AE312 : Atmospheric Flight Mechanics

A Report submitted

For internal assessment for Coarse

Atmospheric Flight Mechanics

in

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by

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Contents

Chapter 1

ABSTRACT

In this assignment, our primary objective is to decide between a jet engine and a propeller engine for a specific aircraft, given its well-defined geometry, mass, inertia characteristics, and a comprehensive aerodynamic model. This decision will be founded upon a comprehensive analysis of plotted data and mathematical computations that scrutinize the aircraft's performance across various scenarios.

The aircraft parameters at our disposal encompass crucial details such as the mean aerodynamic chord, wing span, aspect ratio, wing area, mass, moment of inertia, and maximum engine thrust and power at sea level. These parameters, along with the propeller efficiency, form the basis of our evaluation.

The heart of our analysis lies in the aircraft's aerodynamic model, which relies on longitudinal aerodynamic equations. These equations encapsulate the fundamental parameters for lift (CL) and drag (CD), drawing from a spectrum of aerodynamic derivatives such as zero-lift drag (CD0), lift slope (CL), and control surface effectiveness (CLe). These derivatives have been meticulously specified for the aircraft in question.

To arrive at an informed decision regarding the engine choice, we will create a series of essential plots:

Flight Envelope (h-VTAS): This plot will illuminate the intricate relationship between altitude and true airspeed (TAS). It serves as a pivotal tool for assessing the aircraft's performance boundaries, shedding light on its capabilities under diverse altitudes.

Flight Envelope (h-VEAS): Much like the first plot, this one will delineate the interplay between altitude and equivalent airspeed (EAS). Understanding this relationship is paramount for evaluating the aircraft's prowess under varying altitudes.

TRmin vs. h: In this plot, we will undertake a comparative analysis of the minimum thrust required at different altitudes for both jet and propeller engines. This metric is critical in gauging the appropriateness of each engine type.

PRmin vs. h: Here, we will scrutinize the minimum power demands of the aircraft at different altitudes for both engine categories. This data offers invaluable insights into the power requirements of each engine.

The thrust, power, and efficiency relations are derived from the provided sea-level thrust and power values, taking into account the fluctuations in air density with changing altitudes. Our altitude increments are conveniently set at 250 meters, and the density model, sourced from class materials, will be employed to account for the varying atmospheric conditions.

Throughout this assignment, our focus will be on the interpretation of these plots and the use of this data to substantiate our choice of engine for the designated aircraft. We will provide articulate comments and justifications for each plot, always taking into consideration the aircraft's performance attributes and inherent limitations. Ultimately, this analytical journey will guide us in determining whether a jet engine or a propeller engine stands as the more suitable propulsion system for the specific aircraft, all in line with its intended operational conditions and mission profile.

Chapter 2

Methodology

2.1 Problem to solve

The assignment is to determine which of the two engines, jet or propeller, is suitable for the aircraft based on the provided parameters. The following plots will be used to justify the engine choice:

1. Flight Envelope (h-VTAS)
2. Flight Envelope (h-VEAS)
3. TRmin vs h
4. PRmin vs h

Thrust/Power Model:

- $T_{\text{max}} = T_{\text{maxSL}} \cdot \sigma$
- $P_{\text{max}} = P_{\text{maxSL}} \cdot \sigma^{1/3}$
- $\eta_P = \eta_{P\text{SL}} \cdot \sqrt{\sigma}$

The altitude steps are taken as 250m, and the density model can be obtained from class notes.

In this report, we will analyze the provided data and plots to make an informed decision on whether a jet or propeller engine is more suitable for the given aircraft. The choice will be based on altitude, airspeed, efficiency, and mission requirements.

Parameter	**Value**
Wing Span, b	10.47 m
Aspect Ratio, AR	8.8
Wing Area, S	12.47 m^2
Mass, m	750 kg
Max Engine Thrust at S.L., T_{SL}	3500 N
Max Engine Power at S.L., P_{SL}	150 HP
Propeller Efficiency at S.L., η_P	0.9
C_{D0}	0.036
C_{L0}	0.365
e	0.8
$C_{L\text{max}}$	1.5

2.2 Steps involve in Matlab code

2.2.1 Standard Atmosphere model

In this analysis, I used the International Standard Atmosphere (ISA) model provided by MATLAB. The International Standard Atmosphere is a widely accepted model for the variation of atmospheric properties with altitude. MATLAB's atmosisa function is utilized to calculate key atmospheric parameters, including temperature (T), speed of sound (a), pressure (P), and air density (rho), at different altitudes. This model is commonly employed as a reference for aeronautical and aerospace engineering calculations, allowing us to account for the variations in atmospheric conditions with altitude during our analysis.

[T, a, P, rho] = atmosisa(altitude);

2.2.2 Absolute ceiling

As the name implies, absolute ceiling is the absolute maximum altitude that an aircraft can ever maintain level fight. In other words, the absolute ceiling is the altitude at which the rate of climb* is zero. So, the aircraft is not able to climb higher than the absolute ceiling. The absolute ceiling is sometimes referred to as the maximum operating altitude (MOA).

