Def-Space Tech Winter Internship 2025

Trim, Thrust Required, and Power Required Analysis of a Cropped Delta Wing UAV using MATLAB

Aircraft Design

Project by -

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1. PROJECT REPORT

a) Problem Description

Unmanned Aerial Vehicles (UAVs) require careful performance analysis to ensure efficient and stable operation across different flight conditions. Cropped Delta Wing UAVs, considered unconventional due to the absence of the traditional stabilizing surfaces like horizontal or vertical tails, have complex flight dynamics that change significantly with varying flight conditions compared to conventional aircraft designs. Understanding these changes is essential for safety, stability, and mission efficiency.

The objective of this project is to analyse the trim condition, thrust required, and power required of a cropped delta wing UAV in steady, level flight using specified geometric and aerodynamic parameters. The study examines how key performance variables—lift coefficient, drag coefficient, flight velocity, thrust required, and power required—vary with angle of attack and influence stability and endurance.

The analysis assumes steady, level flight, where lift balances weight, thrust balances drag, and the pitching moment is zero. The UAV is modelled as a wing-alone configuration using linear aerodynamic relations and a parabolic drag polar, while effects such as unsteady aerodynamics, propulsion dynamics, and atmospheric variations are neglected.

A MATLAB-based iterative method is employed in which the angle of attack is varied over a defined range. For each angle, the trim elevator deflection is calculated from the pitching moment equilibrium, followed by the evaluation of lift, velocity, drag, thrust required, power required, and performance metrics such as lift-to-drag ratio and endurance parameters. The results are presented through plots to identify key performance trends and optimal operating conditions.

b) Geometry and Aerodynamic Modelling

Geometry

The UAV is modelled as a cropped delta wing, wing-alone configuration.
The following geometric parameters are computed:

Taper ratio

$$\lambda = \frac{C_t}{C_r} = 0.1667 \qquad \text{Equation (1.1)}$$

Wing planform area

$$S = \frac{b}{2} C_r (1 + \lambda) = 0.7875 \qquad \text{Equation (1.2)}$$

Aspect ratio

$$AR = \frac{b^2}{S} = 2.8571 \qquad \text{Equation (1.3)}$$

Note- The induced drag correction factor k is calculated to account for the additional drag generated due to lift production by the wing.

Induced Drag Correction Factor

$$k = \frac{1}{\pi e AR} = 0.1252 \qquad \text{Equation (1.4)}$$

The calculated value of k is subsequently used in aerodynamic modelling of the UAV

These above calculated parameters are assumed constant for all flight conditions and are used in the aerodynamic and performance calculations.

Aerodynamic Modelling

The aerodynamic behaviour of the UAV is modelled using linear aerodynamic coefficient relationships, valid over the considered angle of attack range.

Lift coefficient

$$C_L = C_{L0} + C_{L\alpha}\alpha + C_{L\delta_e}\delta_e \qquad \text{Equation (2.1)}$$

Pitching Moment Equation

$$C_m = C_{m0} + C_{m\alpha}\alpha + C_{m\delta_e}\delta_e \qquad \text{Equation (2.2)}$$

This expression accounts for the inherent pitching tendency of the wing and the control effect of elevator deflection.

Drag Modelling

The drag coefficient is modelled using a parabolic drag polar:

$$C_D = C_{D0} + kC_L^2 \qquad \text{Equation (3.1)}$$

This formulation captures both:

- Zero-lift drag/Parasite drag (C_{D0})
- Lift-dependent induced drag due to finite wing effects (kC_L^2)

Modelling Assumptions

- Flow is incompressible
- Aerodynamic coefficients vary linearly with angle of attack
- Unsteady aerodynamic and nonlinear high-angle effects are neglected
- The UAV operates in steady, level flight conditions

c) Trim Equations and Assumptions

For steady, level flight, the UAV must satisfy force and moment equilibrium conditions. In particular, trimmed flight requires that the net pitching moment about the center of gravity be zero.

From *Equation (2.2)*, the pitching moment coefficient is modelled as:

$$C_m = C_{m0} + C_{m\alpha}\alpha + C_{m\delta_e}\delta_e$$

For trimmed flight:

$$C_m = 0 \qquad \text{Equation (4.1)}$$

Substituting into the pitching moment equation:

$$0 = C_{m0} + C_{m\alpha}\alpha + C_{m\delta_e}\delta_e \qquad \text{Equation (4.2)}$$

Solving for the trim elevator deflection:

$$\delta_{e,\text{trim}} = -\frac{C_{m0} + C_{m\alpha}\alpha}{C_{m\delta_e}} \qquad \text{Equation (4.3)}$$

This expression is used to compute the required elevator deflection for each angle of attack considered in the analysis.

