AE312 : Atmospheric Flight Mechanics

A Report submitted

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Atmospheric Flight Mechanics

in

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by

Shingala Vaidik Pareshbhai

(SC21B054)

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Department of Aerospace Engineering

Indian Institute of Space Science and Technology

to

Dr. Dhayalan

INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

THIRUVANANTHAPURAM

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Contents

Abstract

This report provides a comprehensive analysis of the V-n diagram and its variants, specifically focusing on the V-n diagram with gust analysis and the VTAS-n diagram. The V-n diagram is a critical tool in aviation, illustrating the relationship between airspeed and load factor. Understanding this diagram is crucial for ensuring the safe operation of an aircraft.

The report delves into the flight envelope, detailing the permissible combinations of flight parameters and the importance of staying within these limits for safety and stability. Elements of the V-n diagram, including positive and negative stall areas, load factors, corner velocity, and dive speed, are thoroughly explained.

Turn performance analysis is explored, covering parameters such as the fastest turn and tightest turn, providing insights into an aircraft's maneuverability. The section on V-n diagram with gust analysis emphasizes the impact of gusts on an aircraft's structural integrity. Equations for calculating gust-induced load factors are introduced, and the process of combining basic and gust V-n diagrams is explained to construct a flight envelope that considers both maneuver and gust loads.

The VTAS-n diagram, highlighting the significance of True Airspeed in assessing aircraft performance under real-world flight conditions. Dynamic airspeed considerations, effects of altitude and temperature, efficiency and range analysis, and gust and turbulence analysis are discussed in the context of the VTAS-n diagram.

Chapter 1

Methodology

1.1 Problem to solve

The assignment is to bring out the following plots for the above aircraft. You may use 3 altitudes to conduct the analysis for gust and VTAS, between Sea level and 5000 m.

1. V-n Diagram
2. V-n Diagram with gust analysis
3. VTAS-n Diagram

Include the values of speed and load factor for Tightest Turn and Fastest Turn in the above envelopes. Provide appropriate explanation for the plots with these values. The thrust relations are provided below. Thrust model

$$T_{\text{max}} = T_{\text{maxSL}} \cdot \sigma$$

The density model can be taken from the class notes. Provide appropriate comments and justification about the plots. Proper justifications are required for your comments. Try to use the plots in a proper way to support your comments.

Parameter	**Value**	**Parameter**	**Value**
Wing Span, b	10.47 m	Limit Load factor, n_{lim}	3
Aspect Ratio, AR	8.8	Ultimate Load factor, $n_{\text{max.lim}}$	6
Wing Area, S	12.47 m^2	Limit Load factor, $-n_{\text{lim}}$	-2
Mass, m	750 kg	Ultimate Load factor, $-n_{\text{max.lim}}$	-4
Max Engine Thrust at S.L., T_{SL}	3500 N	C_{D0}	0.036
Max Engine Power at S.L., P_{SL}	150 HP	C_{L0}	0.365
Propeller Efficiency at S.L., η_P	0.9	e	0.8
Dive Speed, V_{D}	150 m/s	$C_{L_{\text{max}}}$	1.5
$-C_{L_{\text{max}}}$	-0.8	C_α	4.2

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.

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

1.2 V-n Diagram

Detailed Explanation of V-n Diagram

The V-n diagram is a critical tool in aviation, depicting the relationship between airspeed (V) and load factor (n) for an aircraft. Understanding this diagram is crucial for pilots, engineers, and designers as it provides insights into the aircraft's structural limitations and maneuvering capabilities.

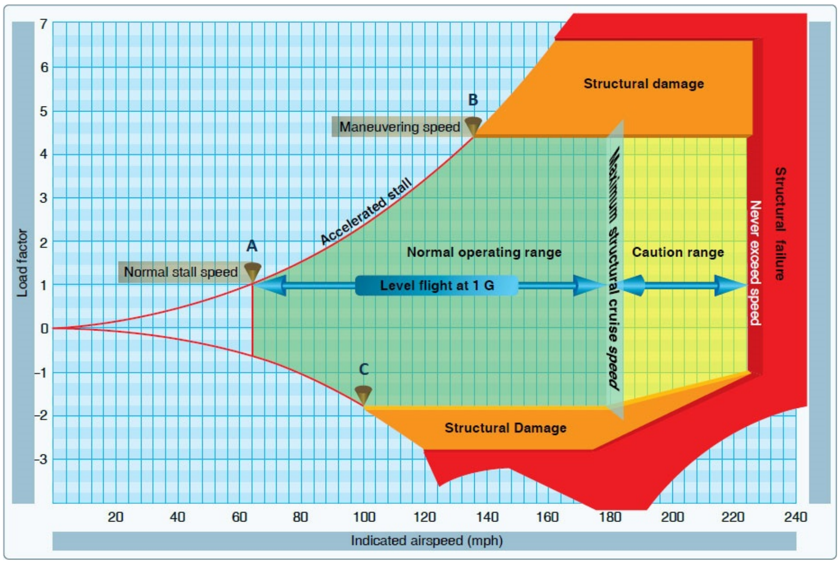


Figure 1.1: Standard V-n Diagram illustrating the aircraft's permissible load factors at various air speeds. The diagram delineates the boundaries within which the aircraft can safely maneuver, depicting the relationship between load factor (n) and velocity (V).

Flight Envelope and Safety

1. Flight Envelope Definition:

- The flight envelope encompasses all permissible combinations of flight parameters, including speeds, altitudes, weights, and configurations.
- Staying within this envelope is essential for ensuring the safety and stability of the aircraft.
- There are two type of load factors, *Maximum Producible Load Factor:* Achievable by using maximum engine thrust/power. *Maximum Allowable Load Factor:* Limited by the strength of the aircraft structure.

2. Importance of V-n Diagram:

- The V-n diagram is a graphical representation of the flight envelope.
- It helps pilots and engineers understand the aircraft's limits, preventing operations that could lead to instability or structural failure.

Elements of the V-n Diagram

1. Positive and Negative Stall Areas:

- *Definition:* Represented by curves on the left side of the diagram.
- *Significance:* Indicates the aerodynamic limit on the load factor imposed by the stall. Exceeding these limits results in a stall, which can be dangerous.

- *Calculation:*The load factor (n) in a turn is calculated using the equation:

$$n = \frac{\rho \cdot V^2 \cdot S \cdot C_{L_{\max}}}{2 \cdot W} \tag{1.1}$$

For Obtaining Negative Stall Curve take $-C_{L_{max}}$.

2. **Positive Load Factors:**

- **Limit Load Factor ($n_{\mathbf{lim}}$):**
  - **Definition:** The maximum load factor that the aircraft is certified to sustain during normal operations.
  - **Significance:** Exceeding this limit may result in imminent, but not permanent, deformation of the aircraft structure. Biological damage should be avoided.
  - **Safety Aspect:** Pilots must adhere to this limit to prevent structural damage and ensure the safety of the aircraft.
- **Ultimate Load Factor ($n_{\mathbf{max.lim}}$):**
  - **Definition:** The maximum allowable load factor limit, representing the structural limit beyond which failure may occur, leading to a fall or damage to the aircraft structure.
  - **Significance:** Exceeding this limit may result in catastrophic failure, causing severe damage to the structure, and poses a fatal risk.
  - **Safety Aspect:** Pilots should never cross this limit under any circumstances to prevent dire consequences.

3. **Corner Velocity (V* or Maneuvering Speed): Corner Velocity (V^*):** The corner velocity is a key parameter in the context of V-n diagrams, representing the speed at which an aircraft can achieve its maximum load factor (n_{max}) in a level turn without stalling. This velocity is crucial for understanding the limits of an aircraft's maneuverability. The equation for calculating the corner velocity is derived from the load factor equation in a level turn:

$$V = \sqrt{\frac{2 \cdot W \cdot n}{\rho \cdot S \cdot C_L}}$$

For the corner velocity (V^*), which is associated with the tightest turn performance, the load factor (n) is equal to the maximum positive limit load factor ($n_{\text{max.lim}}$):

$$V^* = \sqrt{\frac{2 \cdot W \cdot n_{\text{max.lim}}}{\rho \cdot S \cdot C_L}} = \sqrt{n_{\text{max.lim}}} \cdot V_{\text{stall}} \tag{1.2}$$

where, Stall Velocity

$$V_{\text{stall}} = \sqrt{\frac{2W}{\rho \cdot S \cdot C_{L_{\max}}}} \tag{1.3}$$

This speed is critical for pilots to ensure safe maneuvering within the specified load factor limits.

4. **Dive Speed (VD or Never-Exceeded Speed):**

- *Definition:* Vertical line on the right side of the diagram.
- *Significance:* Denotes the high-speed limit. Exceeding this speed can lead to destructive phenomena such as flutter and aileron reversal, resulting in structural damage. Also known as never-exceeded speed (VNE).

5. **Negative Load Factors:**
   - **Negative Limit Load Factor ($-n_{\text{lim}}$):**
     – **Definition:** The minimum load factor in the negative direction that the aircraft is certified to sustain during normal operations.
     – **Significance:** Exceeding this limit in the negative direction may result in imminent, but not permanent, deformation of the aircraft structure and potential biological damage.
     – **Safety Aspect:** Pilots must avoid crossing this limit to prevent structural damage and ensure safety.
   - **Negative Ultimate Load Factor ($-n_{\text{max.lim}}$):**
     – **Definition:** The maximum allowable negative load factor limit, representing the structural limit in the negative direction beyond which failure may occur.
     – **Significance:** Exceeding this limit in the negative direction may result in catastrophic failure, causing severe damage to the structure, and poses a fatal risk.
     – **Safety Aspect:** Pilots should never cross this limit under any circumstances to prevent dire consequences.
6. **Cruise Speed Analysis:** Cruise speed is a pivotal parameter in aircraft performance, influencing fuel efficiency, range capabilities, and overall mission planning. The determination of an optimal cruise speed involves a careful balance between minimizing fuel consumption and achieving the desired travel range.

