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Study on UAV Performance using eCalc

Mohammad Shahrulnizam Idy[1], **Siti Juita Mastura Mohd Saleh**[1,*]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: Address the need of longer flight duration on hover state for the hexacopter UAV. The main parameters involve was selected and configurations was developed. The configurations will be test and analyzed using open-source web calculator for UAV called eCalc. The relationship of propeller size is inversely proportional to the motor rating. The best configuration for the longest flight time was determined and all configurations can be used as model for future experiment.

Keywords: UAV, UAV Performance, Ecalc

1. Introduction

The drone is one of the flying aircraft that use no human being to be a pilot. Technically, the drone is an Unmanned Aerial Vehicle (UAV) that operates and flies without a pilot control[1]. However, even though it is an unmanned aerial vehicle, the drone still needs a pilot, but control remotely means there still a human factor involved. Thus, current research still working on how to make the drone complete a flight course autonomously because the drone does not fit the characteristic of its name as an unmanned aerial vehicle flying aircraft if there still human intervention.

Autonomous it is by Cambridge Dictionary [2] as independent and having the power to make your own decisions. From the context of flying aircraft, fly autonomously is the ability of it to perform aerial maneuvers on its own. There are two main types of UAV, which are the fixed-wing aircraft and rotary-wing aircraft [3] where it generates lift when moving forward driven by the propeller or jet engine-powered and vertical lift by power-driven horizontal propellers respectively [4]. Drone also build with several parts which are body frame, motor, Electric Speed Controller (ESC), propellers, flight controller, battery, GPS Module, and transmitter [5].

The performance of the drone can be affected by two main parts which are power consumption and flight duration. They are different divisions but relate to each other that resulting in how long endurance the drone can be experienced during flight.

Currently, the maximum flight time for the small class UAV is 30 minutes with a range of 10 to 100 kilometres [6]. Unfortunately, UAV technologies are limited by their applications. The main reason

**Corresponding author: juita@uthm.edu.my*

why the UAVs were consumed by many due to their ergonomic characteristic. They have a low maintenance cost, east of deployment, high-mobility, and the ability to hover.

However, the drone only can cover a small area in a short amount of time when utilizing in the agriculture field and multiple drones are needed for surveillance. Thus, the idea to create a drone that has maximum flight duration and maximum thrust seems would overcome such limitations and provide better solutions that are more beneficial to the commercial industry.

Currently, there are a lot of demand in industries that requires the drones to fly in a long period of time. The limitation of drones such as short flight duration, high power consumption, and selection of optimal parts to create one of them make the researchers and inventors have no obligation to ignore such constraints.

With that in mind, not all factors can be studied at one time as it will essentially consume much time. Due to that, only factors that contribute to the ability of a drone to fly longer will be studied. These factors are the size of the propeller, rating of the motor in term of speed, and battery capacitance that relate to power consumption and thrust. But the study will focus on flight duration during hovering.

However, a constant power out does not result in a steady hovering state. As time goes by, more energy is needed to keep the drone hovering. Therefore, the optimal configuration of the UAV needs to be identified to break the current limit.

2. Materials and Methods

2.1 Materials

Main components selection is propeller size, motor rating or speed of motor, and battery capacitance. These three selected components can also be called parameters that influence the performance of UAV. The configuration was developed based on these parameters.

2.2 Methods

The configurations proposed were analyzed by using eCalc software [7]. However, before entered the data in eCalc software, a few details of others components that contribute to the hexacopter performance were determined as shown in Table 1.

Table 1: Details of additional components

No	Component	Data contained	Unit
1	Frame	weight, size	g/oz, mm/inch
2	Rotor configuration	flat, coaxial	-
3	Environment	field elevation, pressure, air pressure	m ASL/ft ASL, ℃/°F, hPa/inHg
4	Propeller	Number of blades	-
5	Battery	State of charge	-

2.3 Equations

The equation used to find the thrust and use in simplified form to find static and dynamic thrust equation. By fixing the material of the propeller, the size selection of the propeller can be done using the equation above with the known desired motor’s speed[8].

Static thrust,

$$F = 1.225\frac{\pi(0.0254\cdot d)^2}{4}\left(RPM_{prop}\cdot 0.0254\cdot pitch\cdot\frac{1\,min}{60\,sec}\right)^2\cdot\left(\frac{d}{3.29546\cdot pitch}\right)^{1.5} \quad \text{Eq 1}$$

Dynamic thrust,

$$F = 1.225\frac{\pi(0.0254\cdot d)^2}{4}\left[\left(RPM_{prop}\cdot 0.0254\cdot pitch\cdot\frac{1\,min}{60\,sec}\right)^2 - \left(RPM_{prop}\cdot 0.0254\cdot pitch\cdot\frac{1\,min}{60\,sec}\right)V_o\right]\left(\frac{d}{3.29546\cdot pitch}\right)^{1.5} \quad \text{Eq 2}$$

3. Results and Discussion

3.1 Flight Performance Analysis

The analysis start with analyzed the results of battery configurations as shown in Table 2.

