# AE630
## Homework Assignment – 2

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PROBLEM STATEMENT :
The objective is to write a computer program that can carry out conceptual design of a quadrotor that can lift a payload of 200 grams for 20 minutes.

INPUTS TO BE TAKEN:
Endurance, Rotor radius, Rotor operating $C_T$, solidity, Aspect ratio of blades, Number of blades per rotor, Number of battery cells, Payload weight, Initial Gross Takeoff Weight(GTOW)

VALUES OF FIXED PARAMETERS:

| | |
|---|---|
| density of air(rho) | 1.225 kg/m$^3$ |
| endurance(endur) | 20 minutes |
| payload(p_weight) | 200 grams |
| motor efficiency(ef) | 0.8 |
| Lift Curve slope(Cl_a) | 5.73 |
| Drag coefficient(Cd) | 0.01 |
| acceleration due to gravity(g) | 9.8 |
| Number of rotors(N) | 4 |

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SOLUTION:

OVERVIEW OF THE ALGORITHM:

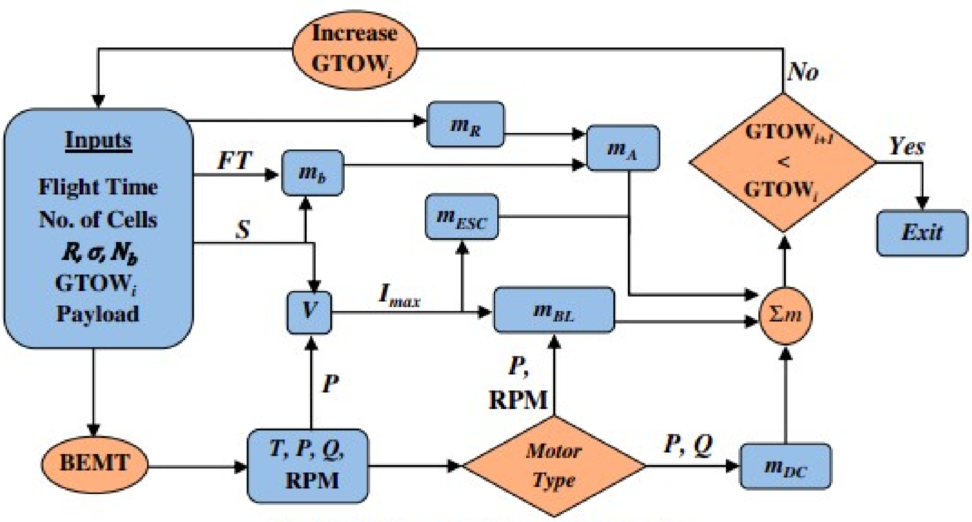



Fig. 16 Sizing algorithm and interactions.

1) INITIAL GUESS DESIGN:

I put the following values as intial guesses:
Disc loading(DL) = 90
Aspect ratio(AR) = 10
Number of blades per rotor(Nb) = 2
Number of battery cells(S) = 4

Geometric and Physical Specifications

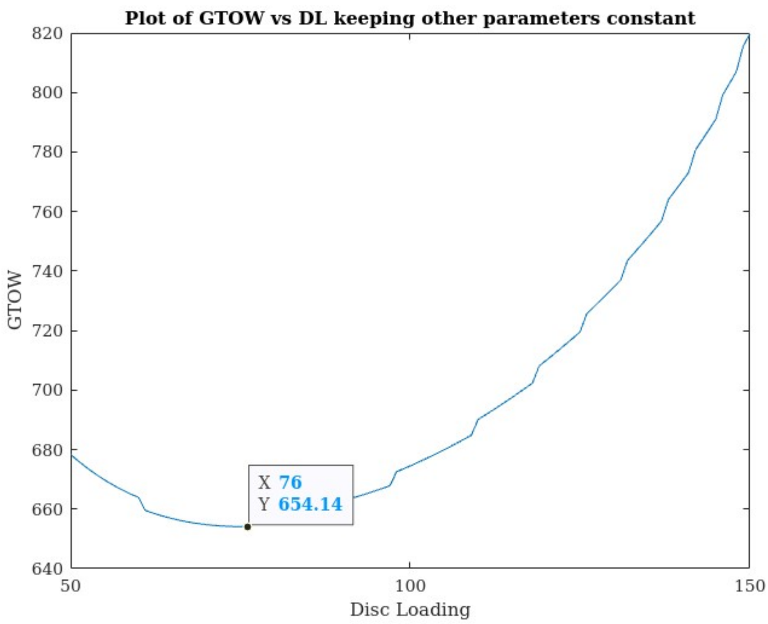
| | Initial Value | Final Value |
|---|---|---|
| Rotor radius(R) | 0.0721 | 0.0721 |
| Chord(b_chord) | 0.0072 | 0.0072 |
| Motor Kv | 1063.5 | 1114 |
| Current Rating(I_max) | 3.1306 | 3.5987 |
| Battery capacity(C) | 1475.8 | 1696.4 |
| Thrust Coefficient(C_t) | 0.0052 | 0.0052 |
| Torque Coefficient(C_q) | 0.00039019 | 0.00039019 |
| Brushless motor length(l_BL) | 15.4403 | 16.3771 |
| brushless motor diameter(d_BL) | 22.8583 | 23.2747 |
| RPM | 15740 | 16488 |

