A COMPREHENSIVE REPORT ON THE DESIGN AND ANALYSIS OF A HAND-GLIDER

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1. INTRODUCTION:

Gliders are aircraft that operate without an engine, relying solely on aerodynamic forces to sustain flight. They are used for various purposes, including sport, research, and training.

There are several types of gliders, including:

- Sailplanes: High-performance gliders designed for long-distance and endurance flying, often launched by winches or tow planes.

- Hang Gliders: Lightweight, foot-launched gliders controlled by shifting body weight.

- Paragliders: Soft, fabric-winged gliders designed for controlled descent and soaring.

- Radio-Controlled (RC) Gliders: Small, unmanned gliders controlled remotely, often used in competitions and hobbyist activities.

- Hand-Thrown Gliders: Simple, lightweight gliders designed for short-range, unpowered flight, typically used for educational and recreational purposes.

2. **GENERAL USE OF GLIDERS:**

Gliders are commonly used for:

- Educational purposes in aerodynamics and flight mechanics.
- Recreational sports and hobby flying.
- Experimental studies in aerodynamics and material testing.
- Preliminary design validation before powered aircraft development.

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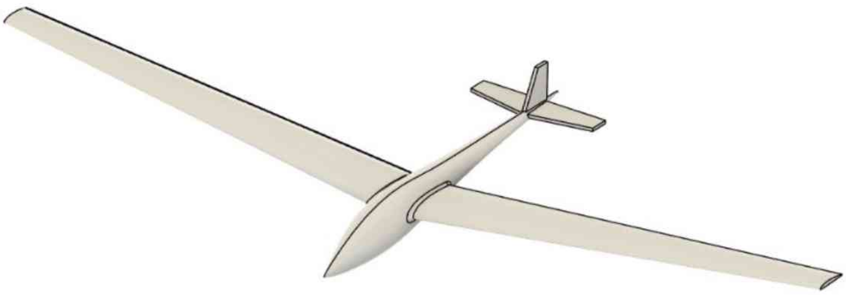
3. **DESIGN AND DEVELOPMENT**

This report focuses on the design, calculations, and fluid analysis of a hand-thrown glider, emphasizing its aerodynamic efficiency and structural integrity.



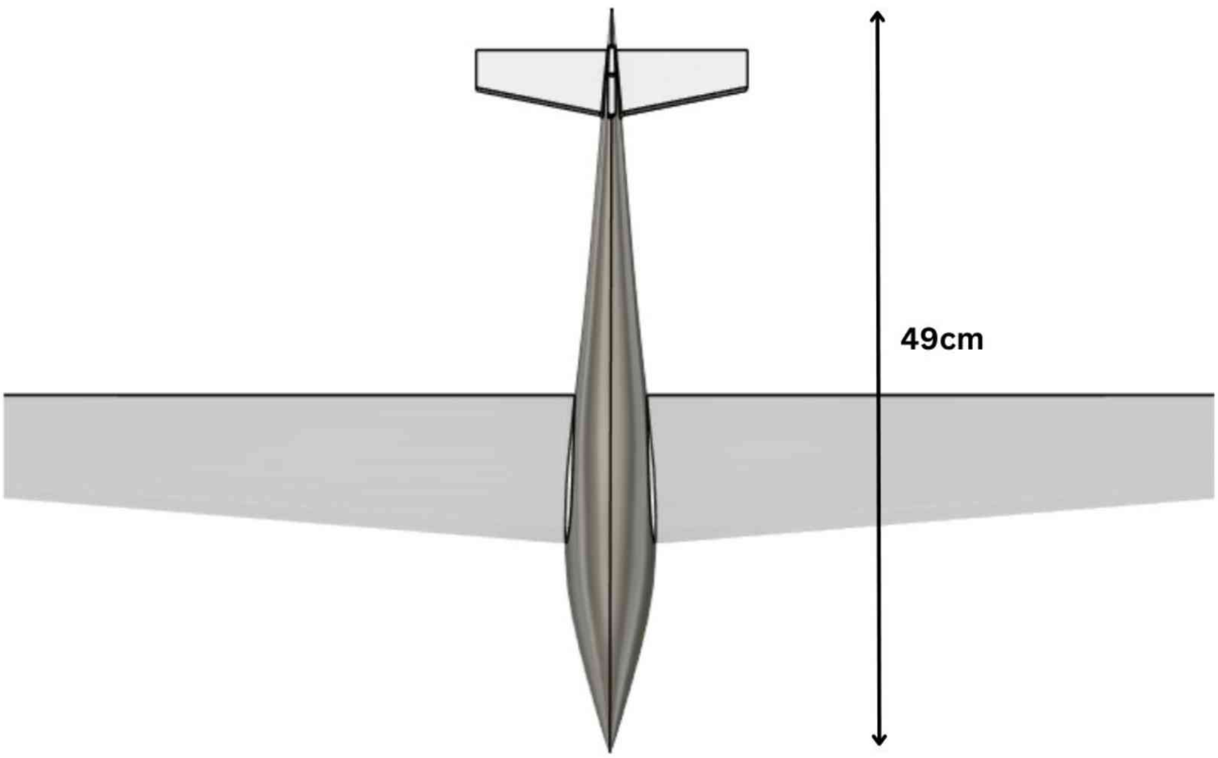
The development of the hand glider followed a systematic approach, including conceptualization, CAD modeling, aerodynamic calculations, and fluid analysis. The key components of the glider include the main wings, tail wings, and vertical stabilizer. Each part was designed to ensure optimal lift, stability, and control.

