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Conceptual Design of a Micro Aerial Vehicle

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ABSTRACT

The main objective is to design a hybrid model of an MAV for surveillance purpose, where reverse motion can be made possible. The hybrid model designed has coaxial rotor for main thrust, and flaps are also fitted for the purpose of Directional Stability. Coaxial rotors are a pair of helicopter rotors mounted one above the other on concentric shafts, with the same axis of rotation, but that turn in opposite directions (contra-rotation). Flapping wings are used here for stability purpose and helps the MAV in moving backwards. Ultimately reverse motion possibility has been tested and analyzed.

Keywords: Hybrid, Surveillance, reverse motion, coaxial rotor, directional stability, shafts

I. INTRODUCTION

Ever since the first flight by Wright brothers the aircraft industry revolutionized the world. It has been nearly a century since the discovery of piston engine. Even today piston engines are being used in the thousands of aircraft all over the world. Internal combustion engine is a heat engine that helps in converting chemical energy in a fuel to mechanical energy that could be made possible by a rotating output shaft.

With the invention of autonomous control and monitoring of aircraft led to the special interests of other aerial vehicles. This technology resulted in unmanned aerial vehicle (UAV). The greatest advantage of UAV comprises the elimination for the need of air crews on board.

Due to the advancement in this technology the growth of UAV's has increased widely which led to the problem of classification. Then a decision was taken to classify them according to their mission aspects and performance specifications. Specifications of a UAV include weight, endurance, payload, speed, range, wing loading etc. The aspects of missions include ISTAR, Combat, VTOL, RADAR, Communication relay, Aerial delivery etc.

Research and development of UAV and MAV are getting into higher age of development as they can be applied to various areas such as rescue mission, military, agriculture, film making etc. Even they are used for military applications where infrared cameras assist the mission to search the target. The main goal of this project is to create light weight flyer that can maintain a steady altitude in flight, has a simple interface for controlling, and has the capability to carry a payload. A design and controller based on beginner-level pilot skills are essential to the project. The basic features that could be implemented for this model fabrication is as follows,

1. To create a light weight, wireless-controlled MAV with a mounted camera.
2. To build a MAV which can hover and maintain an altitude at a relatively stable position
3. The Ornithopter must be able to be controlled via computer interface via a separate controller.
4. The Ornithopter must be able to receive the signals from transmitter.
5. The Ornithopter must have the capability to take video or pictures.
6. To prove the concept of reverse motion.

There are two basic novelties involved in this project.

1. Hybrid Model – Integrating the coaxial [18] rotor system with flapping subsystem, which is unique and has not been implemented anywhere.
2. Reverse motion possibility – Till date the concept of reverse motion acts as a challenge to most of the researchers all around the world. There are stability problem involved in activation of this concepts in any aero system. All those problems could be dealt by this concept or the model proposed.

II. LIFT AND FLIGHT STABILIZATION

Basic Force that should be considered for flight stability is the Lift force. Lift is basically upward vertical component acting on an airfoil's aerodynamic centre. This force reacts to the thrust of the airfoil that acts in the perpendicular direction to the airfoil that is represented as a vertical and horizontal force. The horizontal vector that moves in opposition to the thrust is the drag force.

Lift is related to air density given by the following

$$\textit{Lift equation } L = C_l \, q \, S$$

Where, C_l is the lift coefficient, q is the dynamic pressure and S is the plan form area, or the area of the blade or airfoil.

For measuring the lift of a helicopter the propeller speed is taken into account comparatively to the thrust vector. The reason behind the fact is that the propeller that works vertically is now operating now in a horizontal plane.

Propeller design also depends on the blade turns outward from the centre, which results in a change of angle of attack to its optimum angle at tips of the propeller blade.