   For our case aircraft **Cruising at a speed of 60 m/s(EAS)**, the aircraft operates within the range of V_{min} and V_{max}, ensuring optimal fuel efficiency and adherence to safety limits. This moderate cruise speed strikes a balance between minimizing operational costs and achieving the desired travel range.

1.3 Turn Performance Analysis

To assess the aircraft's turning capabilities, two critical parameters are often evaluated: the Fastest Turn and the Tightest Turn. These values provide insights into the aircraft's maneuverability under specific conditions.

Fastest Turn

The velocity (V_{FT}) for the fastest turn is determined by the equation:

$$V_{\text{FT}} = \sqrt{\frac{2 \cdot W}{\rho \cdot S \cdot \sqrt{\frac{C_{D0}}{K}}}} \tag{1.4}$$

where: W is the aircraft weight, ρ is the air density, S is the wing area, C_{D0} is the zero-lift drag coefficient, K is a factor related to the aircraft's aerodynamics.

The load factor (n_{FT}) corresponding to the fastest turn is calculated as:

$$n_{\text{FT}} = \sqrt{2 \cdot n_m - 1} \tag{1.5}$$

Here, n_m represents the maximum producible load factor given by:

$$n_m = \frac{T_{\text{max}}}{W \cdot 2 \cdot \sqrt{C_{D0} \cdot K}} \tag{1.6}$$

This load factor is a critical parameter as it indicates the maximum load that the aircraft structure can handle in a turn.

Tightest Turn

The velocity (V_{TT}) for the tightest turn is determined by the equation:

$$V_{\text{TT}} = \sqrt{\frac{4 \cdot K \cdot W^2}{\rho \cdot T_{\text{max}} \cdot S}} \tag{1.7}$$

The corresponding load factor (n_{TT}) is given by:

$$n_{\text{TT}} = \sqrt{2 - \frac{1}{n_m^2}} \tag{1.8}$$

The tightest turn represents a scenario where the aircraft is making the smallest possible turn radius for a given speed.

These calculations provide valuable insights into the aircraft's dynamic performance during turns, aiding in understanding its agility and limits in different flight conditions.

Note:

1. The corner velocity (V*) corresponds to the speed at which both lift coefficient and load factor are at their highest values.
2. For most aircraft, this speed is associated with the tightest turn and fastest turn performance.

1.4 V-n Diagram with Gust Analysis

The atmosphere is a dynamic system that encompasses various undesired phenomena, such as wind, turbulence, gust, wind shear, jet stream, mountain wave, and thermal flow. This section focuses on gust and turbulence loads, which are unpredictable but commonly expected during cruising flight.

Gust Load Considerations

When plotting the V-n diagram, attention must be given to gust loads, as the loads experienced during strong gusts can impact the aircraft's structural integrity. Gust velocities are challenging to measure accurately, and design requirements are often derived from flight test data.

Effect of Gust on Angle of Attack

A gust can induce a sudden change in the angle of attack ($\Delta\alpha$), modeled as an induced angle of attack. The instantaneous change is determined by:

$$\Delta\alpha \approx \tan^{-1}\left(\frac{V_g}{V}\right)$$

This change in angle of attack results in a sudden change in lift coefficient (ΔC_L):

$$\Delta C_L = a \cdot \Delta\alpha$$

Impact on Lift and Load Factor

The change in lift (ΔL) due to the change in lift coefficient is given by:

$$\Delta L = \frac{1}{2}\rho V^2 S \cdot \Delta C_L$$

Consequently, this change in lift creates a change in load factor (Δn):

$$\Delta n = \frac{\Delta L}{W}$$

Gust Load Factor Calculation

The gust-induced load factor (n_{gE}) is a crucial parameter in assessing the aircraft's response to gusts. It can be calculated through the following steps:

$$\mu_g = \frac{2W}{\rho \cdot c_{\text{bar}} \cdot C_{L_\alpha} \cdot S \cdot g} \tag{1.9}$$

The parameter μ_g is known as the aircraft mass ratio and characterizes the aircraft's response to gusts.

The next step involves determining the gust alleviation factor (K_g):

$$K_g = \frac{0.88\mu_g}{5.3 + \mu_g} \tag{1.10}$$

K_g reflects the effectiveness of gust alleviation, considering the aircraft's mass ratio.

Now, the gust-induced load factor (n_{g}) and its negative counterpart ($n_{\text{g,neg}}$) can be expressed as:

$$n_{\text{g}} = 1 + \frac{K_g V_{gE} V_E C_{L_\alpha} S}{2W} \tag{1.11}$$

$$n_{\text{g,neg}} = 1 - \frac{K_g V_{gE} V_E C_{L_\alpha} S}{2W} \tag{1.12}$$

Where:

V_{gE} : Gust equivalent speed

V_E : Aircraft equivalent airspeed

C_{L_α} : Wing lift curve slope during gust encounter

c_{bar} : Mean geometric chord of the wing

In these equations:

- n_{g} represents the positive load factor induced by the gust.
- $n_{\text{g,neg}}$ represents the negative load factor induced by the gust.

Combined V-n Diagram

To construct the flight envelope, the basic V-n diagram is combined with the gust V-n diagram. The procedure involves placing both diagrams in one plot, identifying intersection points, and connecting outer intersection points with straight lines. The resulting combined V-n diagram represents the aircraft's structural limits, considering both maneuver and gust loads.

A typical combined V-n diagram is illustrated in Figure 1.2. The maximum load factor is determined based on the intersection points, ensuring that the aircraft operates within the specified flight envelope.

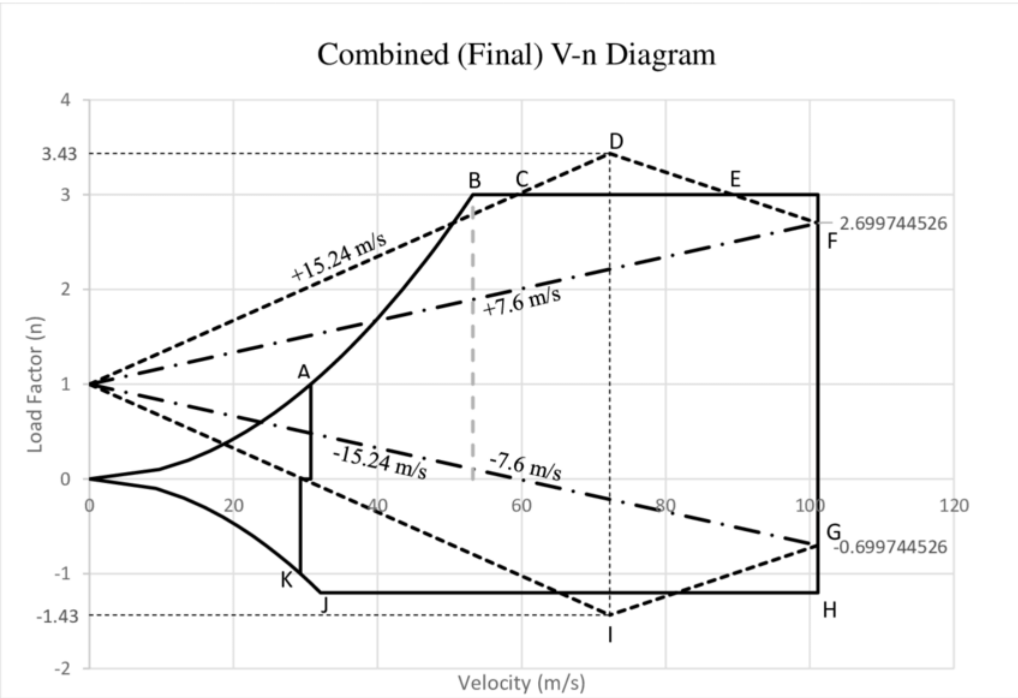


Figure 1.2: Combined V-n Diagram with Gust Analysis

This combined diagram is unique for each aircraft, and pilots are required to operate within this flight envelope to ensure safe and reliable flight operations.

Calculation of Gust Velocity (V_g) with Altitude

The gust velocity (V_g) is a critical parameter in understanding the impact of gusts on an aircraft. The formula for calculating V_g with respect to altitude is given by:

(5) The following reference gust velocities apply:

(i) At airplane speeds between V_B and V_C: Positive and negative gusts with reference gust velocities of 56.0 ft/sec EAS must be considered at sea level. The reference gust velocity may be reduced linearly from 56.0 ft/sec EAS at sea level to 44.0 ft/sec EAS at 15,000 feet. The reference gust velocity may be further reduced linearly from 44.0 ft/sec EAS at 15,000 feet to 20.86 ft/sec EAS at 60,000 feet.

(ii) At the airplane design speed V_D: The reference gust velocity must be 0.5 times the value obtained under § 25.341(a)(5)(i).

Figure 1.3: Reference Model for Gust Velocity Calculation

$$\text{altitude\_feet} = \text{altitude} \times 3.28084$$

The reference gust velocity is determined based on a linear reduction model:

$$\text{if altitude\_feet} \leq 15000 :$$

$$V_g = 56.0 - \frac{56.0 - 44.0}{15000} \times \text{altitude\_feet}$$

$$\text{else:}$$

$$V_g = 44.0 - \frac{44.0 - 20.86}{50000 - 15000} \times (\text{altitude\_feet} - 15000)$$

This model accounts for the decrease in gust velocity with increasing altitude. The resulting V_g is then converted from feet per second to meters per second:

$$V_g = \text{gustVelocity} \times 0.3048$$

The calculated gust velocity at a given altitude is then displayed.

