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UAV Design:

It is required to design an UAV for crop surveying task on a field of 0.2km x 0.5km dimension. For the minimum energy consideration and minimum time taken for surveillance, the flight path A with the velocity 15 m/s is selected with the propeller APC 9x7.5 SF with the RPM of 6000. The motor selected is Motor: AXI 2217/12 and the batter configuration is Turnigy 3-cell 30C 2650 mAh Lipo Battery. The procedure and analysis for this particular design is given in Analysis I.

The provision should be there for the take-off and landing of the UAV at the beginning and at the end of the path. The weather condition will affect the performance of UAV, but these are not analysed over here. The crosswind effect will affect the lift of the fixed wing UAV that have direct effect on energy consumption. The fog, rain or adverse weather may affect in the signal transmitting. So, if the turns may not be accurate then the crop surveillance will affect to a greater extent. These are some of the weather condition effects to be considered for detailed analysis.

Procedure:

The methodology is accomplished in different sections: the path selection, propeller selection, motor selection and battery selection. Before that the assumption that are made are as follows:

S = wing area = 0.4 m^2 (could take 0.3 m^2 for less drag but it affects the lift also. But, checked with both the values and found that the change is very less, so the area 0.4 m^2 is assumed)

ρ = density = 1.225 kg/m^3 (considered sea level as the altitude of UAV will not be too high)

Flight Path Selection:

All the four flight paths are compared based on the distance, energy and power required. For a particular path, with a given radius and velocity, the load factor (n) is calculated using the following equation.

$$R = \frac{V^2}{g * \tan(\phi)}, \quad n = \frac{1}{\cos(\phi)}$$

$$Where\ \phi = bank\ angle, \quad V = velocity, \quad g = 9.81\frac{m}{s^2}, \quad R = Radius$$

Then, the total distance covered by the UAV is calculated manually. After getting the total distance and the load factor n, the thrust required is calculated for the straight path, the turn with smaller radius and turn with the bigger radius using the following equation.

$$T_R = q_\infty S C_{D0} + \frac{n^2 W^2}{pi * e * AR * q_\infty S}$$

$$where\ q_\infty = \left(\frac{1}{2}\right) * \rho * V^2$$

Where, for straight path n = 1, and n is taken as per calculation accordingly to the turn radius. The minimum thrust required will the maximum thrust (usually will be of smaller radius turn).

The Thrust required is multiplied by the total distance to get the energy required.

$$E_{req} = T_R(for\ straight\ path) * straight\ distance + T_R(big\ turn) * big\ arc\ distance + T_R(small\ turn) * small\ arc\ distance$$

The Power required is calculated based on the maximum thrust required by the following equation,

$$P_{req} = T_R(maximum) * V$$

We can calculate the time required for the UAV to cover the required distance with given speed by the relation,

$$t_{req} = \frac{total\ distance}{V}$$

Then based on the minimum energy required or minimum thrust required, the analysis for the propeller is made.

Propeller Selection:

Based on the thrust required calculated in the flight path selection, the propeller is determined that is sufficient to provide the required amount of thrust. First, the propeller and RPM (rotational speed of the propeller) is assumed. Then, the thrust for the propeller is assumed to be equal to the minimum thrust required. Then, $C_T\ and\ J$ is calculated based on the following equations,

$$n = \frac{RPM}{60}\ \left(\frac{rev}{sec}\right) \qquad C_T = \frac{T}{\rho * n^2 * D^4} \qquad J = \frac{V}{n * D}$$

After getting J, the UIUC database is used for the assumed propeller, RPM and calculated J, the value of C_T is measured through linear interpolation. Thus, the C_T obtained through equation and C_T measured through the UIUC database is compared to have similar values (usually C_T measured >= C_T calculated through equation, because the thrust by the propeller should not be less than the thrust required).