Once the trim elevator deflection is obtained, the corresponding lift coefficient is calculated using *Equation (2.1)* -

$$C_L = C_{L0} + C_{L\alpha}\alpha + C_{L\delta_e}\delta_{e,\text{trim}}$$

This ensures that the lift coefficient used in performance calculations corresponds to a trimmed flight condition.

Trim and Flight Assumptions

- The UAV is in steady, level flight
- Net pitching moment about the center of gravity is zero
- Aerodynamic coefficients vary linearly with angle of attack and elevator deflection
- Control surface deflection is sufficiently small for linear theory to apply
- Dynamic effects such as pitch rate and angular acceleration are neglected

d) MATLAB Algorithm

The trim and performance analysis is implemented using a modular MATLAB algorithm consisting of a main script (main.m) and two supporting functions (constParams.m and loop.m). The algorithm separates constant geometric preprocessing from angle-of-attack–dependent calculations to improve clarity and computational efficiency.

Before varying the angle of attack, geometric parameters that remain constant throughout the analysis are computed using a separate function. These include taper ratio, wing planform area, aspect ratio, and the induced drag correction factor. Since these parameters depend only on wing geometry and not on flight condition, they are calculated once and reused in all subsequent computations.

The angle of attack is varied from $0°$to $12°$in increments of $0.5°$. For each angle of attack, a corresponding trimmed steady-flight condition is evaluated. Arrays are preallocated to store the computed trim, aerodynamic, and performance parameters for each angle of attack.

The angle of attack values are converted from degrees to radians prior to computation to ensure consistency with the aerodynamic coefficients, which are defined per radian and the following values are calculated with each iteration:

1. **Trim Elevator Deflection**

$$\delta_{e,\text{trim}} = -\frac{C_{m0} + C_{m\alpha}\alpha}{C_{m\delta_e}} \qquad \text{Equation (4.3)}$$

2. **Lift Coefficient at Trim**

$$C_L = C_{L\alpha}\alpha + C_{L\delta_e}\delta_e \qquad \text{Equation (2.1)}$$

3. **Flight Velocity (Lift Equilibrium)**

   For steady, level flight, lift balances weight:

$$L = W = \frac{1}{2}\rho V^2 S C_L \qquad \text{Equation (5.1)}$$

   Solving for flight velocity:

$$V = \sqrt{\frac{2W}{\rho S C_L}} \qquad \text{Equation (5.2)}$$

4. **Drag Coefficient**

$$C_D = C_{D0} + kC_L^2 \qquad \text{Equation (3.1)}$$

5. **Thrust Required**
   In steady flight, thrust required equals drag:

$$T_r = D = \frac{1}{2}\rho V^2 S C_D \qquad \text{Equation (5.3)}$$

6. **Power Required**

$$P_r = T_r V \qquad \text{Equation (5.4)}$$

7. **Performance Metrics**
   The following performance parameters are evaluated:

$$\frac{C_L}{C_D}, \frac{C_L^{3/2}}{C_D}$$

Handling Zero-Degree Edge Case

At α = 0°, several assumptions in aircraft performance theory break or become singular, especially for a wing-alone cropped delta UAV. At α = 0°, the aircraft trim solutions mathematically exist but physically cannot sustain steady level flight. The corresponding lift coefficient approaches zero, resulting in non-physical velocity and power requirements. Therefore, zero angle of attack is treated as an analytical edge case rather than a valid operating point.

To handle this edge case, the velocity, thrust, and power values corresponding to zero angle of attack are explicitly excluded from further analysis by assigning undefined values. This ensures numerical stability and prevents distortion of performance plots.

Only physically valid data points are used for visualization. The computed parameters are plotted to show their variation with angle of attack and flight velocity, including trim behaviour, aerodynamic coefficients, thrust required, power required, and performance metrics.

e) Results and Discussions

Fig. 1 shows the angle of attack at which the UAV is simultaneously in lift equilibrium (L=W) and in moment equilibrium ($C_m = 0$) for a given flight speed. Basically, it tells what angle the UAV must fly at to remain trimmed for that specific velocity. The trend seen in the plot is of α_{trim} decreasing non-linearly with increasing velocity.

Region-wise Interpretation

Low-speed region (≈ 10–15 m/s)

- Very high α_{trim} (6°–12°)
- Aircraft is flying near stall
- Small speed variation leads to large α_{trim} increase

Therefore, aerodynamically risky region

Medium-speed region (≈ 18–30 m/s)

- Moderate α_{trim} (≈ 2°–4°)
- Good lift margin
- Stable trim behaviour

Therefore, **most practical operating region**

High-speed region (≈ 35–50 m/s)

- Very low α_{trim} (< 1°)
- Parasite drag dominates
- Higher thrust and power needed

Therefore, inefficient despite being safe from stall

Fig. 2 shows the relation between angle of attack α and trim elevator deflection $\delta_{e,trim}$. It answers the question of the exact elevator angle relative to its neutral position required to maintain trim at a specific α. The trend seen in the plot is of $\delta_{e,trim}$ decreasing linearly with increase in α.