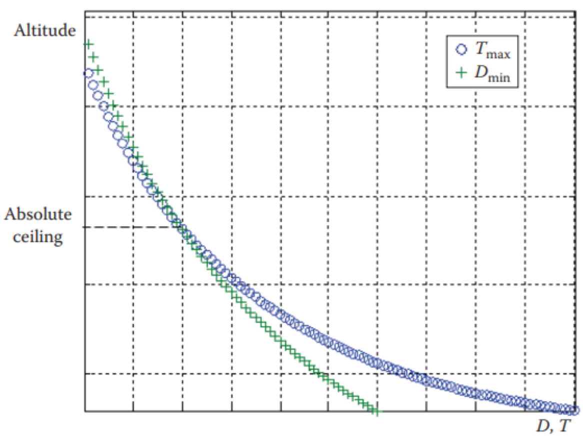


Figure 2.1: engine thrust, aircraft drag for jet aircraft [1]

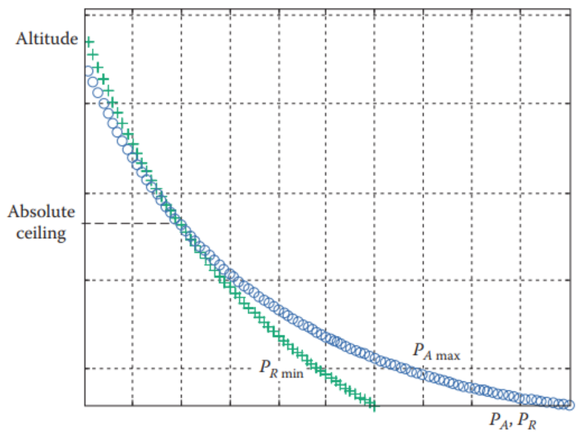


Figure 2.2: engine power and aircraft required power for propeller aircraft [1]

2.2.2.1 For jet aircraft

With respect to Figure 2.1, if an aircraft is planned to fly up to its ceiling, it must use its maximum thrust. Furthermore, it must produce a minimum drag. In a technical terms, the prerequisite for the absolute ceiling is that the maximum engine thrust(aircraft maximum available thrust) is equal to the aircraft minimum drag (aircraft minimum required thrust): ==> $T_{rmin} = T_{amax}$

2.2.2.2 For propeller aircraft

At the absolute ceiling, the aircraft must fly with the lowest required power (i.e., the minimum power airspeed; see Figure 2.2) and provide the highest available power: ==> $P_{rmin} = P_{amax}$

$$\rho_{ac} = \left(\frac{2 \cdot \rho_0^{1.83} \cdot V_{minP_E}^3 \cdot S \cdot C_{D_0}}{\eta_p \cdot P_{max_{SL}}} \right)^{\frac{1}{0.833}} \qquad V_{minP_E} = \sqrt{\frac{2 \cdot W}{\rho \cdot S \cdot \sqrt{3 \cdot \frac{C_{D_0}}{K}}}} \tag{2.1}$$

2.2.3 Stall velocity

Stall velocity represents the minimum airspeed at which an aircraft can maintain level flight without stalling. It is a critical parameter in aviation. The stall velocity (V_{stall}) can be calculated using the following formula:

$$V_{stall} = \sqrt{\frac{2W}{\rho SCL_{max}}} \tag{2.2}$$

Equivalent Airspeed (EAS) is a measure of airspeed that accounts for variations in air density with altitude. It is useful in aviation because it represents the indicated airspeed corrected for changes in air density. EAS provides a more consistent measure of an aircraft's performance across different altitudes. ==> $V_{stallEAS} = V_{stall} \cdot \sqrt{\sigma}$

2.2.4 Plotting Flight Envelope (h-VTAS)

The Flight Envelope defines the limits within which an aircraft can safely and efficiently operate, considering various performance parameters. it focuses on the relationship between altitude (h) and True Airspeed (VTAS).

2.2.4.1 For jet aircraft

we know that thrust is constant for jet aircraft,To determine the flight envelope for jet aircraft, specifically the h-VEAS (altitude vs. Equivalent Airspeed). The idea is to find the velocities at which the aircraft can operate under available thrust, and these velocities are represented by Vmax and Vmin. The method used here is based on the equation of thrust and the aircraft's aerodynamic properties.
The equation for thrust is as follows:

$$T_a = q \cdot S \cdot C_{D0} + \frac{q \cdot S}{K} \cdot W^2 \tag{2.3}$$

Given this equation, the code to solve for V by transforming it into a quadratic equation of the form $AV^4 + BV^2 + C = 0$, where the coefficients A, B, and C are determined by substituting the expressions for T_a and q from the thrust equation further simplification give below to equation for $V_{max}$and V_{min} .