The MATLAB code is developed to loop through all the propeller data and RPM. So, the output will give the matrix of data of all the five propellers for the RPM values of 3000, 4000, 5000, 6000, and 7000. Among that, the propeller and RPM value that satisfies the criteria and has better propeller efficiency is selected for the analysis further. The more efficient propeller is selected based on the propeller efficiency (η). The C_p value is also obtained by the linear interpolation through J value. The propeller parameters like C_Q, P, Q, efficiency (η) are calculated based on the equations given below,

$$C_Q = \frac{C_p}{2 * pi}\ , \qquad P = C_p * \rho * n^3 * D^5\ , \qquad Q = C_Q * \rho * n^2 * D^5\ , \quad \eta = \frac{C_T * J}{C_P}$$

Motor Selection:

After selecting the suitable propeller, the propeller characteristics parameters are calculated. As there are two options for motor given, both the motors are selected one after the another and the parameters are measured that gives more power efficiency. The Ω (rotational speed in rad/s) is calculated and then the propeller torque Q is used to find the motor current i_m using the equations as shown below.

$$\Omega = 2 * pi * n\ , \qquad Q = K_t(i_m - i_0)\ , \qquad \text{so, } i_m = \frac{Q}{K_t} + i_0$$

Then, the motor voltage v_{mi} is calculated based on the rotational speed and the equation shown below,

$$\Omega = K_v(v_{mi} - i_m * r_m)$$

$$where, K_v, K_t, r_m are\ the\ motor\ paramters\ that\ are\ given$$

Then, based on the ESC resistance r_e, the voltage across the output of ESC v_{e0} is calculated by the following equation,

$$v_{e0} = v_{mi} + i_m * r_e$$

Also, the current through the ESC, $i_{e0} = i_m$

The efficiency of motor is calculated as output/input, i.e. $\frac{P_{prop}}{P_m} * 100,\ where\ P_m = v_{mi} * i_m$

The power across the ESC output can be calculated as $P_{ESC} = v_{e0} * i_{e0}$

For the comparison of the two motor, the efficiency of the motor is calculated, and the selection is made for the higher efficient motor.

Battery Selection:

Turnigy 30C Lipo 2 or 3 cell Battery is required to be selected for the UAV. The nominal voltage is 3.7 V as taken from standard data. Therefore, based on the number of cell, the battery voltage is calculated as $v_b = v_{nominal} * number\ of\ cells$.

Now, the ESC throttle (k_e) is calculated from the known values of $v_b$and v_{e0} and using that throttle value the battery current (i_b) is calculated as given by the equation,

$$k_e = \frac{v_{e0}}{v_b}\ , \qquad i_b = i_{e0} * k_e$$

The Energy of the Battery is calculated using the equation,

$$E_b = v_b * \frac{Capacity}{1000} * 3600$$

The energy is calculated based on the range and endurance required. The battery is drained to 80% of its capacity,

$$Range = \frac{E_b}{T * \eta_e * \eta_m}$$

$$where\ T = thrust\ required\ by\ motor\ or\ propeller, \qquad \eta_b = efficiency\ of\ the\ battery\ (80\%),$$
$$\eta_m = motor\ efficiency$$

$$Endurance = T_E = \frac{E_b * \eta_e * \eta_m}{P}$$

$$where, P = propeller\ power$$

Then based on the relation between, battery and capacity, we can determine the battery capacity required. Also, if we pre-select the battery capacity, then we can determine how many times the battery needs to be recharged to accomplish the surveillance task.

Analysis:

Analysis I:

Minimum Energy Consideration (minimum distance consideration):

The MATLAB code is developed to loop all the flight path and to find the path with minimum distance and minimum energy required. The Battery weight is assumed to be 0.3 kg and then it is found that the 3-cell battery with 0.232 kg works very well after the iteration based on the battery required. The following table shows the data for all the flight path with the velocity 15 m/s.

Path	Min Thrust Required	Min Energy Required	Time taken (min)	Power required
A	2.581	46538.55	26.102	38.72
B	2.538	48931.57	27.476	38.07
C	2.055	50314.78	28.863	30.83
D	2.718	62026.53	34.624	40.77

From the table it is seen that the flight path A requires minimum amount of energy and so it is selected for the analysis. The calculated parameters for the flight path A are given below.

Weight	22.6726 N
Thrust Required	2.581 N
Energy Required	46538.55 J
Power Required	38.72 W
Total distance	23.492 km
Time required (endurance expected)	26.102 min

Now, using the thrust required, the MATLAB code is developed to loop all the propeller and the data for all the propeller at given RPM is shown in following table.

