AE 667: Assignment 2

Weightage: 20% of the total grades

Deadline: 1st October. 2023 (Sunday) 11:59 PM
(Submissions after this deadline will attract 5% penalty for each 30 minutes delay. For example, 15% will be deducted from the assignment grades if the submission happens at 1:30 AM)

A note on plagiarism:

This is an individual assignment. While discussion is encouraged, simply copying someone else's work will attract zero marks for all involved.

Background

You have created a drone startup, and you have won a project on developing a reconnaissance drone that meets Indian Navy's requirements. The drone is supposed to carry a surveillance payload containing passive sonar weighing. The drone should be able to take-off and land vertically from a ship deck and also be able to dive in the water to install the sonar strategically on the ocean floor. A sample mission profile provided by the navy is as follows:

1. Take-off from ship deck carrying the sonar
2. Travel 5 km (on a calm day) over the sea
3. Dive inside the water to a depth of about 500 meters
4. Search the ocean bed and leave the payload at an appropriate location.
5. Rise back to the surface
6. Return to the ship and land.

Relevant payload specifications:

- Weight = 5 kg
- Volume = 0.0025 m^3
- Water proof (until 1000m depth)

Goal:

Design the **tail rotor** and an **articulated hub of the main rotor** of the amphibian drone helicopter such that it is able to do the following:

1. Steady level forward flight at the speed of 100 km/hr in air and 0.5 m/s in water
2. Vertical climb at the rate of 3 m/s in air and 0.5 m/s in water

Tasks

1. **Develop a simulator tool** that computes thrust (T), torque (Q), hub pitching moment (M_P), and hub rolling moment (M_R) for rotors for a given set of flight controller inputs (collective and cyclic pitch inputs) and flight condition.
2. **Understand the control inputs** by plotting how thrust, torque, hub pitching moment, and hub rolling moment vary with collective and cyclic pitch inputs.

3. **Design the tail rotor** based on counter torque requirement estimates from the simulator tool.
4. **Find trim settings** for the main rotor ($\theta_{o,m}$, β_o, $\beta_{1c} + \theta_{1s}$ and $\beta_{1s} - \theta_{1c}$) and the tail rotor ($\theta_{o,t}$) for the stated steady level forward flight and vertical climb conditions. Find the necessary pitch and flap limits to be incorporated in the hub design based on the trim settings.
5. **Plot thrust distribution** (T' = sectional thrust per unit span) over the entire main rotor disk through a contour diagram. Here T' is the sectional thrust.

Hints:

1. Assume simplistic untwisted constant chord tail rotor. Tail rotor design will then involve selecting rotor radius, number of blades, airfoil selection, chord length, rotor speed, and rotor pitch angle limits.
2. Articulated hub design involves deciding the pitch and flap limits for the rotor blades accounting for the maximum pitch and flap angles experienced by the rotor blades at all the desired flight conditions.
3. The non-uniform main rotor inflow for forward flight is modelled using the following expression:

$$\frac{\lambda_i}{\lambda_{i_{Glauert}}} = 1 + \left[\frac{{}^4\!/_3 \frac{\mu}{\lambda_G}}{1.2 + \frac{\mu}{\lambda_G}}\right] \frac{r}{R} \cos\psi$$

   Here λ_G is the total inflow ratio (induced inflow + free stream component) found using Glauert's method and $\lambda_{i_{Glauert}}$ is the induced inflow part found using Glauert's method.
4. In the reverse flow region, assume that the airfoil is operating as if its leading and trailing edges are flipped.
5. Choosing the reference frame wisely while dealing the main rotor will make life easier.
6. Assume there is enough power available for the stated forward flight and climb manoeuvres.

Report Structure

1. Starting Assumptions & Data

1.1. State all assumptions/data on environment, vehicle, physics, rotor design, etc. utilized while doing the assignment. [5]

2. The Simulator Tool

2.1. Working/Algorithm/Logic Flow Diagram of the simulator tool [16]

3. Control Input Variations (in air)

3.1. T vs $\theta_{o,m}$, Q vs $\theta_{o,m}$, M_P vs $\theta_{o,m}$ & M_R vs $\theta_{o,m}$ plots and observations [6]

3.2. T vs θ_{1s} , Q vs θ_{1s} , M_P vs θ_{1s} & M_R vs θ_{1s} plots and observations [6]

3.3. T vs θ_{1c} , Q vs θ_{1c} , M_P vs θ_{1c} & M_R vs θ_{1c} plots and observations [6]

4. Tail Rotor Design.

Mention the following about your tail rotor design with sufficient explanation/justification/supporting calculations. [6]

Design Parameter	**Quantity**
Airfoil	
Rotor Radius	
Rotor Speed	
Number of Blades	
Chord Length	
Root Cutout	

5. Trim Settings

5.1. Fill the following table with the trim settings and resultant forces and moments [20]

	Forward Flight (Air)	**Vertical Climb (Air)**	**Forward Flight (Water)**	**Vertical Climb (Water)**
$\theta_{o,m}$				
θ_{1s}				
θ_{1c}				
$\theta_{o,t}$				
α_{TPP}				
β_o				
Net Vertical Force				
Net Longitudinal Force				
M_P				
M_R				

5.2. Observations and comments on computed trim settings [5]

6. Thrust Distribution

6.1. T' (sectional thrust) contour diagram for forward flight in **air** and observations [5]

6.2. T' (sectional thrust) contour diagram for vertical climb in **air** and observations [5]

7. Acknowledgement

Mandatory to acknowledge people you discussed with or took help for any part of the assignment

8. References

List all references (books, paper, websites, etc.) used while doing the assignment

9. Code/Tool

As a separate zip file, along with its user manual [20]

Guidance on the computer program:

1. **Programming language**: Use only freely available ones. (-5% for MATLAB, etc.)
2. **Thoroughly commented** and user friendly (- 5% if not done)
3. **User Manual**: Clear guide to tell the user how to run the program and use it. (-5% if not done)
4. **In case the program is not working by the time of the submission**:
    a. Describe the logic flow in section 3 in good detail.
    b. Use someone else's program who is using the same algorithm as you were trying to implement. Do not forget to acknowledge the creator of the code, otherwise you will be caught for plagiarism.
    c. Generate results using the code for doing the later parts of the assignment.
    d. You may still want to get your code ready at some point for modifying it for the next assignment.
    e. Obviously, there are marks for a working tool!
5. **Naming convention**: (- 5% if not done right)
    a. All files & functions of the program (including user manual, excluding report) to be packed in a .zip file named after your roll number eg. "193010100.zip"
    b. The main file of the program to be named after your roll number. Eg. "193010100.py"
    c. The report in PDF format also to be named after your roll number. Rg. ""193010100.pdf""

Through this assignment, we are aiming at gaining and/or practicing our ability to:

1. Apply concepts learnt for forward flight condition
2. Use a prediction tool to trim the rotors for steady flight
3. Do some basic programming