$$V_{max} = \left(\frac{W}{S \cdot \rho \cdot CD0}\right)^{0.5} \cdot \left(\frac{Tmax}{W} + \sqrt{\left(\frac{Tmax}{W}\right)^2 - 4 \cdot CD0 \cdot K}\right)^{0.5} \tag{2.4}$$

$$V_{min} = \left(\frac{W}{S \cdot \rho \cdot CD0}\right)^{0.5} \cdot \left(\frac{Tmax}{W} - \sqrt{\left(\frac{Tmax}{W}\right)^2 - 4 \cdot CD0 \cdot K}\right)^{0.5} \tag{2.5}$$

2.2.4.2 For propeller aircraft

we know that thrust is constant for propeller aircraft,The idea is to find the velocities at which the aircraft can operate under available power, and these velocities are represented by Vmax and Vmin. The method used here is based on the equation of thrust and the aircraft's aerodynamic properties. Now, let's calculate Vmax and VminP using this theory. The equation that relates power (P) to thrust (TR) and airspeed (V) is:

$$P = TR \cdot V \tag{2.6}$$

For steady-level flight, the required thrust (TR) is equal to the aircraft's drag (D). Using the expression for drag , we have:

$$D = q \cdot S \cdot C_{D0} + \frac{q \cdot S}{K} \cdot W^2 \tag{2.7}$$

By substituting this expression for drag into the power equation, we obtain:

$$P = \frac{1}{2}\rho V^3 \cdot S \cdot C_{D_0} + \frac{2 \cdot W^2 \cdot K}{\rho \cdot S \cdot V} \tag{2.8}$$

So we have equation $AV^4 + BV + C = 0$. For finding Vmax and Vmin we have to solve quadratic than we have to ensure that only real and positive roots are considered, other than all roots we have to ignore. Other than that If there are fewer than 2 valid roots (which could occur for specific altitudes or conditions), we have to ignore that also. After all this we get two values than Vmax and Vmin is maximum and minimum of root respectively.

2.2.5 plotting Flight Envelope (h-VEAS)

Equivalent airspeed (EAS) is obtained by dividing the true airspeed (TAS) by the square root of the air density ratio (sigma,σ).

$$V_{maxEAS} = V_{max} \cdot \sqrt{\sigma} \tag{2.9}$$

2.2.6 Minimum Thrust Required

we know that foe level flight T=D so Minimum Thrust Required is nothing but Minimum drag at that altitude. The minimum drag speed represents the point at which the aircraft encounters the least resistance from the air. Lower drag translates to reduced thrust requirements, which results in more efficient flight. Pilots and operators aim to operate the aircraft at VminD when the objective is to minimize fuel consumption and operating costs. **Thrust is essentially main parameter for jet aircraft, In propeller aircraft thrust don't matter much so i have calculated minimum thrust for jet only.**

We know the drag expression from eq. 2.7, To find VminD, we differentiate the drag equation with respect to airspeed (V) and set it to zero, indicating the minimum point of drag after further simplification give below expression for minimum thrust required.

$$T_{rmin} = 2 \cdot W \cdot C_{D_0} \cdot K^{1/2} \tag{2.10}$$

From Expression we can see that minimum thrust does not very with altitude it is constant.

After finding VminD we have to ensure that it always grater than stall speed. For those aircraft whose minimum drag speeds are lower than the stall speed, a safe minimum drag speed is selected (considered) to be about 10%–20% higher than the stall speed.

2.2.7 Minimum Power Required

As mention above similarly **Power is essentially main parameter for jet aircraft, In jet aircraft Power don't matter much so i have calculated minimum thrust for propelller only.**

The minimum power required for a propeller-driven aircraft is a critical parameter that helps determine the engine's minimum power output necessary for the aircraft to maintain a steady-level flight. We know the drag expression from eq. 2.8, To find VminP, we differentiate the power equation with respect to airspeed (V) and set it to zero, indicating the minimum point of power after further simplification give below expression for minimum thrust required.

$$P_{min} = \frac{2.48 \cdot (W)^{\frac{3}{2}}}{(\eta_p) \cdot \sqrt{\rho \cdot S}} \cdot \frac{C_{D_0}}{K^5}^{-0.25} \tag{2.11}$$

After finding VminP we have to ensure that it always grater than stall speed. For those aircraft whose minimum power speeds are lower than the stall speed than minimum power speed is selected 1.1 to 1.2 of Vstall.