Gust V-n Diagram with $n_{\text{lim}} = 3$ and $n_{\text{max.lim}} = 6$

For the first scenario, the cruise speed is set at 60 m/s, aligning with a moderate operational speed. The Gust V-n diagram is constructed, considering a maximum limit load factor (n_{lim}) of 3, as proposed by J.D. Anderson.

In the second scenario, a higher cruise speed of 105 m/s is considered, pushing the aircraft's dynamic capabilities. The Gust V-n diagram is constructed with a maximum allowable positive load factor ($n_{\text{max.lim}}$) set at 6, as indicated by Mohammad H. Sadraey.

So i have plotted both scenario in this report

1.5 VTAS-n Diagram

Introduction

While the traditional V-n diagram provides a comprehensive understanding of an aircraft's structural limits and maneuvering capabilities, the introduction of True Airspeed (VTAS) into the analysis through the VTAS-n diagram enhances our ability to assess the aircraft's performance under real-world flight conditions.

Dynamic Airspeed Considerations

Unlike Indicated Airspeed (IAS) or Calibrated Airspeed (CAS), True Airspeed (VTAS) accounts for changes in air density with altitude. This is particularly important because aircraft performance is directly affected by the true speed through the air. The VTAS-n diagram allows for a more accurate representation of an aircraft's dynamic response to varying airspeeds.

Effects of Altitude and Temperature

VTAS incorporates the effects of altitude and temperature on air density, providing a more realistic measure of an aircraft's performance. As an aircraft climbs or descends, the VTAS-n diagram allows us to visualize how load factors change with true airspeed under different atmospheric conditions.

Efficiency and Range Analysis

Understanding True Airspeed is essential for optimizing fuel efficiency and determining the range capabilities of an aircraft. The VTAS-n diagram aids in evaluating the load factors associated with specific true airspeeds, enabling pilots and engineers to make informed decisions about fuel consumption and mission planning.

Gust and Turbulence Analysis

When assessing the impact of gusts and turbulence, True Airspeed becomes a critical parameter. The VTAS-n diagram provides insights into how load factors vary with changes in true airspeed during turbulent conditions, assisting in designing aircraft that can withstand such disturbances.

Relation Between EAS and TAS

The relationship between True Airspeed (TAS) and Estimated Airspeed (EAS) can be described by the following formula:

$$v_{\text{EAS}} = v_{\text{TAS}} \times \sqrt{\frac{\rho}{\rho_0}}$$

where: v_{TAS} is True Airspeed, v_{EAS} is Estimated Airspeed, ρ is the air density at the current altitude, ρ_0 is the standard sea level air density.

1.6 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*9.8;        % Mass (kg)
TmaxSL = 3500;     % Max Engine Thrust at Sea Level (N)
VD = 150;       % Dive Speed (m/s)
nlim = 3;       % Limit Load factor
nmax_lim = 6;   % Ultimate Load factor
nlim_neg = -2;  % Limit Load factor (negative)
nmax_lim_neg = -4;  % Ultimate Load factor (negative)

% Aerodynamic derivatives
CD0 = 0.036;        CL0 = 0.365;       Cm0 = 0.05;
CDalpha = 0.041;    CLalpha = 4.2;     Cmalpha = -0.59;
e = 0.8;            CLq = 27.3;        Cmq = -9.3;
CDdelta_e = 0.026;  CLalphadot = 8.3;  Cmalphadot = -4.3;
CLmax = 1.8;        CLmax_neg = -0.8;  Cmdelta_e = -1.008;

K = 1 / (pi * e * AR);

% At sea level ---------------------------------------------------------------

disp('(I) V-n Graph')
% (I) V-n Graph
plotAltitudeDiagram(0);
% if we take altitude 0 than it is nothing but v-n diagram because at sea level sigma is 1.

disp('(III) V(TAS)-n Graph')
% (III) V(TAS)-n Graph
plotAltitudeDiagram(1000);
plotAltitudeDiagram(2500);
plotAltitudeDiagram(4000);

disp('(II)  V-n Diagram with gust analysis taking nlim = 3')
% (II)  V-n Diagram with gust analysis
% gust velocities with altitude
GustAltittudeDiagramWithnlim(0);
GustAltittudeDiagramWithnlim(1000);
GustAltittudeDiagramWithnlim(2500);
GustAltittudeDiagramWithnlim(4000);

disp('(II)  V-n Diagram with gust analysis taking nmax_lim = 6')
% (II)  V-n Diagram with gust analysis
% gust velocities with altitude
GustAltittudeDiagramWithnmax_lim(0);
GustAltittudeDiagramWithnmax_lim(1000);
GustAltittudeDiagramWithnmax_lim(2500);
GustAltittudeDiagramWithnmax_lim(4000);

function plotAltitudeDiagram(altitude)
    % Aircraft parameters
    AR = 8.8;       % Aspect Ratio
    S = 12.47;      % Wing Area (m^2)
    W = 750*9.8;        % Mass (kg)
    TmaxSL = 3500;     % Max Engine Thrust at Sea Level (N)
    VD = 150;       % Dive Speed (m/s)
    nlim = 3;       % Limit Load factor
    nmax_lim = 6;   % Ultimate Load factor
    nlim_neg = -2;  % Limit Load factor (negative)
    nmax_lim_neg = -4;  % Ultimate Load factor (negative)
    % Aerodynamic derivatives
    CD0 = 0.036;
    e = 0.8;
    CLmax = 1.8;  CLmax_neg = -0.8;

    K = 1 / (pi * e * AR);

    % Calculate standard atmosphere parameters at the given altitude
    [~, ~, ~, rho] = atmosisa(altitude);
    sigma = rho / 1.225;

    % Calculate maximum thrust at the given altitude
    Tmax = TmaxSL * sigma;

    % Calculate stall speeds at the given altitude
    V_stall = (2 * W / (S * rho * CLmax))^(1/2);
    V_stall_neg = (2 * W / (S * rho * (-1) * CLmax_neg))^(1/2);
%     V_stall=V_stall*sqrt(sigma);
%     V_stall_neg = V_stall_neg*sqrt(sigma);
    % Calculate corner speeds for diagram
    V_cor_pos = sqrt(nlim) * V_stall;
    V_cor_pos_e = sqrt(nmax_lim) * V_stall;
    V_cor_neg = sqrt(-1*nlim_neg) * V_stall_neg;
    V_cor_neg_e = sqrt(-1*nmax_lim_neg) * V_stall_neg;
```

```
    % Calculate cruise speed 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);
    Vc=60;
%     Vmax=Vmax*sqrt(sigma);
    % Generate V-n diagram data for positive and negative stalls
    V_s1 = linspace(V_stall, V_cor_pos, 100);
    n_stall1 = rho * V_s1.^2 * S * CLmax / (2 * W);
    V_s2 = linspace(V_cor_pos, V_cor_pos_e, 100);
    n_stall2 = rho * V_s2.^2 * S * CLmax / (2 * W);
    V_s3 = linspace(V_stall_neg, V_cor_neg, 100);
    n_stall_neg1 = rho * V_s3.^2 * S * CLmax_neg / (2 * W);
    V_s4 = linspace(V_cor_neg, V_cor_neg_e, 100);
    n_stall_neg2 = rho * V_s4.^2 * S * CLmax_neg / (2 * W);
    V_s5 = linspace(0, V_stall, 100);
    n_stall3 = rho * V_s5.^2 * S * CLmax / (2 * W);
    V_s6 = linspace(0, V_stall_neg, 100);
    n_stall_neg3 = rho * V_s6.^2 * S * CLmax_neg / (2 * W);

    % Calculate Tightest Turn and Fastest Turn values
    V_FT=sqrt(2*W/(rho*S*sqrt(CD0/K)));
    n_m=(Tmax/(W*2*sqrt(CD0*K)));
    n_FT=sqrt(2*n_m-1);
    V_TT=sqrt(4*K*W^2/(rho*Tmax*S));
    % n_tt=rho*V_corner^2*S*CLmax/(2*W);
    n_TT=sqrt(2-(1/(n_m^2)));
    fprintf('Velocity of Fastest Turn: %.2f m/s at %d m\n', V_FT ,altitude);
    fprintf('Load Factor for Fastest Turn: %.2f at %d m\n', n_FT,altitude);
    fprintf('Velocity of Tightest Turn: %.2f m/s at %d m\n', V_TT,altitude);
    fprintf('Load Factor for Tightest Turn: %.2f at %d m\n', n_TT,altitude);