The nature of this plot can also be realised from the trim equation,

$$0 = C_{m0} + C_{m\alpha}\alpha + C_{m\delta_e}\delta_e \qquad \text{Equation (4.2)}$$

After rearranging,

$$\delta_{e,\mathrm{trim}} = -\frac{C_{m0} + C_{m\alpha}\alpha}{C_{m\delta_e}} \qquad \text{Equation (4.3)}$$

Alternatively, of the form:

$$\delta_{e,\mathrm{trim}} = c + m\alpha \qquad \text{(Linear relation)}$$

Therefore, forming a straight-line plot

Physical Interpretation

Sign convention taken:

Positive δ_e = Nose-up pitching moment
Negative δ_e = Nose-down pitching moment

As α increases, the wing produces more nose-up pitching moment. The elevator must corresponding deflect more nose-down to counteract that moment. This leads to negative slope.

At high angles of attack, the required elevator deflection becomes large, indicating increased control effort and reduced control margin.

Fig. 3 represents the lift coefficient C_L generated by the wing for every specified angle of attack α. The plot shows a linear positive slope relation (pre-stall due to lack of curvature) between the two parameters.

The linear dependence is evident from the lift coefficient equation,

$$C_L = C_{L0} + C_{L\alpha}\alpha + C_{L\delta_e}\delta_e \qquad \text{Equation (2.1)}$$

C_{L0} and $C_{L\alpha}$ are constants from the given parameters
δ_e varies linearly with α as seen from the previous plot

Therefore, overall linear dependence and straight-line plot.
The slope of the line represents $C_{L\alpha}$.

Physical Interpretation

Increase in α increases camber, circulation and pressure difference between the upper and lower surfaces of the wing. Therefore, lift coefficient increases.

The increase in lift coefficient directly affects the flight velocity required to maintain steady, level flight.

Fig. 4 shows the drag C_D experienced by the aircraft at varied angle of attacks α. The trend seen in the plot is a non-linear increasing curve.

$$C_D = C_{D0} + kC_L^2 \qquad \text{Equation (3.1)}$$

C_L varies linearly with α, so C_L^2 varies quadratically/parabolically. Hence, the reason for non-linearity of the curve.

Region-wise Interpretation

Low α (0–2°)

- Drag dominated by parasite drag
- Induced drag is minimal
- $C_D \approx C_{D0}$

Therefore, **efficient cruise region**

Moderate α (4–8°)

- Induced drag becomes significant
- Total drag increases faster

Therefore, **typical endurance flight region**

High α (10–12°)

- Induced drag dominates
- Sharp rise in C_D
- Aerodynamically inefficient

Therefore, high drag and high control effort

At higher angles of attack, the increased lift coefficient leads to a rapid rise in induced drag, which significantly influences thrust and power requirements.

Fig. 5 depicts how much thrust is needed to maintain steady level flight at a specific flight velocity. In other words, how much thrust is required to exactly balance aerodynamic drag according to *Equation 5.3*.

$$T_r = D = \frac{1}{2}\rho V^2 S C_D \qquad \text{Equation (5.3)}$$

The plot exhibits a U-shaped curve that reflects two competing drag components – induced and parasite.

Region-wise Interpretation

Low-speed region (≈ 12–18 m/s)

- High angle of attack leads to high $C_L$which gives high induced drag
- Thrust required is large

Therefore, inefficient and risky

Mid-speed region (≈ 20–30 m/s)

- Balanced lift and drag
- Induced drag decreases and parasite drag still moderate
- Best aerodynamic balance
- Efficient cruise region

Therefore, **minimum thrust required occurs here**

High-speed region (≥ 35 m/s)

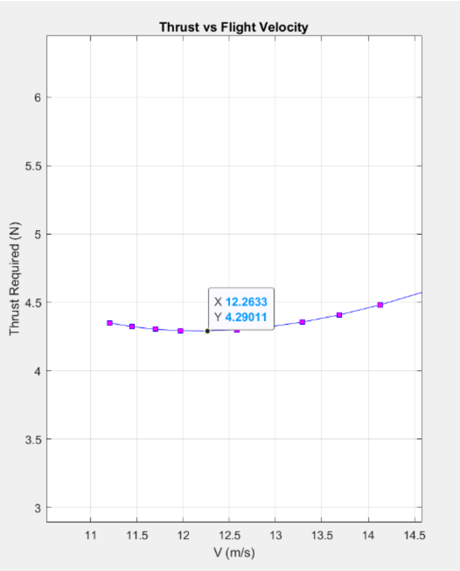
- Low angle of attack
- Parasite drag $\propto V^2$
- Drag increases rapidly

Therefore, thrust required increases again

From the plot analysis, an optimum operating point can be concluded. The flight velocity at which thrust required is minimum. Such a parameter leads to:

- Minimum drag
- Maximum aerodynamic efficiency

The required point occurs is the lowest point of the curve:



Therefore, the **optimum flight velocity ≈ 12.3 m/s** requiring **minimum thrust ≈ 4.3 N**

Fig. 6 represents how much power is required for steady-level flight at a specific velocity. Power required is the rate at which the propulsion system must supply energy to overcome aerodynamic drag and maintain steady, level flight at a given speed. Lower the power, longer the endurance.

