Compound Helicopter – Individual Assignment 1

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Section 1:
Additional Assumptions & Data

1.1 Individual Assumptions/Data

- **Dragless fuselage**
- **2 Blade Rotor System**
- **2Blade Tail System**
- **NACA 0012 Airfoil**
- **Engine Power at Sea Level: 1900 KW**
- **Blade Stall angle 18 degrees**
- **10% Engine Power Loss**

1.2: Rough schematic sketch of own compound helicopter

Section 2: Preliminary Drone Design

2.1: Design Parameters of your Design

Parameter	Rotor 1	Rotor 2	Rotor ...
Rotor Description (role)	Main Rotor	Tail Rotor	
Airfoil	NACA 0012	NACA 0012	
Rotor Radius (m)	5m	0.75	
Rotor Speed (m)	41 rad/s	250 rad/s	
Number of Blades	2	2	
Chord Length Variation	0.263 to 0.25		
Twist Variation	4 degree to 1 degree	Nil	
Root Cutout	0.25	0.1	

		Main	Tail
2.2	Maximum main and tail rotor thrusts before stall	39540 N	1140 N

```
b = 3
rho = 1.2040847588826422
altitude = 0
R_tip = 5
R_root = 0.5
Omega = 43
sigma = 0.04297183463481174
a = 5.73
V_val = 0
AR = 20.0

Sample values at selected r:
 r (m)   theta (deg)  F (tip loss)  lambda  v_induced (m/s)  phi (deg)  chord (m)    Cl      Cd
   0.5      23.000       1.0000 0.02298       4.9411          12.943     0.2500 1.0058 0.02712