RPM/1000	J	C_T calculated	C_T UIUC graph	C_P	η	C_Q	Q
Propeller: APC 8x3.8 SF							
3.0000	1.4764	0.4944	NaN	NaN	NaN	NaN	NaN
4.0000	1.1073	0.2781	NaN	NaN	NaN	NaN	NaN
5.0000	0.8858	0.1780	NaN	NaN	NaN	NaN	NaN
6.0000	0.7382	0.1236	NaN	NaN	NaN	NaN	NaN
7.0000	0.6327	0.0908	0.0047	0.0220	0.1360	0.0035	0.0202
Propeller: APC 8x6 SF							
3.0000	1.4764	0.4944	NaN	NaN	NaN	NaN	NaN
4.0000	1.1073	0.2781	NaN	NaN	NaN	NaN	NaN
5.0000	0.8858	0.1780	0.0171	0.0318	0.4773	0.0051	0.0149
6.0000	0.7382	0.1236	0.0543	0.0544	0.7374	0.0087	0.0367
7.0000	0.6327	0.0908	0.0773	0.0666	0.7347	0.0106	0.0612
Propeller: APC 9x6 SF							
3.0000	1.3123	0.3087	NaN	NaN	NaN	NaN	NaN
4.0000	0.9843	0.1736	NaN	NaN	NaN	NaN	NaN
5.0000	0.7874	0.1111	0.0239	0.0337	0.5570	0.0054	0.0285
6.0000	0.6562	0.0772	0.0606	0.0535	0.7440	0.0085	0.0651
7.0000	0.5624	0.0567	0.0819	0.0639	0.7208	0.0102	0.1059
Propeller: APC 9x7.5 SF							
3.0000	1.3123	0.3087	NaN	NaN	NaN	NaN	NaN
4.0000	0.9843	0.1736	0.0097	0.0323	0.2959	0.0051	0.0174
5.0000	0.7874	0.1111	0.0625	0.0663	0.7415	0.0106	0.0561
6.0000	0.6562	0.0772	0.0922	0.0837	0.7229	0.0133	0.1019
7.0000	0.5624	0.0567	0.1131	0.0942	0.6748	0.0150	0.1561
Propeller: APC 10x4.7 SF							
3.0000	1.1811	0.2025	NaN	NaN	NaN	NaN	NaN
4.0000	0.8858	0.1139	NaN	NaN	NaN	NaN	NaN
5.0000	0.7087	0.0729	-0.0189	0.0140	-0.9576	0.0022	0.0200
6.0000	0.5906	0.0506	0.0189	0.0264	0.4234	0.0042	0.0543
7.0000	0.5062	0.0372	0.0422	0.0337	0.6345	0.0054	0.0944

The blue and green highlighted condition satisfies the C_T interpolated greater or equal than C_T calculated. But, the propeller efficiency (η) for the green highlighted condition is more than every other condition (η = 72.29%). So, the green highlighted propeller configuration is selected for the analysis, which is Propeller APC 9x7.5 SF with RPM of 6000.

Therefore, the data for the selected propeller and RPM is shown in the following table.

RPM	6000
J	0.6562
P	63.9964 W
Q	0.1019 Nm
T	3.0843 N
C_T	0.0922
C_P	0.0837
C_Q	0.0133
Propeller efficiency (η)	0.7229 = 72.29 %

Now, based on the propeller torque and RPM, the motor was selected and compared using the motor efficiency. For both the motors, the efficiency is as given in the following table.

Motor: AXI 2217/12	$\eta_m = 78.4821\ \%$
Motor: AXI 2217/20	$\eta_m = 77.0488\ \%$

Therefore, the **AXI 2217/12** motor was selected for the analysis. The various parameters are calculated as follows.

K_V	1380 RPM/V
r_m	0.061 ohm
i_0	0.7 A
Max current through motor $i_{\max}$	32 A
Motor current (i_m)	15.4192 A
Motor voltage (v_{mi})	5.2884 V
Voltage across ESC (v_{e0})	6.0594 V
Current through ESC (i_{e0})	15.4192 A
ESC power (P_{ESC})	93.4302 W
Power across motor input (P_{mi})	81.5427 W

Now, we know the range and endurance required to be satisfied for the given UAV task, i.e. range is total distance covered and endurance is the flight time calculated. Now, the battery efficiency considered is 72% (drained to 80% and efficiency 90%). The result for the energy required by the battery using the range and endurance calculation is shown in the following table.