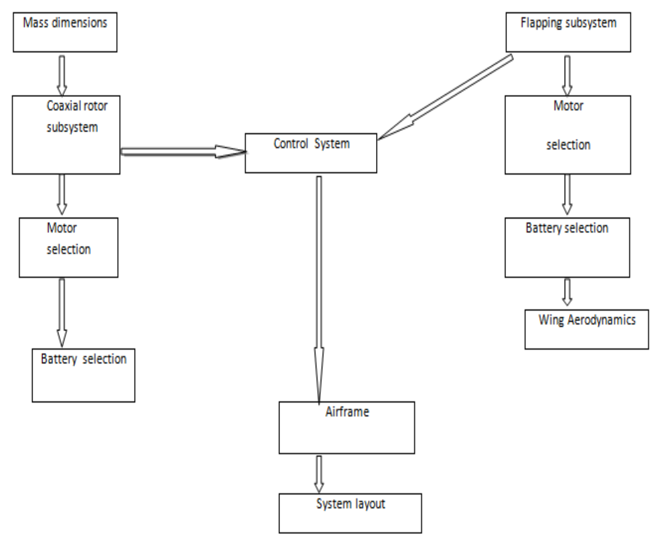
III. REQUIREMENTS AND SPECIFICATIONS

The requirements and specifications for specialized subsystems of the MAV will be addressed individually in the appropriate research subsections of this document. General requirements and specifications are bulleted below:

1. The system should be able to lift 1 kg of mass, including the mass of the unit.
2. Navigation must be accurate to within 10 ft. (X and Y coordinates).
3. A 2.4 GHz signal will be used to transmit telemetry and for direct user control.
4. The system should use the flap subsystem for directional stability.
5. Battery chosen→ 11.1volt. (2200maH)
6. Motor → Brushless, 1250 KV rating. (Produce Thrust of 2100 grams)
7. Propeller blade Dimension→ 11*5.5 E. (Length *pitch).
8. Endurance time → 6 minutes (50%discharge rate)
9. 3.3 minutes (100% discharge rate).

IV. THE PROPOSED MODEL

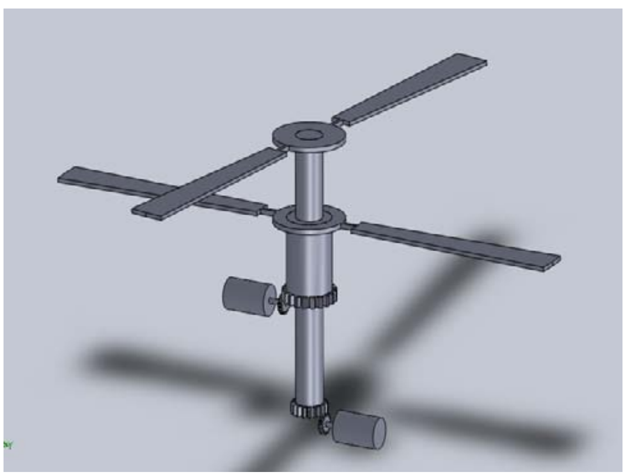
The bio-mimetic [14] inspiration behind evolution of the proposed model is the humming bird. Backward motion is considered as one of their unique features. Wings have the capability to generate lift both in upward and downward stroke. Humming birds 75% of the weight is supported by the downward stroke. The proposed model is a hybrid tech and it is composed of two basic subsystems for the flight. The primary subsystem is the coaxial rotor subsystem that helps in producing the main lift and the secondary subsystem is the Flapping subsystem. The following flow chart explains the system design,



The coaxial rotor [19] subsystem is the main lift production unit of the proposed model. The pictorial representation of the complete system is given in the following section. The rotorcraft concept has various rotor configuration involved in it. Co-axial rotor configuration has been chosen here for the system design. These rotors are nothing but a pair of helicopter rotors fixed one above the other on concentric shafts with the same axis of rotation, but these turn in the opposite directions (contra-rotation). The basic reason behind using coaxial rotors is the sort out the problem of imbalance in the angular momentum. The rotors solve the imbalance of angular momentum by turning the rotors in opposite direction to each other. Equal and opposite torques of the rotor that acts on the helicopter body cancel out each other. Yaw control can be achieved by varying the rotational speed of both the rotors. This setup leads to the rise in controlled dissymmetry of torque. This system suits the model configurations and specifications. The coaxial rotor subsystem comprises of the following components two batteries, one inner shaft, one outer shaft, two blades attached to the outer shaft, two blades attached to the inner shaft, two motors, two main gears and two pinion gears. The second subsystem is the flapping subsystem. This is basically used for proving the reverse motion concept. This system comprises of the following parts one main gear, connecting shaft, pinion gear, battery, motor, connecting rod that connects the subsystem to the main body. The system is modeled in such a way that the coaxial system is to be placed in the top portion of the model and the flap system [12] to be placed in the lower portion of the model.