4. Detailed Breakdown of Components and Specifications

4.1 Fuselage

The fuselage serves as the main structural body of the glider, providing support for the wings and stabilizers. It was designed with an aerodynamic shape to minimize drag and ensure balance. The fuselage also houses the central weight distribution, ensuring proper center of gravity (CG) placement for stable flight.

- Length: 49 cm
- Maximum Diameter: 10 cm



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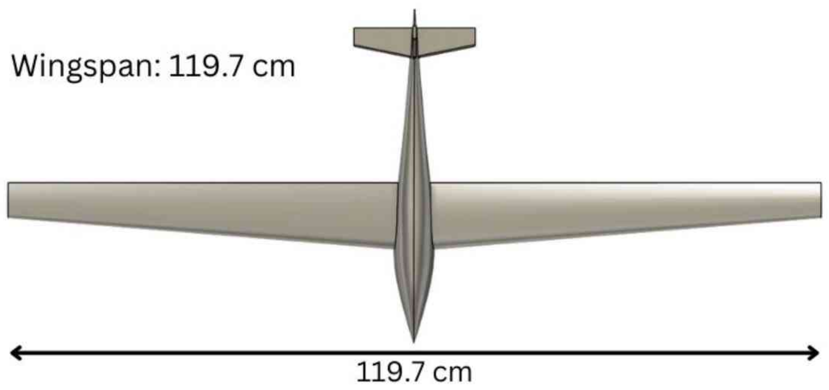
4.2 Main wings

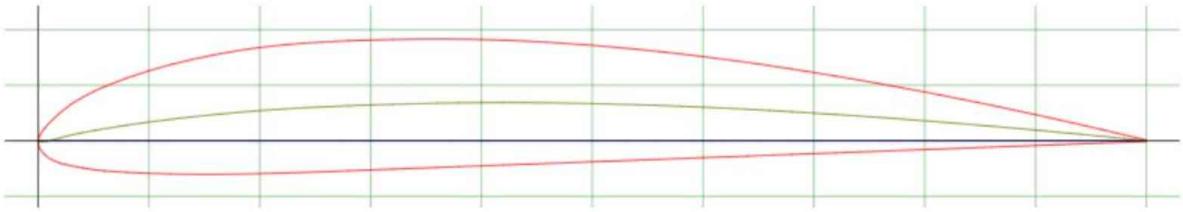
The main wings are responsible for providing lift. The aspect ratio of a wing, typically ranging between 6:1 and 10:1 for efficient gliders, affects its lift-to-drag ratio. Higher aspect ratios improve gliding efficiency by reducing induced drag. The aspect ratio for these wings were chosen to be **8:1**. The chosen dihedral angle of 6° enhances lateral stability by promoting self-leveling tendencies. The tapering helps reduce tip vortices, thereby improving aerodynamic efficiency.