Breakdown of weights

| | | |
|---|---|---|
| Rotor mass(in grams) | Initial Value | 3.05 |
| | Converged Value | 3.05 |
| | Error, % | 0% |
| Motor mass(in grams) | Initial Value | 14.9608 |
| | Converged Value | 16.9641 |
| | Error, % | 13.39% |
| ESC mass(in grams) | Initial Value | 2.5724 |
| | Converged Value | 2.8952 |
| | Error, % | 12.54% |
| Battery mass(in grams) | Initial Value | 166.9673 |
| | Converged Value | 190.1418 |
| | Error, % | 13.88% |
| Airframe mass(in grams) | Initial Value | 170.9159 |
| | Converged Value | 181.4155 |
| | Error, % | 6.14% |
| GTOW(in grams) | Initial Value | 619.6527 |
| | Converged Value | 662.7519 |
| | Error, % | 6.96% |

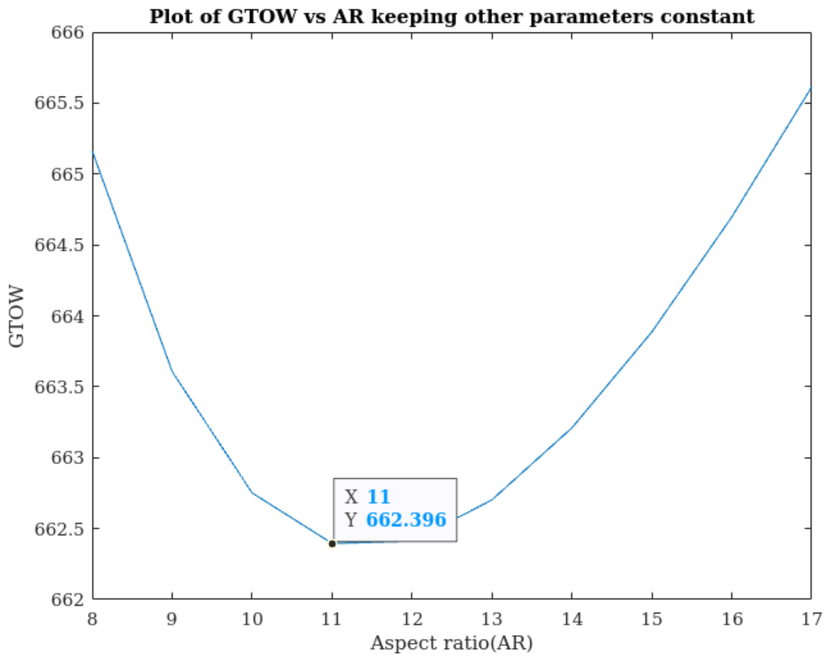
2. INDIVIDUALLY OPTIMIZING SOLUTIONS:

- Varying only Disc Loading(DL):
  (from 50 to 150 N/$m^2$)



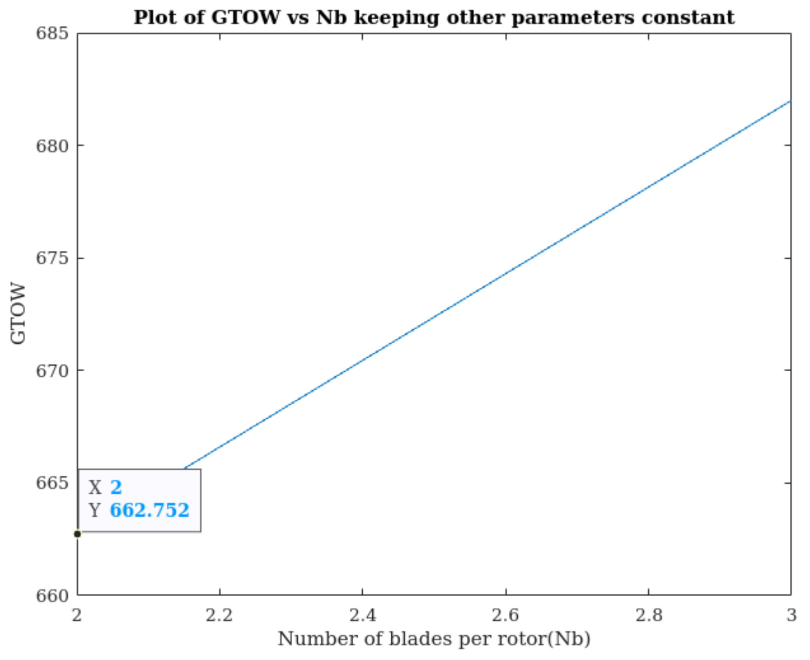
- During the above variation, I got 654.14 gram as the minimum GTOW when DL was equal to 76.