    % Plot the V-n diagram
    figure;
    plot(V_s1, n_stall1, 'b', V_s3, n_stall_neg1, 'r', V_s2, n_stall2, '--', V_s4, n_stall_neg2, '--', V_s5, n_stall3, '--', V_s6,
           n_stall_neg3, '--', 'LineWidth', 1.3);
    xlabel('Velocity (m/s)');
    ylabel('Load Factor (n)');
    if altitude==0
        title(['V-n Diagram']);
    else
        title(['V(TAS)-n Diagram H = ', num2str(altitude), ' m']);
    end
    legend('+Ve Stall', '-Ve Stall');
    grid on;
    hold on;
    scatter(V_FT, n_FT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r','DisplayName', 'Fastest Turn');
    plot([V_FT,V_FT], [0, n_FT], 'k--','HandleVisibility', 'off');
    plot([0, V_FT], [n_FT, n_FT], 'k--','HandleVisibility', 'off');
    scatter(V_TT, n_TT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'b','DisplayName', 'Tightest Turn');
    plot([V_TT,V_TT], [0, n_TT], 'k--','HandleVisibility', 'off');
    plot([0, V_TT], [n_TT, n_TT], 'k--','HandleVisibility', 'off');
    text(V_stall-2, -0.23, 'V_s_1', 'FontSize', 7, 'Color', 'black');
    text(V_stall_neg-2, 0.32, 'V_s_2', 'FontSize', 7, 'Color', 'black');
    text(V_cor_pos+2, 0.32, 'V*', 'FontSize', 7, 'Color', 'black');
    text(Vc+2, 0.32, 'V_C', 'FontSize', 7, 'Color', 'black');
    line([VD, VD], [-2, 3], 'Color', 'green', 'LineWidth', 1.2, 'DisplayName', 'Dive Speed');
    line([VD, VD], [3, 6], 'Color', [0, 0.5, 0], 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([VD, VD], [-2, -4], 'Color', [0, 0.5, 0], 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos, VD], [3, 3], 'Color', [0.5, 0.5, 0.5], 'LineWidth', 2, 'DisplayName', '+ve Limit n ');
    line([V_cor_pos_e, VD], [6, 6], 'Color', [1, 0, 1], 'LineStyle', '--', 'LineWidth', 2, 'DisplayName', '+ve Ultimate n');
    line([V_cor_neg, VD], [-2, -2], 'Color', [0, 0.75, 0.75], 'LineWidth', 2, 'DisplayName', '-ve Limit n');
    line([V_cor_neg_e, VD], [-4, -4], 'Color', [0.5, 0.8, 0], 'LineStyle', '--', 'LineWidth', 2, 'DisplayName', '-ve Ultimate n');
    line([0, VD], [0, 0], 'Color', 'black', 'LineStyle', '-.', 'LineWidth', 1.2, 'DisplayName', 'Zero Load Factor');
    line([V_stall, V_stall], [0, 1], 'Color', 'blue', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall_neg, V_stall_neg], [0, -1], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall, V_stall_neg], [0, 0], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos, V_cor_pos], [0, 3], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1, 'HandleVisibility', 'off');
    line([Vc, Vc], [0, 3], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1, 'HandleVisibility', 'off');
    hold off;
    lgd = legend('Location', 'northeastoutside');
    xlim([0, 1.05 * 150]);
    ylim([-4 * 1.2, 6 * 1.2]);
end

function GustAltittudeDiagramWithnlim(altitude)
    % Aircraft parameters
    c_bar = 1.211;  % Mean Aerodynamic Chord (m)
    AR = 8.8;       % Aspect Ratio
    S = 12.47;      % Wing Area (m^2)
    W = 750*9.8;        % Mass (kg)
    TmaxSL = 3500;     % Max Engine Thrust at Sea Level (N)
    VD = 150;       % Dive Speed (m/s)
    nlim = 3;       % Limit Load factor
    nmax_lim = 6;   % Ultimate Load factor
    nlim_neg = -2;  % Limit Load factor (negative)
    nmax_lim_neg = -4;  % Ultimate Load factor (negative)

    % Aerodynamic derivatives
    CD0 = 0.036; CLalpha = 4.2;
    e = 0.8; CLmax = 1.8; CLmax_neg = -0.8;
    K = 1 / (pi * e * AR);
```

```
    % Calculate standard atmosphere parameters at the given altitude
%     [~, ~, ~, rho1] = atmosisa(altitude);
%     sigma1 = rho1 / 1.225;
    rho=1.225;
    sigma=1;
    Tmax=TmaxSL*sigma;
    % gust velocities with altitude
    altitude_feet = altitude * 3.28084;

    % Calculate reference gust velocity based on the linear reduction
    if altitude_feet <= 15000
        gustVelocity = 56.0 - (56.0 - 44.0) / 15000 * altitude_feet;
    else
        gustVelocity = 44.0 - (44.0 - 20.86) / (50000 - 15000) * (altitude_feet - 15000);
    end

    % Convert gust velocity from ft/sec to m/s
    V_g = gustVelocity * 0.3048;
    disp(['Gust velocity at ', num2str(altitude), ' meters: ', num2str(V_g), ' m/s']);

    % Calculate cruise speed 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);
    Vc=60;
%     Vmax=Vmax*sqrt(sigma);
    mu_g=2*W/(rho*c_bar*CLalpha*S*9.8);
    K_g=0.88*mu_g/(5.3+mu_g);
    V=linspace(0, Vc, 100);
    n_g=1+(K_g*V_g*V*rho*CLalpha*S/(2*W));
    n_g_neg=1-(K_g*V_g*V*rho*CLalpha*S/(2*W));

    V1=linspace(0, VD, 100);
    V_gD=0.5*V_g;
    n_g1=1+(K_g*V_gD*V1*rho*CLalpha*S/(2*W));
    n_g_neg1=1-(K_g*V_gD*V1*rho*CLalpha*S/(2*W));

    max_n_g = n_g(end);
    max_n_g_neg = n_g_neg(end);
    max_n_g1 = n_g1(end);
    max_n_g_neg1 = n_g_neg1(end);
    V_n_g_3 = interp1(n_g, V, 3);
    V_n_g_neg_2 = interp1(n_g_neg, V, -2);
    Vxx=Vc+((3-max_n_g)*(VD-Vc)/(max_n_g1-max_n_g));
    Vxx2=Vc+((-2-max_n_g_neg)*(VD-Vc)/(max_n_g_neg1-max_n_g_neg));

    % Calculate stall speeds at the given altitude
    V_stall = (2 * W / (S * rho * CLmax))^(1/2);
    V_stall_neg = (2 * W / (S * rho * (-1) * CLmax_neg))^(1/2);
    % noe for V-n diagram
    V_stall=V_stall*sqrt(sigma);
    V_stall_neg = V_stall_neg*sqrt(sigma);
    % Calculate corner speeds for diagram
    V_cor_pos = sqrt(nlim) * V_stall;
    V_cor_pos_e = sqrt(nmax_lim) * V_stall;
    V_cor_neg = sqrt(-1*nlim_neg) * V_stall_neg;
    V_cor_neg_e = sqrt(-1*nmax_lim_neg) * V_stall_neg;

    % Generate V-n diagram data for positive and negative stalls
    V_s1 = linspace(V_stall, V_cor_pos, 100);
    n_stall1 = rho * V_s1.^2 * S * CLmax / (2 * W);
    V_s2 = linspace(V_cor_pos, V_cor_pos_e, 100);
    n_stall2 = rho * V_s2.^2 * S * CLmax / (2 * W);
    V_s3 = linspace(V_stall_neg,V_cor_neg, 100);
    n_stall_neg1 = rho * V_s3.^2 * S * CLmax_neg / (2 * W);
    V_s4 = linspace(V_cor_neg, V_cor_neg_e, 100);
    n_stall_neg2 = rho * V_s4.^2 * S * CLmax_neg / (2 * W);
    V_s5 = linspace(0, V_stall, 100);
    n_stall3 = rho * V_s5.^2 * S * CLmax / (2 * W);
    V_s6 = linspace(0, V_stall_neg, 100);
    n_stall_neg3 = rho * V_s6.^2 * S * CLmax_neg / (2 * W);

    % Calculate Tightest Turn and Fastest Turn values
    V_FT=sqrt(2*W/(rho*S*sqrt(CD0/K)));
    n_m=(Tmax/(W*2*sqrt(CD0*K)));
    n_FT=sqrt(2*n_m-1);
    V_TT=sqrt(4*K*W^2/(rho*Tmax*S));
    % n_tt=rho*V_corner^2*S*CLmax/(2*W);
    n_TT=sqrt(2-(1/(n_m^2)));
    if altitude==0
    % for V-n diagram it didn't depends on altitude so for all altitude this is same
    fprintf('Velocity of Fastest Turn: %.2f m/s at %d m\n', V_FT ,altitude);
    fprintf('Load Factor for Fastest Turn: %.2f at %d m\n', n_FT,altitude);
    fprintf('Velocity of Tightest Turn: %.2f m/s at %d m\n', V_TT,altitude);
    fprintf('Load Factor for Tightest Turn: %.2f at %d m\n', n_TT,altitude);
    end



    plot(V_s1, n_stall1, 'b', V_s3, n_stall_neg1, 'r', V_s2, n_stall2, '--', V_s4, n_stall_neg2, '--', V_s5, n_stall3, '--', V_s6,
           n_stall_neg3, '--',V,n_g,'--',V,n_g_neg,'--',V1,n_g1,'--',V1,n_g_neg1,'--', 'LineWidth', 1.3);
```

```
    xlabel('Velocity (m/s)');
    ylabel('Load Factor (n)');
    title(['V-n Diagram with gust analysis H = ', num2str(altitude), ' m']);
    legend('+Ve Stall', '-Ve Stall');
    grid on;
    hold on;
    scatter(V_FT, n_FT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r','DisplayName', 'Fastest Turn');
    plot([V_FT,V_FT], [0, n_FT], 'k--','HandleVisibility', 'off');
    plot([0, V_FT], [n_FT, n_FT], 'k--','HandleVisibility', 'off');
    scatter(V_TT, n_TT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'b','DisplayName', 'Tightest Turn');
    plot([V_TT,V_TT], [0, n_TT], 'k--','HandleVisibility', 'off');
    plot([0, V_TT], [n_TT, n_TT], 'k--','HandleVisibility', 'off');
    text(V_stall-2, -0.23, 'V_s_1', 'FontSize', 7, 'Color', 'black');
    text(V_stall_neg-2, 0.32, 'V_s_2', 'FontSize', 7, 'Color', 'black');
    text(V_cor_pos+2, 0.32, 'V*', 'FontSize', 7, 'Color', 'black');
    text(Vc+2, 0.32, 'V_C', 'FontSize', 7, 'Color', 'black');
    line([VD, VD], [max_n_g_neg1, max_n_g1], 'Color', 'green', 'LineWidth', 1.2, 'DisplayName', 'Dive Speed');
    line([VD, VD], [max_n_g1, 6], 'Color', [0, 0.5, 0], 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([VD, VD], [max_n_g_neg1, -4], 'Color', [0, 0.5, 0], 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos, VD], [3, 3], 'Color', [0.5, 0.5, 0.5], 'LineWidth', 2, 'DisplayName', '+ve Limit n ');
    line([V_cor_pos_e, VD], [6, 6], 'Color', [1, 0, 1], 'LineStyle', '--', 'LineWidth', 2, 'DisplayName', '+ve Ultimate n');
    line([V_cor_neg, VD], [-2, -2], 'Color', [0, 0.75, 0.75], 'LineWidth', 2, 'DisplayName', '-ve Limit n');
    line([V_cor_neg_e, VD], [-4, -4], 'Color', [0.5, 0.8, 0], 'LineStyle', '--', 'LineWidth', 2, 'DisplayName', '-ve Ultimate n');
    line([0, VD], [0, 0], 'Color', 'black', 'LineStyle', '-.', 'LineWidth', 1.2, 'DisplayName', 'Zero Load Factor');
    line([V_stall, V_stall], [0, 1], 'Color', 'blue', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall_neg, V_stall_neg], [0, -1], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall, V_stall_neg], [0, 0], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos, V_cor_pos], [0, 3], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1, 'HandleVisibility', 'off');
    line([Vc, Vc], [max_n_g_neg, max_n_g], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    if max_n_g-3>0
    line([V_cor_pos, V_n_g_3], [3, 3], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_cor_neg, V_n_g_neg_2], [-2, -2], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_n_g_3, Vc], [3, max_n_g], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_n_g_neg_2, Vc], [-2, max_n_g_neg], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g, max_n_g1], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g_neg, max_n_g_neg1], 'Color', 'black','LineStyle', '--', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vxx2,VD], [-2, max_n_g_neg1], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    else
    line([V_cor_pos, VD], [3, 3], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_cor_neg, VD], [-2, -2], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g, max_n_g1], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g_neg, max_n_g_neg1], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    end
    hold off;
    lgd = legend('Location', 'northeastoutside');
    xlim([0, 1.05 * 150]);
    ylim([-4 * 1.3, 6 * 1.2]);
end