2.3 Matlab Code

```
% Aircraft Parameters
c_bar = 1.211;     % Mean Aerodynamic Chord (m)
b = 10.47;         % Wing Span (m)
AR = 8.8;           % Aspect Ratio
S = 12.47;         % Wing Area (m^2)
W = 750*(9.81);    % Weight (N)
Ixx = 873;         % Moment of Inertia Ixx (kg-m^2)
Iyy = 907;         % Moment of Inertia Iyy (kg-m^2)
Izz = 1680;        % Moment of Inertia Izz (kg-m^2)
Ixz = 1144;        % Moment of Inertia Ixz (kg-m^2)
TmaxSL = 3500;        % Max Engine Thrust at Sea Level (N)
PmaxSL = 150 * 745.7; % Max Engine Power at Sea Level (W) (Convert HP to Watts)
etaP_SL = 0.9;        % Propeller Efficiency at Sea Level

% Aerodynamic Coefficients
CD0 = 0.036; % CD0: Zero Lift Drag Coefficient
CL0 = 0.365; % CL0: Zero Lift Angle of Attack Coefficient
Cm0 = 0.05; % Cm0: Zero Lift Pitching Moment Coefficient
CD_alpha = 0.041; % CD_alpha: Change in Drag Coefficient with Angle of Attack
CL_alpha = 4.2; % CL_alpha: Change in Lift Coefficient with Angle of Attack
Cm_alpha = -0.59; % Cm_alpha: Change in Pitching Moment Coefficient with Angle of
    Attack
e = 0.8; % e: Oswald Efficiency Factor
CL_q = 27.3; % CL_q: Change in Lift Coefficient with Pitch Rate
Cmq = -9.3; % Cmq: Change in Pitching Moment Coefficient with Pitch Rate
CD_delta_e = 0.026; % CD_delta_e: Change in Drag Coefficient with Elevator
    Deflection
CL_alpha_dot = 8.3; % CL_alpha_dot: Change in Lift Coefficient with Rate of Change
     of Angle of Attack
Cm_alpha_dot = -4.3; % Cm_alpha_dot: Change in Pitching Moment Coefficient with
    Rate of Change of Angle of Attack
CL_max = 1.5; % CL_max: Maximum Lift Coefficient
CL_delta_e = 0.26; % CL_delta_e: Change in Lift Coefficient with Elevator
    Deflection
Cm_delta_e = -1.008; % Cm_delta_e: Change in Pitching Moment Coefficient with
    Elevator Deflection


%
    ------------------------------------------------------------------------------------


% JET AIRCRAFT ====>
```

```
% Finding absulate celling(jet aircraft) for that avlaible thrust is equal to min drag at that altitude

K = 1 / (pi * e * AR);
% Calculate the required density at absolute ceiling for available thrust
rhoabc = (2*W*(CD0*K)^(1/2)*1.225)/TmaxSL;
% Iterate through altitudes to find absolute ceiling
Ta=zeros; aa=zeros; Pa=zeros; rhoa=zeros;
for i=1:250:20000
    [Ta(i), aa(i), Pa(i), rhoa(i)] = atmosisa(i); % International Standard Atmosphere model by Matlab
    if rhoa(i)<rhoabc
        disp(['Absolute Ceiling at Altitude for jet aircraft (m): ' num2str(i)]);
        break; % Exit the loop when the condition is satisfied
    end
end
Acelling=i-1;
% Atmosphere Parameters
altitude = 0:250:i;  % Altitude steps (m)
% International Standard Atmosphere model by Matlab
[T, a, P, rho] = atmosisa(altitude);
sigma = rho/1.225; % density at sea level

% Thrust/Power Model
Tmax = TmaxSL .* sigma; % Thrust at altitude based on air density

% Stall Velocity Calculation
Vstall=(2.*W./(S.*rho.*CL_max)).^(1/2);
VstallEAS=Vstall.*sqrt(sigma);

% (1) Flight Envelope (h-VEAS) ------
% For Avialable thrust we have to find velocity, We know eqation of thrust
% T_a = q*S*CD0 + kW^2/q*s where q=(1/2)*rho*v^2
% So we get eqation for velocity ==> AV^4+BV^2+C=0

% Calculate velocity using quadratic equation for jet aircraft
Vmax=(W./(S.*rho.*CD0)).^(1/2).*((Tmax./W)+((Tmax./W).^2-4.*CD0.*K).^(1/2)).^(1/2);
Vmin=(W./(S.*rho.*CD0)).^(1/2).*((Tmax./W)-((Tmax./W).^2-4.*CD0.*K).^(1/2)).^(1/2);

%  Plot Flight Envelope (h-VTAS) for jet aircraft
figure;
plot(Vmax, altitude, 'r', Vmin, altitude, 'b', Vstall, altitude, 'g');
xlabel('Velocity (m/s)');
```

```
ylabel('Altitude (m)');
ax=gca;
% Draw a dashed horizontal line at Acelling
line([ax.XLim(1), ax.XLim(2)], [Acelling, Acelling], 'Color', 'r', 'LineStyle', '
    --');
title('Flight Envelope (h-VTAS) for jet aircraft');
legend({'Maximum Velocity', 'Minimum Velocity', 'Stall Velocity'});
grid on;
% Adjust the axis limits for a better scale
xlim([0, max(Vmax) * 1.2]); % Set x-axis limits
ylim([0, max(altitude) * 1.2]); % Set y-axis limits
% Add axis labels
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
% Add a legend for better clarity
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');

% (2) Flight Envelope (h-VEAS) ------
VmaxEAS=Vmax.*sqrt(sigma);
VminEAS=Vmin.*sqrt(sigma);

% Plot Flight Envelope (h-VEAS) for jet aircraft
figure;
plot(VmaxEAS, altitude, 'r', VminEAS, altitude, 'b', VstallEAS, altitude, 'g');
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
title('Flight Envelope (h-VEAS) for jet aircraft');
line([ax.XLim(1), ax.XLim(2)], [Acelling, Acelling], 'Color', 'r', 'LineStyle', '
    --');
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');
grid on;
% Adjust the axis limits for a better scale
xlim([0, max(Vmax) * 1.2]); % Set x-axis limits
ylim([0, max(altitude) * 1.2]); % Set y-axis limits
% Add axis labels
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
% Add a legend for better clarity
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');

% (3) Minimum Thrust Required ------