- Varying only Aspect Ratio(AR):
  (from 8 to 17)



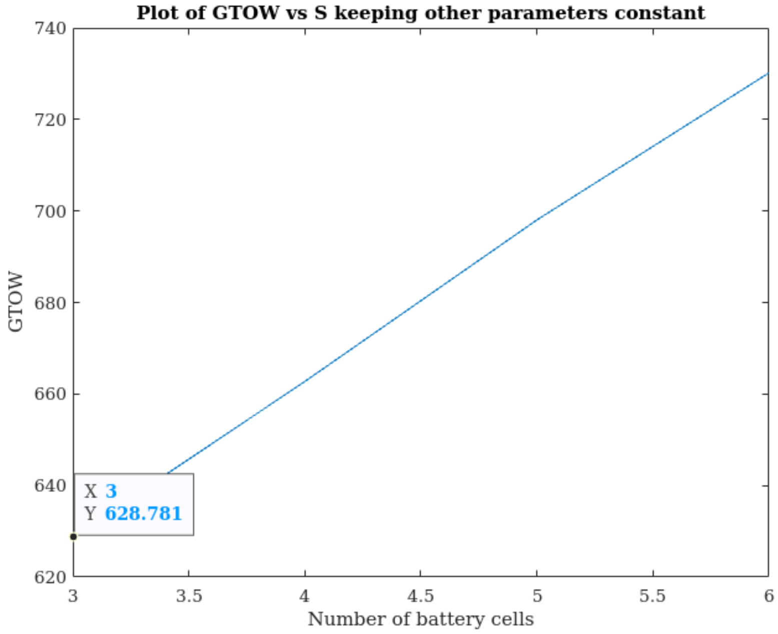

- During the above variation, I got 662.396 gram as the minimum GTOW when AR was equal to 11.

- Varying only Number of blades per rotor(Nb):
  (from 2 to 3)




- During the above variation, I got 662.752 gram as the minimum GTOW when Nb was equal to 2.

- Varying only Number of battery cells(S):
  (from 3 to 6)




  - During the above variation, I got 628.781 gram as the minimum GTOW when S was equal to 3.

## 3. MY MOST OPTIMAL SOLUTION:

| Parameter | Guess Value | Optimal Value |
|---|---|---|
| Disc Loading | 90 | 76 |
| Aspect Ratio | 10 | 11 |
| Number of blades per rotor | 2 | 2 |
| Number of battery cells | 4 | 3 |
| Rotor mass | 3.05 | 3.7095 |
| Battery mass | 190.1418 | 156.3846 |
| Motor mass | 16.9641 | 14.5429 |
| ESC mass | 2.7846 | 3.1331 |
| Airframe mass | 181.4155 | 184.7616 |
| GTOW | 662.7519 | 626.6884 |
| Battery capacity | 1696.4 | 1915.1 |
| Rotor radius | 0.0721 | 0.0785 |
| RPM | 16488 | 14004 |
| Motor Kv | 1114 | 1261.6 |
| Current Rating | 3.5987 | 4.0626 |

## 4. FILES INCLUDED:

- Codes:
  - adjust_weights.m : It does one iteration of the total weight and gives the new GTOW and the error between the current and previous GTOW.
  - sizing_algo.m : It calls adjust_weights.m function and give the final GTOW when the error/difference between the previous and current GTOW becomes less than 5 grams.

    - BEMT.m : It gives the thrust and torque coefficient and it is being called inside the adjust_weights.m function.
    - sizing_algo2.m : It is almost same as the sizing_algo.m and the only difference is that in this one I have made DL, AR, Nb and S as it's paramters while in the former one it had no parameters. I did so because it was needed to individually optimize the solution.
    - DL_vs_GTOW.m : It finds and plots the minimum GTOW and the corresponding value of DL by varying DL only and keeping other parameters constant.
    - AR_vs_GTOW.m : It finds and plots the minimum GTOW and the corresponding value of AR by varying AR only and keeping other parameters constant.
    - Nb_vs_GTOW.m : It finds and plots the minimum GTOW and the corresponding value of Nb by varying Nb only and keeping other parameters constant.
    - S_vs_GTOW.m : It finds and plots the minimum GTOW and the corresponding value of S by varying S only and keeping other parameters constant.
- Graphs/Plots:
  (Following are the graphs obtained for individually optimizing the solution.)
    - DL_vs_GTOW.png
    - AR_vs_GTOW.png
    - Nb_vs_GTOW.png
    - S_vs_GTOW.png

<u>5. SUMMARY:</u>

What I did for the whole assignment is the following:

- I initially put guess values for the parameters like disc loading, aspect ratio, number of battery cells, etc. and obtained a guess design
- Then I varied those few parameters individually keeping other parameters constant. I found the minimum GTOW in each case and the value of the variable paramter at which that minima is attained.
- Finally, I used all those values of the parameters for which I had obtained the minimum GTOW and then obtained my most optimal design.