   1.0      22.444       1.0000 0.03607       7.7554          10.224     0.2444 1.2222 0.03672
   1.5      21.889       1.0000 0.04597       9.8825           8.711     0.2389 1.3179 0.04155
   2.0      21.333       1.0000 0.05404      11.6192           7.694     0.2333 1.3640 0.04401
   2.5      20.778       1.0000 0.06088      13.0901           6.943     0.2278 1.3836 0.04509
   3.0      20.222       0.9999 0.06680      14.3615           6.353     0.2222 1.3871 0.04528
   3.5      19.667       0.9988 0.07201      15.4819           5.873     0.2167 1.3794 0.04486
   4.0      19.111       0.9871 0.07694      16.5420           5.493     0.2111 1.3619 0.04390
   4.5      18.556       0.8916 0.08449      18.1658           5.363     0.2056 1.3193 0.04163
   5.0      18.000       0.0000 0.00000       0.0000           0.000     0.2000 1.8001 0.07147

Converged T (Thrust) = 39540.16839468222 N
Converged D (Drag)    = 5527.143476188744 N
Converged Q (Torque)  = 19780.26327959552 Nm
Converged P (Power)   = 850551.3210226076 W
```

```
b = 2
rho = 1.2040847588826422
altitude = 0
R_tip = 0.75
R_root = 0.1
Omega = 250
sigma = 0.08488263631567752
a = 5.73
V_val = 0
AR = 6.5

Sample values at selected r:
 r (m)   theta (deg)  F (tip loss)  lambda  v_induced (m/s)  phi (deg)  chord (m)    Cl      Cd