%  Minimum Thrust Required Calculation for jet aircraft
VminD=(2*W./(rho.*S.*(CD0/K).^(1/2))).^(1/2);
Checking1=min(VminD - Vstall);
Trmin = 2*W*(CD0*K)^(1/2);
```

```
disp(['Minimum difference between VminD_c and Vstall = ' , num2str(Checking1)]);
disp('VminD_c is always greater than Vstall, as seen from the positive difference.
    ');
% Display the calculated minimum thrust required
disp(['Minimum Thrust Required for jet aircraft(Trmin) = ', num2str(Trmin), ' N'])
    ;
disp('We know that Minimum Thrust Required for jet aircraft does not change with
    altitude')

% Vmins=zeros;
% for i=1:1:60
% if Vmin(i)<Vstall(i)
%     Vmins(i)=Vstall(i);
% else
%     Vmins(i)=Vmin(i);
% end
% end
% % (4) Minimum power Required ------
% % Power minimum can calculated by Prmin=Trmin*Vmin
% Prminj=Trmin*Vmins;
% plot(Prminj,altitude, 'g');
% ylabel('Altitude (m)');
% xlabel('Minimum Power Required (W)');
% title('Minimum Power Required vs. Altitude for jet aircraft')
% grid on;


%
    ------------------------------------------------------------------------------


% PROPELLER AIRCRAFT ====>
Vminpi=((2.*W.*S)./(1.225.*(3.*CD0./K).^(1/2))).^(1/2);
rhoi=((2*(1.225)^(1.83)*(Vminpi)^(3)*S*CD0)/(etaP_SL*PmaxSL))^(1/0.833);
Tai=zeros; aai=zeros; Pai=zeros; rhoai=zeros;
for ip=1:250:20000
    [Ta(ip), aa(ip), Pa(ip), rhoa(ip)] = atmosisa(ip); % International Standard
        Atmosphere model by Matlab
    if rhoa(ip)<rhoabc
        disp(['Absolute Ceiling at Altitude for propeller aircraft (m): ' num2str(
            ip)]);
        break; % Exit the loop when the condition is satisfied
    end
end
Acellingp=11500;% because i done the calculation till 14750 but above Acelling
    solutoin not exit for equation AV^4+BV+C=0
```

```
% Atmosphere Parameters
altitudep = 0:250:14750;  % Altitude steps (m)
% International Standard Atmosphere model by Matlab
[Tp, ap, Pp, rhop] = atmosisa(altitude);
sigmap = rhop/1.225; % density at sea level
% Thrust/Power Model
Tmaxp = TmaxSL .* sigmap; % Thrust at altitude based on air density
Pmaxp = PmaxSL .* (sigmap).^(1/3); % Power at altitude based on air density
etap = etaP_SL .* sqrt(sigmap); % Efficiency at altitude based on air density
% Stall Velocity Calculation
Vstallp=(2.*W./(S.*rhop.*CL_max)).^(1/2);
VstallEASp=Vstall.*sqrt(sigmap);

% (1) Flight Envelope (h-VEAS) ------
% For Propeller aircraft finding velocity, we have equation AV^4+BV+C=0
% Coefficients of the quartic equation: Ax^4 + Bx^3 + Cx^2 + Dx + E = 0
% Create a vector of coefficients for the quartic polynomial
% coefficients = [A, B, C, D, E];
Vhmaxp=zeros; Vhminp=zeros;
for i = 1:1:60
    p = [(CD0*(0.5*rhop(i)*S)^2),0,0,(-0.5*rhop(i)*S*Pmaxp(i)*etap(i)),(K*W^2)];
    sol = roots(p);
    sol = sol(imag(sol)==0);
    sol = sol(real(sol)>0);

    if length(sol) < 2
        sol = [NaN;NaN];
    end
    Vhmaxp(1,i) = max(sol);
    Vhminp(1,i) = min(sol);
end

% Plot Flight Envelope (h-VTAS) for propeller aircraft
figure;
plot(Vhmaxp, altitudep, 'r', Vhminp, altitudep, 'b', Vstallp, altitudep, 'g');
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
title('Flight Envelope (h-VTAS) for propeller aircraft');
line([ax.XLim(1), ax.XLim(2)], [Acellingp, Acellingp], 'Color', 'r', 'LineStyle',
    '--');
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');
grid on;
% Adjust the axis limits for a better scale
xlim([0, max(Vmax) * 1.2]); % Set x-axis limits
```

```
ylim([0, max(altitude) * 1.2]); % Set y-axis limits
% Add axis labels
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
% Add a legend for better clarity
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');

% (2) Flight Envelope (h-VEAS) ------
VmaxEASp=Vhmaxp.*sqrt(sigmap);
VminEASp=Vhminp.*sqrt(sigmap);

% Plot Flight Envelope (h-VEAS) for jet aircraft
figure;
plot(VmaxEASp, altitudep, 'r', VminEASp, altitudep, 'b', VstallEASp, altitudep, 'g
    ');
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
title('Flight Envelope (h-VEAS) for propeller aircraft');
line([ax.XLim(1), ax.XLim(2)], [Acellingp, Acellingp], 'Color', 'r', 'LineStyle',
    '--');
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');
grid on;
% Adjust the axis limits for a better scale
xlim([0, max(Vmax) * 1.2]); % Set x-axis limits
ylim([0, max(altitude) * 1.2]); % Set y-axis limits
% Add axis labels
xlabel('Velocity (m/s)');
ylabel('Altitude (m)');
% Add a legend for better clarity
legend('Maximum Velocity', 'Minimum Velocity', 'Stall Velocity');

% (4) Minimum Power Required ------
Vminp = ((2.*W)./(rho.*S*(3.*CD0./K).^(1/2))).^(1/2);
Checking=min(Vminp - Vstallp);
if Checking<0
    Vminp_c=1.1 * Vstallp;% I am taking safe range V_minp = K*v_s
    Prmin=(1/2.*rhop.*Vminp_c.^3.*S.*CD0)+(2.*K.*W.^2./(rhop.*Vminp_c.*S));
else
    Vminp_c=Vminp;
    % 'We can use the direct equation for Pmin (minimum power).'
    Prmin=(2.48.*(W).^(3/2).*(CD0./K.^5).^(-0.25))./(etap.*sqrt(rhop.*S));
end
Checking_c=min(Vminp_c-Vstallp);
disp(['Minimum difference between Vminp_c and Vstall = ' , num2str(Checking_c)]);
```