Energy required acc. to range	100636.8 J
Energy required acc. to flight time (endurance)	105355.1 J

It can be seen that the energy required by the battery is nearly double that of the energy required by the flight path calculated before. Now, the battery model is selected and the data for both the 2 cell and 3 cell battery is shown below. The nominal voltage is taken as 3.7 V.

2 cells		3 cells	
v_b	7.4 V	v_b	11.1 V
k_e	0.8188	k_e	0.5459
i_b	12.6257 A	i_b	8.4171 A

Capacity	3954.8 mAh	Capacity	2636.5 mAh
i_{b-max}	118.6431 A	i_{b-max}	79.0954 A
Battery selected	30C 4000 mAh	Battery Selected	30C 2650 mAh
i_{b-max}	120 A	i_{b-max}	79.5 A
Weight	0.241 kg	Weight	0.232 kg

It is observed that the 3-cell battery with the less capacity is lighter in weight compared to the 2-cell battery with more capacity. The weight data is taken from the reference [1]. Therefore, when the weight of the battery in analysis is substituted with the final weight found, then also the result remains same. Finally, the endurance for the UAV is given as:

Endurance battery have (E_b/P_{motor})	27.5781 min

The flight time condition also satisfies the required design. The rate of climb is $\frac{P_A-P_R}{W} = 2.413\ m/s$. Also, the power and energy available is larger than the required so the take-off and landing situation also satisfies the UAV design. Using that extra energy, the UAV can be take-off and land. Also, based on the rate of climb, the fixed wing UAV can take-off from certain distance before the start point and land at a certain distance after the end point.

Analysis II:

Minimum Power Consideration (Minimum Thrust Consideration):

From the analysis of flight path, it is observed that the path C consumes minimum energy and requires minimum thrust. So, the C path is selected for the second analysis. The design result for the analysis is shown in following table below.

Thrust required	2.0303 N
Energy Required	49749 J
Time required	28.8632 min
Propeller selected	APC 8x6 SF with RPM 7000
Propeller efficiency	73.47 %
Motor selected	AXI 2217/12
Motor efficiency	83.1250 %
ESC power (P_{ESC})	58.5236 W
Power across motor input (P_{mi})	53.9690 W
Battery selected	3-cell 30C 2200 mAh
Exact capacity required	1983.9 mAh
Weight of battery obtained	0.193 kg
Endurance battery have (E_b/P_{motor})	32.6604 min

The detailed analysis is given in the Appendix A. Here, the 3-cell battery has lighter weight and satisfies the required condition. The rate of clime for this case is 1.258 m/s. For this case also, the UAV has required amount of energy and power to fulfil the take-off and landing condition.

Analysis III:

Minimum Energy and time consideration (V = 10 m/s):

For this condition also, the path A satisfies the minimum energy and time condition whose result and analysis is shown in the following table. The detailed analysis is shown in Appendix A.

Thrust required	2.3253 N
Energy Required	48355 J
Time required	39.1539 min
Propeller selected	APC 9x7.5 SF with RPM 5000
Propeller efficiency	65.51 %
Motor selected	AXI 2217/12
Motor efficiency	78.2141 %
ESC power (P_{ESC})	60.5976 W
Power across motor input (P_{mi})	53.18 W
Battery selected	3-cell 30C 2650 mAh
Exact capacity required	2565 mAh
Weight of battery obtained	0.232 kg
Endurance battery have (E_b/P_{motor})	42.4314 min

Here also, the 3-cell battery has lighter weight and satisfies the required condition. The rate of clime for this case is 1.647 m/s. For this case also, the UAV has required amount of energy and power to fulfil the take-off and landing condition.

Conclusion:

Comparison between Analysis I and Analysis III: It is observed that the design consideration for both the analysis is exactly same except the propeller selected. As the velocity is reduced is analysis III, the thrust required is less and so the propeller size and RPM require is lesser than the analysis I. So, for the analysis I, the propeller selected is APC 9x7.5 SF with RPM 6000 while that for the analysis III, the propeller selected is 9x7.5 with the RPM of 5000. Thus, the capacity of battery require will be quite less for the analysis III. We can see that for analysis III Capacity require is 2565 mAh while that for analysis I is 2636.5 mAh. But, commercially the Turnigy 2650 mAh battery is available so it is selected.

