dronePowertrainSizingNotes

Hover power

List of methods (non-CFD)

1. Momentum theory
2. Blade element theory

Momentum theory

- *Momentum* refers to the linear momentum of the airflow that is accelerated as the rotor (propeller) spins
- The theory is based on momentum conservation, which translates to the increase in momentum corresponding to equal and opposite reaction force (thrust) generated by the propeller
- Assumptions
  - propeller is an actuator disk
  - flow is incompressible
  - air is accelerated from still air to fully developed wake
    - $v_{wake} = v_{induced}$
- Links
  - link1
  - link2

Equation

$$P_{hover} = \frac{W^{3/2}}{\sqrt{2\rho(n_{prop}A)}} \times \frac{1}{\eta_{hover}}$$

Symbol	Description	Unit
W	weight of aircraft	N
ρ	air density	kg/m^3
n_{prop}	number of propellers	-
A	disk area of a single prop	m^2
η_{hover}	prop efficiency at hover	-

Cruise power

List of methods (non-CFD)

1. Lift-to-drag (L/D) ratio based
2. Drag based

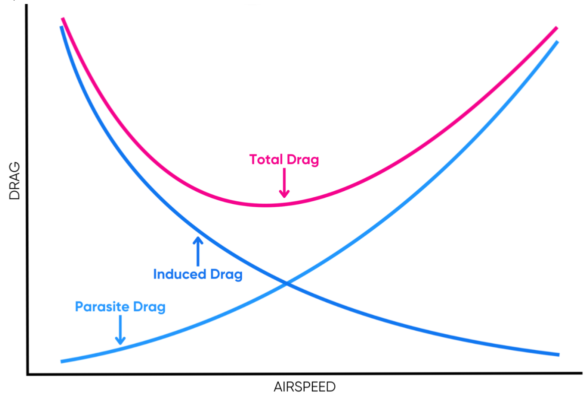
L/D method

1. Every aircraft will have a L/D curve
2. It is parabolic in nature with a minimum at the best cruise speed
3. Obviously, lift = weight at cruise (fully airborne $\rightarrow$ weight fully supported by the wings)

Equation

$$P_{cruise} = \frac{W}{L/D} v_{cruise} \times \frac{1}{\eta_{cruise}}$$

L/D (just drag, as lift is constant in wing-borne flight) has a parabolic dependence on cruise speed



For derivation aero101 > Equations

Battery sizing

Power sizing

Additional parameters / models necessary

1. $\eta_{powertrain}$ powertrain efficiency

$$P_{maxBattery} = \frac{1}{\eta_{powertrain}} \times max(P_{hover},\ P_{cruise})$$

- Most likely $P_{hover} >> P_{cruise}$ around *best range* speed
- There will be slight difference (a percent or two) in $\eta_{powertrain}$ during hover and cruise

Energy sizing

Additional Parameters / models / requirements necessary

1. $\eta_{powertrain}$ powertrain efficiency
2. d total range requirement
3. t_{hover} hover time
4. v_{cruise} cruise speed

$$E_{total} = (t_{hover} \times P_{hover} + \frac{d}{v_{cruise}} \times P_{cruise}) \times \frac{1}{\eta_{powertrain}} \times \frac{1}{1000 \times 3600} \ kWh$$

Cell architecture

- number of cells in series is a simple

  $$n_s = \frac{V_{bat_{min}}}{V_{cell_{min}}}$$

  $V_{bat_{min}}$ is a requirement, $V_{cell_{min}}$ is cell specification
- number of cells is parallel (#parallel branches of series cell) needs two main consideration
  - energy required for the mission
  - maximum discharge C-rate of the cell
- if the cell chemistry doesn't allow, we might need to add parallel branches just to be below the maximum allowable discharge C-rates and end up with higher than required energy

Choice of cell chemistry

Comparison is limited to Li-Polymer and Li-ion

- Li-Po is more popular for drones
- Li-Po has more than twice the power density W/kg (higher C-rates) and about 25% less energy density Wh/kg
- Depending on the ratio of battery-to-drone mass the 25% might look even less
- But if the range requirements are *really* high, Li-ion batteries might be a better option as this reasoning would no longer be valid
- For *heavy* lifting Li-Po are a better option
- Other relevant differences - Li-Po $\rightarrow$
  - life span is lower by about 50% (300 cycles)
  - safety
    - more prone to swelling
    - less prone to thermal runaway
  - higher lowest operating voltage (part of reason why less energy dense)
  - comes mostly in pouch configuration (as opposed to cylindrical Li-ion), but pouch cells might need structural reinforcements that might take away the volumetric density advantage of Li-Po (pouch cell) when it comes to making a battery with multiple cells
    - note that when making a battery, the volumetric density drops for both types of cells (wasted space for cylindrical), (structural reinforcements for punch), but the mass density will also decrease for pouch cells

Motor sizing