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Design Process Formulas

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List of 19 Design Process Formulas

Design Process

1) Battery Weight Fraction

Open Calculator

fx $$\mathrm{WBF} = \left(\frac{\mathrm{R}}{\mathrm{E_{battery}} \cdot 3600 \cdot \eta \cdot \left(\frac{1}{[\mathrm{g}]} \right) \cdot \mathrm{LDmax_{ratio}}} \right)$$

ex $$0.054049 = \left(\frac{10\mathrm{km}}{21\mathrm{J/kg} \cdot 3600 \cdot 0.80 \cdot \left(\frac{1}{[\mathrm{g}]} \right) \cdot 30} \right)$$

2) Cost Index given Minimum Design Index

Open Calculator

fx $$\mathrm{CI} = \frac{(\mathrm{DI_{min}} \cdot 100) - (\mathrm{WI} \cdot \mathrm{P_w}) - (\mathrm{TI} \cdot \mathrm{P_t})}{\mathrm{P_c}}$$

ex $$1327.913 = \frac{(160 \cdot 100) - (50.98 \cdot 15.1) - (95 \cdot 19)}{10.11}$$

3) Electric Power for Wind Turbine

Open Calculator

fx $$\mathrm{P_e} = \mathrm{W_{shaft}} \cdot \eta_\mathrm{g} \cdot \eta_\mathrm{transmission}$$

ex $$0.192\mathrm{kW} = 0.6\mathrm{kW} \cdot 0.8 \cdot .4$$

4) Fuel Load

Open Calculator

fx $$\mathrm{W_f} = \mathrm{W_{misf}} + \mathrm{W_{resf}}$$

ex $$9499\mathrm{kg} = 8761\mathrm{kg} + 738\mathrm{kg}$$

5) Induced Inflow Ratio in Hover

Open Calculator

$$\lambda = \frac{v_i}{R_{rotor} \cdot \omega}$$

$$4.142857 = \frac{58\text{m/s}}{0.007\text{km} \cdot 2\text{rad/s}}$$

6) Maximum Payload Capability

Open Calculator

$$W_{pay} = MTOW - W_{OE} - W_f$$

$$52370\text{kg} = 62322\text{kg} - 453\text{kg} - 9499\text{kg}$$

7) Minimum Design Index

Open Calculator

$$DI_{min} = \frac{(CI \cdot P_c) + (WI \cdot P_w) + (TI \cdot P_t)}{100}$$

$$160 = \frac{(1327.913 \cdot 10.11) + (50.98 \cdot 15.1) + (95 \cdot 19)}{100}$$

8) Mission Fuel

Open Calculator

$$W_{misf} = W_f - W_{resf}$$

$$8761\text{kg} = 9499\text{kg} - 738\text{kg}$$

9) Period of Design Index given Minimum Design Index

Open Calculator

$$TI = \frac{(DI_{min} \cdot 100) - (WI \cdot P_w) - (CI \cdot P_c)}{P_t}$$

$$95.00008 = \frac{(160 \cdot 100) - (50.98 \cdot 15.1) - (1327.913 \cdot 10.11)}{19}$$

10) Priority of Objective Cost in Design Process given Minimum Design Index

Open Calculator

$$P_c = \frac{(DI_{min} \cdot 100) - (WI \cdot P_w) - (TI \cdot P_t)}{CI}$$

$$10.11 = \frac{(160 \cdot 100) - (50.98 \cdot 15.1) - (95 \cdot 19)}{1327.913}$$

11) Priority of Objective Period of Design given Minimum Design Index

Open Calculator

$$P_t = \frac{(DI_{min} \cdot 100) - (WI \cdot P_w) - (CI \cdot P_c)}{TI}$$

$$19.00002 = \frac{(160 \cdot 100) - (50.98 \cdot 15.1) - (1327.913 \cdot 10.11)}{95}$$

12) Priority of Objective Weight in Design Process given Minimum Design Index

Open Calculator

$$P_w = \frac{(DI_{min} \cdot 100) - (CI \cdot P_c) - (TI \cdot P_t)}{WI}$$

$$15.10003 = \frac{(160 \cdot 100) - (1327.913 \cdot 10.11) - (95 \cdot 19)}{50.98}$$

13) Propulsion Net Thrust

Open Calculator

$$Ft = m_{af} \cdot (V_J - V_f)$$

$$9.81N = 0.9kg/s \cdot (60.90m/s - 50m/s)$$

14) Range Increment of Aircraft

Open Calculator

$$\Delta R = R_D - R_H$$

$$334km = 1220km - 886km$$

15) Reserve Fuel

Open Calculator

$$W_{resf} = W_f - W_{misf}$$

$$738\text{kg} = 9499\text{kg} - 8761\text{kg}$$

16) Summation of Priorities of all Objectives that need to be Minimized

Open Calculator

$$P_{min} = P_c + P_w + P_t$$

$$44.21 = 10.11 + 15.1 + 19$$

17) Summations of Priorities of Objectives that need to be Maximized (Millitary planes)