Comparison between Analysis I and Analysis II: It is observed that for the analysis III, the thrust require is less as it has minimum thrust and power require so the propeller size and RPM is also less. The propeller selected in analysis II is APC 8x6 SF with RPM 7000 while that for analysis I is 9x7.5 with RPM 6000. Thus, capacity of battery required for the analysis II is less around 1983.9 mAh. But, commercially 2200 mAh battery is available for that.

In conclusion, though the Analysis I take higher RPM of propeller and higher battery capacity compared to Analysis II and III, it does the surveillance task fast and with less energy. Therefore, it is preferred if the time and energy are main preferred condition.

Reference:

[1] "Lipo", *Hobbyking*, 2020: https://hobbyking.com/en_us/batteries-chargers/batteries/lipo

[2] "UIUC PDB - Vol 1", *M-selig.ae.illinois.edu*, 2020.https://m-selig.ae.illinois.edu/props/volume-1/propDB-volume-1.html

[3] "A Lipo Battery Guide to Understand Lipo Battery", *Genstattu.com*, 2020. https://www.genstattu.com/bw

Appendix A

Analysis II

The detailed analysis of the second condition with the flight path C is shown below.

Battery Weight	0.232 kg
Weight	22.3096 N
Thrust Required	2.0303 N
Energy Required	49749 J
Power Required	30.4538 W
Total distance	25.977 km
Time required (endurance expected)	28.8632 min
Propeller selected: APC 8x6 SF with RPM 7000	
RPM	7000
J	0.6327
P	44.8617 W
Q	0.0612 Nm
T	2.1973 N
C_T	0.0773
C_P	0.0666
C_Q	0.0106
Propeller efficiency (η)	0.7347 = 73.47 %
Motor: AXI 2217/12	$\eta_m = 83.1250\ \%$
Motor: AXI 2217/20	$\eta_m = 82.4923\ \%$
Motor: AXI 2217/12 selected	
K_V	1380 RPM/V
r_m	0.061 ohm
i_0	0.7 A
Max current through motor $i_{\max}$	32 A
Motor current (i_m)	9.5442 A
Motor voltage (v_{mi})	5.6547 V
Voltage across ESC (v_{e0})	6.1319 V
Current through ESC (i_{e0})	9.5442 A
ESC power (P_{ESC})	58.5236 W
Power across motor input (P_{mi})	53.9690 W
Energy required acc. to range	79276 J
Energy required acc. to flight time (endurance)	72972 J

2 cells		3 cells	
v_b	7.4 V	v_b	11.1 V
k_e	0.8286	k_e	0.5524
i_b	7.9086 A	i_b	5.2724 A
Capacity	2975.8 mAh	Capacity	1983.9 mAh
i_{b-max}	89.2748 A	i_{b-max}	59.5165 A
Battery selected	30C 3300 mAh	Battery Selected	30C 2200 mAh
i_{b-max}	99 A	i_{b-max}	66 A
Weight	0.204 kg	Weight	0.197 kg

Analysis III

The detailed analysis of condition III, with the velocity of 10 m/s is shown below.

Battery Weight	0.269 kg
Weight	22.6726 N
Thrust Required	2.3253 N
Energy Required	48355 J
Power Required	23.2526 W
Total distance	23.492 km
Time required (endurance expected)	39.1539 min
Propeller selected: APC 9x7.5 SF with RPM 5000	
RPM	5000
J	0.5249
P	41.5942 W
Q	0.0794 Nm
T	2.7250 N
C_T	0.1173
C_P	0.0940
C_Q	0.0150
Propeller efficiency (η)	0.6551 = 65.51 %
Motor: AXI 2217/12	$\eta_m = 78.2141\ \%$
Motor: AXI 2217/20	$\eta_m = 76.9231\ \%$
Motor: AXI 2217/12 selected	
K_V	1380 RPM/V
r_m	0.061 ohm
i_0	0.7 A
Max current through motor $i_{\max}$	32 A
Motor current (i_m)	12.18 A
Motor voltage (v_{mi})	4.3662 V
Voltage across ESC (v_{e0})	4.9752 V
Current through ESC (i_{e0})	12.18 A
ESC power (P_{ESC})	60.5976 W
Power across motor input (P_{mi})	53.18 W
Energy required acc. to range	88912 J
Energy required acc. to flight time (endurance)	102500 J

