International Journal of Advancements in Mechanical and Aeronautical Engineering – IJAMAE
Volume 1 : Issue 3 [ISSN 2372 –4153]
Publication Date : 30 September, 2014

FLAPCOPTER-FFB

Karishmaa.S.Iyer[1], Nikhilesh Loknath[2]
[1,2]Students, SRM University, India

Abstract: This project aims at the development of a bio-mimetic propulsion mechanism for a Flapping Wing Small Unmanned Aerial Vehicle (SUAV), with the addition of tilt rotors in the design for stability. The purpose of this design is to benefit the surveillance system of our country during disaster, combat and spying missions. A key benefit of flapping wing flight is low frequency wing flapping, enabling very quiet flight relative to propeller-driven aircraft. The aerodynamic and kinematic pattern of hummingbirds, bats, insects and small birds are summarized. Based on this review several different concepts of mechanisms for flapping wings are generated, which are separated for the flapping motion and the pitching motion. The specifications of the tilt rotors are studied. This artificial bird will be the size of approximately 1000 grams. This artificial bird has two levels, ground level consisting of a pair of tilt rotors, first level consisting of a pair of wings and the last level consisting of the stabilizers. Using a qualitative evaluation, the quality of the concepts are determined according to different criteria such as weight, size, robustness, mechanical complexity, expected power consumption and accuracy.

Keywords: Flapping wing mechanism, Machine design and dynamics, MEMS, Safety and risk assessment, Tilt rotors.

I) Introduction

Anyone will be convinced that the domestic use of SUAVs to conduct surveillance and collect other information will have a broad and significant impact on the everyday lives of millions of people. Some of the important applications can be:

1) Highway monitoring

2) Atmospheric research

3) Disaster relief

4) Wildlife research

II) Configuration Selection

In order to aid the choice of configuration, a scoring table was made. Four particular configurations were chosen: a conventional fixed wing airplane and an ornithopter from the thrust hanging group, a tilt rotor from the thrust vectoring group and a compound helicopter (gyroplane) from the orthogonal thrust group. A qualitative assessment of several parameters was made. The parameters were:

- Forward flight performance: covers agility and speed envelope in forward flight;
- Hover flight performance: covers ease of control in hover flight in all 6 degrees of freedom;
- Complexity: covers both mechanical and electronic systems complexity (higher score denotes less complexity);
- Scaling: covers how well the configuration scales within the size range defined;
- Forward flight efficiency: covers overall efficiency in forward flight in terms of both thrust and lift;
- Hover efficiency: covers efficiency and endurance in hover flight;
- Transition: covers ease and smoothness of transition between hover and forward flight modes;
- Payload: covers payload capability and any limitations imposed by the aircraft on the payload;
- Reference: covers the amount of reference work that was readily available at the time.

These parameters were evaluated for each of the configurations. For each a score from 1 (very bad) to 5 (very good) was attributed. It was decided to give the same weight to all of the parameters. The results are presented in table.

Table 1: Comparison of configurations

Feature	Conventional	Ornithopter	Tilt rotor	Gyroplane
Forward performance	5	5	4	3
Hover performance	1	2	3	4
Complexity	5	3	2	1
Scaling	3	2	4	3
Forward efficiency	5	4	4	3
Hover efficiency	1	4	4	3
Transition	2	2	3	4
Payload	1	2	4	4
Reference	4	5	1	1
Total	27	29	29	27

From the scores presented, the two best contenders were the ornithopter and the tilt rotor configurations.

III) Biological outlook of flapping wing mechanism

In the following table the characterization of the kinematics of the different investigated flying animals [Insects-Drosophila fruit fly, rufous Hummingbirds, and Flying Fox Bat (*Pteropus scapulatus*)] are summarized for hovering flight. Note that morphological data and results out of biological experiments are taken either as average values or most suited values.

Table 2: Characterization of kinematics of different flying animals

Parameter	Insects	Hummingbirds	Bats	Siskin
Weight (g)	<<1	3-4	1180	14
Wingspan (mm)	-	109	1500	160-180
Wing chord (mm)	-	12	-	40
Single wing area (mm^2)	1-2	500-600	22k-31k	2650
Joints in wing	0	1	12	1
Flapping frequency	250	40-45	7.8-11	20-26

Bat: Advantages –highly manoeuvrable -hovering and forward flight possible -low flapping frequency compared to animal's size -can generate greater lift for less energy due to stretchy membrane. It also has a high aspect ratio of about 8.4 and wing loading of 57.8.