4.2.1 Airfoil selection: CLARK Y

The CLARK Y airfoil was selected for this glider due to its well-balanced aerodynamic characteristics, making it ideal for low-speed flight. This airfoil is widely used in trainer aircraft and model planes because of its moderate thickness and relatively flat bottom, which simplifies construction. Some key advantages include:

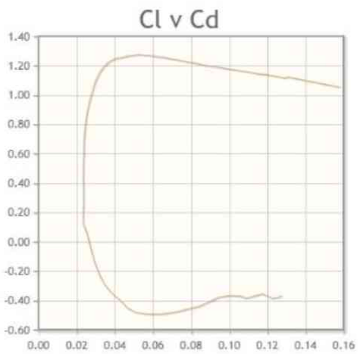
- Good lift-to-drag ratio at low Reynolds numbers.
- Gentle stall characteristics, providing stability in flight.
- Ease of manufacturing due to its nearly flat lower surface.



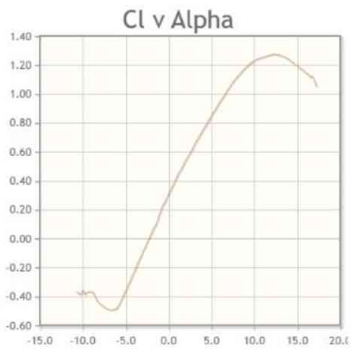
CLARK Y

Details:
Max thickness 11.7% at 28% chord.
Max camber 3.4% at 42% chord

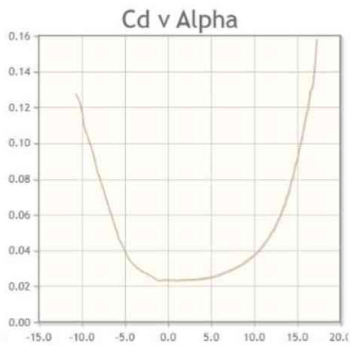
To better understand the aerodynamic properties of the CLARK Y airfoil, the following graphs are included:



Cl vs Cd Graph: This graph illustrates the lift-to-drag efficiency across different angles of attack.



Cl vs Alpha Graph: Demonstrates the relationship between lift and angle of attack, highlighting stall behavior.



Cd vs Alpha Graph: Shows how drag varies with changing angles of attack.

(All values are taken at Reynold’s number = 50000, Angle of attack = 35°)

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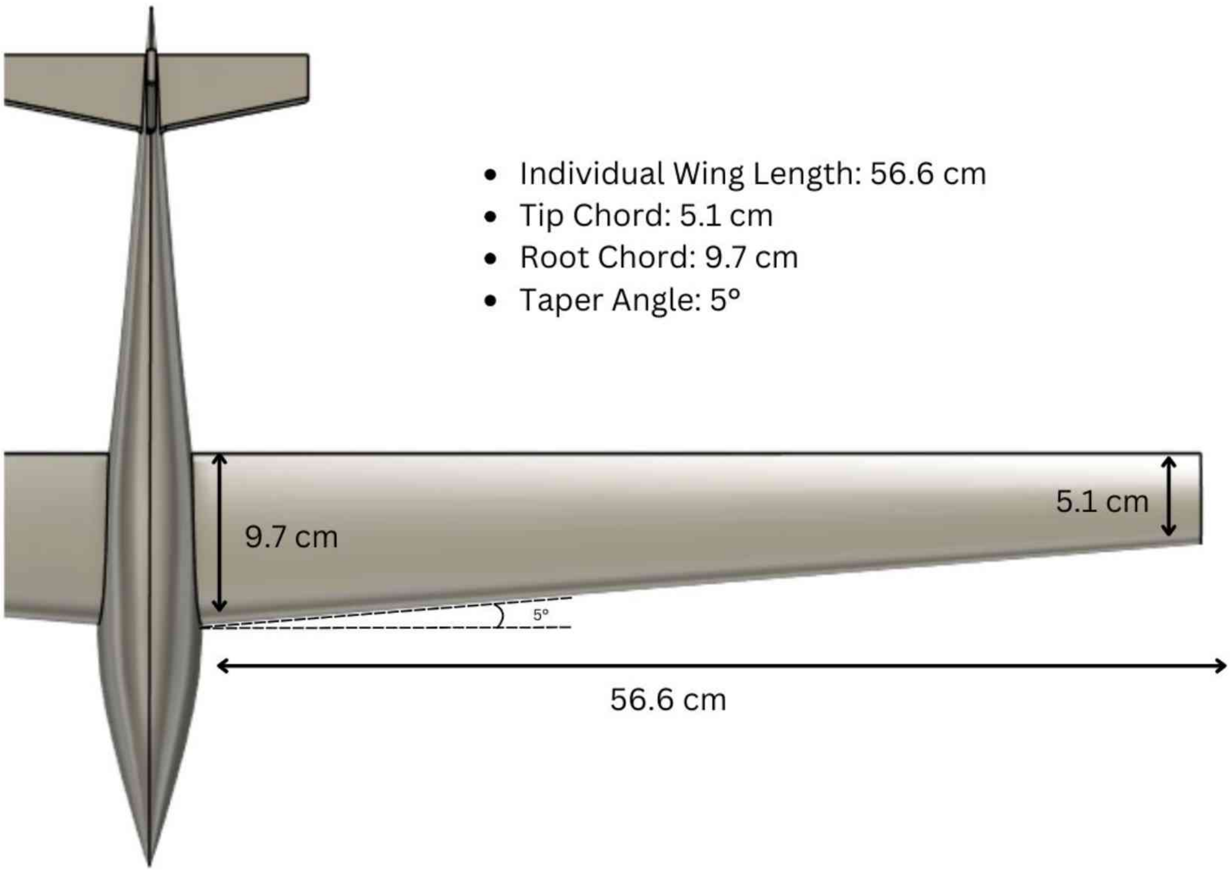
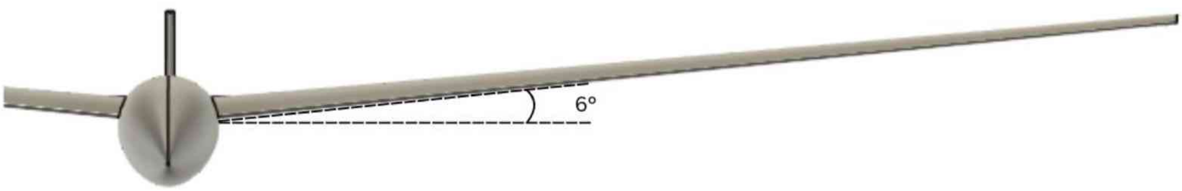
4.2.2 Wing specification