  0.100     22.000       1.0000 0.03314       6.2130          13.956     0.1 0.8044 0.11961
  0.172     21.556       1.0000 0.04819       9.0359          11.852     0.1 0.9704 0.13764
  0.244     21.111       1.0000 0.06029      11.3052          10.481     0.1 1.0631 0.14918
  0.317     20.667       0.9998 0.07051      13.2213           9.481     0.1 1.1186 0.15660
  0.389     20.222       0.9985 0.07942      14.8910           8.708     0.1 1.1515 0.16117
  0.461     19.778       0.9922 0.08744      16.3947           8.094     0.1 1.1684 0.16357
  0.533     19.333       0.9693 0.09526      17.8616           7.630     0.1 1.1704 0.16385
  0.606     18.889       0.8987 0.10454      19.6011           7.377     0.1 1.1512 0.16113
  0.678     18.444       0.7015 0.12122      22.7297           7.640     0.1 1.0805 0.15147
  0.750     18.000       0.0000 0.00000       0.0000           0.000     0.1 1.8001 0.27836

Converged T (Thrust) = 1140.429787580088 N
Converged D (Drag)    = 330.33243097899253 N
Converged Q (Torque)  = 182.80732003322487 Nm
Converged P (Power)   = 45701.83000830622 W
```
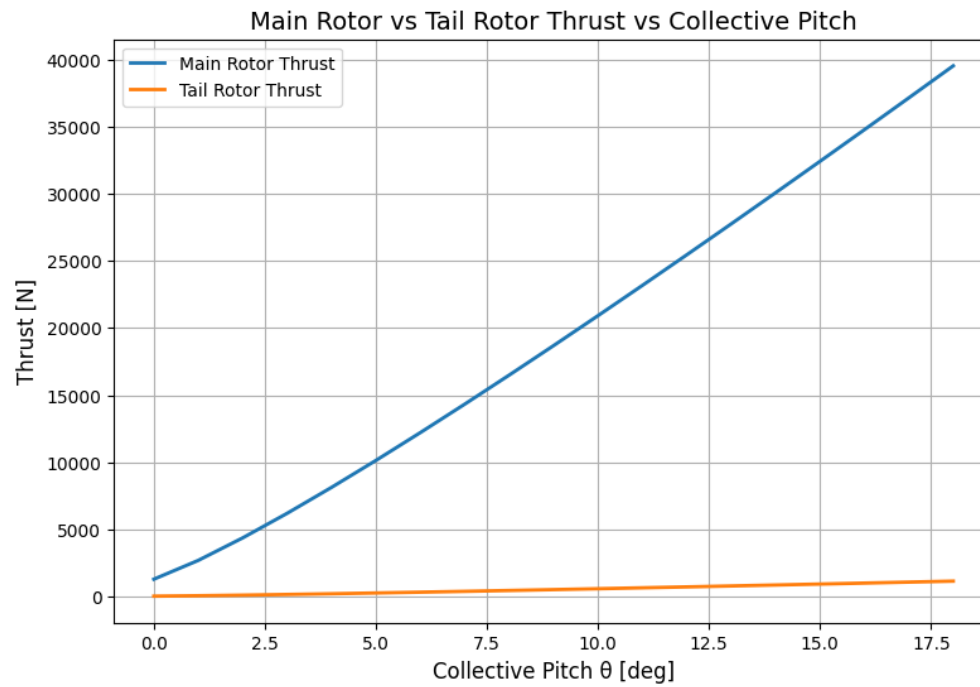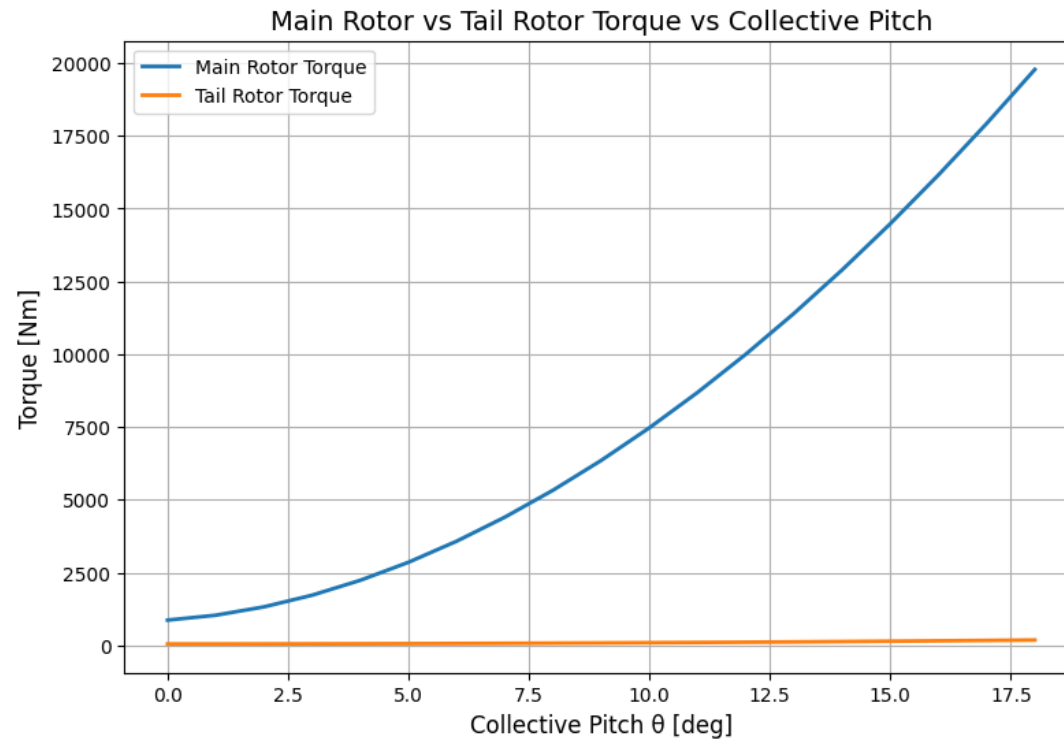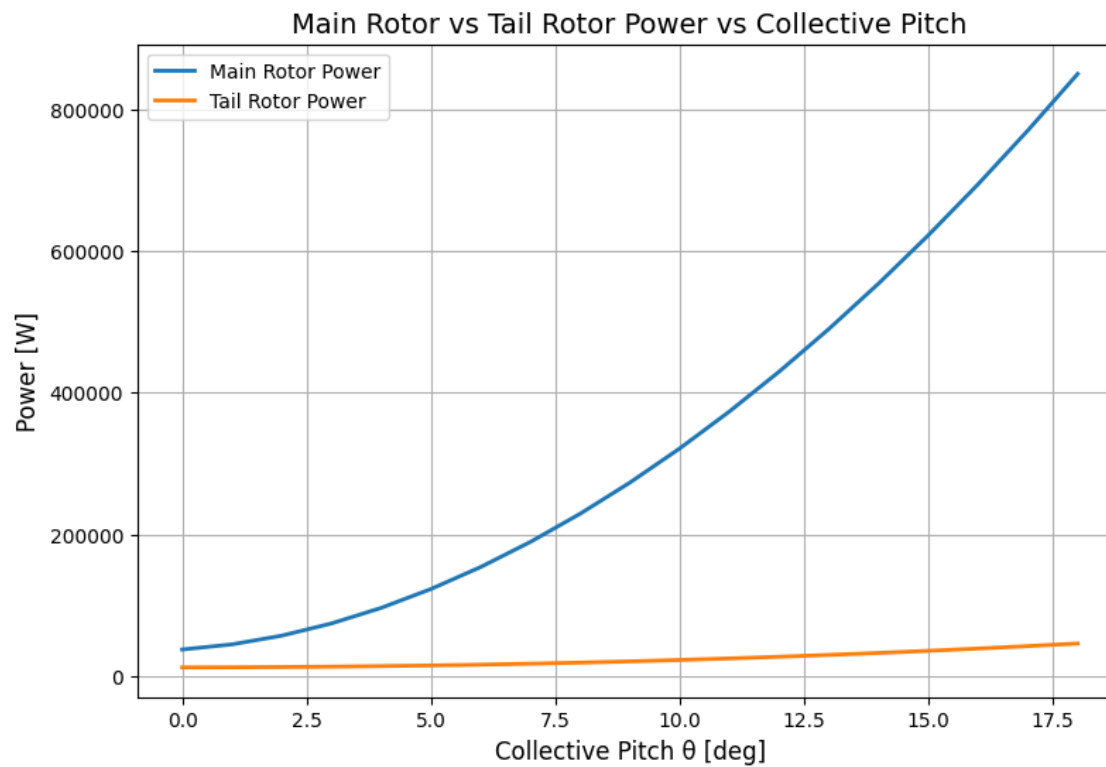
Stall Angle 18 degrees = theta - phi