From previous sections we know,

$$P_r = T_r V \quad \text{Equation (5.4)}$$

The curve of this plot is therefore very similar to the thrust-velocity curve.

Region-wise Interpretation

Low-speed region (≈ 12–18 m/s)

- High thrust required due to induced drag
- Velocity is small
- Power remains moderate

Therefore, long endurance is possible but risky

Moderate speed region (≈ 18–25 m/s)

- Thrust decreases
- Velocity increases
- Stable trim condition
- Power reaches a minimum

Therefore, **best endurance flight condition**

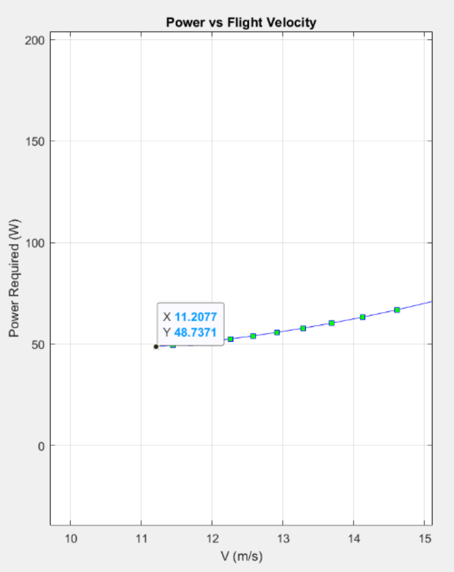
High-speed region (≥ 30 m/s)

- Thrust increases sharply
- Velocity is large
- Power increases very rapidly

Therefore, inefficient

Similar to the previous plot, we can conclude an optimum operating point. The flight velocity at which power is minimum and endurance is maximum.

The required point occurs at the curve minimum:



This minimum power condition is particularly important for endurance-focused UAV missions, as operating near this point minimizes energy consumption.

Therefore, the **optimum flight velocity ≈ 11.2 m/s** with **minimum power consumed** ≈ **48.7 W**

Note- The optimum flight velocity for minimum power consumption is lower than that for minimum thrust required

Fig. 7 talks about the performance metric C_L/C_D against flight velocity. It answers the questions of how aerodynamically efficient the UAV is at a specific speed. The plot is curved and reflects the trade-offs between induced drag and parasite drag.

Physical Meaning

C_L/C_D represents the amount of lift produced per unit drag.

- High C_L/C_D means very aerodynamically efficient
- Low C_L/C_D means lots of drag for little lift

Region-wise Interpretation

Low-speed region (≈ 11–14 m/s)

- High lift, high induced drag
- Efficiency rising toward peak

Therefore, efficiency not maximum yet

Peak region (≈ 13–15 m/s)

- Balanced induced and parasite drag
- Drag is minimized relative to lift
- Maximum C_L/C_Doccurs

Therefore, **aerodynamically optimal condition**

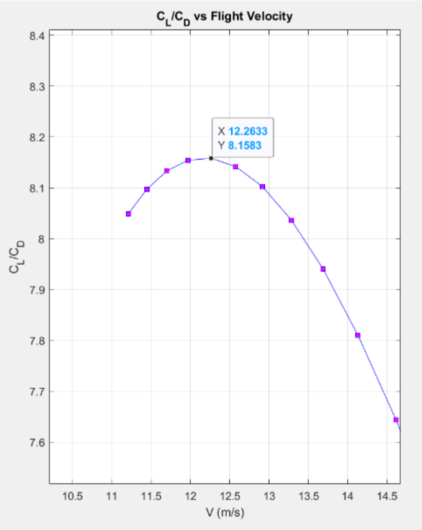
High-speed region (≥ 20 m/s)

- Very low α
- Parasite drag dominates
- Drag increases faster than lift

Therefore, efficiency drops rapidly

The plot shows a clear peak at an intermediate flight velocity, indicating the condition of maximum aerodynamic efficiency. This point corresponds to optimal cruise conditions where the UAV achieves maximum lift for a given drag penalty.

The required point is the highest point in the curve:



The point indicates the speed required for maximum range. It corresponds to:

- Minimum drag
- Minimum thrust required
- Best distance per unit energy

Therefore, the **optimum flight velocity ≈ 12.3 m/s** for **maximum C_L/C_D ratio ≈ 8.2**

Fig. 8 links the performance efficiency metric $C_L^{3/2}/C_D$ to flight velocity. It tells how suitable a specific flight velocity is for maximum endurance flight. The plot shows a curved line related to the two drags.

