AE 244
Low Speed Aerodynamics

Prof: Dhwanil Shukla

Assignment - 3

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22B0073

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

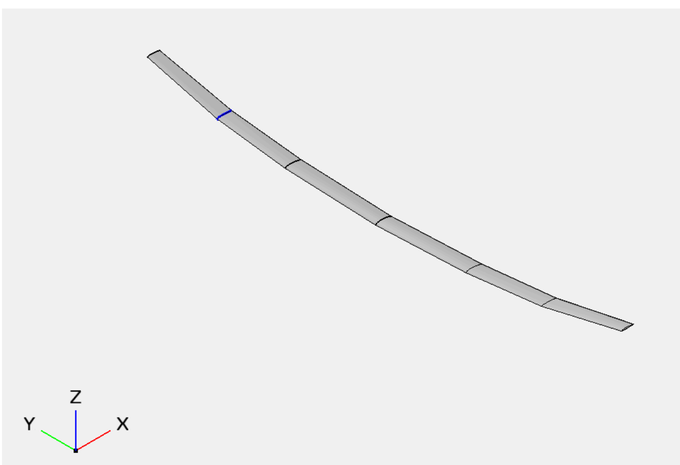
7. <u>References</u>

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

1. Wing Design:

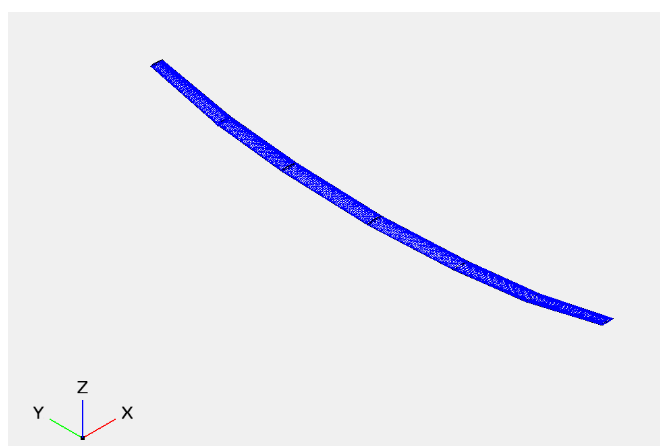
1.1. Full description of wing designed

NACA	4311
Taper Ratio	0.76
Angle of Attack	0
Twist	0 Degree
Sweep	5 Degree
Dihedral	4 Degree

