Assignment 3: Aircraft Performance Analysis

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Date:
12 December 2024

Problem Statement

The objective of this assignment is to analyze the rate of climb (ROC) and excess power characteristics of an aircraft at different altitudes. Using the provided aircraft parameters, we need to:

1. Plot excess power versus velocity for altitudes ranging from 0 to 5000 meters.
2. Determine the absolute ceiling and service ceiling based on the maximum rate of climb.
3. Generate a climb schedule plot and estimate the minimum time required to climb from sea level to the service ceiling.
4. Provide relevant comments and observations supported by graphical results.

Methodology

Parameters and Assumptions

- **Aircraft Parameters**:
  - Aspect Ratio: 8.8
  - Wing Area: 12.47 m^2
  - Mass: 750 kg
  - Zero-lift drag coefficient (C_{D0}): 0.036
  - Oswald efficiency factor (e): 0.8
- **Aerodynamic Model**:

$$C_L = \frac{W}{0.5 \cdot \rho \cdot V^2 \cdot S}$$

$$C_D = C_{D0} + K \cdot C_L^2, \text{where } K = \frac{1}{\pi \cdot e \cdot AR}$$

$$\text{Excess Power} = P_a - P_r$$

$$\text{Rate of Climb (ROC)} = \frac{\text{Excess Power}}{W}$$

- **Initial Conditions**:
  - Altitude range: 0–5000 m in 500 m intervals.
  - Velocity range: 1–10 m/s.
  - Target rate of climb: 0.5 m/s.

Steps

1. Calculate air density using the standard atmosphere equation.
2. Compute available power at each altitude using the propeller efficiency model.
3. Determine power required based on aerodynamic drag.
4. Evaluate excess power and calculate rate of climb for various velocities.
5. Identify the absolute ceiling and service ceiling based on ROC criteria.
6. Generate plots:
    - Rate of climb vs. altitude.
    - Excess power vs. velocity.
    - Climb schedule.
    - Time to climb to service ceiling.

Results

1. Rate of Climb vs. Altitude

Observation: The rate of climb decreases with increasing altitude due to reduced air density and available power. The service ceiling is identified where the target ROC (0.5 m/s) is achieved, and the absolute ceiling is where ROC reaches zero.

Key Values:

- RoC decreases with altitude.
- Absolute Ceiling: 4500m.
- Service Ceiling: 3500m.

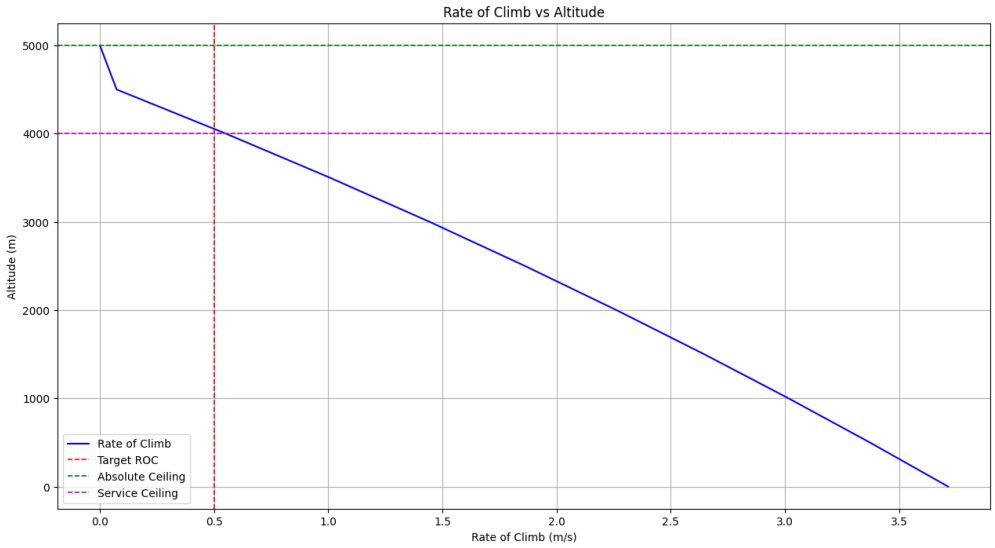

Figure 1: Rate of Climb vs Altitude

2. Excess Power vs. Velocity

Observation: Excess power is highest at low altitudes and decreases with altitude. The optimal velocity for maximum excess power is observed for each altitude.