2 cells		3 cells	
v_b	7.4 V	v_b	11.1 V
k_e	0.6723	k_e	0.4482
i_b	8.1889 A	i_b	5.4592 A
Capacity	3847.5 mAh	Capacity	2565 mAh
i_{b-max}	115.4255 A	i_{b-max}	76.9503 A
Battery selected	30C 4000 mAh	Battery Selected	30C 2650 mAh
i_{b-max}	120 A	i_{b-max}	79.5 A
Weight	0.241 kg	Weight	0.232 kg

Appendix B (MATLAB)

MATLAB code to run the simulation.


```
clear; clc;
```

```
length = 500;
width = 200;
in2m = 0.0254;
rho = 1.225;            % considering at sea level
V = 15;
S = 0.4;                % assumption
Wbat = 0.232*9.81;      % assumption
e = 0.65;
AR = 7;
Clmax = 1.2;
n_max = 1.5;
Cd0a = 0.0072;
Cd0b = 0.0062;
Wea = 11.7672;
Web = 8.4037;
We = Wea + Web*S;
Wcam = 0.5*9.81;
Cd0 = Cd0a + Cd0b/S;
W = We + Wbat + Wcam;
q = 0.5*rho*(V^2);
Cl = W/(q*S);
if Cl > Clmax
    fprintf('Cl is greater than Clmax. Check W or S again');
end
g = 9.81;
```

Path Comparison

```
TE_comp = zeros(4,2);
for i = 1:4
    path = strcat('path',num2str(i),'.m');
    run(path);

    % Drag
    Cd = Cd0 + ((nb^2)*(W^2))/(pi*e*AR*(q^2)*(S^2));

    % Thrust Required
    Tr_st = q*S*Cd0 + (W^2)/(pi*e*AR*q*S);
    Tr_tb = q*S*Cd0 + (((nb^2)*(W^2))/(pi*e*AR*q*S));
    Tr_ts = q*S*Cd0 + (((ns^2)*(W^2))/(pi*e*AR*q*S));
```

```
    % minimum thrust required
    Tr = max([Tr_st Tr_tb Tr_ts]);
    TE_comp(i,1) = Tr;

    % Energy Required
    E1 = Tr_st*ls;
    E2 = Tr_tb*arc_b;
    E3 = Tr_ts*arc_s;
    Ereq = E1+E2+E3;
    TE_comp(i,2) = Ereq;                % Energy required
    TE_comp(i,3) = (dist_tot/V)/60;     % time required
    TE_comp(i,4) = TE_comp(i,1)*V;      % Power required

end
```

Path Selection

Path is selected based on the Energy Required. The path with lowest energy is selected for the design.

```
[Emin, i] = min(TE_comp(:,2));
E = Emin;
Treq = TE_comp(i,1);
Preq = Treq*V;
min_dist = TE_comp(i,3)*60*V;
T_endu = TE_comp(i,3);
```

Propeller Selection

```
prop = ["apcsf_8x3.8"       % APC 8x3.8 SF
    "apcsf_8x6"             % APC 8x6 SF
    "apcsf_9x6"             % APC 9x6 SF
    "apcsf_9x7.5"           % APC 9x7.5 SF
    "apcsf_10x4.7"];        % APC 10x4.7 SF
propd = [8 8 9 9 10];
prop_dat = [];
for i = 1:5
    prop_nm = prop(i);
    prop_d = propd(i);
    count = 1;
    for RPM = 3000:1000:7000
        dat = read_prop_data(prop_nm,RPM,'G:\UofT\4_Fall_2020\AER1216\Project\UIUC-propDB\UIUC-
propDB\volume-1\data');
        n = RPM/60;         % unit rev/sec
        D = prop_d*in2m;
        J = V/(n*D);
        const = Treq/(rho*(D^2)*(V^2));
        Ct1 = const*(J^2);
        Jmat = dat(:,1);
        Ctmat = dat(:,2);
        Cpmat = dat(:,3);
        etamat = dat(:,4);
        Ct2 = interp1(Jmat,Ctmat,J,'linear');
        Cp2 = interp1(Jmat,Cpmat,J,'linear');
        Cq2 = Cp2/(2*pi);
        eta2 = (Ct2*J)/Cp2;
```

```
        Q2 = Cq2*rho*(n^2)*(D^5);
        % plot(Jmat,Ctmat);
        prop_dat(count,1) = RPM/1000;
        prop_dat(count,2) = J;
        prop_dat(count,3) = Ct1;
        prop_dat(count,4) = Ct2;
        prop_dat(count,5) = Cp2;
        prop_dat(count,6) = eta2;
        prop_dat(count,7) = Cq2;
        prop_dat(count,8) = Q2;
        count = count + 1;
    end
    propeller_data(:,:,i) = prop_dat;
    % propeller and rpm with very close Ct1 and Ct2 are selected for required thrust (Ct2>=Ct1)
end
```