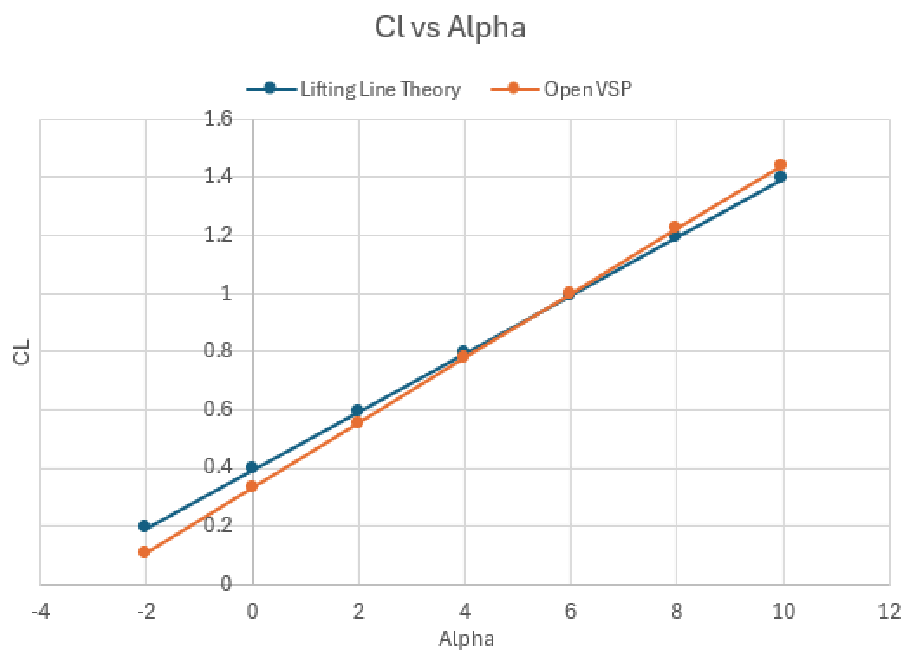


Shaded Wing

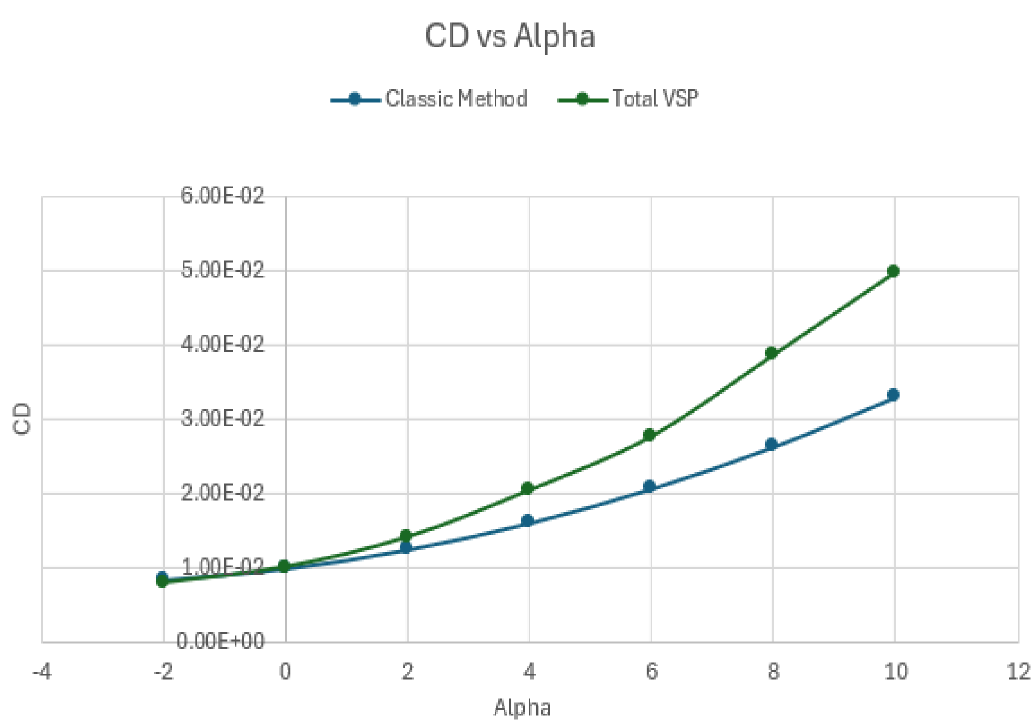
Wing Wire Frame



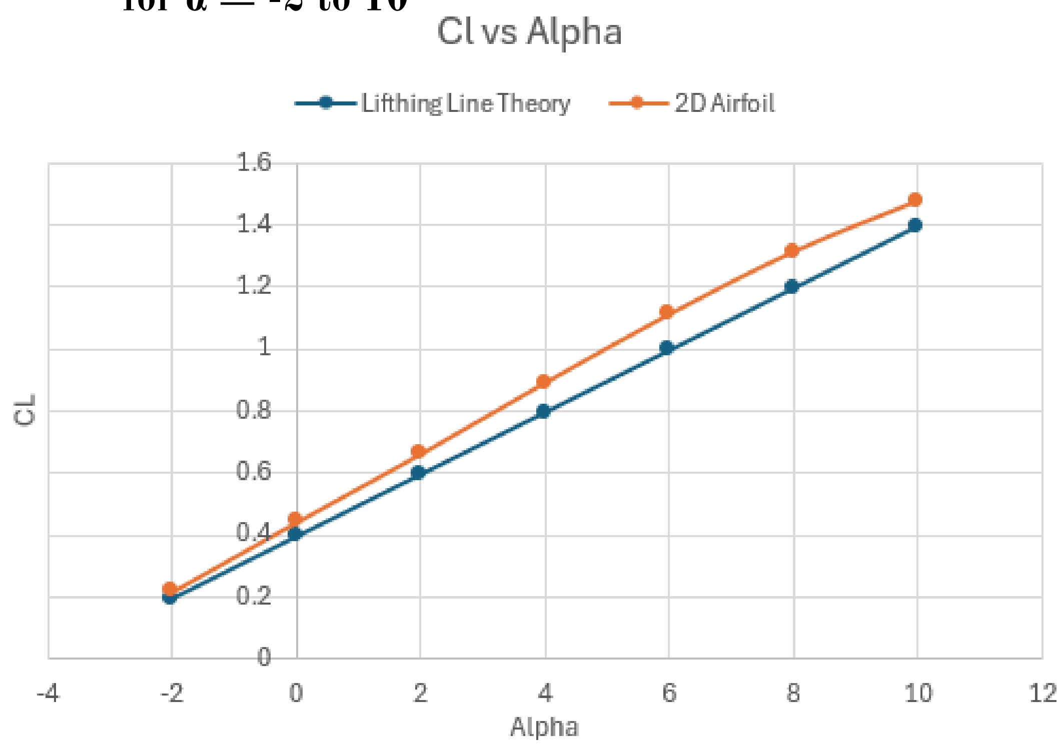
1.2 CL vs α curves of the wing for α = -2 to 10



1.3 CD vs α curves of the wing for α = -2 to 10



1.4 CL vs α of the wing and Cl vs α of the constituent airfoil for α = -2 to 10

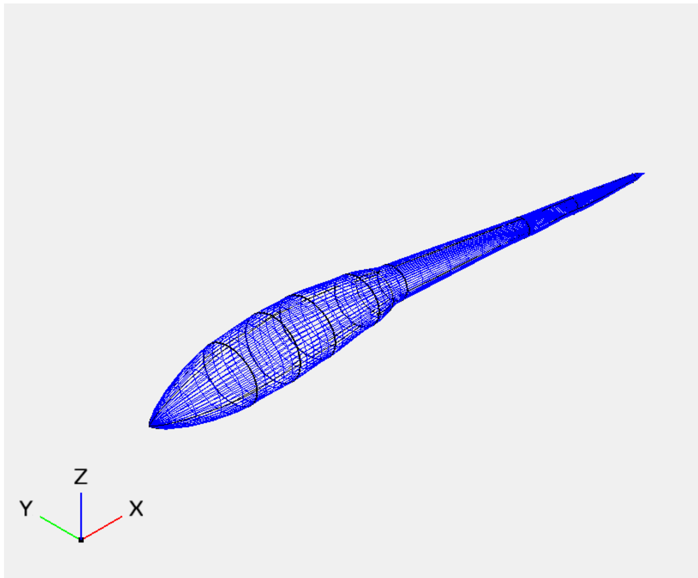


1.5 Main observations and interpretations from sections 1.2 1.3, and 1.4

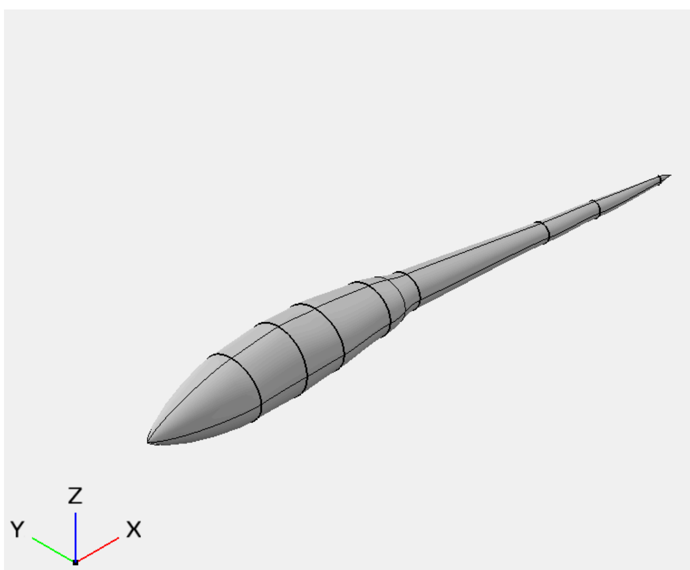
- In 1.2 curves are almost overlapping on each other, still it is little deflected because in glider wings have diheldral which are accounted by the vsp model but lifting line theory do not account for it.
- They have less error bracause the dihelral give to the wings is 4 degree and it is very little so it the we get almost similar result.
- In 1.3 Cd curve for lower angle of attack matches in both the methods and when angle increase it begins to deflect,
- In 1.4 Cl from lifting line theory and 2D airfoil have same Angle of attack at which they have zero Cl value, both are similar but wing curve have less slope as compared to 2D wing this is because in 2D airfoil we dont consider down wash and vortices, in wing is is taken into account we leads to reduction in Cl for same angle of attack.