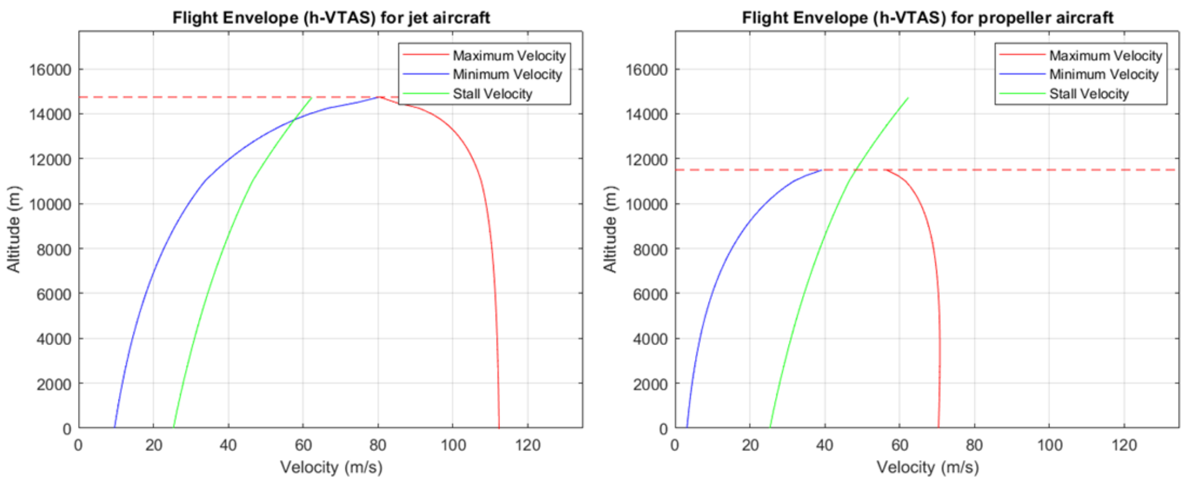
```
disp('Vminp_c is always greater than Vstall, as seen from the positive difference.
    ');
% Plot Minimum Power Required vs. Altitude
figure;
plot(Prmin,altitudep, 'g');
ylabel('Altitude (m)');
xlabel('Minimum Power Required (W)');
title('Minimum Power Required vs. Altitude for propeller aircraft')
grid on;

% (3) Minimum Thrust Required ————
%  Minimum Thrust Required Calculation for Propeller aircraft
% it is same as minimum thrust for jet aircraft
```