2.3.1: Thrust vs θ plots

Main Rotor vs Tail Rotor Thrust vs Collective Pitch

2.3.2: Torque vs θ plots

2.3.3: Thrust vs Power plots

Section 3:
Hover Mission Test

	Plots	Value
3.1	Maximum Take Off Weight based on blade stall at 2000 m AMSL	32589 kgf
3.2	Maximum Take Off Weight based on power requirement at 2000 m AMSL	9908 kgf

```
b = 3
rho = 0.9927072111836429
altitude = 2000
R_tip = 5
R_root = 0.5
Omega = 43
sigma = 0.04297183463481174
a = 5.73
V_val = 0
AR = 20.0

Sample values at selected r:
 r (m)  theta (deg)  F (tip loss)  lambda  v_induced (m/s)  phi (deg)  chord (m)    Cl     Cd
  0.5     23.000      1.0000 0.02298      4.9411          12.943     0.2500 1.0058 0.02712
  1.0     22.444      1.0000 0.03607      7.7554          10.224     0.2444 1.2222 0.03672
  1.5     21.889      1.0000 0.04597      9.8825           8.711     0.2389 1.3179 0.04155
  2.0     21.333      1.0000 0.05404     11.6192           7.694     0.2333 1.3640 0.04401
  2.5     20.778      1.0000 0.06088     13.0901           6.943     0.2278 1.3836 0.04509
  3.0     20.222      0.9999 0.06680     14.3615           6.353     0.2222 1.3871 0.04528
  3.5     19.667      0.9988 0.07201     15.4819           5.873     0.2167 1.3794 0.04486
  4.0     19.111      0.9871 0.07694     16.5420           5.493     0.2111 1.3619 0.04390
  4.5     18.556      0.8916 0.08449     18.1658           5.363     0.2056 1.3193 0.04163
  5.0     18.000      0.0000 0.00000      0.0000           0.000     0.2000 1.8001 0.07147