2. Fuselage Design

2.1 CAD of the fuselage

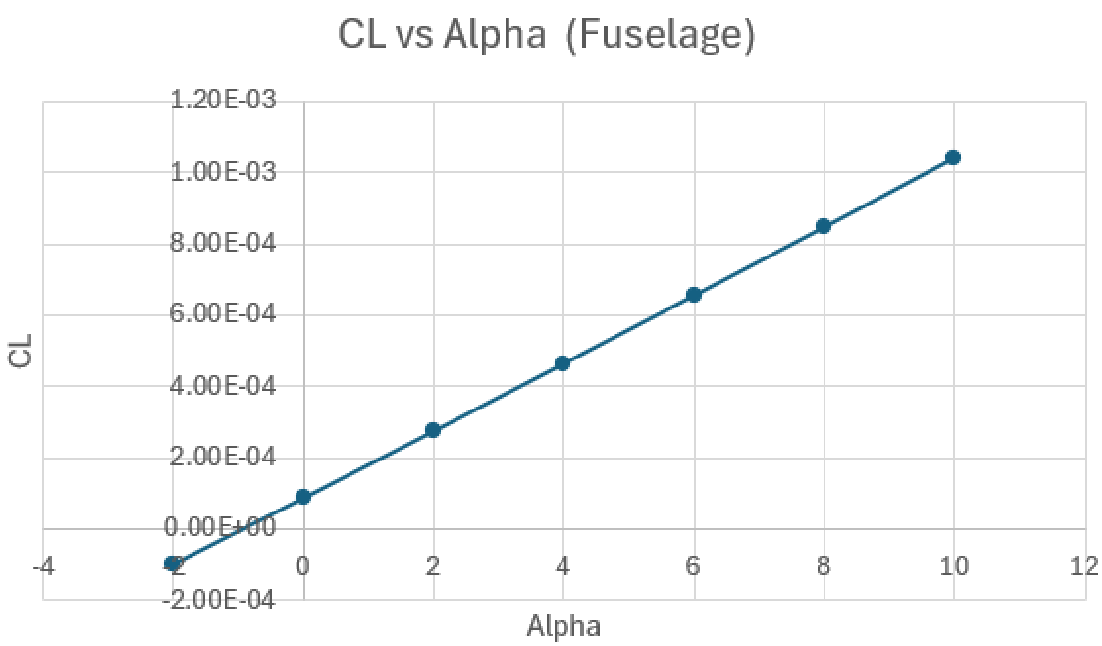


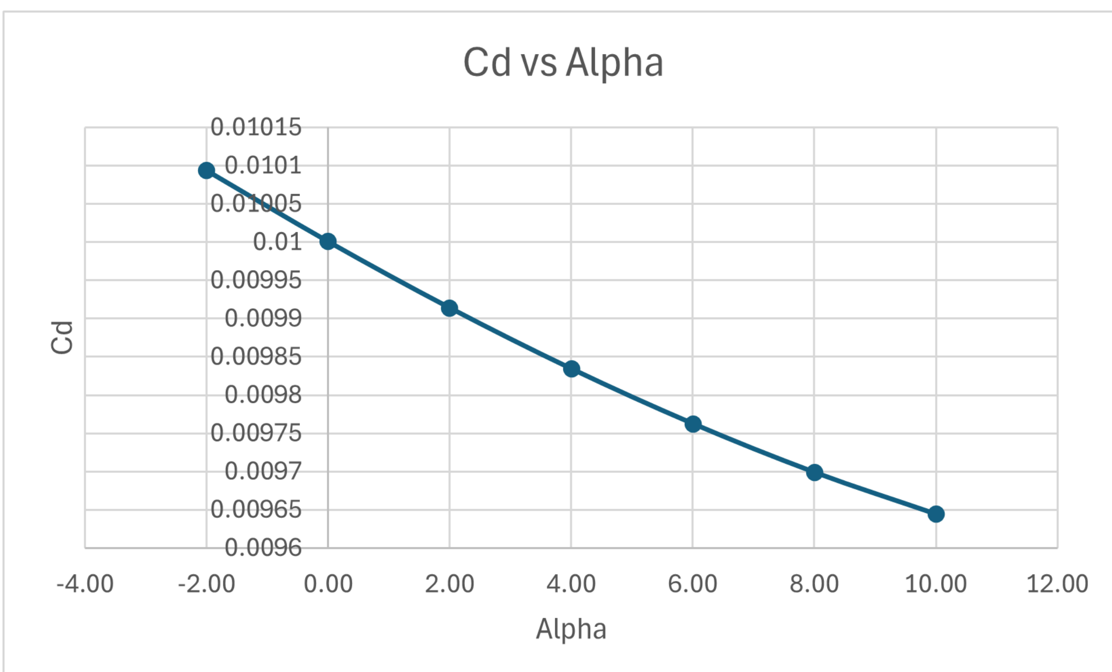
Fuselage Wire Frame



Shaded Fuselage

2.2 Lift and drag estimates from OpenVSP at α = -2 to 10





2.3 Parasitic drag estimates based on empirical method

$$Re_L = \frac{\rho_\infty U_\infty L}{\mu_\infty} \quad \text{(L is fuselage length)}$$

$$\bar{C_f} = \frac{0.455}{(\log_{10} Re_L)^{2.58}} - \frac{1700}{Re_L}$$

$$C_{D_0} = \sum_{i=1}^{N} \frac{K_i \overline{C}_{f_i} S_{\mathrm{wet}_i}}{S_{\mathrm{ref}}}$$

$$R_e = \frac{1.225 \times 30 \times 9.14}{1.5 \times 10^{-5}} = 2.24 \times 10^{7}$$

$$\overline{C_f} = 2.57 \times 10^{-3}$$

$$C_{D_0} = 0.01014$$

2.4 Comparison of drag results from 2.2 and 2.3, and comments

- In 2.2 Cl vs Alpha have positive slope because fuselage look little similar to a airfoil having positive camber.
- The curve is linear because open vsp do not consider the flow separation thats why it do not show stall.
- Cd vs Alpha curve is decreasing, it is estimated by open vsp which we calculated by adding induced drag and parasitic drag.
- Drag estimated by empirical method is constant as compared to the total drag which is combination of variable induced drag and parasitic drag.

3. Stabilizer Design

3.1 Horizontal and Vertical stabilizer designs

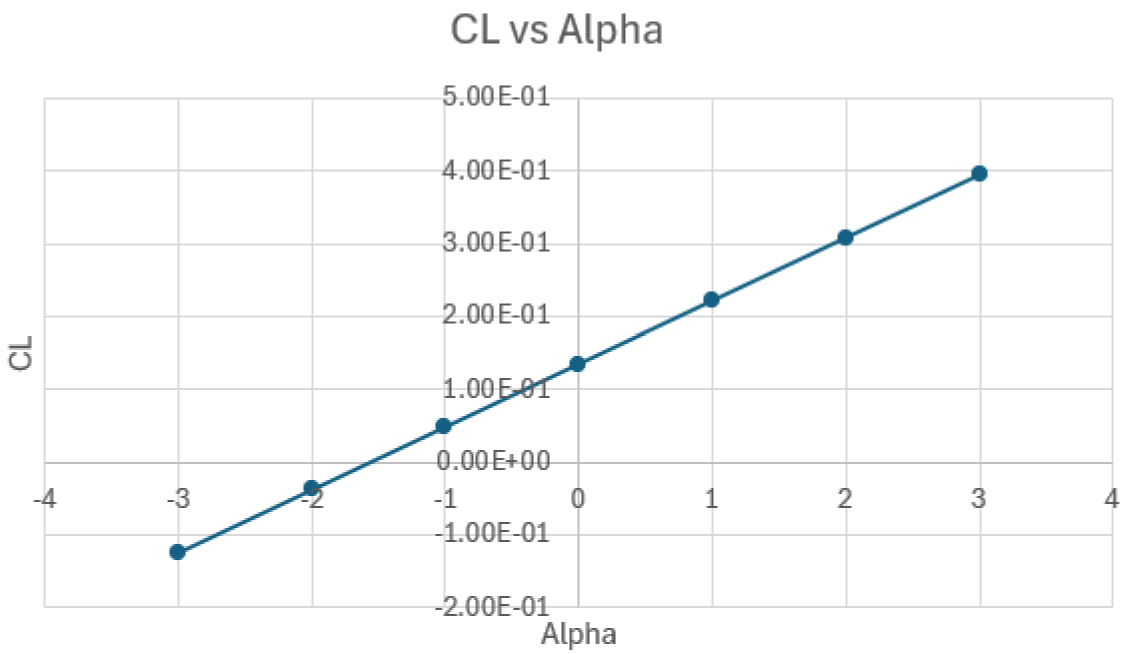
- **Vertical Stabilizer**
  - NACA = 0009
  - Semi-span = 2.6m
  - Avg Chord = 0.86
  - Taper Ratio = 0.76
  - Sweep = 22.2 Degree

