Technical review

Propellers and motors

<u>Hover propellers:</u> the propellers were chosen for low speed (hover) with the assistance of the experimental results shown in the next figure:

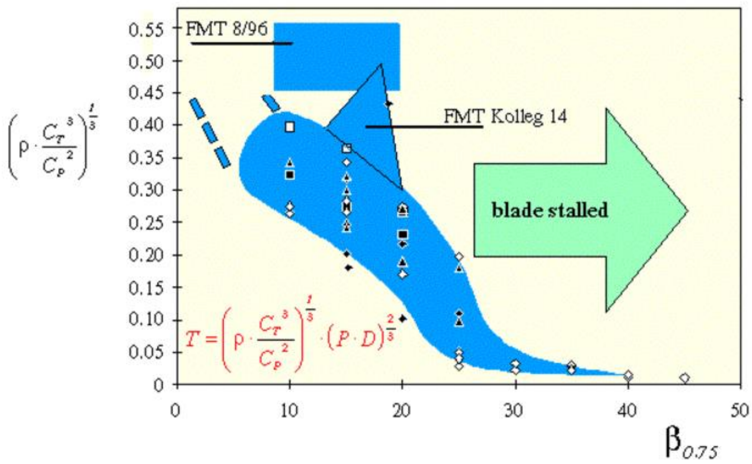


Figure1 - static propeller thrust

*The figure was taken from 'Propulsion by propellers'

The propeller diameter suited to battery power is 30". The propeller model is:

The motor was chosen by the power available and rpm suited for the propellers:

Specs:
KV(RPM/V): **90**
LiPo Cells: **8~12s**
Max Power: **1200W**
Max Amps: **36A**
No Load Current: **.5A @ 10v**
Internal Resistance: **0.186ohm**
Dimensions(Dia.xL): **92 x 29mm**
Motor Shaft: **3mm**
Prop Shaft: **33mm hole to hole for bolt through style props**
Weight: **401g (each)**
Bolt Hole Spacing: **40mm**
Suggested Propeller: **26x6.5**

Included:
1 x 9226-90kv Multistar motors
Propeller mounting hardware
Motor mounting hardware

<u>Cruise propellers and motors:</u> The propellers and motors were chosen to support TVC mode (explained later).

<u>Power and energy review</u>

<u>Hover battery:</u> ZIPPY Flightmax 8000mAh 6S1P 30C.

<u>Hover batteries power margin:</u> hover motors power needed: 4690W (from Spec sheet) Batteries maximum power: 5328W (from energy parameters file). The margin obtained: 13%.

<u>Hover batteries energy margin:</u> hover motors energy needed: 562KJ (from Spec sheet) Batteries energy capacity: 639KJ (from energy parameters file). The margin obtained: 13%.

<u>Cruise batteries:</u> Panasonic NCR18650B, Lithium-Ion. 80 batteries in total, packed in series of 8 batteries each to provide 28.8V which sufficient for the cruise motors. The 8 battery series are connected in parallel.

<u>Cruise batteries power margin:</u> cruise motors power needed for 25Kg total weight: 500W (from Spec sheet) Batteries maximum power: 665W (from energy parameters file). The margin obtained: 33%. The cruise batteries

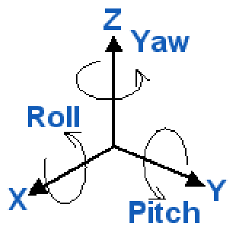
<u>Cruise batteries energy margin:</u> cruise motors energy needed for 23Kg total weight and 100km: 1.85MJ (from Spec sheet). Energy needed for 25Kg and 60km: 1.26MJ. Batteries energy capacity: 2.9 (from energy parameters file). The margin obtained: 55%.

TVC calculation

General Explanation: The drone uses 3 propellers for cruise. The propellers are located in a Triangle near the center of mass of the drone. The upper propeller is aligned with the cruise direction in the cruise speed. The other two propellers are tilted upward from the cruise direction to provide Roll moment. The tilting angle is 15° degrees which corresponding to 25% Thrust portion utilized for Roll and 90% Thrust remains for cruise direction. The configuration wastes about 6.5% percent of total cruise power and energy.

Zero angles calculation: The calculation assumes 33% cruise power excess which enables 100% thrust addition for one propeller. The rolling moment is coupled with the Yaw and Pitch moments and in 100% thrust addition and in zero Yaw, Pitch and Roll angles the overall moment is:

$$\underline{M} = L\hat{x} + P\hat{y} + N\hat{z}$$



With the geometry chosen, the numbers are:

$$L = 0.5N \cdot m$$
$$P = 1.5N \cdot m$$
$$N = 2.5N \cdot m$$

The Pitch moment can be opposed by the upper propeller and the Yaw moment is in the direction of the Roll moment. The initial angular accelerations with respect to the drone's moments of inertia are:

$$p = 10\deg/s^2$$
$$r = 5\deg/s^2$$

These values with the stability derivatives of the drones can provide good enough maneuverability for the mission.

Motors failure cases

Hover motors: The hover motors can supply 150 percent more thrust then their nominal. Thus, the overall thrust of 3 motors (in a case of 1 motor failure) is 28.1Kg. For 25 Kg drone 3 motors are enough to hover and to land safely. In a case of 1 hover motor failure the additional power required will be obtained from the cruise batteries.

Cruise motors: In a case of a failure of the upper motor, the maneuverability of the drone is limited. The motors thrust margin guarantees enough thrust for cruise continuation.
In a case of one bottom motor failure the drone can't maneuver (without hover motors correction). The failure response is to cruise in maximum L/D angle of attack only with the upper motor until landing. In this case the glide angle is about 1deg and the glide speed is about 0.5[m/s].

Batteries failure cases

Hover battery: the connection will be redundant (double cable). No response for battery failure except of parachute.

Cruise batteries: the batteries are connected in parallel series. The power and energy margin is sufficient in a case of one series failure.

Motors stopping time with reverse current

Hover motors: hover motors and propellers estimated moment of inertia: 10^-2 [Kg*m^2]. Therefore, for five seconds stopping time, the reverse torque shall be 1Nm (neglecting friction and drag).

Cruise motors: cruise motors and propellers estimated moment of inertia: 10^-3 [Kg*m^2]. Therefore, for five seconds stopping time, the reverse torque shall be 0.1Nm (neglecting friction and drag).

Batteries charging time

Hover battery: the hover battery (Li-Po) charging time is 12 minutes. Therefore, the charging can be carried out in the turnaround time.

Cruise batteries: the cruise batteries (Li-Ion) charging time is 240 minutes. Therefore, it is necessary to replace the batteries in the turnaround.