- Individual Wing Length: 56.6 cm
- Tip Chord: 5.1 cm
- Root Chord: 9.7 cm
- Taper Angle: 5°

- **Aspect Ratio Formula**: $AR = \frac{b^2}{S}$
- **Wing Area Formula**: $S = \frac{b \times (c_r + c_t)}{2}$

Dihedral Angle: 6°



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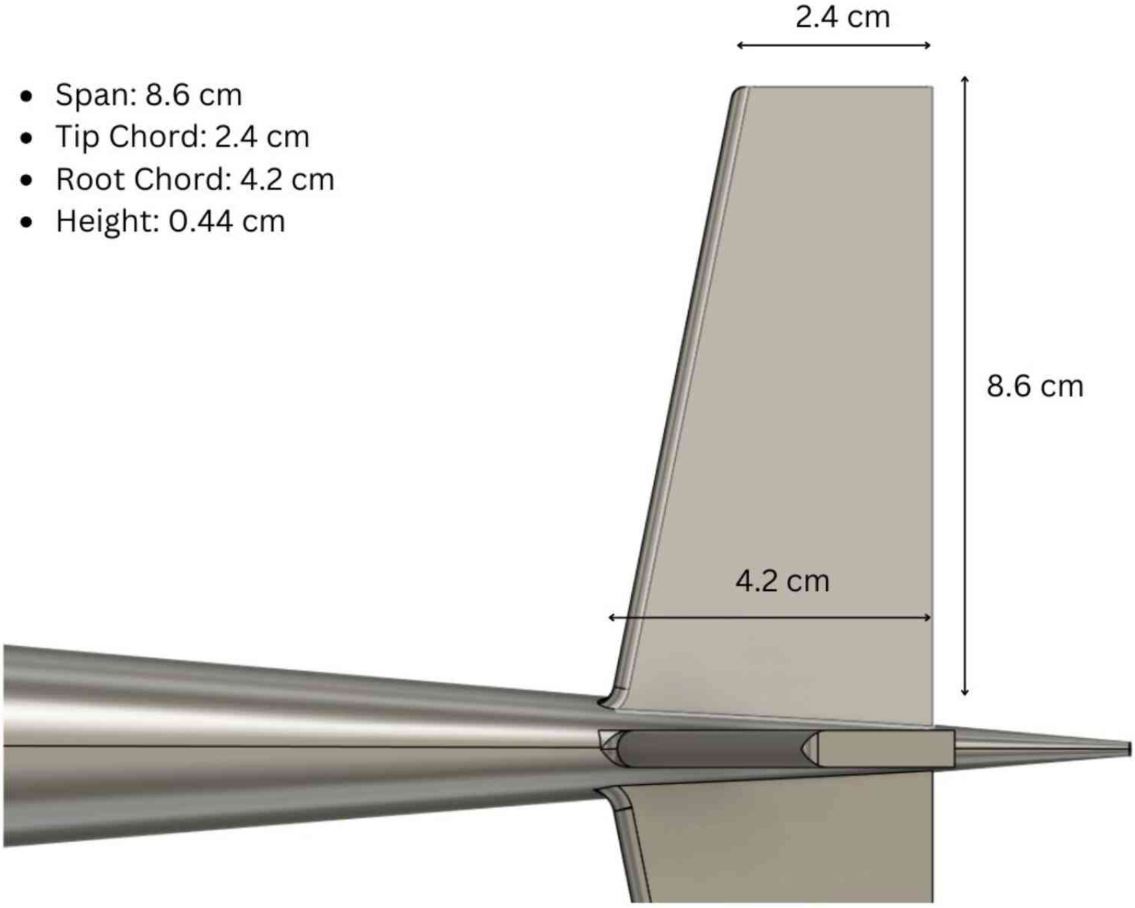
4.4 Horizontal stabilizer