Manually select the propeller from the matrix of propeller_data and then proceed further. Selecting Prop APC 9x7.5 SF with RPM 6000

```
prp_sel = "apcsf_9x7.5";
prp_dia = 9;            % inch
D = prp_dia*in2m;       % metres
RPM = 6000;
[datf, rpm] = read_prop_data(prp_sel,RPM,'G:\UofT\4_Fall_2020\AER1216\Project\UIUC-propDB\UIUC-
propDB\volume-1\data');
n = RPM/60;
Jdata = datf(:,1);
Ctdata = datf(:,2);
Cpdata = datf(:,3);
etadata = datf(:,4);
J = V/(n*D);
Ct = interp1(Jdata,Ctdata,J,'linear');
Cp = interp1(Jdata,Cpdata,J,'linear');
Cq = Cp/(2*pi);
Q = Cq*rho*(n^2)*(D^5);
P = Cp*rho*(n^3)*(D^5);
T = Ct*rho*(n^2)*(D^4);
eta = (Ct*J)/Cp;
```

```
Files Chosen = apcsf_9x7.5_2574rd_5610.txt apcsf_9x7.5_2573rd_5621.txt
Using Static Data at RPM = 5607.000000
```

Motor Selection

AXI 2217/12: Kv=1380RPM/V, rm=0.061, i0=0.7A, imax=32A AXI 2217/20: Kv=840RPM/V, rm=0.185, i0=0.4A, imax=20A

```
% ESC
re = 0.05;
Q = Q;
omega = 2*pi*n;
mKv = [1380 840];
mrm = [0.061 0.185];
mi0 = [0.7 0.4];
```

```
mimax = [32 20];
for i = 1:2
    Kv = mKv(i);              % RPM/V
    Kv = Kv*(2*pi)/60;      % rad/s/V
    Kt = 1/Kv;
    rm = mrm(i);
    i0 = mi0(i);
    imax = mimax(i);
    im(i) = (Q/Kt) + i0;
    if im(i)>imax
        fprintf('im is greater than imax. Change motor or prop');
    end
    Vmi(i) = (omega/Kv) + im(i)*rm;
    V_e0(i) = Vmi(i) + im(i)*re;
    i_e0(i) = im(i);
    P_esc(i) = V_e0(i)*i_e0(i);
    P_mi(i) = Vmi(i)*im(i);                          % Power across motor input
    eff_m_p(i) = (P/P_mi(i))*100;
end
[eff_max, motor_number] = max(eff_m_p);
```

Battery

Turnigy 30C Lipo Battery (2 or 3 cell) lets take 3 cell 1300 mAh 30C battery

```
E_eta = 0.72;                          % 80% draining battery and 90% efficient = 0.8*0.9 = 0.72
Eb_reqT = T_endu*E_eta*P_esc(motor_number)*60;
Eb_reqR = (min_dist*T)/E_eta;
Eb_req = max(Eb_reqT, Eb_reqR);
DCR = 30;

cell = [2 3];

for i = 1:2
    nc = cell(i);
    v_nom = 3.7;
    vb(i) = v_nom*nc;
    ke(i) = V_e0(1)/vb(i);
    if ke(i) < 1
        cell_f = cell(i);
        ib(i) = i_e0(1)*ke(i);
        Cap(i) = Eb_req*1000/(3600*vb(i));
        ib_max(i) = DCR*Cap(i)/1000;
    end
end

% So capacity of the battery required is
% Thus, battery selected is 30C 2650 mAh 3 cell Lipo battery
% weight is 0.232 kg.
```

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