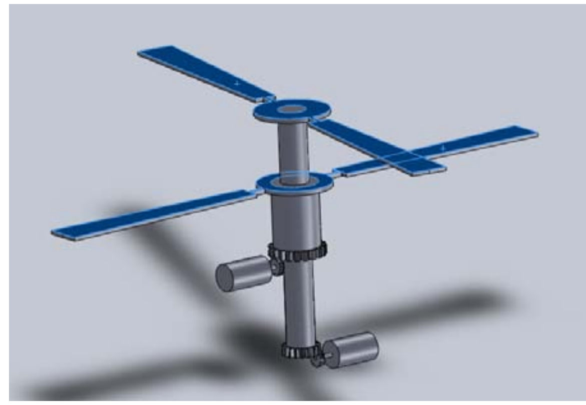
V. PICTORIAL REPRESENTATION OF THE PROPOSED MODEL

The following design shows the main coaxial rotor system providing lift force for the model.

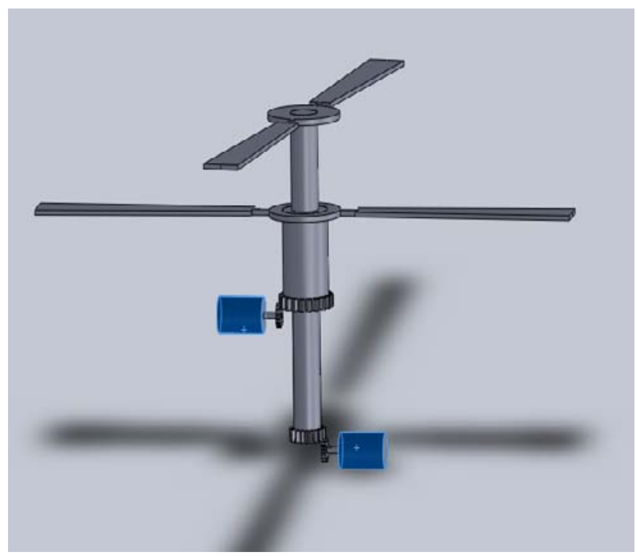


The following design shows the front view of the subsystem

The following design shows the main rotor blades of the subsystem, where the upper blades are connected to the inner shaft and lower blades are connected to the outer shaft.

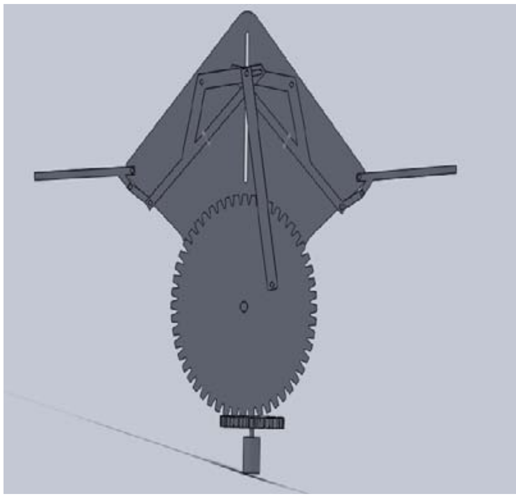


The following design shows the motor that is connected to the pinion gear, which in turn is connected to the main gear of the system.



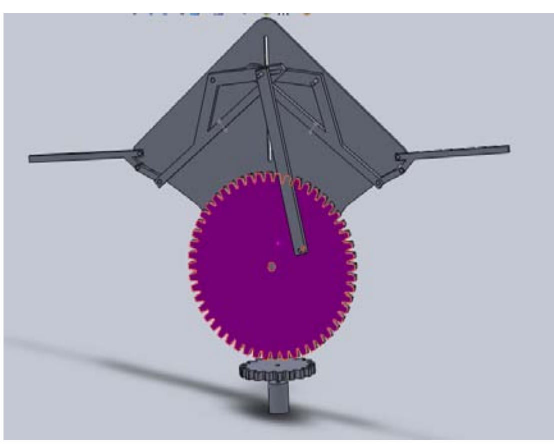
VI. FLAPPING WING SUBSYSTEM

This is the main flap mechanical system where you could see the motor pinion gear, Main gear, circular disc, connecting shaft, and the rod for wings to get attached.