- **Horizontal Stabilizer**
  - NACA = 0009
  - Span = 6m
  - Avg Chord = 0.86m
  - Taper Ratio = 0.76
  - Sweep = 11 Degree

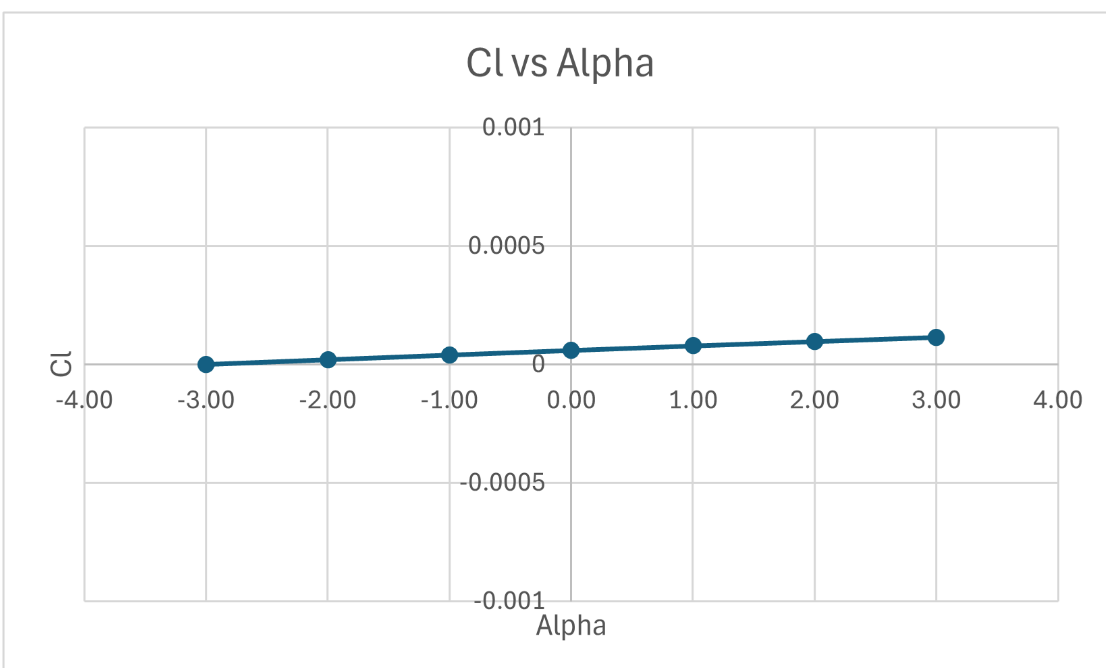
- Both the airfoils are selected to be symmetric to ensure balanced aerodynamic performance. It helps maintain stability and control during flight.
- The horizontal stabilizer is located on top of the vertical stabilizer to improve the vertical stabilizer's aerodynamic efficiency.
- In this the center of Pressure in above the horizontal plane which leads to a steady equilibrium about central axis of the fuselage.
- Sweep is used to reduce the Drag,