Physical Meaning

$C_L^{3/2}/C_D$ measures how efficiently lift can be produced for minimum power

From lift equilibrium,

$$V = \sqrt{\frac{2W}{\rho S C_L}} \qquad \text{Equation (5.2)}$$

Alternatively,

$$V \propto \sqrt{\frac{1}{C_L}} \qquad \text{Equation (6.1)}$$

From power required and thrust required,

$$P = T_r V = DV = \frac{1}{2}\rho V^3 S C_D \qquad \text{Equation (5.3) and Equation (5.4)}$$

Substituting *Equation (6.1)* in the above equation,

$$P \propto = \frac{C_D}{C_L^{\frac{3}{2}}}$$

Therefore, maximum $C_L^{3/2}/C_D$ gives minimum power which leads to maximum endurance.

Region-wise Interpretation

Low-speed region (≈ 11–14 m/s)

- High α, high C_L
- Induced drag increasing rapidly
- High $C_L^{3/2}/C_D$
- Favourable for endurance

Therefore, efficiency is high initially but not optimal yet.

Peak region (≈ lowest velocity point)

- Induced drag dominates

- Maximum $C_L^{3/2}/C_D$
- Minimum power required

Therefore, **maximum endurance condition**

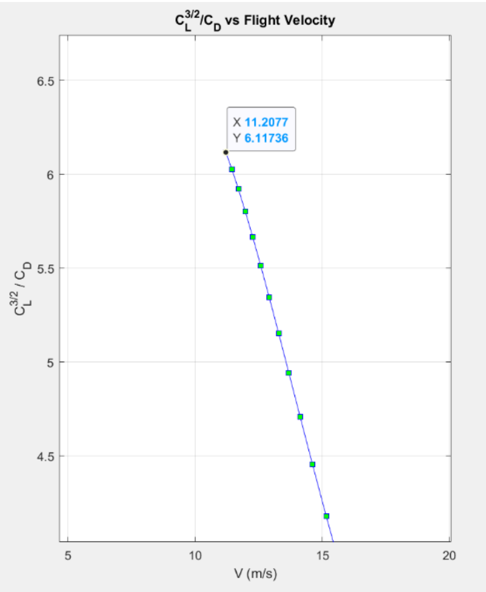
High-speed region (≥ 20 m/s)

- C_L drops rapidly
- Parasite drag dominates
- Efficiency collapses

Therefore, extremely inefficient for endurance

From plot analysis, we find the most optimum endurance point. The flight velocity at which maximum endurance or maximum $C_L^{3/2}/C_D$ occurs.

The required points occurs where the curve is at its maximum:



Therefore, **optimum flight velocity ≈ 11.2 m/s** for **maximum endurance metric $C_L^{3/2}/C_D \approx 6.1$**

Note- This optimum flight velocity is less than that for maximum C_L/C_D and same as that for minimum power consumed.

Overall Observations

Trim angle of attack decreases with increasing velocity, while elevator deflection varies linearly with angle of attack, indicating stable longitudinal trim and adequate control authority. The lift coefficient increases linearly with angle of attack and the drag coefficient increases nonlinearly, confirming operation within the linear pre-stall regime and validating the aerodynamic model used.

The performance plots identify clear optimal operating conditions. Thrust and power required exhibit classical U-shaped trends, with minimum thrust occurring at a higher speed than minimum power. The peak of C_L/C_Dcorresponds to the maximum range condition, while the peak of $C_L^{3/2}/C_D$corresponds to the maximum endurance condition at lower speed. These results highlight the trade-off between efficiency, speed, and energy consumption and are consistent with classical fixed-wing performance theory.

f) Key Performance Trends

1. Trim angle of attack decreases nonlinearly with increasing flight velocity; low-speed flight requires high α (near stall), while high-speed flight occurs at very low α with higher parasite drag.

2. Trim elevator deflection varies linearly with angle of attack; higher α demands larger nose-down deflections, indicating increased control effort and reduced control margin at high α.

3. Lift coefficient increases linearly with angle of attack, confirming operation within the linear pre-stall regime and a predictable lift response.

4. Drag coefficient increases nonlinearly with angle of attack due to induced drag dominance at high lift coefficients, while parasite drag dominates at low α.

5. Thrust required exhibits a U-shaped variation with velocity, with high thrust at low speeds (induced drag) and high speeds (parasite drag), and a distinct minimum thrust condition at an intermediate velocity.

6. Power required also follows a U-shaped trend, with a minimum at a lower velocity than the minimum thrust condition, representing the maximum endurance operating point.

7. The lift-to-drag ratio (C_L/C_D) reaches a maximum at an intermediate velocity, corresponding to the maximum range condition and minimum drag state.

8. The $C_L^{3/2}/C_D$ metric peaks at a lower velocity than C_L/C_D, identifying the maximum endurance condition and aligning with minimum power required.