Drawbacks -very complex wing structure, more than two dozen independently controlled joints -highly articulated motion and complex kinematics -deforming bones

IV) Robotic design features and materials

It is important that every component of the overall system is light and minimal in weight, especially the wings. The calculated weight of each wing of our design is around 177gms, with 7 joints driven by 3 Servo motors each. The conventional way to construct the wings is to build the wing spars and membranes from light yet very strong materials. For many reasons we claim the new MEMS wing technology is necessary because MEMS wings enable systematic research in terms of repeatability, size control, weight minimization, mass production, and fast turn-around time. For this project, we have chosen titanium-alloy metal (Ti-6Al-4V) for several reasons. It is light and strong and can be easily tapered to vary the thickness of wingspans. Because titanium-alloy is ductile, it also can be bent to create wing camber to improve performance. In addition, the etching process of titanium-alloy can be conducted at room temperature and yields a reasonable etching rate. For wing membranes, we selected parylene-C. There are several advantages of using parylene-C as wing membrane:

1) It can be deposited directly onto titanium-alloy at any desired thickness;

2) Its adhesion to titanium-alloy is excellent;

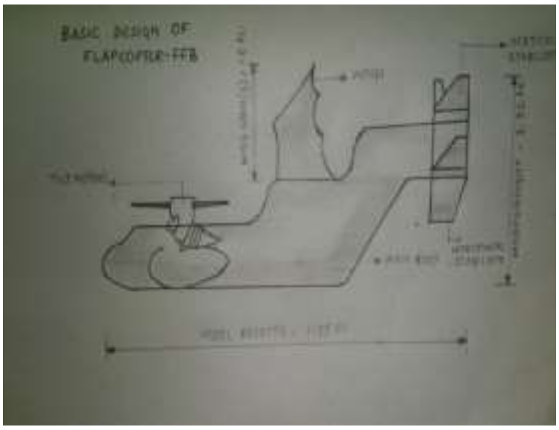
3) Parylene film is light and strong, and can withstand high flapping frequency of more than 30 hertz without tearing; This new wing design results in a 40% wing area reduction compared to the non-MEMS wings and yet still outperformed them in terms of lift and thrust productions.

V) Transmission design

A lightweight, low-friction transmission mechanism was built to convert the rotary motion of the driving motor into the flapping motion of the wings. Four transmission designs have been considered based on simplicity, minimal weight, and flapping symmetry. This design restricts the flapping motion in a plane perpendicular to the motor shaft. A small DC motor with gearbox ratio of 22:1 is used to drive the transmission. The power of 2.5 KW can be used to drive this motor. At this power, with no wing attached, the transmission can flap up to 42 Hz continuously for a few minutes without overheating the motor. The wings will be then mounted on the transmission system. They could withstand more than 30 Hz of flapping. Neither breaking nor tearing of wing membrane will be observed.

VI) Proposed Design

Figure 1: Proposed design of Flapcopter-FFB



VII) Tilt rotor specifications

A) General sizing

The basic sizing of the aircraft had two main constraints. One of them is the dimension of the of the-shelf components for the aircraft. The other comes from the mission requirements. These state that the aircraft should be able to fly through the threshold of a standard door. Considering a clearance of 120[mm] to each side, to allow a safety margin, a maximum width of 460[mm] can be decided for the aircraft. A minimum width was also established, since it is tied to the smaller diameter of opposite rotation propeller pairs that can be chosen to use as rotors. The smallest pair found was in the GWS 3-Blade series, at a diameter of 127[mm] (5[in]). Also the size of the electronic components to include in the fuselage must be taken into account. Based on the observed dimensions of several necessary components, a minimum fuselage width of 35[mm] was decided. This along with fuselage wall thickness and necessary propeller clearances, lead to a minimum width of about 310[mm]. For height, it was decided to set a reference limit of 100[mm], this being the standard width of balsa wood plates that would become an integral part of fuselage construction.

B) Selection of rotor, motor and esc

The driving requirement for propeller selection is static thrust, since in the most demanding flight condition (hover), there will be little airflow perpendicular to the rotor disk. The corresponding lack of efficiency in forward flight (versus a high speed propeller) is offset by the existence of two propellers instead of one in the aircraft. Variable pitch airplane propellers have also been considered. These would allow changing pitch to optimize the propeller performance for both hover and forward flight conditions. However, these propellers are often commercialized as integrated systems (propeller, motor and blade pitch servo) and in a very narrow range of sizes, the smallest of them being too large for the intended aircraft size. Other drawbacks include the mechanical complexity and overall smaller efficiency of the system in either of the flight regimes, versus a specialized propeller. There were four main parameters important to the selection of the propeller: the diameter, pitch, direction of rotation and number of blades. The diameter was constrained to a maximum defined by the general dimensioning described above.