3.2 CL vs α curves for both stabilizers for α = -3 to 3

- **Horizontal Stabilizer**

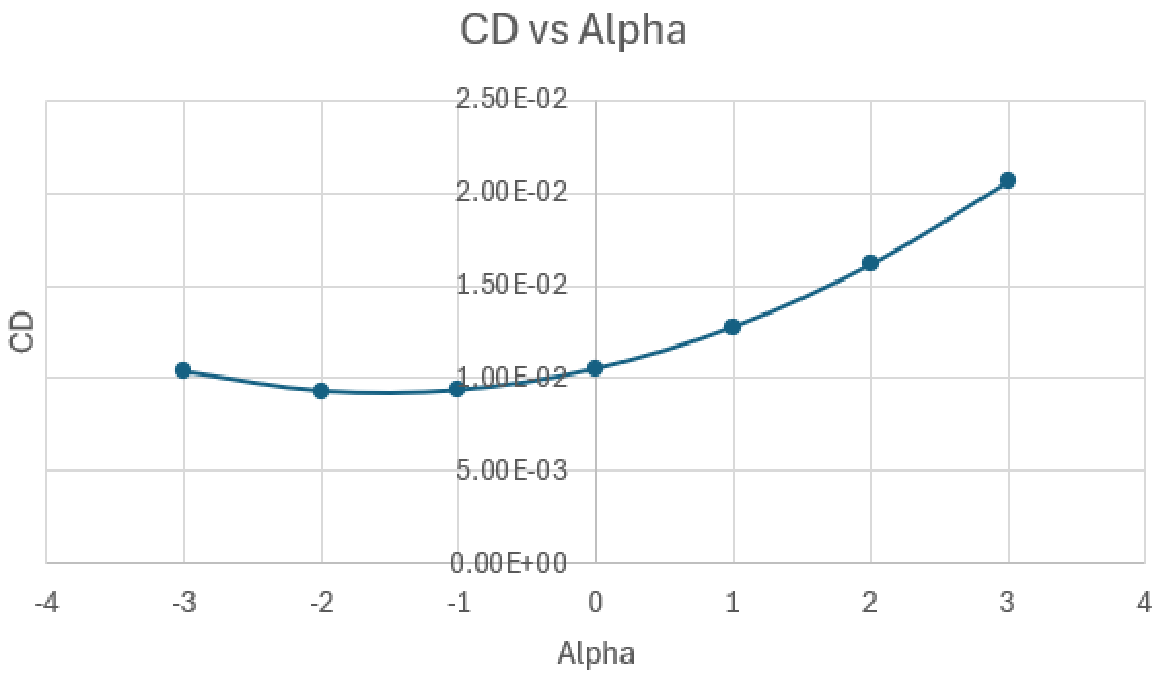


- **Vertical Stabilizer**

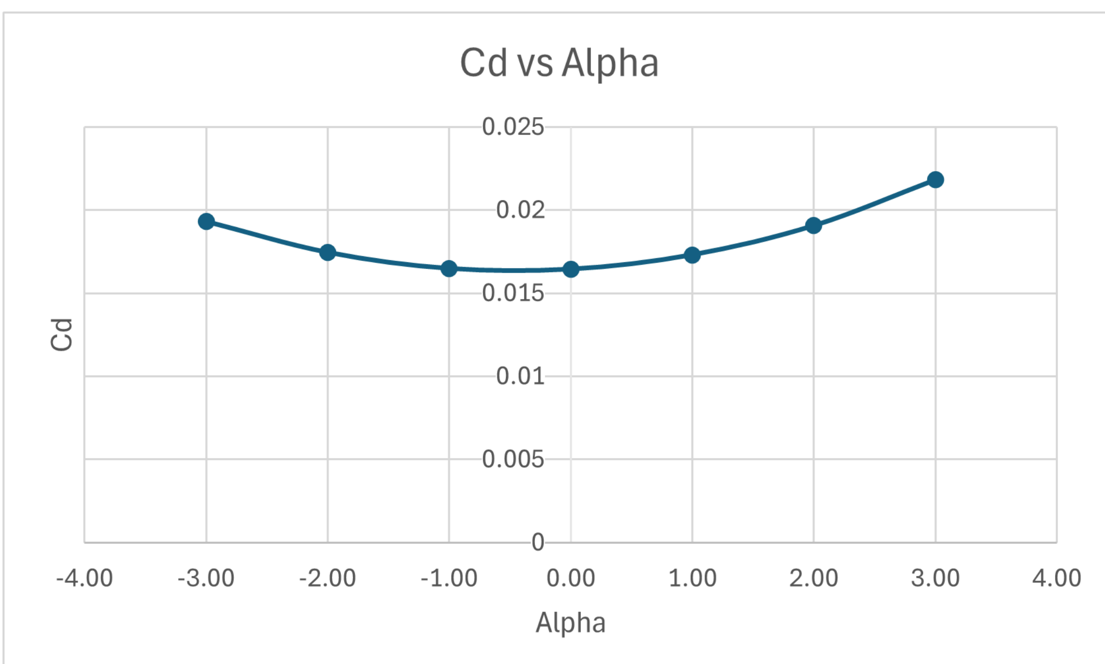


3.3 CD vs α curves for both stabilizers for α = -3 to 3

- **Horizontal Stabilizer**



- **Vertical Stabilizer**

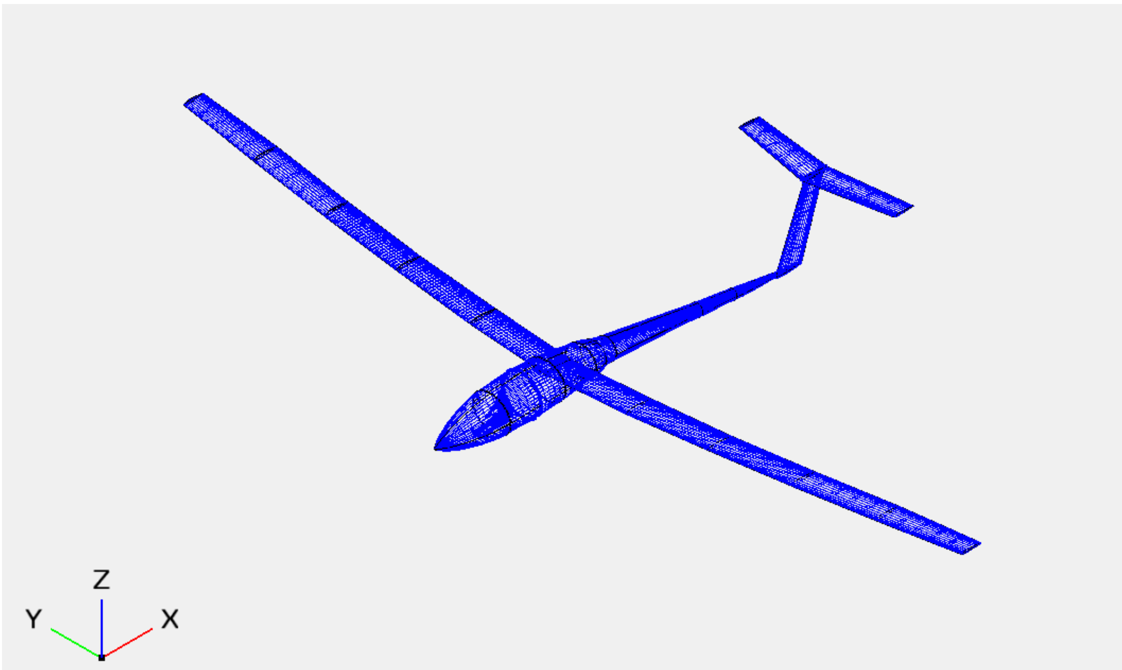


3.4 Comments on findings from 3.2, 3,3.

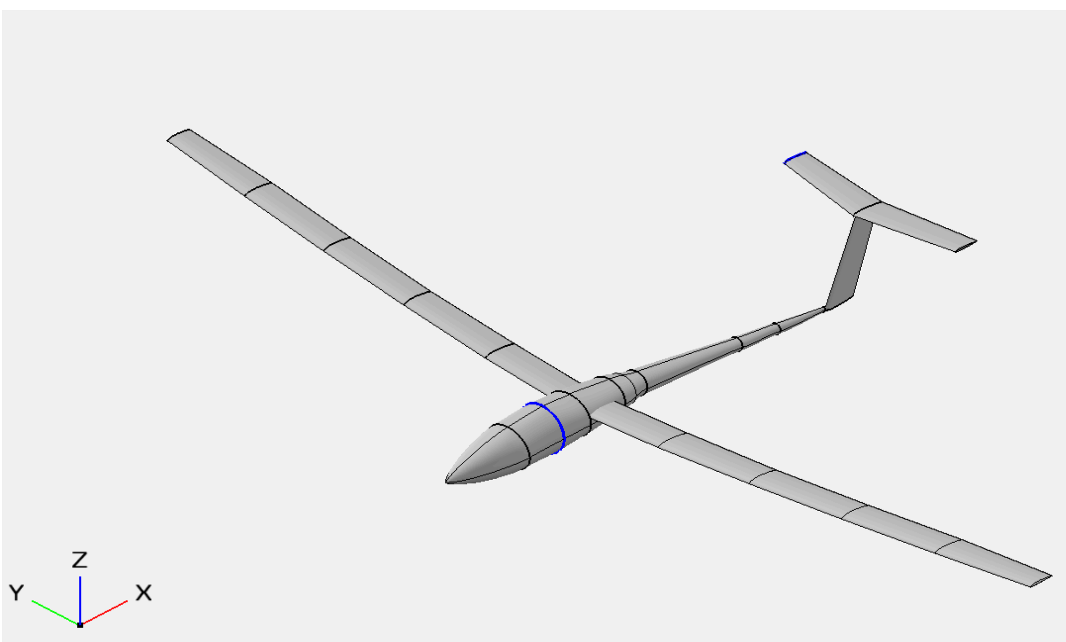
- The stabalizer are used to maintain a stable flight in yaw ,roll and pitch motion.
- The horizontal stabilizer and vertical stabiliser are symmetric airfoil shapes so it can maintain its stability and give zero lift at zero angle of attack with respective their chord.
- Cl values for horizontal stabilizer are higher as compared to vertical stabilizer, this is because vertical stabilizer is vertical and it does not make any sense to calculate for it and it is symmetric so values are near to zero.
- For horizontal stabilizer , it is mounted at a positive angle of attack so it is giving positive Cl at zero angle of attack, note that it is symmetric.