%------------------------------------------------------------------------------------------
function GustAltittudeDiagramWithnmax_lim(altitude)
    % Aircraft parameters
    c_bar = 1.211;  % Mean Aerodynamic Chord (m)
    AR = 8.8;        % Aspect Ratio
    S = 12.47;       % Wing Area (m^2)
    W = 750*9.8;         % Mass (kg)
    TmaxSL = 3500;      % Max Engine Thrust at Sea Level (N)
    VD = 150;        % Dive Speed (m/s)
    nlim = 3;        % Limit Load factor
    nmax_lim = 6;    % Ultimate Load factor
    nlim_neg = -2;  % Limit Load factor (negative)
    nmax_lim_neg = -4;  % Ultimate Load factor (negative)

    % Aerodynamic derivatives
    CD0 = 0.036; CLalpha = 4.2;
    e = 0.8; CLmax = 1.8; CLmax_neg = -0.8;
    K = 1 / (pi * e * AR);

    % Calculate standard atmosphere parameters at the given altitude
%     [~, ~, ~, rho1] = atmosisa(altitude);
%     sigma1 = rho1 / 1.225;
    rho=1.225;
    sigma=1;
    Tmax=TmaxSL*sigma;
    % gust velocities with altitude
    altitude_feet = altitude * 3.28084;

    % Calculate reference gust velocity based on the linear reduction
    if altitude_feet <= 15000
        gustVelocity = 56.0 - (56.0 - 44.0) / 15000 * altitude_feet;
    else
        gustVelocity = 44.0 - (44.0 - 20.86) / (50000 - 15000) * (altitude_feet - 15000);
    end

    % Convert gust velocity from ft/sec to m/s
    V_g = gustVelocity * 0.3048;
    disp(['Gust velocity at ', num2str(altitude), ' meters: ', num2str(V_g), ' m/s']);

    % Calculate cruise speed 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);
```

```
    Vc=105;
%     Vmax=Vmax*sqrt(sigma);
    mu_g=2*W/(rho*c_bar*CLalpha*S*9.8);
    K_g=0.88*mu_g/(5.3+mu_g);
    V=0:1:Vc;
    n_g=1+(K_g*V_g*V*rho*CLalpha*S/(2*W));
    n_g_neg=1-(K_g*V_g*V*rho*CLalpha*S/(2*W));

    V1=0:1:VD;
    V_gD=0.5*V_g;
    n_g1=1+(K_g*V_gD*V1*rho*CLalpha*S/(2*W));
    n_g_neg1=1-(K_g*V_gD*V1*rho*CLalpha*S/(2*W));

    max_n_g = n_g(end);
    max_n_g_neg = n_g_neg(end);
    max_n_g1 = n_g1(end);
    max_n_g_neg1 = n_g_neg1(end);
    V_n_g_6 = interp1(n_g, V, 6);
    V_n_g_neg_4 = interp1(n_g_neg, V, -4);
    Vxx=Vc+((6-max_n_g)*(VD-Vc)/(max_n_g1-max_n_g));
    Vxx2=Vc+((-4-max_n_g_neg)*(VD-Vc)/(max_n_g_neg1-max_n_g_neg));

    % Calculate stall speeds at the given altitude
    V_stall = (2 * W / (S * rho * CLmax))^(1/2);
    V_stall_neg = (2 * W / (S * rho * (-1) * CLmax_neg))^(1/2);
    % noe for V-n diagram
     V_stall=V_stall*sqrt(sigma);
    V_stall_neg = V_stall_neg*sqrt(sigma);
    % Calculate corner speeds for diagram
    V_cor_pos = sqrt(nlim) * V_stall;
    V_cor_pos_e = sqrt(nmax_lim) * V_stall;
    V_cor_neg = sqrt(-1*nlim_neg) * V_stall_neg;
    V_cor_neg_e = sqrt(-1*nmax_lim_neg) * V_stall_neg;

    V_s2 = linspace(V_stall, V_cor_pos_e, 100);
    n_stall2 = rho * V_s2.^2 * S * CLmax / (2 * W);
    V_s4 = linspace(V_stall_neg, V_cor_neg_e, 100);
    n_stall_neg2 = rho * V_s4.^2 * S * CLmax_neg / (2 * W);

    V_s5 = linspace(0, V_stall, 100);
    n_stall3 = rho * V_s5.^2 * S * CLmax / (2 * W);
    V_s6 = linspace(0, V_stall_neg, 100);
    n_stall_neg3 = rho * V_s6.^2 * S * CLmax_neg / (2 * W);

    % Calculate Tightest Turn and Fastest Turn values
    V_FT=sqrt(2*W/(rho*S*sqrt(CD0/K)));
    n_m=(Tmax/(W*2*sqrt(CD0*K)));
    n_FT=sqrt(2*n_m-1);
    V_TT=sqrt(4*K*W^2/(rho*Tmax*S));
    % n_tt=rho*V_corner^2*S*CLmax/(2*W);
    n_TT=sqrt(2-(1/(n_m^2)));
    if altitude==0
    % for V-n diagram it didn't depends on altitude so for all altitude this is same
    fprintf('Velocity of Fastest Turn: %.2f m/s at %d m\n', V_FT ,altitude);
    fprintf('Load Factor for Fastest Turn: %.2f at %d m\n', n_FT,altitude);
    fprintf('Velocity of Tightest Turn: %.2f m/s at %d m\n', V_TT,altitude);
    fprintf('Load Factor for Tightest Turn: %.2f at %d m\n', n_TT,altitude);
    end

    plot(V_s2,n_stall2,'b',V_s4,n_stall_neg2,'r',V,n_g,'--',V,n_g_neg,'--',V1,n_g1,'--',V1,n_g_neg1,'--',V_s5,n_stall3,'--',V_s6,
           n_stall_neg3,'--','LineWidth', 1.3);
    xlabel('Velocity (m/s)');
    ylabel('Load Factor (n)');
    title(['V-n Diagram with gust analysis H = ', num2str(altitude), ' m']);
    legend('+Ve Stall', '-Ve Stall');
    grid on;
    hold on;
    scatter(V_FT, n_FT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'r','DisplayName', 'Fastest Turn');
    plot([V_FT,V_FT], [0, n_FT], 'k--','HandleVisibility', 'off');
    plot([0, V_FT], [n_FT, n_FT], 'k--','HandleVisibility', 'off');
    scatter(V_TT, n_TT, 'o', 'filled', 'MarkerEdgeColor', 'b', 'MarkerFaceColor', 'b','DisplayName', 'Tightest Turn');
    plot([V_TT,V_TT], [0, n_TT], 'k--','HandleVisibility', 'off');
    plot([0, V_TT], [n_TT, n_TT], 'k--','HandleVisibility', 'off');
    text(V_stall-2, -0.23, 'V_s_1', 'FontSize', 7, 'Color', 'black');
    text(V_stall_neg-2, 0.32, 'V_s_2', 'FontSize', 7, 'Color', 'black');
    text(V_cor_pos_e+2, 0.32, 'V*', 'FontSize', 7, 'Color', 'black');
    text(Vc+2, 0.32, 'V_C', 'FontSize', 7, 'Color', 'black');
    line([V_stall, V_stall], [0, 1], 'Color', 'blue', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall_neg, V_stall_neg], [0, -1], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_stall, V_stall_neg], [0, 0], 'Color', 'red', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos_e, V_cor_pos_e], [0, 6], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1, 'HandleVisibility', 'off');
    line([V_cor_neg_e, VD], [-4, -4], 'Color', [0.5, 0.8, 0], 'LineStyle', '--', 'LineWidth', 1.2, 'DisplayName', '-ve Ultimate n');
    line([0, VD], [0, 0], 'Color', 'black', 'LineStyle', '-.', 'LineWidth', 1.2, 'DisplayName', 'n=0');
    line([V_cor_pos_e, VD], [6, 6], 'Color', [1, 0, 1], 'LineStyle', '--', 'LineWidth', 1.2, 'DisplayName', '+ve Ultimate n');
    line([VD, VD], [-4, 6], 'Color', 'green', 'LineWidth', 1.2, 'DisplayName', 'Dive Speed');
    line([Vc, Vc], [max_n_g_neg, max_n_g], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([V_cor_pos, VD], [3, 3], 'Color', [0.5, 0.5, 0.5], 'LineStyle', '--', 'LineWidth', 1.2, 'DisplayName', '+ve Limit n ');
    line([V_cor_neg, VD], [-2, -2], 'Color', [0, 0.75, 0.75], 'LineStyle', '--', 'LineWidth', 1.2, 'DisplayName', '-ve Limit n');
    if max_n_g-6>0
    line([V_cor_pos_e, V_n_g_6], [6, 6], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
```