9. Zero angle-of-attack conditions do not satisfy lift equilibrium and are excluded from the performance analysis.

10. Overall, trim, aerodynamic efficiency, and propulsion requirements are strongly coupled, and numerical analysis is essential for identifying optimal operating conditions of the cropped delta wing UAV.

2. MATLAB CODE

main.m

```
%% Constant Parameters Calculation

[taper_ratio,S,AR,k]=constParams();   % from constParams.m

%% AOA Loop

alpha=0:0.5:12;  % varying angle of attacks
                 % creates a 1x25 matrix of values from 0 to 12 with a step value
of 0.5

[deltae,cl,cd,v,t,p,metric1,metric2]=deal(zeros(1,25)); % assigns an all zero 1x25
matrix to all variables
                                                        %deltae-trimmed elevator
deflection
                                                        % cl - trimmed lift
coefficient
                                                        %cd-corresponding drag
coefficient
                                                        % v - corresponding
velocity
                                                        % t - corresponding thrust
                                                        % p - corresponding power
                                                        % metric1 - cl/cd
                                                        % metric2- (cl^(3/2))/cd

% main computing loop
for i=1:length(alpha)

    aoa=deg2rad(alpha(i));  % degrees converted to radians for computation

    % assigns computed value to index in each matrix specified by i
    [deltae(i),cl(i),cd(i),v(i),t(i),p(i)]=loop(aoa,k,S);  % from loop.m

    % handling zero aoa edge case
    if alpha(i)==0
        [v(i),t(i),p(i)]=deal(NaN);
    end

end
deltae=rad2deg(deltae);  % radians converted back to degrees after computation
```

```
%Computing performance metrics
metric1=cl./cd;
metric2=(cl.^(3/2))./cd;


%% Visualization

valid=~isnan(v); % to exclude all NaNs from plots

figure(1)

% 1. Trim Angle of Attack vs Flight Velocity
plot(v(valid),alpha(valid),'-bs','MarkerFaceColor','m')
grid on
xlabel('V (m/s)')
ylabel('\alpha (deg)')
title('Trim Angle of Attack vs Flight Velocity')

figure(2)

% 2. Trim Elevator Deflection vs Angle of Attack
subplot(2,3,1)
plot(alpha,deltae,'-bs','MarkerFaceColor','m')
grid on
xlabel('\alpha (deg)')
ylabel('\delta_e (deg)')
title('Trim Elevator Deflection vs Angle of Attack')

% 3. Trim Lift Coefficient vs Angle of Attack
subplot(2,3,3)
plot(alpha,cl,'-bs','MarkerFaceColor','g')
grid on
xlabel('\alpha (deg)')
ylabel('C_L')
title('Trim Lift Coefficient vs Angle of Attack')

% 4. Trim Drag Coefficient vs Angle of Attack
subplot(2,3,5)
plot(alpha,cd,'-bs','MarkerFaceColor','c')
grid on
```

```
xlabel('\alpha (deg)')
ylabel('C_D')
title('Trim Drag Coefficient vs Angle of Attack')

figure(3)

% 5. Thrust vs Flight Velocity
subplot(1,2,1)
plot(v(valid),t(valid),'-bs','MarkerFaceColor','m')
grid on
xlabel('V (m/s)')
ylabel('Thrust Required (N)')
title('Thrust vs Flight Velocity')

% 6. Power vs Flight Velocity
subplot(1,2,2)
plot(v(valid),p(valid),'-bs','MarkerFaceColor','g')
grid on
xlabel('V (m/s)')
ylabel('Power Required (W)')
title('Power vs Flight Velocity')

figure(4)

% 7. C_L/C_D vs Flight Velocity
subplot(1,2,1)
plot(v(valid),metric1(valid),'-bs','MarkerFaceColor','m')
grid on
xlabel('V (m/s)')
ylabel('C_L/C_D')
title('C_L/C_D vs Flight Velocity')

% 8. C_L^{3/2}/C_D vs Flight Velocity
subplot(1,2,2)
plot(v(valid),metric2(valid),'-bs','MarkerFaceColor','g')
grid on
xlabel('V (m/s)')
ylabel('C_L^{3/2} / C_D')
title('C_L^{3/2}/C_D vs Flight Velocity')
```

constParams.m

```
% Pre-Processing Calculations (done before varying angle of attack)
function [taper_ratio,wing_area,aspect_ratio,k] = constParams()

%% Given data
% Geometry
cr=0.9; % Wing root chord length
ct=0.15; % Wing tip chord length
b=1.5; % Wing span
e=0.89; % Oswald efficiency factor

%% Calculations
% Taper ratio
taper_ratio=ct/cr;

% Wing area
wing_area=(b/2)*cr*(1+taper_ratio);

% Aspect ratio
aspect_ratio=(b^2)/wing_area;

% Induced drag correction factor
k=1/(pi*e*aspect_ratio);

end
```