The horizontal stabilizer is responsible for longitudinal stability and assists in maintaining level flight. The span and chord dimensions were chosen to ensure a good balance between control authority and drag minimization. A typical horizontal stabilizer has an aspect ratio between 3:1 and 4:1 to maintain efficiency. This glider uses simple thin-plate airfoil as a horizontal stabilizer.

- **Horizontal Stabilizer Area Formula:** $S = b \times \frac{(c_r+c_t)}{2}$

- Span: 8.6 cm
- Tip Chord: 2.4 cm
- Root Chord: 4.2 cm
- Height: 0.44 cm



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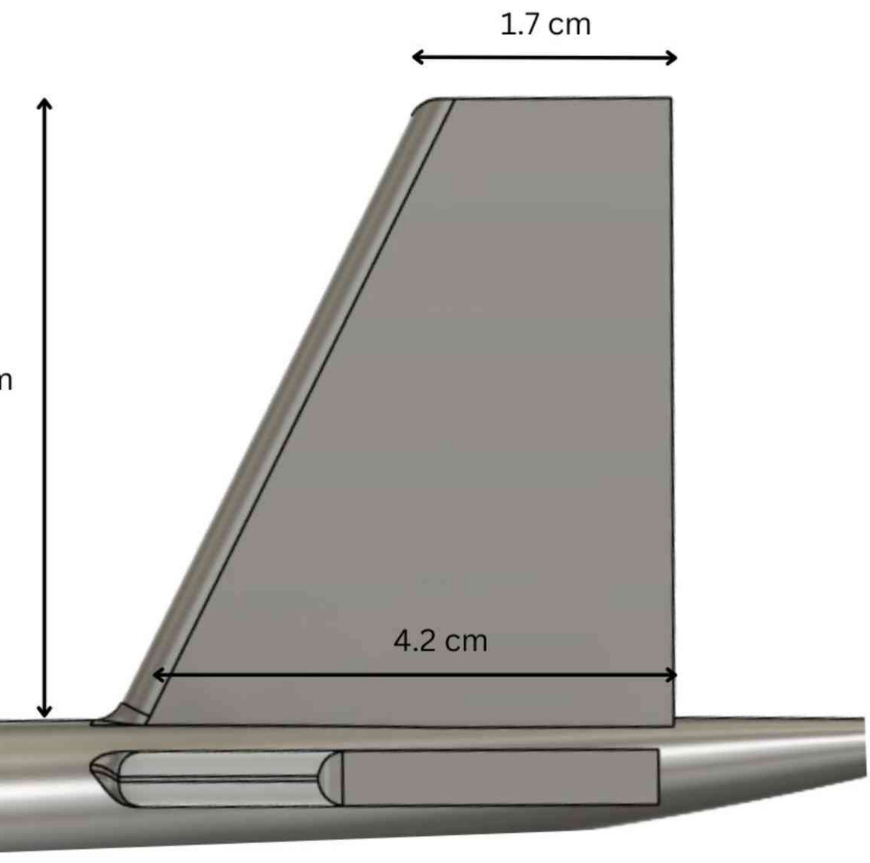
4.5 Vertical stabilizer

The vertical stabilizer provides yaw stability, preventing unwanted side-to-side movement. The size and shape of the stabilizer influence directional control. Generally, a larger vertical stabilizer provides better stability but increases drag. The dimensions were selected to complement the overall aerodynamics and balance of the glider.