Considering the selected layout, the largest (standard) diameter size was 178[mm] (7[in]). As for the minimal diameter, opposite rotation pairs were available also for 5[in] and 6[in] diameters. The final decision fell to the largest diameter in order to have a greater propulsive efficiency for the same thrust (i.e. accelerating a greater mass of air by a smaller amount). The pitch in the commercial propellers considered varied little in the same diameter.

Since a pair of propellers with opposite direction of rotation was needed, a market search was conducted. Two propeller types matching the already defined conditions were found: the GWS 7x3.5x3 and the Master Airscrew 7x4x21. The three bladed propellers would seem like the obvious choice for greater static thrust. However the deciding parameter was thrust per current drawn by the motor.

Regarding motors, brushless motors have a static arrangement of windings that are excited in such a way as to create a rotating magnetic field.

The batteries considered were two and three cell lithium-polymer batteries. Since for the same capacity a two cell battery weighs about two thirds of the three cell battery (and also costs less), it was decided to choose a motor that had a 7[in] propeller as its largest recommended propeller, and use the two cell battery. Within that range however, the largest available Kv ratio was chosen, in order to get the greatest possible thrust with the arrangement. Based on this, the motor selected as the AX1806N.

The criteria for ESC selection, the selected model was the Turnigy Plush 10A, rated at 10[A] maximum continuous current and 12[A] burst current, and with a BEC rated at 2[A] continuous.

C) Battery

The Hyperion LVX was chosen, being rated for 3D and aerobatic RC aircraft (thus delivering good performance), but with prices still within an acceptable range.

The next step was to list all the batteries of that model and to filter out the ones that couldn't deliver the necessary maximum discharge current, which was majored by the sum of the maximum (continuous) currents that the two ESC and one BEC could withstand (2*10+2 = 22[A]). This established a lower threshold. The upper threshold is then defined by weight constraints. So, by estimating a fraction of the total mass to belong to the battery (20[%] to 25[%]), two batteries were chosen for the flight testing, with capacities of 1200 and 1500 [mAh].

D) Hovering

For pitch stability, it is important to consider the longitudinal and vertical locations of the centre of gravity. In an ideal hover situation, when no aerodynamic surfaces are creating significant forces, the centre of gravity should be in the same longitudinal coordinate as the tilting pivot and the only applied forces will be aircraft weight and rotor lift. In terms of vertical location, the aircraft will exhibit neutral stability with the centre of gravity either above or below the pivot. In order to improve this situation, an artificial stability augmentation needed to be added to the aircraft. This consisted of rate gyro set to input feedback control on the pitch control channel. The implementation can be made with the-shelf components that are usually known only as gyros.

Regarding pitch control, the rotors can be tilted symmetrically, changing the orientation of the thrust vector to produce a horizontal component. This component, multiplied by vertical the distance between the tilting pivot and the centre of gravity the centre of gravity creates a pitching moment. This method is the simplest and uses the same actuator and mechanism for the tilt control and it was chosen for the aircraft.

E) Radio control

The radio selected was the HK-T6A sold by United Hobbies (the same basic model has been sold under other brand names in the past). This radio, although inexpensive, provides some features that made it desirable for this particular project: six channels, being the fifth and sixth assignable to knobs; operating frequency band of 2.4[GHz] with spread spectrum technology, which is less susceptible to environmental interference than the standard 35 MHz's.

VIII) Payloads

1) Infrared sensors

2) Cooled infrared detectors

3) Laser rangefinder

4) Laser designator

IX) Conclusions

The proposed design weighs around 1.5 Kgs and has the following advantages:

1) Energy consumption is less compared to the lift provided by the fixed-wing propelled aircrafts;

2) The forward speed for this mechanism is on higher edge compared to the conventional aircraft;

3) High manoeuvrability;

4) Highly stable & highly reliable;

5) Both Vertical and Horizontal lift-off and landing exist;

X) References

[1] American Institute of Aeronautics & Astronautics, www.AIAA.org

[2] Cornell University, www.creativemachines.cornell.edu/ornithopters

[3] Delft University, www.delfly.nl

[4] Fundamentals of Modern Unsteady Aerodynamics, Ulgen Gulcat

XI) About Authors

1)

Karishmaa.S.Iyer

Currently pursuing Bachelors in Aerospace Engineering (III Year) in SRM University

Interest: Aerodynamics

2)

Nikhilesh Loknath

Currently pursuing Bachelors in Aerospace Engineering (III Year) in SRM University

Interest: Propulsion