```
    line([V_cor_neg_e, V_n_g_neg_4], [-4, -4], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_n_g_6, Vc], [6, max_n_g], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_n_g_neg_4, Vc], [-4, max_n_g_neg], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g, max_n_g1], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g_neg, max_n_g_neg1], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vxx,VD], [6, 6], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vxx2,VD], [-4, -4], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    else
    line([V_cor_pos_e, VD], [6, 6], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([V_cor_neg_e, VD], [-4, -4], 'Color', 'black', 'LineWidth', 1.3, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g, max_n_g1], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    line([Vc,VD], [max_n_g_neg, max_n_g_neg1], 'Color', 'black', 'LineStyle', '--', 'LineWidth', 1.2, 'HandleVisibility', 'off');
    end
    hold off;
    lgd = legend('Location', 'northeastoutside');
    xlim([0, 1.05 * 150]);
    ylim([-4 * 1.3, 6 * 1.2]);
end
```

1.7 Output of Matlab code

```
(I) V—n Graph
Velocity of Fastest Turn: 32.84 m/s at 0 m
Load Factor for Fastest Turn: 3.29 at 0 m
Velocity of Tightest Turn: 13.52 m/s at 0 m
Load Factor for Tightest Turn: 1.40 at 0 m

(III) V(TAS)—n Graph
Velocity of Fastest Turn: 34.47 m/s at 1000 m
Load Factor for Fastest Turn: 3.12 at 1000 m
Velocity of Tightest Turn: 14.90 m/s at 1000 m
Load Factor for Tightest Turn: 1.40 at 1000 m

Velocity of Fastest Turn: 37.16 m/s at 2500 m
Load Factor for Fastest Turn: 2.87 at 2500 m
Velocity of Tightest Turn: 17.31 m/s at 2500 m
Load Factor for Tightest Turn: 1.40 at 2500 m

Velocity of Fastest Turn: 40.16 m/s at 4000 m
Load Factor for Fastest Turn: 2.63 at 4000 m
Velocity of Tightest Turn: 20.22 m/s at 4000 m
Load Factor for Tightest Turn: 1.39 at 4000 m

(II)  V—n Diagram with gust analysis taking nlim = 3
Gust velocity at 0 meters: 17.0688 m/s
Velocity of Fastest Turn: 32.84 m/s at 0 m
Load Factor for Fastest Turn: 3.29 at 0 m
Velocity of Tightest Turn: 13.52 m/s at 0 m
Load Factor for Tightest Turn: 1.40 at 0 m

Gust velocity at 1000 meters: 16.2688 m/s
```

```
Gust velocity at 2500 meters: 15.0688 m/s

Gust velocity at 4000 meters: 13.8688 m/s

(II)  V—n Diagram with gust analysis taking nmax_lim = 6
Gust velocity at 0 meters: 17.0688 m/s
Velocity of Fastest Turn: 32.84 m/s at 0 m
Load Factor for Fastest Turn: 3.29 at 0 m
Velocity of Tightest Turn: 13.52 m/s at 0 m
Load Factor for Tightest Turn: 1.40 at 0 m