4. Overall glider design

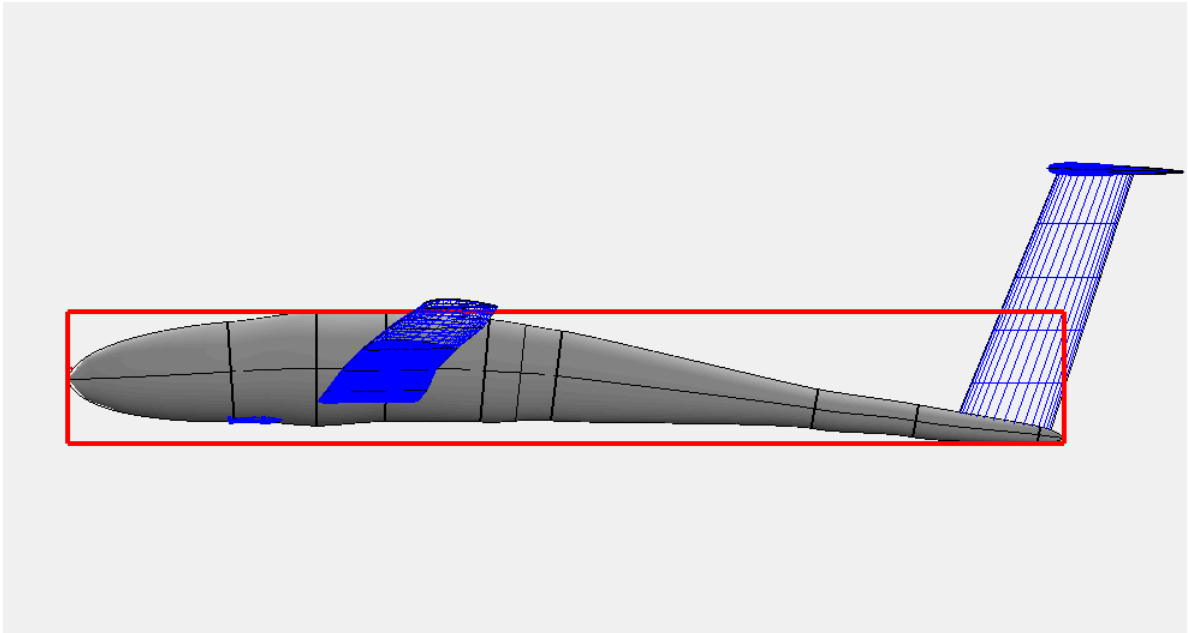
4.1 Overall glider design and CAD



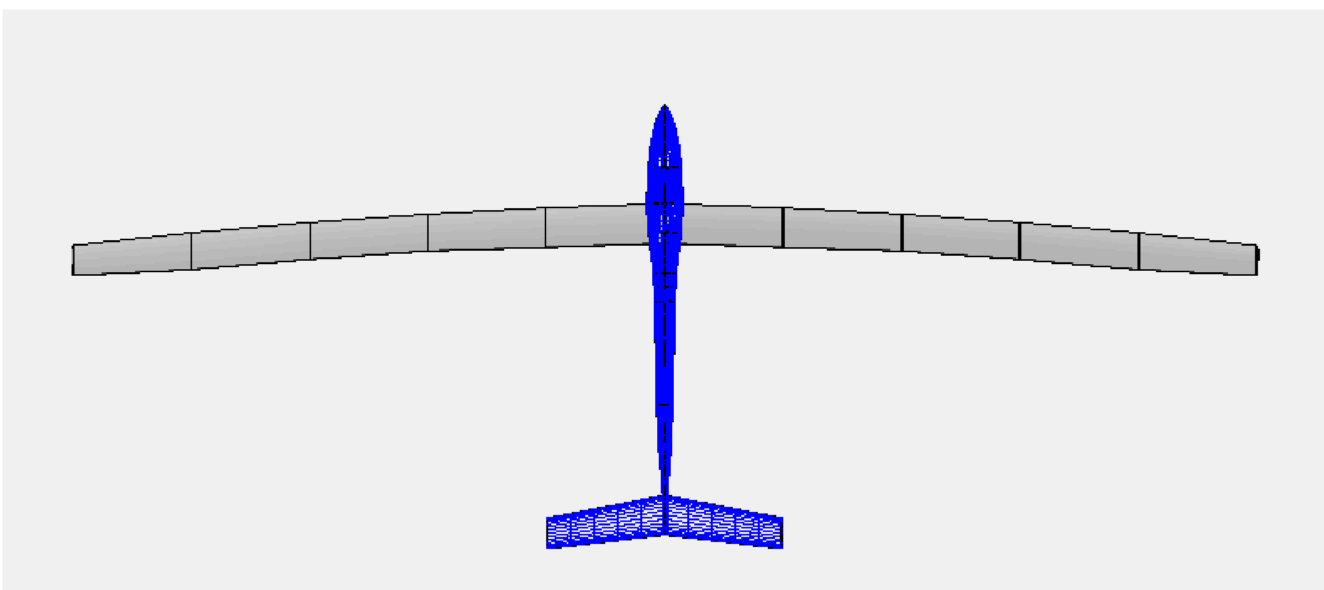
Glider Wire Frame



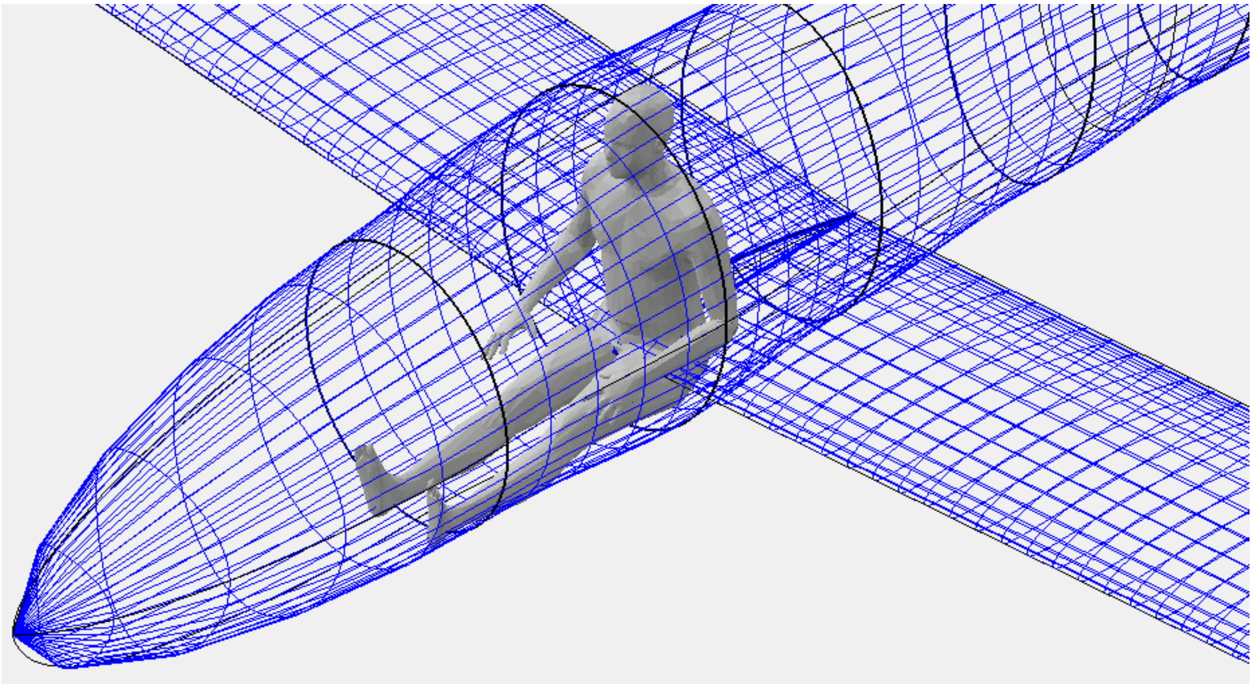
Shaded Glider



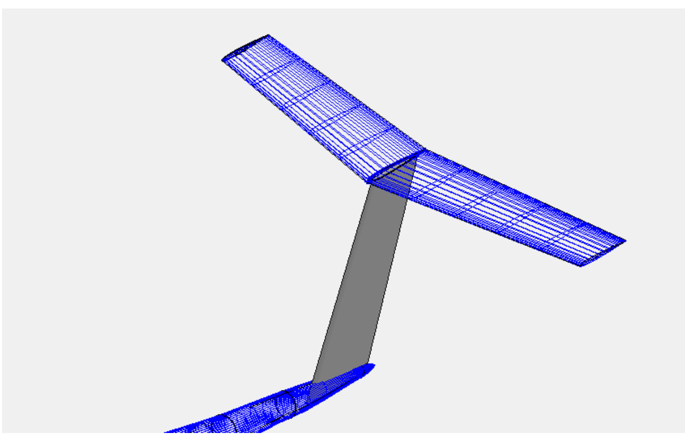
Fuselage



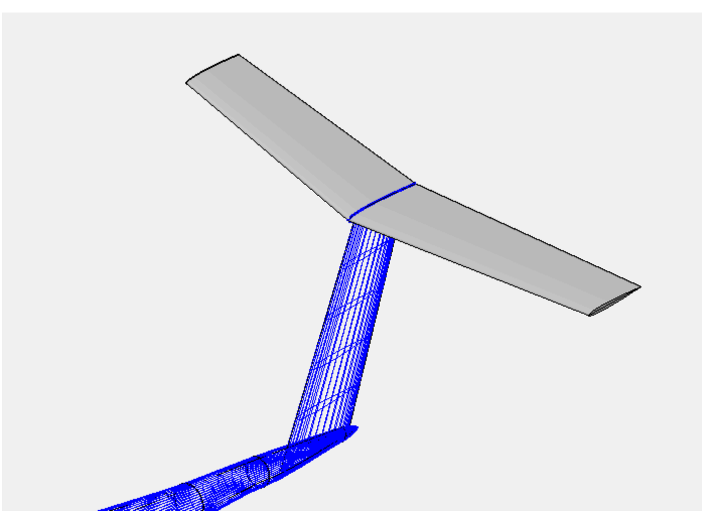
Wing



6 ft Human seating in cockpit



Vertical Stabilizer

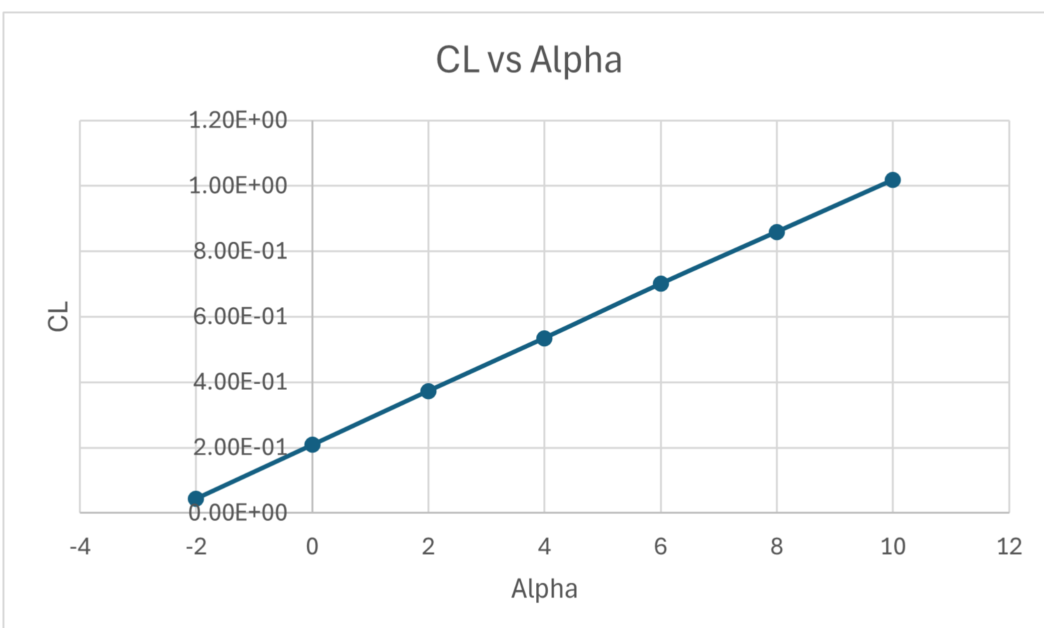


Horizontal Stabilizer

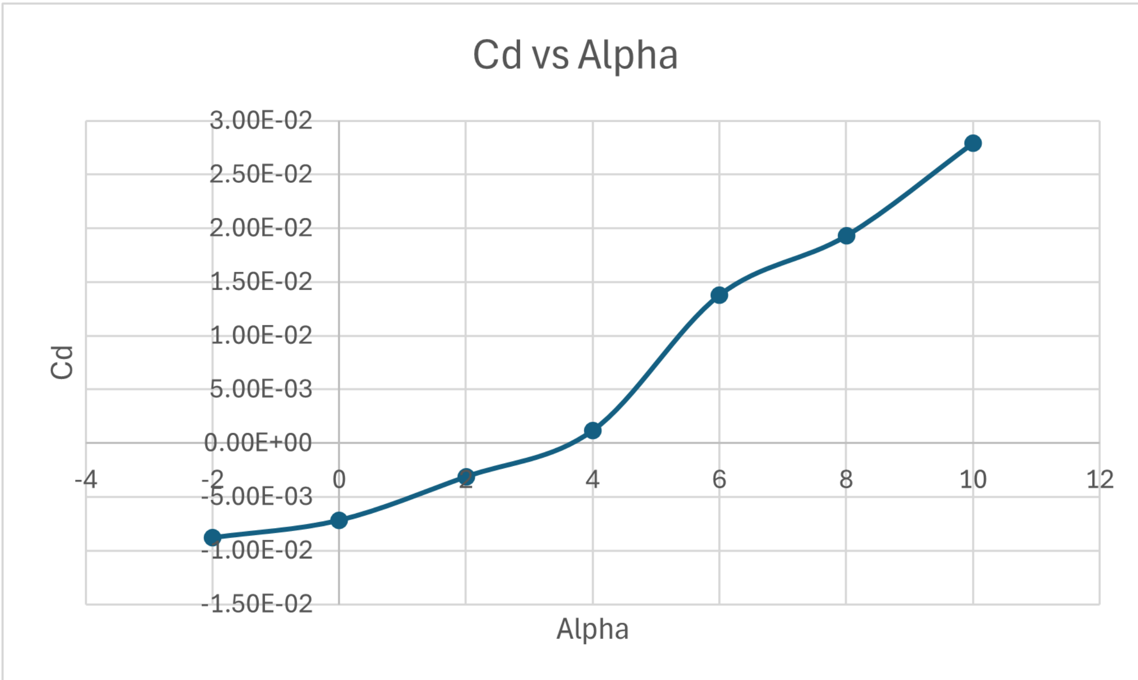
- Wings of the glider have high wing configuration to matain stead equilibrium about the central axis of fuselage.
- This wings also have digeldral in its wing, which make it more stable in Roll motion.
- Aspect Ratio of this glider is 30:1, which will give more lift as wing span incresase, fuselage if half times of wings.
- Fuselage is made in such a way a person 6 feet high can seat of it with his legs are spread forward.
- Wings are tapered. It trys to mimic the elliptical wing, which helps in reducting induced drag and which leads to increase in Lift.
- Horizontal and vertical stabilizer are symmetric to aboid any unnecessary force on glider while pitching and doing yaw.
- At higher angle of attack the flow behind the wing will become turbulent due to formation of vortex and flow separation, in this we have horizontal stabilizer mounted above the vertical stabilizer which will prevent the horizontal stabilizer from stall and turbulent vortex containing flow.