2.4 Output of Matlab code

```
Absolute Ceiling at Altitude for jet aircraft (m): 14751
Minimum difference between VminD_c and Vstall = 7.515
VminD_c is always greater than Vstall, as seen from the positive difference.
Minimum Thrust Required for jet aircraft(Trmin) = 593.677 N
We know that Minimum Thrust Required for jet aircraft does not change with
    altitude
Minimum difference between Vminp_c and Vstall = 2.5342
Vminp_c is always greater than Vstall, as seen from the positive difference.
We can use the direct equation for Pmin (minimum power).
```

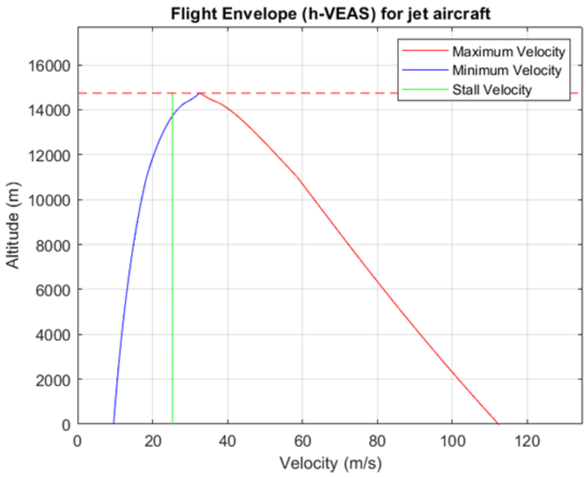
1. **Flight Envelope (h-VTAS) for jet aircraft**



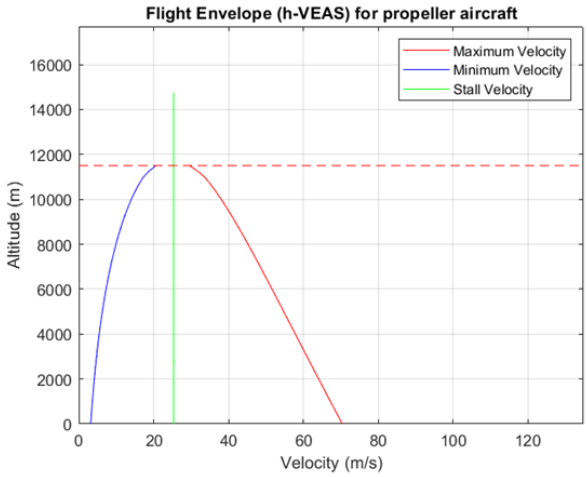
(a) Flight Envelope $(h - V_{TAS})$ for jet aircraft