loop.m

```
% Calculations done with every iteration in angle of attack


function [trim_eldef,trim_lift_coeff,drag_coeff,velocity,thrust,power] =
loop(aoa,k,S)


%% Given data


% Aerodynamic coefficient
cd0=0.03;            % Zero-lift drag coefficient
cm0=0.01;            % Zero AOA pitching moment coefficient
cl0=0;               % assumed since not specified
clalpha=2.92;        % Lift curve slope (per radian)
cldelta=0.265;       % Lift due to elevator deflection
cmalpha=-0.292;      % Pitching moment due to AOA
cmdelta=-0.4;        % Pitching moment due to elevator deflection
```

```
% Flight conditions
uav_mass=3.5;
air_density=1.225;
g=10;
uav_weight=uav_mass*g;

%% Calculations

% Trim elevator deflection
% cm = cm0 + cmalpha*AOA + cmdelta*eldef = 0
trim_eldef=-((cm0+cmalpha*aoa)/cmdelta);  % in radians

% Trim lift coefficient
% cl = cl0 + clalpha*aoa + cldelta*eldef
trim_lift_coeff=cl0+clalpha*aoa+cldelta*trim_eldef;

% Drag coefficient
%cd = cd0 + k*(cl^2)
drag_coeff=cd0+k*(trim_lift_coeff^2);

% Velocity
% Lift = Weight = 0.5*air_density*(v^2)*S*cl
velocity=sqrt(uav_weight/(0.5*air_density*S*trim_lift_coeff));

% Thrust
% Thrust = Drag = 0.5*air_density*(v^2)*S*cd
thrust=0.5*air_density*(velocity^2)*S*drag_coeff;

% Power
%Power=Thrust*Velocity
power=thrust*velocity;

end
```