Converged T (Thrust) = 32598.876455542242 N
Converged D (Drag)    = 4556.851289398286 N
Converged Q (Torque) = 16307.830368177049 Nm
Converged P (Power)  = 701236.705831613 W
```

```
b = 3
rho = 0.9927072111836429
altitude = 2000
R_tip = 5
R_root = 0.5
Omega = 43
sigma = 0.04297183463481174
a = 5.73
V_val = 0
AR = 20.0

Converged T (Thrust) = 9975.819174005976 N
Converged D (Drag)    = 840.8000599907942 N
Converged Q (Torque) = 2916.3869338540862 Nm
Converged P (Power)  = 125404.6381557257 W

--- t = 0 min | Phase: HOVER ---
Gross Weight: 1009.13 kg | Fuel Remaining: 199.13 kg
Fuel Rate: 0.8709 kg/min

Mission Feasible ✅
Initial TOGW: 1010.0 kg
Total Fuel Used: 0.87 kg
Final TOGW: 1009.13 kg
collective angle 5.949494949494949
Total Mission Time: 1 minutes
Avialable Power (W) 179135.168656689
Power Required(W) 174173.108549619
```
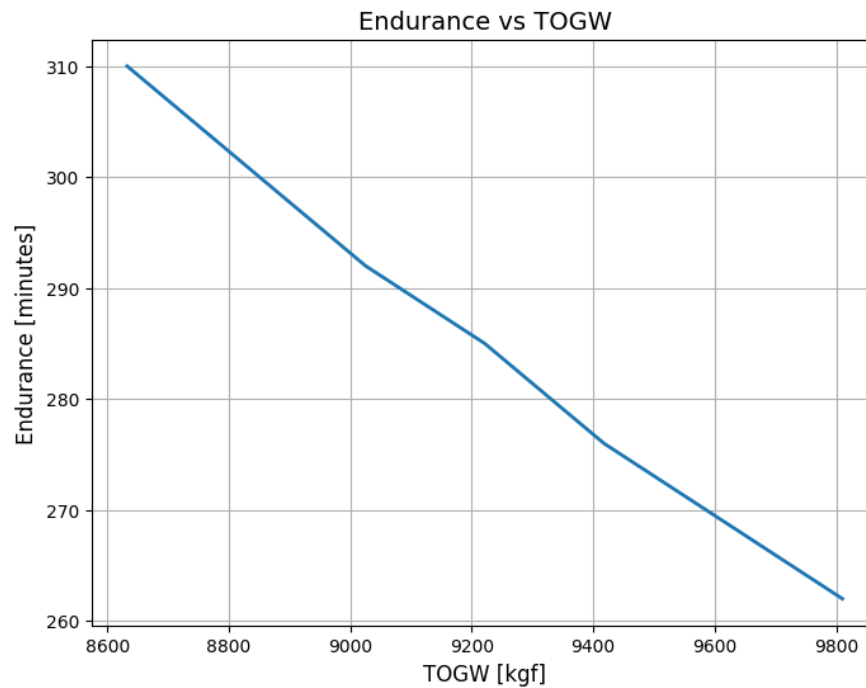
3.3: Fuel Burn Rate (kg/minute) vs Gross Weight (kgf) Plot
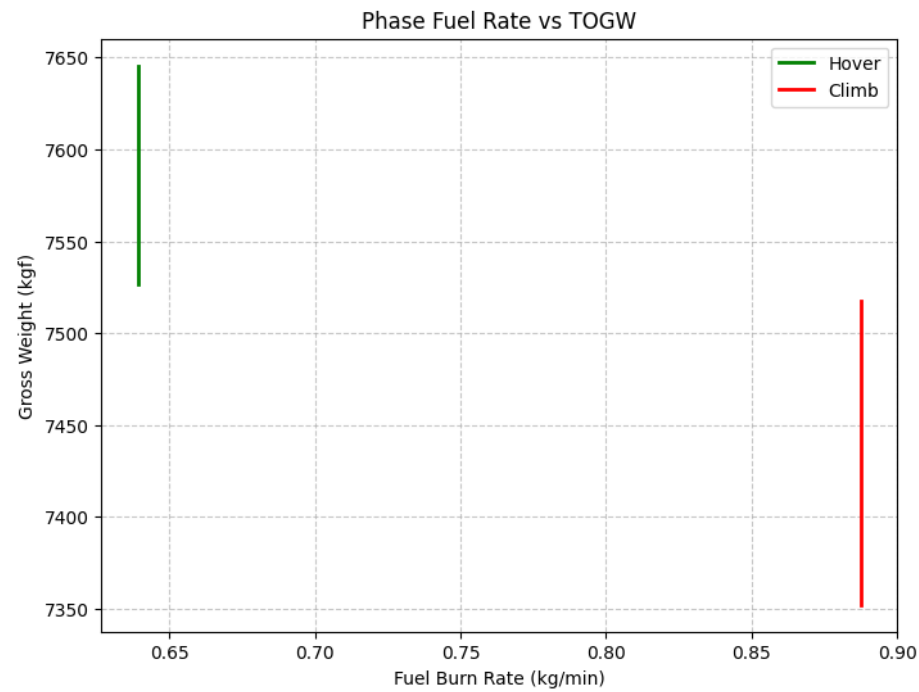
3.4: OGE Hover Endurance (minutes) vs Take-Off-Weight (kgf) plot

Acknowledgement

- GitHub Copilot

- ChatGPT

- Perplexity

Code available at - https://github.com/chaitanyakeshri/Rotary_Aerodynamics

References

- http://airfoiltools.com/airfoil/naca4digit?MNaca4DigitForm%5Bcamber%5D

- Knight, M., & Hefner, R. A. (1937). Static thrust analysis of the lifting airscrew.

- AE667 Course Slides

- https://eaglepubs.erau.edu/introductiontoaerospaceflightvehicles/chapter/helicopters-vtol/