- **Vertical Stabilizer Area Formula:** $S = h \times \frac{(c_r+c_t)}{2}$

- Height: 5 cm
- Root Chord: 4.2 cm
- Tip Chord: 1.7 cm
- Breadth: 0.5 cm



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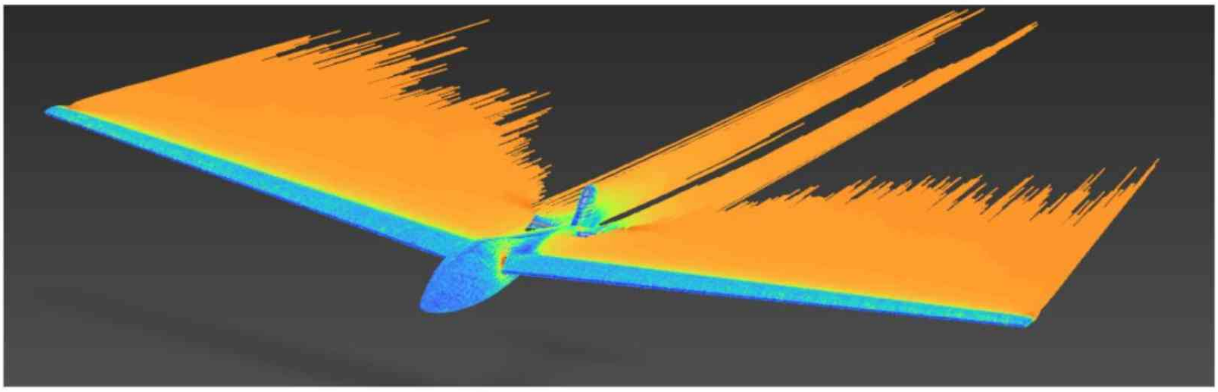
5. Computational Fluid Dynamics (CFD) Analysis

CFD simulations were conducted to analyze airflow behavior, lift distribution, and drag coefficients. These simulations help in visualizing pressure differentials across the surfaces and optimizing the aerodynamic performance of the glider. The results validate the aerodynamic efficiency of the design and provide insights into potential improvements.



The key aspects of the analysis include:

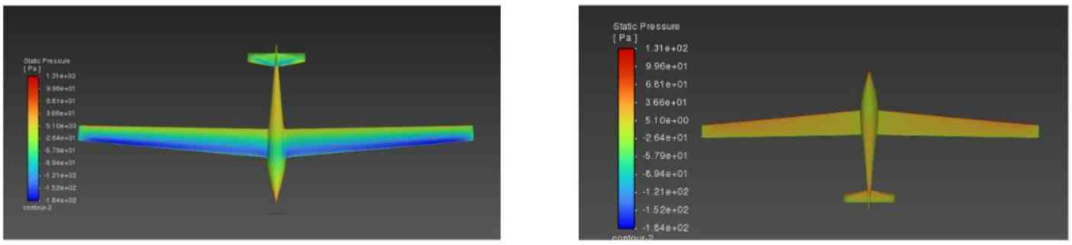
- Mesh Generation: A refined mesh was created with high density near the airfoil surfaces to capture boundary layer effects.
- Boundary Conditions: Inlet velocity and atmospheric conditions were set based on expected flight conditions.

Simulation Conditions:

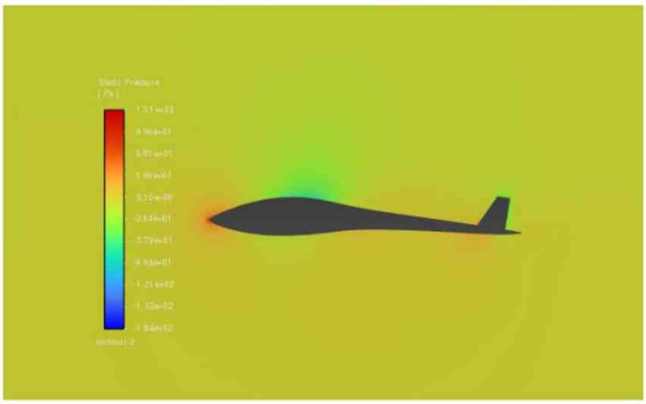
- Airspeed: 15 m/s along the X-axis.
- Atmospheric pressure conditions at sea level.
- Temperature: 27°C.
- No humidity was considered.