(b) Flight Envelope $(h - V_{TAS})$ for propeller aircraft

2. **Flight Envelope (h-VEAS) for jet aircraft**



(a) Flight Envelope $(h - VEAS)$ for jet aircraft



(b) Flight Envelope $(h - VEAS)$ for propeller aircraft

3. **Minimum Power Required vs. Altitude for propeller aircraft**

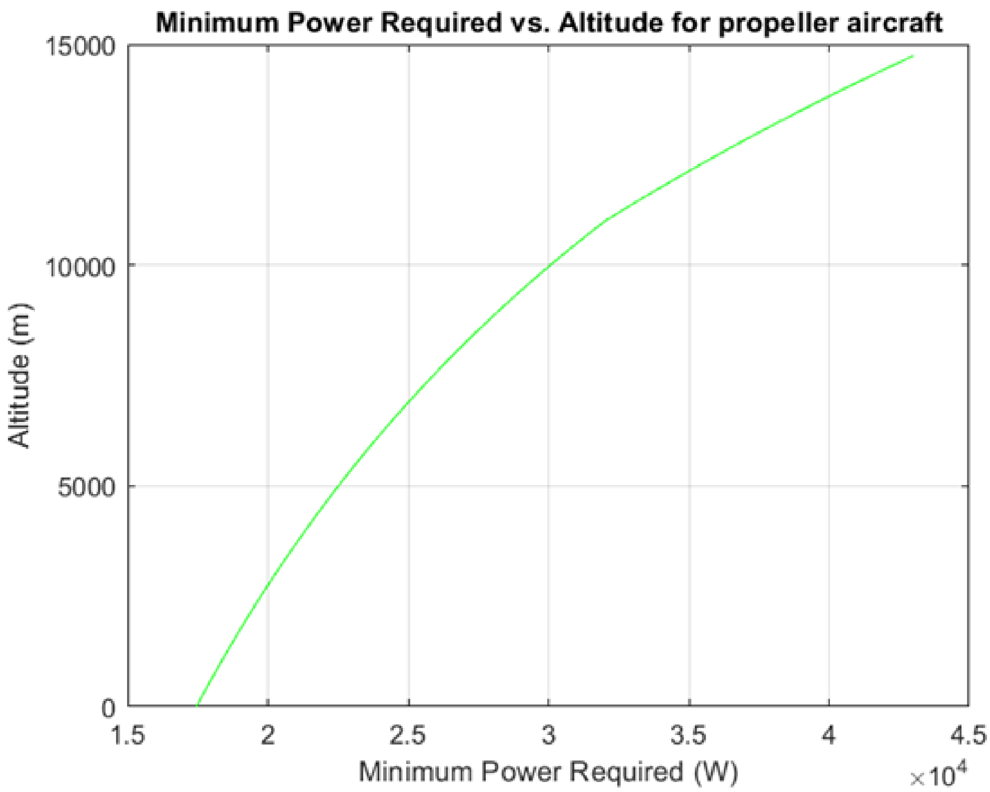


Figure 2.5: Minimum Power Required vs. Altitude for propeller aircraft

Here we can see in flight envelope that velocity is always less than flight maximum speed that can achieve that is 120 m/s.

Chapter 3

Comparison

The jet engine and propeller engine are the driving forces behind flight, but they work differently and have different characteristics. Choosing between one or the other depends on a thorough assessment of the aircraft's mission needs, performance goals, and operating environment.

3.1 Specification

Maximum Height Achieved by jet and propeller aircraft is same 14,750 m, but for propeller aircraft minimum power equation not provided solution after 11500m so here propeller aircraft can't fly above this altitude so absolute ceiling for propeller aircraft is 11500m.

Here I am taking optimum height for jet and propeller aircraft are 14250 m and 1000 m respectively because we can't fly at absolute ceiling we have to fly at service ceiling, here I am assuming that service ceiling is around 250m to 500m below absolute ceiling.

Here,for calculating jet minimum power at particular altitude i am assuming that we can multiple velocity at that altitude with minimum thrust at that altitude.

Performance Metric	**Jet Engine**	**Propeller Engine**
Maximum Height Achieved	14,750 m	11,500 m
Maximum Velocity (V_{max}) at Sea Level	112.413 m/s	70.44 m/s
Optimal Flight Height	14,250 m	11,000 m
Velocity (EAS) at Optimal Height	66.6355 m/s	61.6108
Velocity (TAS) at Optimal Height	28.11 m/s	33.58 m/s
Stall Velocity (EAS) at optimal Height	46.49 m/s	46.49 m/s
Stall Velocity (TAS)	25.34 m/s	25.34 m/s
Minimum Thrust Required	593.6770 N	-
Minimum Power Required at Optimal Height	39559.9637 W	32018.9 W
Range of Velocity	57.75 m/s - 112.413 m/s	48.36 m/s - 70.44 m/s

3.2 Conclusions

The choice of propulsion system for an aircraft is a critical decision that significantly impacts its performance, efficiency, and suitability for specific mission requirements. In this study, we have explored the performance metrics of both jet and propeller engines to determine the optimal choice for your aircraft. Here are the key findings and conclusions:

1. Altitude Advantage:

We aim to maximize our operational altitude because flying at higher altitudes offers several advantages. As altitude increases, air density decreases, resulting in reduced drag. This reduction in drag leads to increased fuel efficiency, making flights more economical and environmentally friendly.

2. Jet Engine Performance:

The jet engine showcases remarkable performance characteristics. It achieves a maximum altitude of 14,750 meters, making it highly suitable for missions that demand high-altitude flight. At sea level, it reaches a maximum velocity of 112.413 m/s, demonstrating its capability for high-speed operations.

Moreover, the jet engine operates optimally at an altitude of 14,250 meters. At this height, it maintains a true airspeed (TAS) of 28 m/s, providing versatility for various mission profiles. While the stall speed in true airspeed (TAS) is relatively high at 25.34m/s, it aligns with the jet's focus on high-altitude, high-speed flight.

3. Propeller Engine Performance:

The propeller engine, while achieving a maximum altitude of 11,500 meters, does not match the jet's high-altitude capabilities. Its maximum velocity at sea level is 70.44 m/s, which is lower than the jet engine's speed.

The optimal flight height for the propeller engine is 11,000 meters, where it attains a true airspeed (TAS) of 33.58 /s. However, the stall speed in true airspeed (TAS) is 25.34 m/s, indicating a more conservative approach to flight compared to the jet engine.

4. Final Conclusion:

After a comprehensive analysis, we conclude that the jet engine offers superior performance and versatility for the given mission requirements. It excels in terms of maximum altitude, speed, and optimal flight height. The jet's broader range of velocity caters to a wider spectrum of mission profiles.

It's important to note that the higher stall speed in the jet engine aligns with its focus on high-altitude, high-speed flight. If the mission prioritizes efficiency at lower altitudes, the propeller engine may be considered.

In summary, our final and decisive conclusion is that the jet engine is the more efficient and suitable choice for this specific mission.

The choice of propulsion system should align with the mission's altitude, speed, and efficiency requirements. The jet engine, with its impressive high-altitude and high-speed capabilities, is well-suited for missions that demand such performance characteristics.