	Tensile strength of PLA is greater than ABS.
ABS has higher melting point compared to PLA .	PLA is cheaper than ABS.

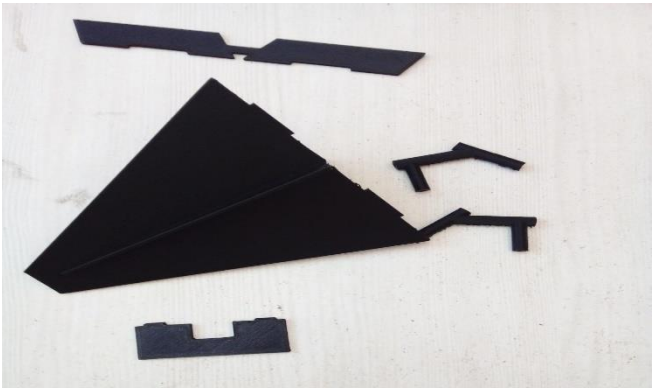

Fig 8 . 3D printed tail wing and wing junction using PLA material.

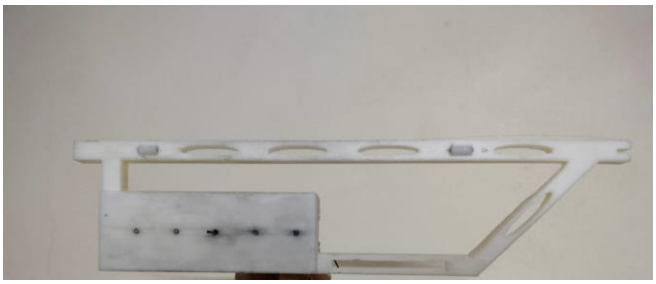

Fig 9 .3D printed Fuselage with ABS material .

XI. CONCLUSION

In this paper we have discussed about ornithopter mechanisms and design. The Ornithopter. The paper also emphasizes on use of 3D printing and various materials used for prototyping the model. The paper gives insights on ornithopter design. I thank my colleagues for their immense support and contributions .

ACKNOWLEDGEMENT

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