5.1 Results and analysis (at 0° angle of attack)

- Pressure Distribution: Contour plots illustrate high and low-pressure regions on the wing surfaces.



Surface plot of pressure variation on the glider body and wings



Contour plots of pressure distribution on XY plane

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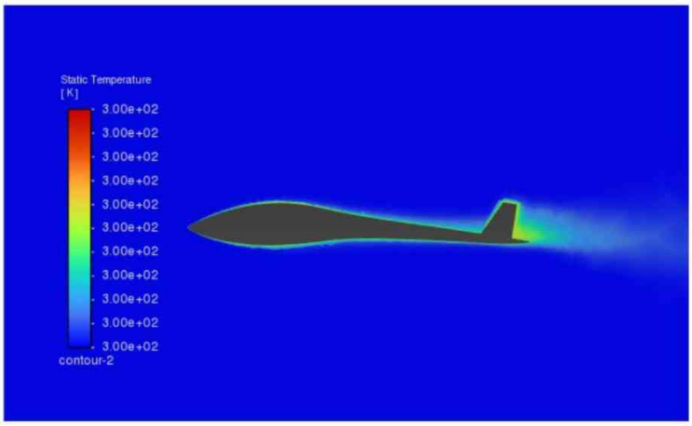
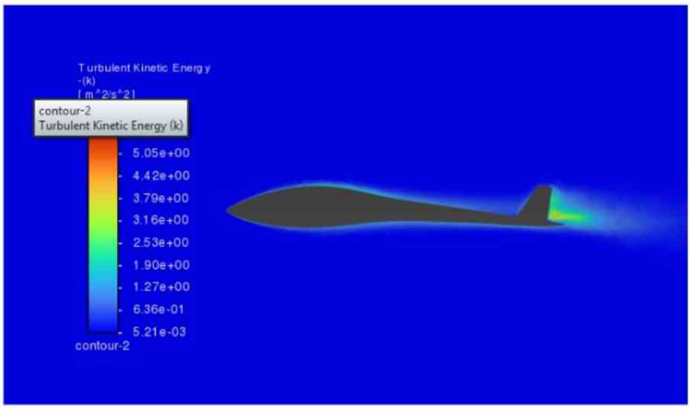
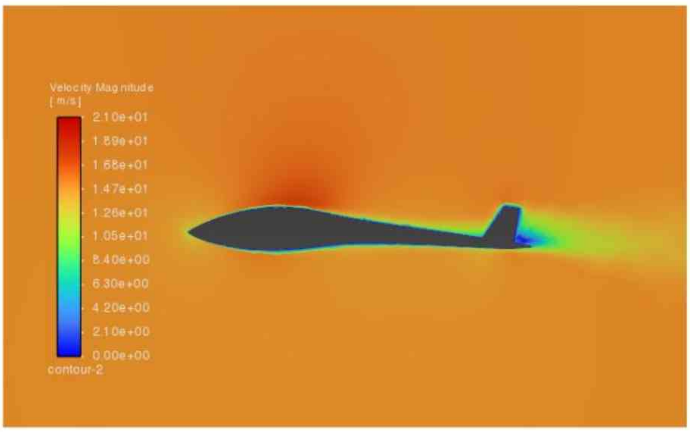
- Parameter countors