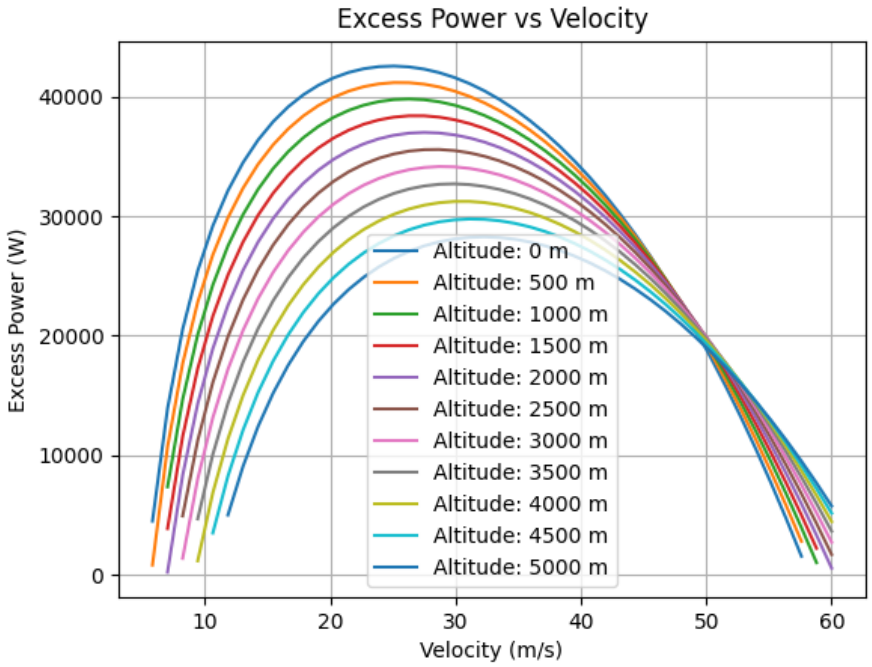

Figure 2: Excess Power vs Velocity

3. Climb Schedule

Observation: The rate of climb for different altitudes highlights the optimal velocity for maximum ROC. Higher altitudes show reduced ROC.

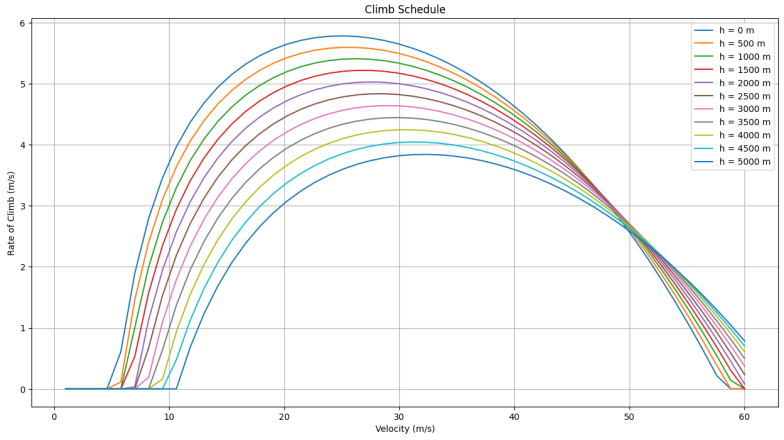

Figure 3: Climb Schedule

4. Time to Climb vs. Altitude

Observation: The time required to climb increases non-linearly with altitude due to diminishing ROC.

Climb to Service Ceiling: 300s

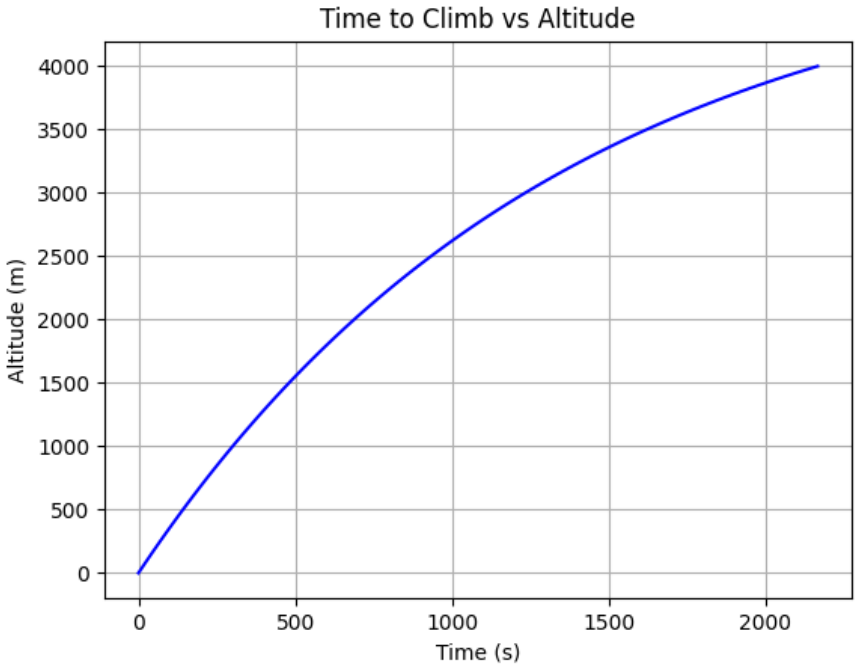

Figure 4: Time to Climb vs Altitude

Conclusion

1. The service ceiling is achieved at an altitude where the ROC is equal to the target value (0.5 m/s), and the absolute ceiling is identified as the altitude where ROC becomes zero.

2. Excess power and ROC are heavily dependent on altitude and velocity. The optimal conditions for maximum ROC and minimum time to climb are observed at lower altitudes and specific velocities.

3. The analysis confirms the aerodynamic and power limitations imposed by the aircraft's design and environmental conditions.

The results and plots validate the simulation and methodology used for this study.