Table 2: Hover flight time for battery configuration

Configuration	Battery Capacitance	Number of Cells (S)	Max. Discharge Rate (%)	Hover Flight Time (minutes)	Specific Thrust (g/W)	Thrust to Weight Ratio (: 1)	Battery Weight (g)
1	2200 mAh	3	70	4.6	7.28	1.9	55
2		4		6.2	7.28	2.8	
1		3	90	5.9	7.28	1.9	
2		4		7.9	7.28	2.8	
3	5000 mAh	3	70	10.7	7.28	2.3	124
4		4		14.3	7.28	3.5	
3		3	90	13.7	7.28	2.3	
4		4		18.4	7.28	3.5	
5	8000 mAh	3	70	17.2	7.28	2.4	197
6		4		23.1	7.28	3.8	
5		3	90	22.2	7.28	2.4	
6		4		29.7	7.28	3.8	

Then, the selected of the best battery configuration used as constant parameters to develop configurations to find the longest hover flight time as shown in Table 3

Table 3: Configuration for Propeller Size and Motor Rating

Configuration	Battery Capacitance (mAh)	Motor rating (Kv)	Propeller Size (inch)
1	8000	1290	10 x 3.8
2			9 x 4.7
3			8 x 3.8
4		1120	10 x 3.8
5			9 x 4.7
6			8 x 3.8
7		880	10 x 3.8
8			9 x 4.7
9			8 x 3.8

Thus, the final results are based on **Error! Reference source not found.** :

i) 10 x 3.8inch propeller should be chosen for the highest specific thrust of 7.89 g/W.
ii) HobbyStar C2216-10 880Kv motor should be chosen as the pair for the chosen propeller.
iii) This configuration should achieve around 24.1 min of hover.
iv) The thrust to weight ratio for this configuration should be 2.2:1 to lift the hexacopter.

3.2 Discussions

The relationship between propeller size and motor rating is inversely proportional. Bigger propeller size needs slower motor speed. This was justified by results shown in **Error! Reference source not found.**.

As shown in **Table 4**, the optimal hexacopter configuration for longest flight duration was determined.

Table 4: Hover flight time for all configurations

Configuration	Battery Capacitance (mAh)	Motor rating (Kv)	Propeller Size (inch)	Hover Flight Time (min)	Specific Thrust (g/W)	Thrust to Weight Ratio (:1)
1			10 x 3.8	22.9	7.52	3.5
2		1290	9 x 4.7	20.9	6.78	3.0
3			8 x 3.8	19.0	6.26	2.2
4			10 x 3.8	23.9	7.83	3.2
5	8000	1120	9 x 4.7	21.6	7.11	2.7
6			8 x 3.8	19.2	6.32	1.9
7			10 x 3.8	24.1	7.89	2.2
8		880	9 x 4.7	21.8	7.15	1.9
9			8 x 3.8	19.3	6.353	1.3

As shown in Figure 1, a combination and of big propeller size and high motor speed not improve the duration of flight time.

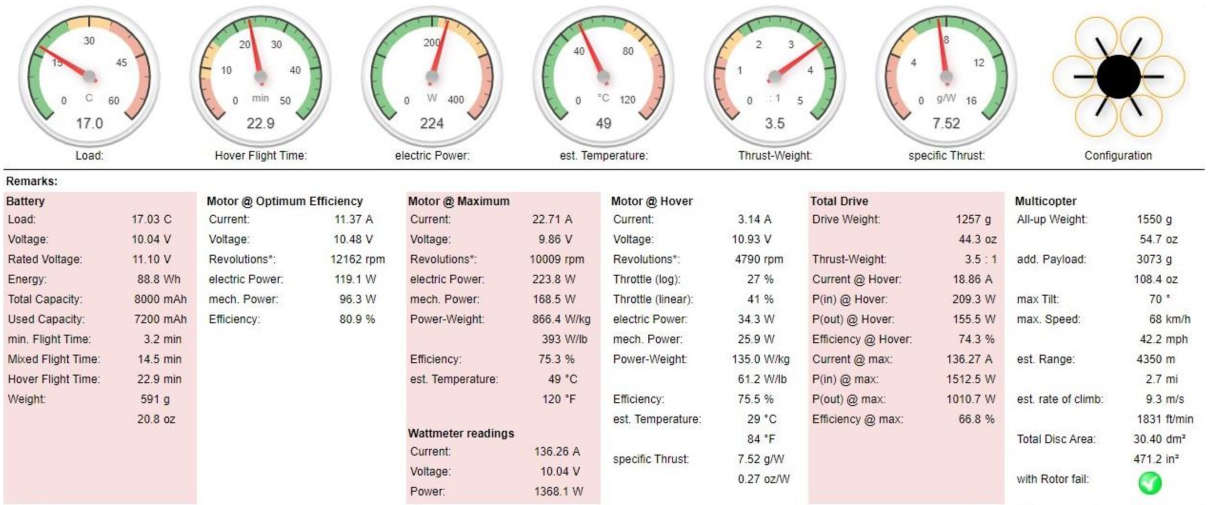

Figure 1: Result of 1290Kv motor with 10 x 3.8 propeller size

4. Conclusion

In conclusion, the methodology in this paper answers the objectives of the study in finding the optimum configuration for a long hovering time.

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