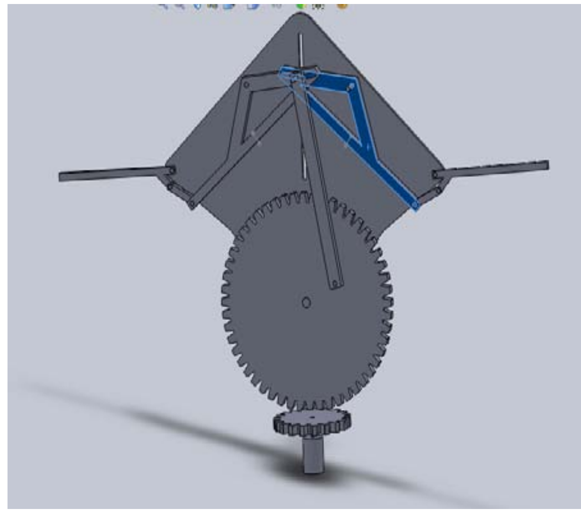


The following model depicts the side view of the flap system.

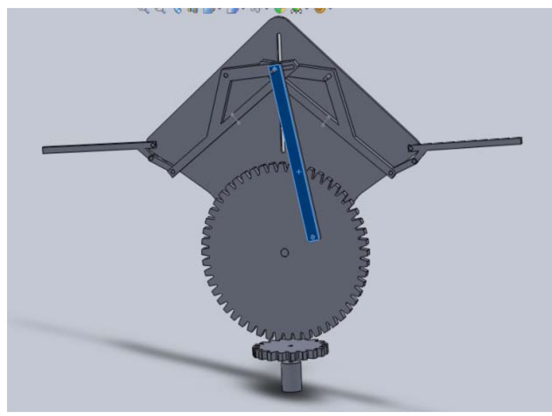
The following diagram describes about the main gear which is connected to the moving shaft of the system. The main gear is connected to the pinion gear located at the lower portion of the system.



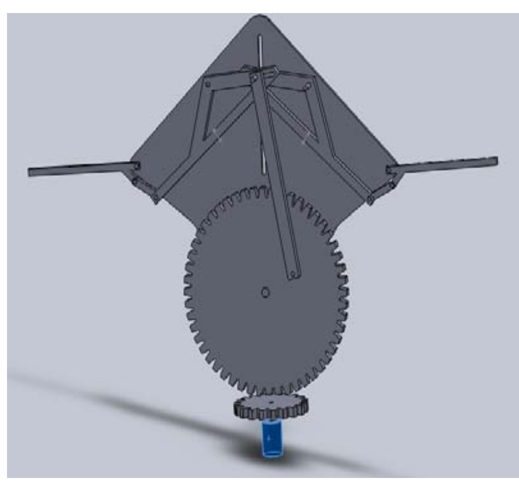
The following picture depicts the connecting system that has a connection with the main shaft that in turn is connected to the main gear.



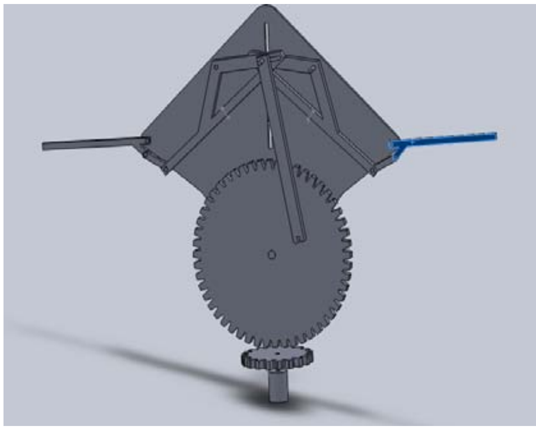
The following design shows the main connecting shaft, which connects the flaps and the main gear.