Contour plot of temperature variation on the XY plane



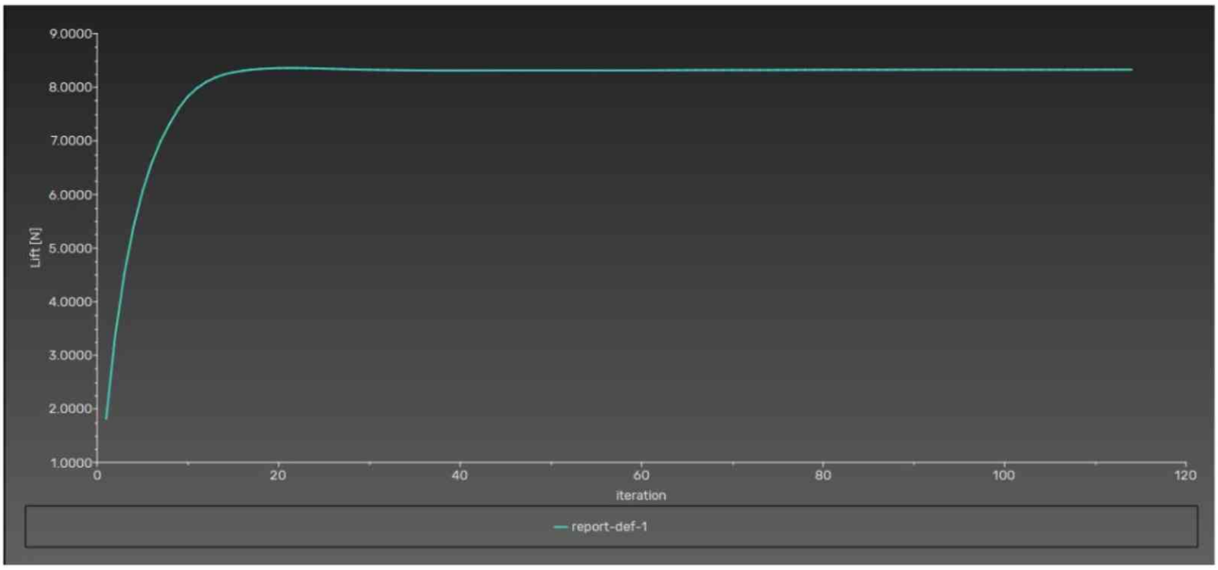
Contour plot of turbulence kinetic energy variation on the XY plane

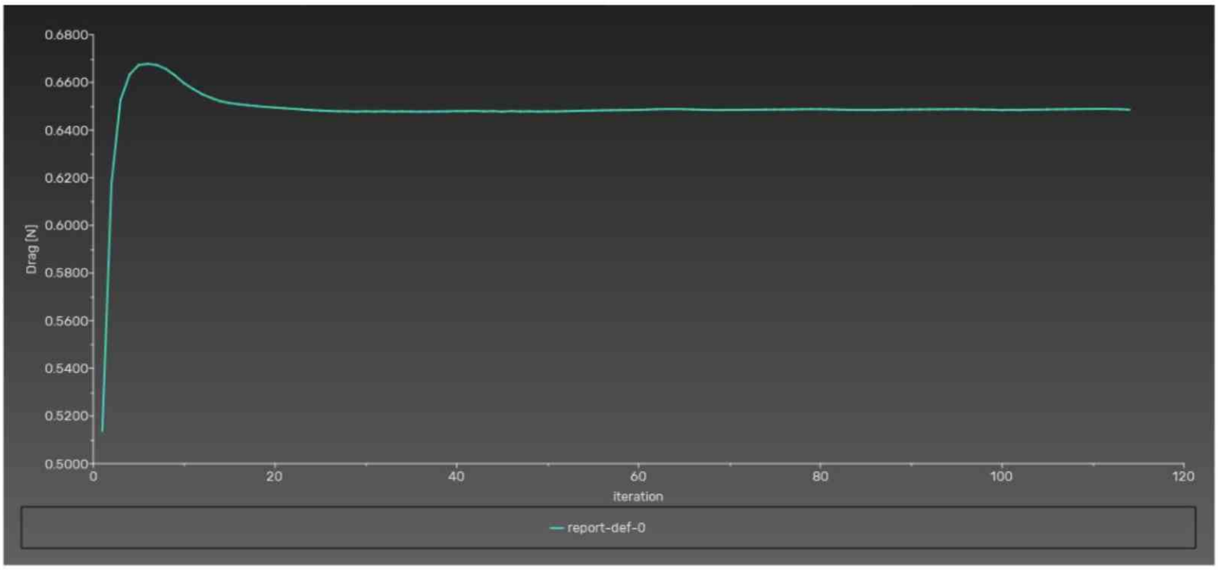


Contour plot of velocity variation in the XY-plane

- Lift and Drag forces:

The forces of lift and drag obtained from the simulation are plotted against the number of iterations.





From the data, it can be calculated that the **L/D** ratio comes out to be **14.56** at 0° angle of attack

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6. Conclusion

The hand glider was successfully designed with optimized aerodynamic properties. The combination of CAD modeling and CFD analysis ensured a well-balanced, efficient design suitable for controlled gliding. Future improvements could include material optimization and experimental flight tests.

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