Gust velocity at 1000 meters: 16.2688 m/s

Gust velocity at 2500 meters: 15.0688 m/s

Gust velocity at 4000 meters: 13.8688 m/s
```

1. **V-n Diagram**

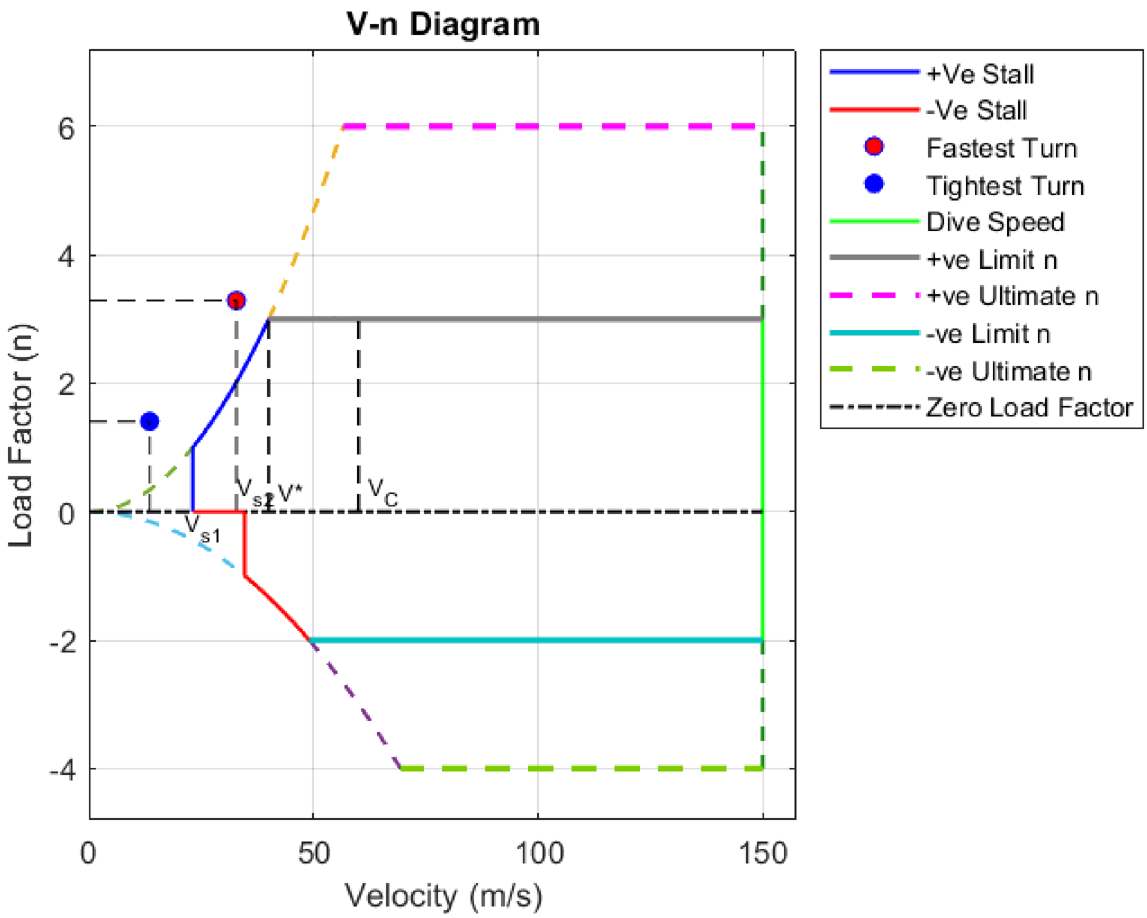
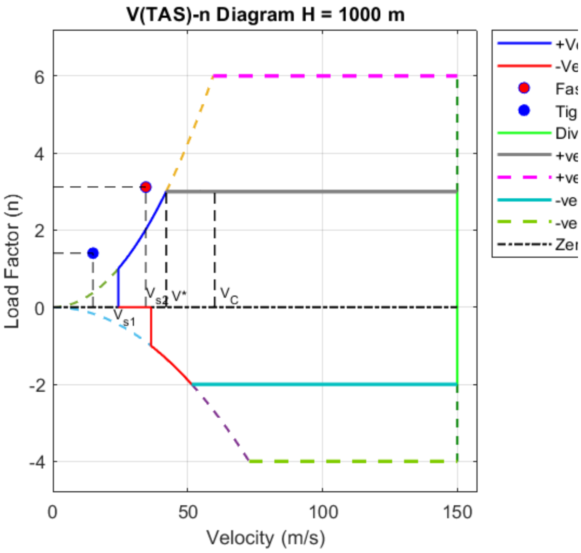
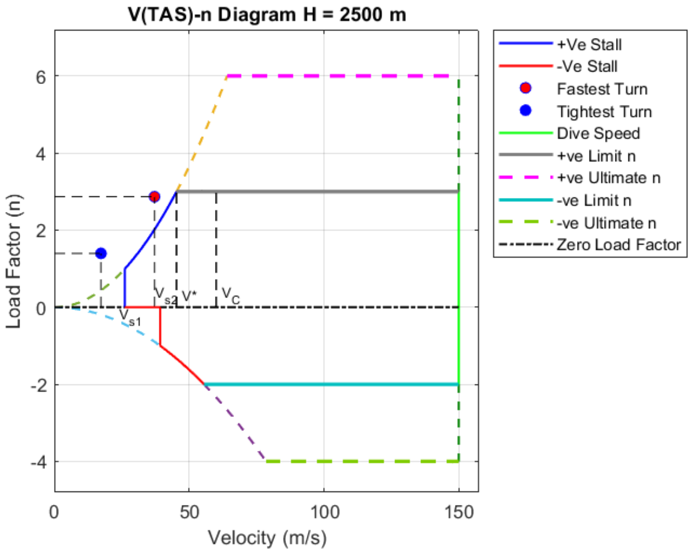


Figure 1.4: V-n Diagram

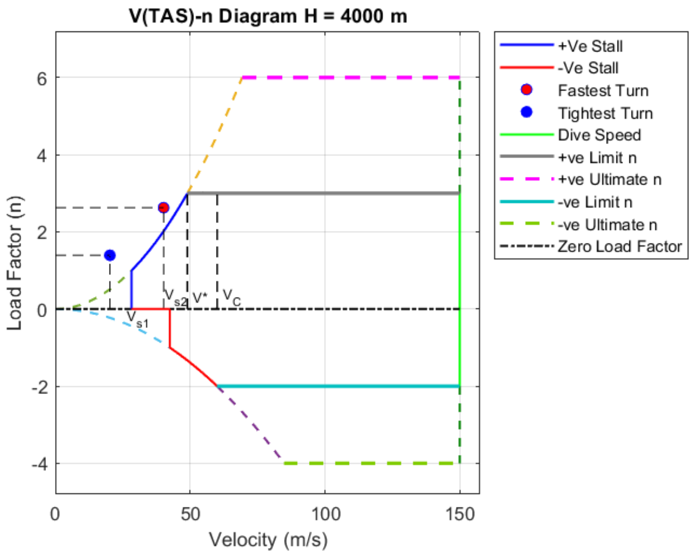
2. VTAS-n Diagram



(a) VTAS-n Diagram at 1000m



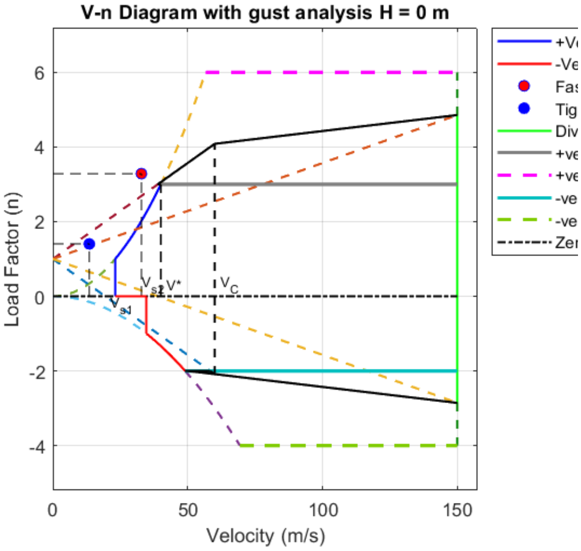
(b) VTAS-n Diagram at 2500m



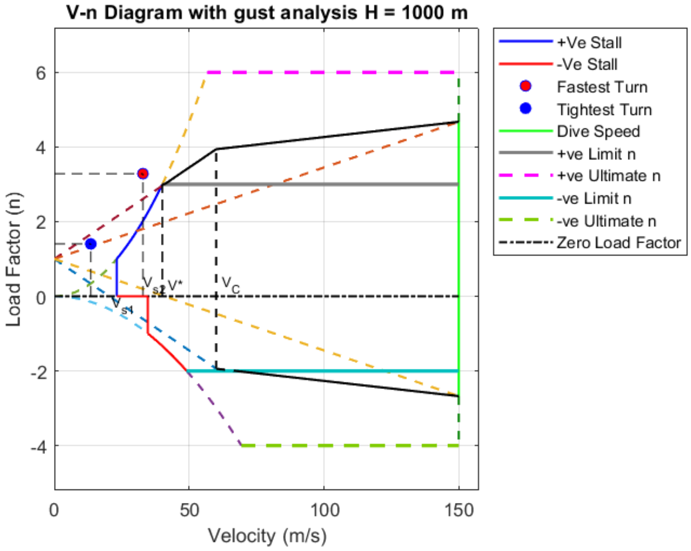
(c) VTAS-n Diagram at 4000m

Figure 1.5: VTAS-n Diagram

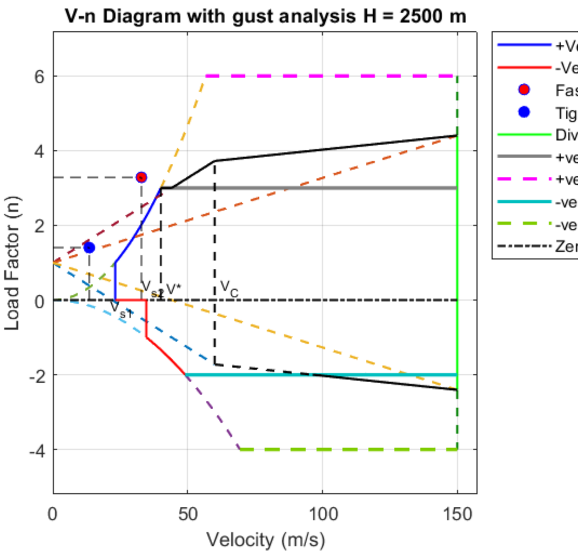
3. **V-n Diagram with gust analysis n_{lim}=3**



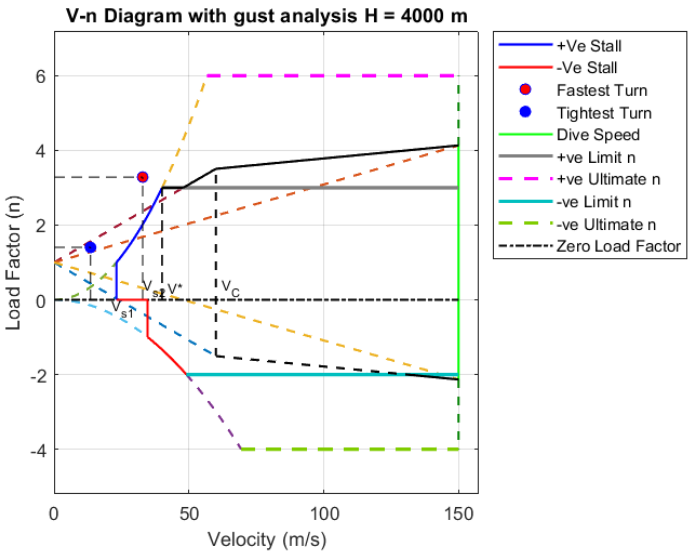
(a) V-n Diagram with gust analysis n_{lim}=3 at 0m



(b) V-n Diagram with gust analysis n_{lim}=3 at 1000m



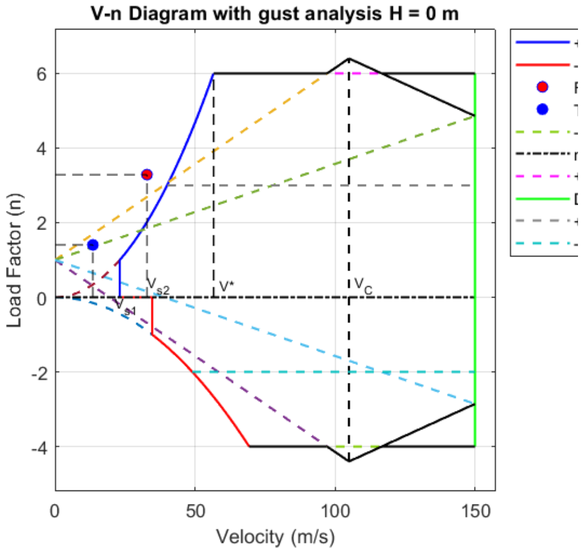
(c) V-n Diagram with gust analysis n_{lim}=3 at 2500m



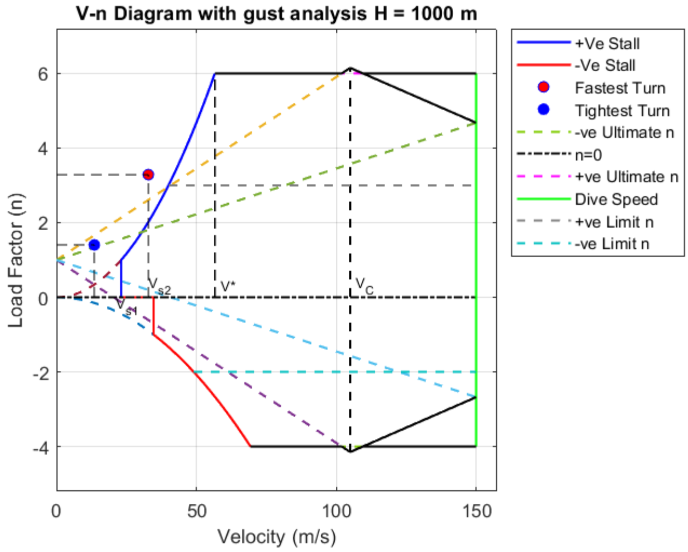
(d) V-n Diagram with gust analysis n_{lim}=3 at 4000m

Figure 1.6: V-n Diagram with gust analysis n_{lim}=3

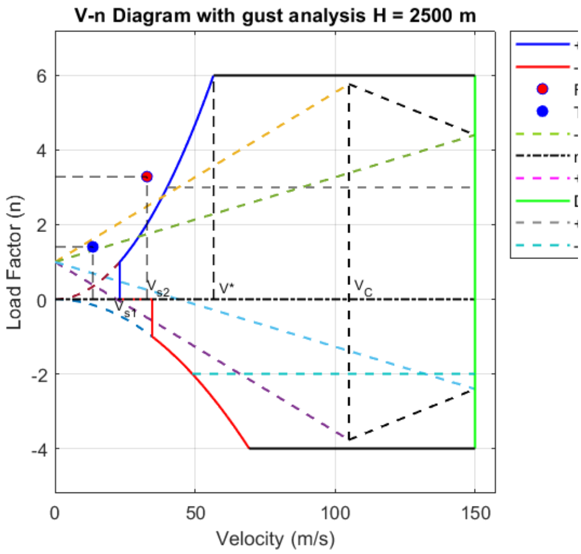
4. **V-n Diagram with gust analysis $n_{\max_{\lim}}$=6**



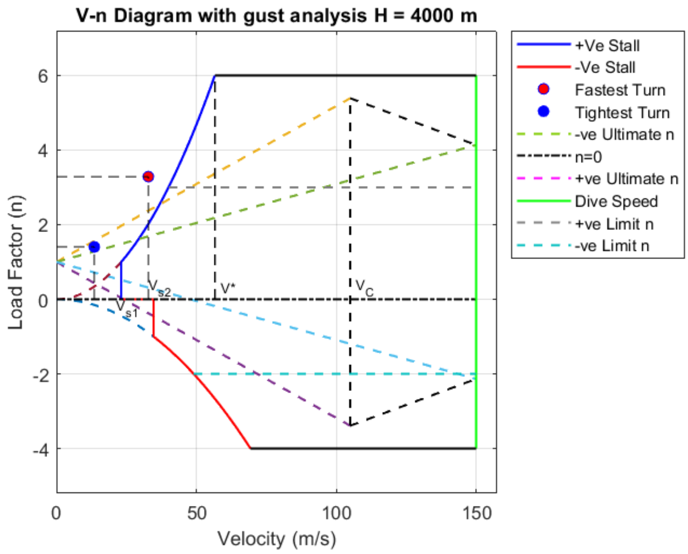
(a) V-n Diagram with gust analysis $n_{\lim}$=6 at 0m



(b) V-n Diagram with gust analysis $n_{\lim}$=6 at 1000m



(c) V-n Diagram with gust analysis $n_{\lim}$=6 at 2500m



(d) V-n Diagram with gust analysis $n_{\lim}$=6 at 4000m

Figure 1.7: V-n Diagram with gust analysis $n_{\max_{\lim}}$=6

Chapter 2

Comparison

In this section given comprehensive analysis of the aircraft's performance during tightest and fastest turns at various altitudes. The analysis includes a comparison of velocities, load factors, and recommended maneuvers based on stall velocities and corner velocities. The aim is to evaluate the feasibility of executing these extreme maneuvers and identify optimal conditions for maneuvering at different altitudes.

2.1 Specification

Table 2.1: Comparison of V-n Graphs and V(TAS)-n Graphs with Gust Analysis

Graph	Altitude (m)	Velocity (m/s)	Load Factor	Gust Velocity (m/s)
I) V-n Graph	0	32.84 (Fastest)	3.29 (Fastest)	-
	0	13.52 (Tightest)	1.40 (Tightest)	-
III) V(TAS)-n Graph	1000	34.47 (Fastest)	3.12 (Fastest)	-
	1000	14.90 (Tightest)	1.40 (Tightest)	-
	2500	37.16 (Fastest)	2.87 (Fastest)	-
	2500	17.31 (Tightest)	1.40 (Tightest)	-
	4000	40.16 (Fastest)	2.63 (Fastest)	-
	4000	20.22 (Tightest)	1.39 (Tightest)	-
II) V-n Diagram	0	32.84 (Fastest)	3.29 (Fastest)	17.0688
	0	13.52 (Tightest)	1.40 (Tightest)	-
	1000	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	16.2688
	2500	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	15.0688
	4000	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	13.8688
II) V-n Diagram (with $n_{\text{max}_{\text{lim}}}$=6)	0	32.84 (Fastest)	3.29 (Fastest)	17.0688
	0	13.52 (Tightest)	1.40 (Tightest)	-
	1000	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	16.2688
	2500	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	15.0688
	4000	Same V_{FT}, V_{TT}	Same n_{FT}, n_{TT}	13.8688

Table 2.2: Stall Velocity and Corner Velocity with Altitude

Altitude (m)	Stall Velocity (m/s)	Corner Velocity (m/s)
0	23.12	40.05
1000	24.27	42.04
2500	26.16	45.31
4000	28.28	48.97

2.2 Tightest Turn Analysis

2.2.1 Sea Level (0 m)

At sea level (0 m), the velocity for the tightest turn is 13.52 m/s, and the corresponding load factor is 1.40.

Analysis:

Considering the stall velocity at sea level 23.12 m/s, Now tightest turn velocity at sea level is 13.52 m/s which less than the stall velocity, because of this performing the tightest turn maneuver may not be feasible at this velocity. Additionally, checking the load factor of 1.40 for maneuvering indicates whether the aircraft can handle the load factor during the tightest turn. which is under limit but we can't do tightest turn for this calculated V_{tt} and n_{tt} so we have to increase velocity more than stall. According to Mohammad H. Sadraey's book on aircraft performance, if the tightest turn velocity is less than the corner velocity and the load factor is not within an acceptable range, increasing the velocity to the corner velocity is recommended for optimal maneuvering. As this will give us max. C_L because load factor is max. which is nothing but 3.So we have to accelerate to corner velocity 40.05 m/s.

2.2.2 Altitude = 1000 m

At an altitude of 1000 m, the velocity for the tightest turn is 14.90 m/s, and the load factor is 1.40.

Analysis:

Considering the stall velocity at 1000 m 24.27 m/s, Now tightest turn velocity at 1000 m is 14.90 m/s which less than the stall velocity, because of this performing the tightest turn maneuver may not be feasible at this velocity. Additionally, checking the load factor of 1.40 for maneuvering indicates whether the aircraft can handle the load factor during the tightest turn. which is under limit but we can't do tightest turn for this calculated V_{tt} and n_{tt} so we have to increase velocity more than stall. So similar to as mention above we have to accelerate to corner velocity 42.04 m/s.