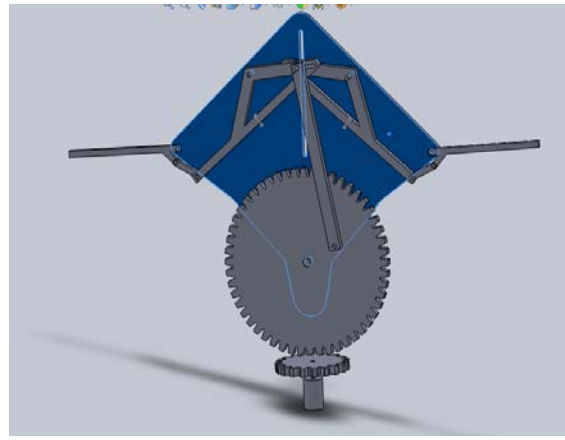
The following picture depicts the motor that is connected to the pinion gear which drives the main flap subsystem.



The following system depicts the main attaching rod connecting the flap to the main body frame.



The following design shows the main body to which the flap subsystem is attached.



VII. CALCULATION

Coaxial Rotor Sub System

The propeller taken here is 11inch, accordingly the radius is taken to be r = 0.1397metre

First the area has been calculated, $A = \pi r^2$ where we got

A= 3.14*(0.1397) ^2 = 0.01628 m^2

Actual speed of the blades,

$\Omega = \eta * V * \frac{KV}{G}$

$\Omega = 0.7 * 11.1 * \frac{1250}{8}$ = 1214.063

$\Omega = \frac{1214.06}{60} = 20.23\frac{rev}{sec}$

$V_b = \Omega * 2 * \pi * r$

$V_b = 20.23 * 2 * 3.14 * 0.1397$ = 17.74m/s

$F_l = 0.5 * C_l * \rho * {V_b}^2 * A$

$F_l = 0.5 * 1.6 * 1.29 * (17.74)^2 * 0.0168$ = 5.46N (For one rotor disc)

$F_d = 0.5 * C_d * \rho * {V_b}^2 * A$

$F_d = 0.5 * 0.5 * 1.29 * (17.74)^2 * 0.01628$= 1.6N

Speed of rotor in hover condition = Lift on 2 rotor disc equivalent to weight of body

$2 * 0.5 * C_l * \rho * {V_b}^2 * A = W_b$

$1.29 * 1.6 * {V_b}^2 * 0.01628 = 9.8$

${V_b}^2 = 291.666$

$V_b = 17.07 m/s$

Flapping Sub System

Wing span (By power Law)

$l = 1.704 * m^{\frac{1}{3}}$ m --> Body Mass.

The span calculated theoretically is about 7.7915m

But considering the concept and after few researches we arrived at a conclusion of 33cm span. When theoretical span is adapted then it is not possibly adaptable to the system or the concept designed. Hence, in order to develop the model without breakage a 33 cm span was taken. For choosing this span a brief study of the ornithopters that has been developed till now has been made, and a final decision has been arrived at.

Semi span = 16.5cm

Chord width = 7cm

$W = L = mg = 9.8 * 9.8 = 96.04N$

Wing loading= $\frac{W}{S} = K_1 W^{\frac{1}{3}}$= 140.11N/m^2

$S = Wing\ Area = L * W = 0.165 * 0.07 = 0.01155 m^2$

Aspect Ratio= $\frac{S}{C} = \frac{0.33}{0.07} = 4.74$

Force exerted by the muscle is directly proportional to the cross section area

$F_m\ directly\ proportional\ to\ 0.01155 m^2$

Torque about the centre of rotation of proximal end of limb can be expressed as

$J_t = F_m l$= 0.01155*0.165 = 0.00190575

I= moment of inertia of limb = $\left(\frac{l}{2}\right)^2\ or\ l^5$

Moment of inertia of limb has uniform density and muscle in action has angular acceleration.

I = $l^5 = (0.165)^5 = 0.0001222$

Angular acceleration = $\frac{J_t}{I} = \frac{0.00190575}{0.0001222} = 15.59533$

Frequency is directly proportional to (Angular acceleration) ^0.5 = 3.949 hertz

VIII. CONCLUSION

The idea proposed in this paper evolved as a concept for individual flying machine, though I have portrayed here for the design of an unmanned aerial vehicle. The basic reason behind choosing the coaxial rotor system is its adaptability with the design configurations. The reverse concept is completely a new phenomenon, which is evident as per the design formulated in this paper.

IX. ACKNOWLEDGEMENT

Setting an endeavor may not always be an easy task, obstacles are bound to come in its way and when this happens, help is welcome and it is necessary to say without help of those People whom we are mentioning here, this journey would not have been successful.

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