Equations

Power-Thrust Calculations

SETUP

\[ W = 11.3891 \text{[lb]} \quad \text{All-up weight of UAV} \]

\[ N_{\text{motor}} = 4 \quad \text{Number of motors/propellers} \]

\[ n = 0.85 \quad \text{Average efficiency of motors} \]

\[ RPM = 7000 \quad \text{Estimated setup RPM} \]

BATTERY

\[ V = 25 \quad \text{Selected motor voltage in volts} \]

\[ N_{\text{Batt}} = 2 \quad \text{Number of batteries in parallel} \]

\[ C = 4000 \quad \text{Battery cell capacity in mAh} \]

PROPELLER

\[ D = 14 \text{[in]} \quad \text{Propeller diameter in inches} \]

\[ \text{Pitch} = 4.7 \text{[in]} \quad \text{Propeller pitch in inches} \]

\[ A = 0.25 \cdot \pi \cdot D^2 \quad \text{Propeller sweep area in square inches} \]

\[ A_{ft} = A \cdot \left| \frac{0.006944444}{\text{in}^2} \right| \quad \text{Propeller sweep area in square feet} \]

FULL THROTTLE

\[ PL = \frac{P_{in} \cdot n}{A_{ft}} \quad \text{Power loading equation} \]

\[ TL = 8.6859 \cdot PL^{-0.3107} \cdot 1 \quad \text{[lbf/hp]} \quad \text{Thrust loading equation} \]

\[ Lift = TL \cdot (P_{in} \cdot n) \quad \text{Lift per Motor} \]

\[ Lift_{Total} = Lift \cdot N_{\text{motor}} \quad \text{Total lift of the UAV} \]

\[ P_{inWatt} = P_{in} \cdot \left| \frac{745.7}{\text{hp}} \right| \quad \text{Power input to motor in Watts} \]

\[ Lift_{Total} = 2 \cdot W \quad \text{Common Thrust-to-Weight Ratioto generate needed lift} \]

\[ I_{\text{tot}} = I_{\text{motor}} \cdot N_{\text{motor}} \quad \text{Total UAV current} \]

\[ I_{\text{motor}} = \frac{P_{inWatt}}{V} \quad \text{Current of motor} \]

\[ P_{inWatt} = P_{outWatt} / n \quad \text{Power relation involving motor efficiency} \]
\( KV_{req} = \frac{RPM}{V} \)  

Required KV of motor

\( NomKV_{req} = KV_{req}/n \)  

Nominal KV (labeled) of motor which accounts for efficiency

\( ESC_{req} = I_{motor} \cdot 1.2 \)  

Required ESC current for motor

HOVER

\[ PL_H = \frac{P_{Hin} \cdot n}{A_{ft}} \]  

Power loading equation for hover

\[ TL_H = 8.6859 \cdot PL_H^{0.3107} \cdot 1 \text{ [lbf/hp]} \]  

Thrust loading equation for hover

\[ Lift_H = TL_H \cdot (P_{Hin} \cdot n) \]  

Lift per motor at hover

\[ Lift_{HTotal} = Lift_H \cdot N_{motor} \]  

Total lift of the UAV at hover

\[ P_{HinWatt} = \frac{P_{Hin}}{745.7} \text{ W [hp]} \]  

Power input to motor at hover in Watts

\[ Lift_{HTotal} = 1 \cdot W \]  

\[ I_{Htot} = I_{Hmotor} \cdot N_{motor} \]  

Total hover UAV current

\[ I_{Hmotor} = \frac{P_{HinWatt}}{V} \]  

Current of motor at hover

\[ P_{HinWatt} = \frac{P_{HoutWatt}}{n} \]  

Power relation involving motor efficiency

ENDURANCE

\[ t_{hover} = \frac{60 \cdot (C/1000) \cdot N_{Batt}}{I_{Htot}} \]  

Hover endurance time based on the battery capacity and motor current with margin of error

\[ t_{fullthrottle} = \frac{60 \cdot (C/1000) \cdot N_{Batt}}{I_{tot}} \]  

Full throttle endurance time based on the battery capacity and motor current with margin of error

\[ t_{average} = \frac{t_{hover} + t_{fullthrottle}}{2} \]  

Average endurance time

Solution

\( A = 153.9 \text{ [in}^2]\)  
\( A_{ft} = 1.069 \text{ [ft}^2]\)

\( C = 4000 \text{ [mA}h]\)  
\( D = 14 \text{ [in]}\)

\( ESC_{req} = 22.15 \text{ [A]}\)  
\( I_{Hmotor} = 6.752 \text{ [A]}\)

\( I_{Htot} = 27.01 \text{ [A]}\)  
\( I_{motor} = 18.46 \text{ [A]}\)

\( I_{tot} = 73.82 \text{ [A]}\)  
\( KV_{req} = 280 \text{ [rpm/V]}\)

\( Lift = 5.695 \text{ [lbf]}\)  
\( Lift_H = 2.847 \text{ [lbf]}\)

\( Lift_{HTotal} = 11.39 \text{ [lbf]}\)  
\( Lift_{Total} = 22.78 \text{ [lbf]}\)

\( n = 0.85\)  
\( N_{omKV} = 329.4 \text{ [rpm/V]}\)

\( N_{Batt} = 2\)  
\( N_{motor} = 4\)

\( Pitch = 4.7 \text{ [in]}\)  
\( PL = 0.492 \text{ [hp/ft}^2]\)
\[ PL_H = 0.18 \text{ [hp/ft}^2\text{]} \quad P_{H_{in}} = 0.2264 \text{ [hp]} \]
\[ P_{H_{in\, Watt}} = 168.8 \text{ [W]} \quad P_{H_{out\, Watt}} = 143.5 \text{ [W]} \]
\[ P_{in} = 0.6187 \text{ [hp]} \quad P_{in\, Watt} = 461.4 \text{ [W]} \]
\[ P_{out\, Watt} = 392.2 \text{ [W]} \quad \text{RPM} = 7000 \text{ [rpm]} \]
\[ TL = 10.83 \text{ [lbf/hp]} \quad TL_{H} = 14.8 \text{ [lbf/hp]} \]
\[ t_{\text{average}} = 12.14 \text{ [min]} \quad t_{\text{fullthrottle}} = 6.502 \text{ [min]} \]
\[ t_{\text{hover}} = 17.77 \text{ [min]} \quad V = 25 \text{ [V]} \]
\[ W = 11.39 \text{ [lb]} \]

**Parametric Table: Table 1**

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**Parametric Table: Table 2**

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**Plot Window 1: Plot 1**

![Plot](image-url)