4.2 Performance of the entire glider using Open VSP

- **Cl vs Alpha**



- **Cd vs Alpha**



4.3 Glider component weight estimates (using CAD) and total weight

- **Surface Areas and Volumes**

Components	Surface Area (m^2)	Volume(m^3)
Main Wing	48.11	1.503
Stabilizer	13.09	0.317
Fuselage	21.55	0.612

- **Weight Estimations**

Compoents	Material	Weight (kg)
Wings, Fuselage, Stabilizers	Carbon Fibre	342.1
Fuselage Spars	Aluminium	159.37
Wings and Stabilizer Spars	Aluminium	315.46
Human	-	80
Total	-	967.08

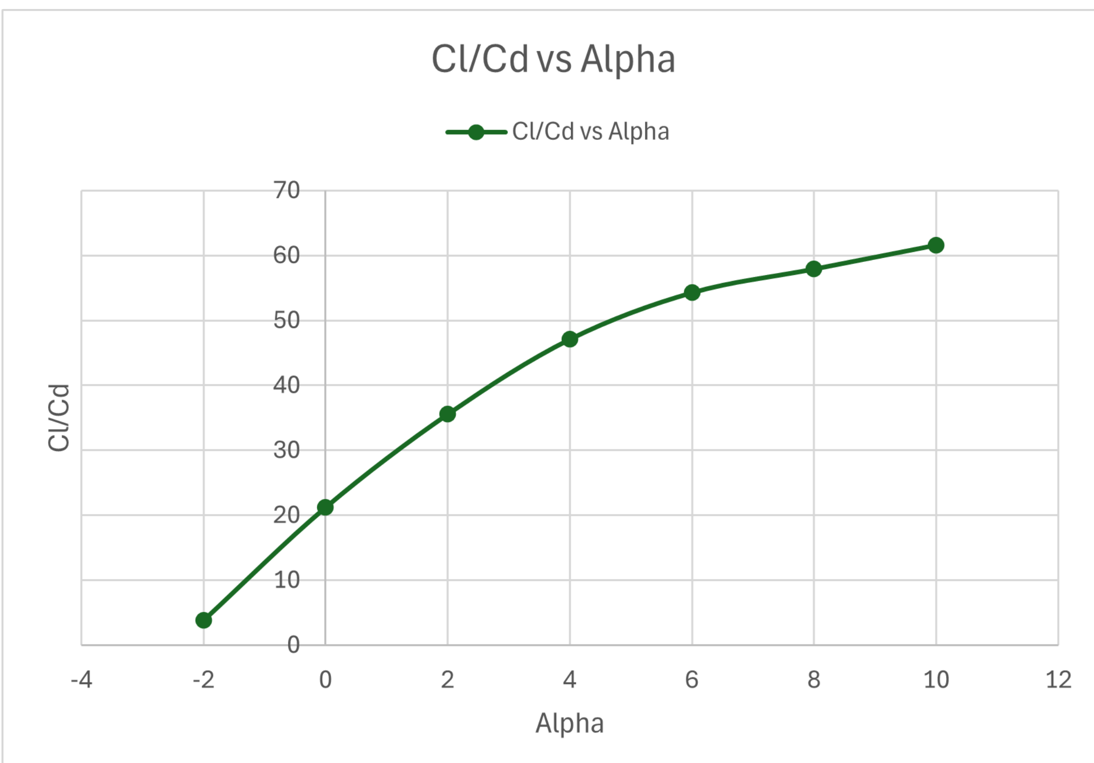
- Components of glider are made up Carbon Fibre and Aluminium.
  Carbon Fibre is used to make the skin of the glider which is exposed to external environment and Aluminiun is used to make the spars to make a skeleton like structure to support the skin and provid rigidity and strength.
- We considered that the 1/8th volume of fuse lage is consumet by the aluminium spars and the 1/16th of Stabilizer area is consumed by spars.
- Weight is calculated on the basis of their density and based on their thickness.
- Carbon Fiber and Aluminium is selected due to their higher strength to weight ratio.
- They have low maintenance and corrosion resistance.

5. Design Validation

5.1 Optimal speed, glide angle, range, descent rate for the designed glider

- Glider at height 1000 meters and it have to travel range 30,000 meters range.
- Glider will be released from height more than 1000 meter so that it will take some altitude to reach equilibrium state.
- In this calculation we have considered the steady state of glider and estimated the values of Cl and Cd.
- We need glide ratio to be equal or more than 30:1.
- We need

$$\frac{L}{D} = \frac{Cl}{Cd} >= \frac{30}{1}$$



Cl/Cd vs Alpha curve for Glider

Taking value of Cl and Cd for which Cl/Cd is greater than 30.
Consider

Cl = 0.793
Cd = 0.0146
Angle of attack = 6 degree

Now estimating value of speed by putting the values of Weight, Sref, Density of air, glide ratio.

Optimised Speed = 28.76 m/s

Lift = 9545.43 N
Drag = 175.74 N

Glide Ratio $= \frac{1}{tan(\theta)} = \frac{Cl}{Cd} = \frac{Range}{Altitude}$

Altitude = 1000
Glide Angle = θ

Glide Angle = 1.054 degree
Range = 54.31 km
Decent Rate 0.1673 m/s

5.2 Comment on glider performance w.r.t original requirement and possible scope for improvements.

- Glider's wing ration must have aspect ration in range og 30:1 to 60:1, and provide large range, aspect ration can be increased.
- Glider can be given wing tip and more dihedral to improve its stability, wing tips will reduce induced drag will increase range and roll stability will be increased.
- Fuselage cross-section must be minimilised to reduce foam drag and to improve its performance.
- We can keep forward sweept wing the advantage in this is that during stall it will happen from root chord to tip chord which will prevent the stall of part of wing which have control surfaces.

6. Acknowledgement

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- Arpit Jain (22B0078)
- Rohan Choudhary (22B0036)

7. References

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- Xflr 5