2.2.3 Altitude = 2500 m

At an altitude of 2500 m, the velocity for the tightest turn is 17.31 m/s, and the load factor is 1.40.

Analysis:

Considering the stall velocity at 2500 m 26.17 m/s, Now tightest turn velocity at 2500 m is 17.31 m/s which less than the stall velocity, because of this performing the tightest turn maneuver may not be feasible at this velocity. Additionally, checking the load factor of 1.40 for maneuvering indicates whether the aircraft can handle the load factor during the tightest turn. which is under limit but we can't do tightest turn for this calculated V_{tt} and n_{tt} so we have to increase velocity more than stall. So similar to as mention above we have to accelerate to corner velocity 45.31 m/s.

2.2.4 Altitude = 4000 m

At an altitude of 4000 m, the velocity for the tightest turn is 20.22 m/s, and the load factor is 1.39.

Analysis:

Considering the stall velocity at 4000 m 28.28 m/s, Now tightest turn velocity at 4000 m is 20.22 m/s which less than the stall velocity, because of this performing the tightest turn maneuver may not be feasible at this velocity. Additionally, checking the load factor of 1.40 for maneuvering indicates whether the aircraft can handle the load factor during the tightest turn. which is under limit but we can't do tightest turn for this calculated V_{tt} and n_{tt} so we have to increase velocity more than stall. So similar to as mention above we have to accelerate to corner velocity 48.97 m/s.

2.3 Fastest Turn Analysis

2.3.1 Sea Level (0 m)

At sea level (0 m), the velocity for the Fastest turn is 34.84 m/s, and the corresponding load factor is 3.29.

Analysis:

Considering the stall velocity at sea level 23.12 m/s, Now Fastest turn velocity at sea level is 34.84 m/s which under stall velocity limit, Now Fastest turn load factor 3.29 which is more than max. load factor limit at fastest turn velocity is nothing but 2.02, So we can't do tightest turn for this calculated V_{tt} and n_{tt}.So for fastest turn one way we can decrease load factor to under limit, another better way According to Mohammad H. Sadraey's book on aircraft performance, if the Fastest turn velocity is less than the corner velocity and the load factor is not within an acceptable range, increasing the velocity to the corner velocity is recommended for optimal maneuvering. As this will give us max. C_L because load factor is max. which is nothing but 3. So we have to accelerate to corner velocity 40.05 m/s.

2.3.2 Altitude = 1000 m

At an altitude of 1000 m, the velocity for the Fastest turn is 34.47 m/s, and the load factor is 3.12.

Analysis:

Considering the stall velocity at 1000 m 24.27 m/s, Now Fastest turn velocity at 1000 m is 34.47 m/s which under stall velocity limit, Now Fastest turn load factor 3.12 which is more than max. load factor limit at fastest turn velocity is nothing but 2.02, So we can't do tightest turn for this calculated V_{tt} and n_{tt}.So for fastest turn one way we can decrease load factor to under limit, another better way similar to as mention above we have to accelerate to corner velocity 42.04 m/s.

2.3.3 Altitude = 2500 m

At an altitude of 2500 m, the velocity for the Fastest turn is 37.16 m/s, and the load factor is 2.87.

Analysis:

Considering the stall velocity at 2500 m 26.16 m/s, Now Fastest turn velocity at 2500 m is 37.16 m/s which under stall velocity limit, Now Fastest turn load factor 2.87 which is more than max. load factor limit at fastest turn velocity is nothing but 2.02, So we can't do tightest turn for this calculated V_{tt} and n_{tt}.So for fastest turn one way we can decrease load factor to under limit, another better way similar to as mention above we have to accelerate to corner velocity 45.31 m/s.

2.3.4 Altitude = 4000 m

At an altitude of 4000 m, the velocity for the Fastest turn is 40.16 m/s, and the load factor is 2.63.

Analysis:

Considering the stall velocity at 4000 m 28.28 m/s, Now Fastest turn velocity at 4000 m is 40.16 m/s which under stall velocity limit, Now Fastest turn load factor 2.63 which is more than max. load factor limit at fastest turn velocity is nothing but 2.02, So we can't do tightest turn for this calculated V_{tt} and n_{tt}.So for fastest turn one way we can decrease load factor to under limit, another better way similar to as mention above we have to accelerate to corner velocity 48.97 m/s.

2.4 Conclusion

the tightest turn analysis highlights the importance of considering stall velocities and load factors at different altitudes. To achieve optimal maneuverability, adjustments such as accelerating to corner velocities are recommended, as per Mohammad H. Sadraey's insights on aircraft performance.
the analysis of the fastest turn underscores the significance of managing load factors within acceptable limits. Accelerating to the corner velocity is recommended to achieve optimal maneuverability and adhere to safety constraints.