Open Calculator

$$P_{max} = P_p + P_f + P_b + P_m + P_r + P_d + P_s$$

$$76 = 11 + 14 + 10.5 + 6 + 13 + 12 + 9.5$$

18) Thrust-to-Weight Ratio given Vertical Velocity

Open Calculator

$$TW = \left(\left(\frac{V_v}{V_a}\right) + \left(\left(\frac{P_{dynamic}}{W_S}\right) \cdot (C_{Dmin})\right) + \left(\left(\frac{k}{P_{dynamic}}\right) \cdot (W_S)\right)\right)$$

$$17.96714 = \left(\left(\frac{54\text{m/s}}{206\text{m/s}}\right) + \left(\left(\frac{8\text{Pa}}{5\text{Pa}}\right) \cdot (1.3)\right) + \left(\left(\frac{25}{8\text{Pa}}\right) \cdot (5\text{Pa})\right)\right)$$

19) Weight Index given Minimum Design Index

Open Calculator

$$WI = \frac{(DI_{min} \cdot 100) - (CI \cdot P_c) - (TI \cdot P_t)}{P_w}$$

$$50.9801 = \frac{(160 \cdot 100) - (1327.913 \cdot 10.11) - (95 \cdot 19)}{15.1}$$

Variables Used

- C_{Dmin} Minimum Drag Coefficient
- **CI** Cost Index
- DI_{min} Minimum Design Index
- $E_{battery}$ Battery Specific Energy Capacity *(Joule per Kilogram)*
- **Ft** Thrust Force *(Newton)*
- **k** Lift Induced Drag Constant
- $LDmax_{ratio}$ Maximum Lift to Drag Ratio of Aircraft
- m_{af} Air Mass Flow Rate *(Kilogram per Second)*
- **MTOW** Maximum Take Off Weight *(Kilogram)*
- P_b Scariness Priority (%)
- P_c Cost Priority (%)
- P_d Disposability Priority (%)
- $P_{dynamic}$ Dynamic Pressure *(Pascal)*
- P_e Electric Power of Wind Turbine *(Kilowatt)*
- P_f Flight Quality Priority (%)
- P_m Maintainability Priority (%)
- P_{max} Priority Sum of Objectives to be Maximized (%)
- P_{min} Priority Sum of Objectives to be Minimized(%)
- P_p Performance Priority (%)
- P_r Producibility Priority (%)
- P_s Stealth Priority (%)
- P_t Period Priority (%)
- P_w Weight Priority (%)
- **R** Range of Aircraft *(Kilometer)*
- R_D Design Range *(Kilometer)*
- R_H Harmonic Range *(Kilometer)*

- R_{rotor} Rotor Radius *(Kilometer)*
- **TI** Period Index
- **TW** Thrust-to-Weight Ratio
- V_a Aircraft Velocity *(Meter per Second)*
- V_f Flight Velocity *(Meter per Second)*
- v_i Induced Velocity *(Meter per Second)*
- V_J Velocity of Jet *(Meter per Second)*
- V_v Vertical Airspeed *(Meter per Second)*
- W_f Fuel Load *(Kilogram)*
- W_{misf} Mission Fuel *(Kilogram)*
- W_{OE} Operating Empty Weight *(Kilogram)*
- W_{pay} Payload *(Kilogram)*
- W_{resf} Reserve Fuel *(Kilogram)*
- W_S Wing Loading *(Pascal)*
- W_{shaft} Shaft Power *(Kilowatt)*
- **WBF** Battery Weight Fraction
- **WI** Weight Index
- **ΔR** Range Increment of Aircraft *(Kilometer)*
- **η** Efficiency
- η_g Efficiency of Generator
- $\eta_{transmission}$ Efficiency of Transmission
- **λ** Inflow Ratio
- **ω** Angular Velocity *(Radian per Second)*

Constants, Functions, Measurements used

- Constant: **[g]**, 9.80665
  Gravitational acceleration on Earth
- Measurement: **Length** in Kilometer (km)
  Length Unit Conversion
- Measurement: **Weight** in Kilogram (kg)
  Weight Unit Conversion
- Measurement: **Pressure** in Pascal (Pa)
  Pressure Unit Conversion
- Measurement: **Speed** in Meter per Second (m/s)
  Speed Unit Conversion
- Measurement: **Power** in Kilowatt (kW)
  Power Unit Conversion
- Measurement: **Force** in Newton (N)
  Force Unit Conversion
- Measurement: **Mass Flow Rate** in Kilogram per Second (kg/s)
  Mass Flow Rate Unit Conversion
- Measurement: **Angular Velocity** in Radian per Second (rad/s)
  Angular Velocity Unit Conversion
- Measurement: **Specific Energy** in Joule per Kilogram (J/kg)
  Specific Energy Unit Conversion

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