3. PLOTS AND FIGURES

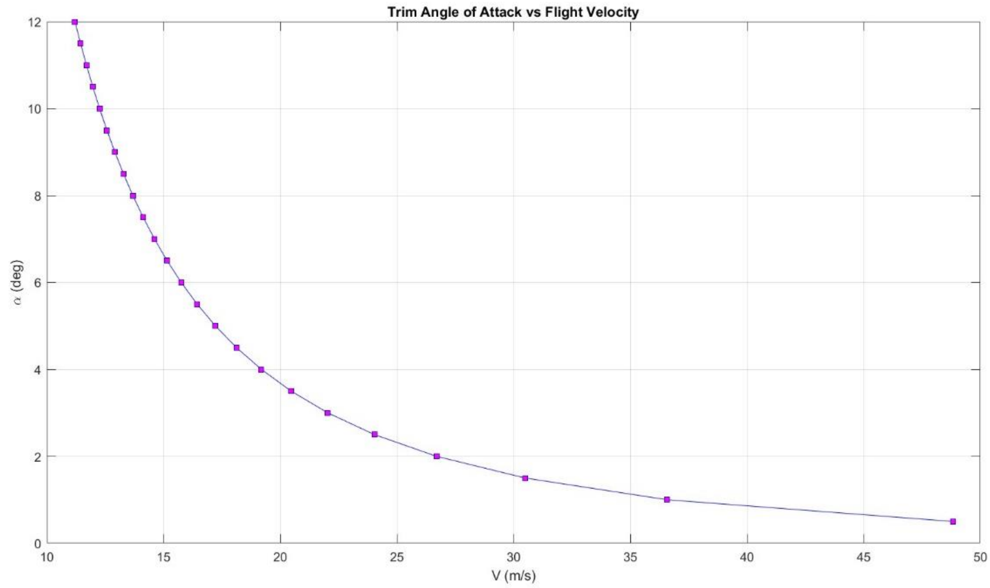


Fig.1

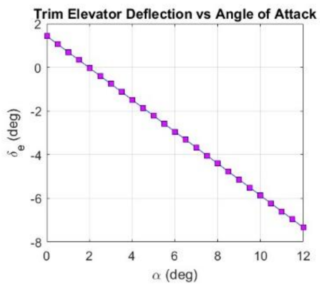


Fig. 2

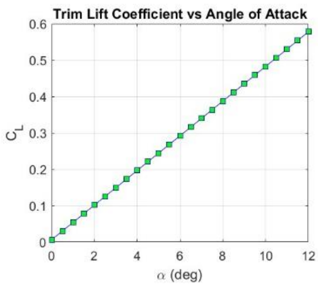


Fig. 3

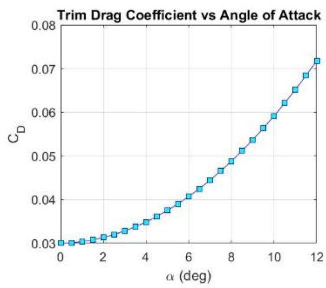


Fig. 4

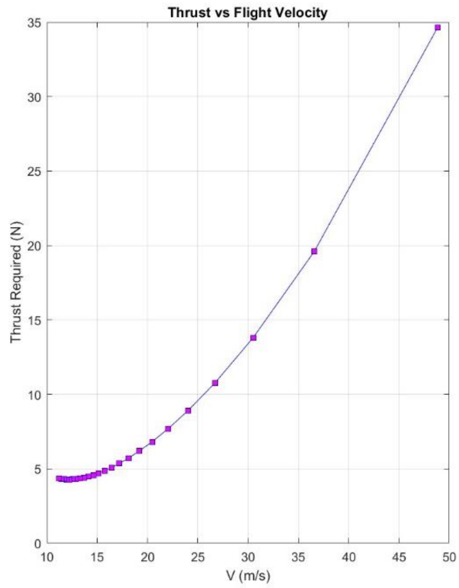


Fig. 5

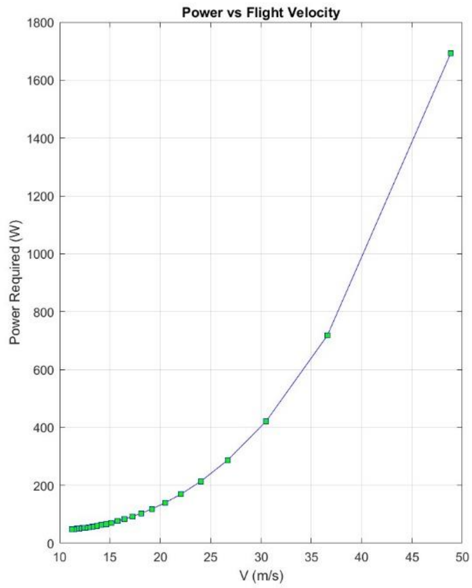


Fig. 6

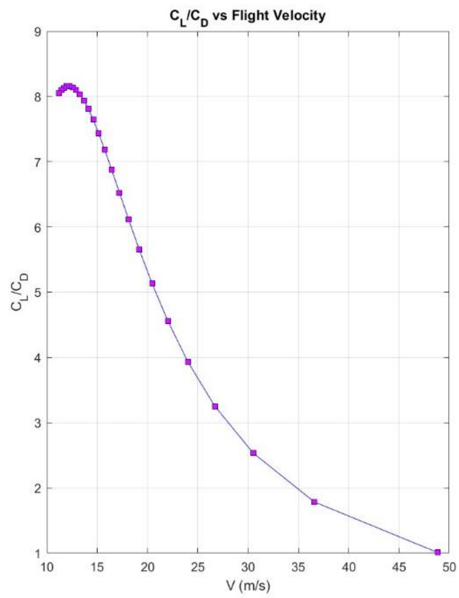


Fig. 7

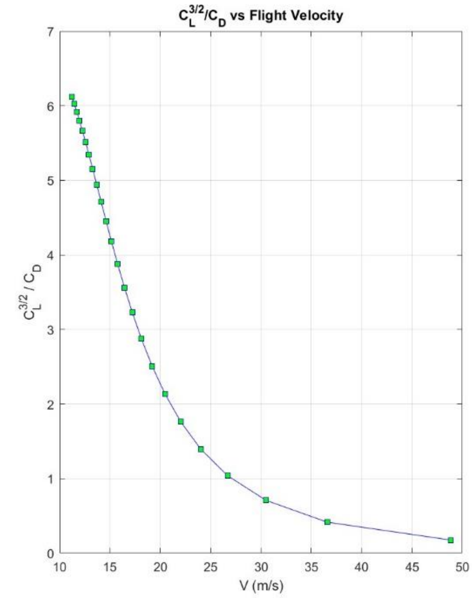


Fig. 8

4. NOMENCLATURE

Configuration = Cropped delta wing (wing-alone)

Flight Condition = Steady level flight

UAV Mass = 3.5 kg

ρ = Air density (sea level) = 1.225 kg/m^3

g = Gravity = 10 m/s^2

W = UAV Weight = UAV Mass*g = 35 N

C_r = Root chord = 0.9 m

C_t = Tip chord = 0.15 m

b = Wing span = 1.5 m

e = Oswald efficiency factor = 0.89

α = Angle of Attack

δ_e = Elevator Deflection

C_{D0} = Zero-lift drag coefficient = 0.03

C_{m0} = Zero AOA pitching moment coefficient = 0.01

$C_{L\alpha}$ = Lift curve slope (per radian) = 2.92 per rad

$C_{L\delta e}$ = Lift due to elevator deflection = 0. 265

$C_{m\alpha}$ = Pitching moment due to AOA = - 0.292

$C_{m\delta e}$ = Pitching moment due to elevator deflection = - 0.4

C_{L0} = Zero AOA lift coefficient = 0.00 (assumed)