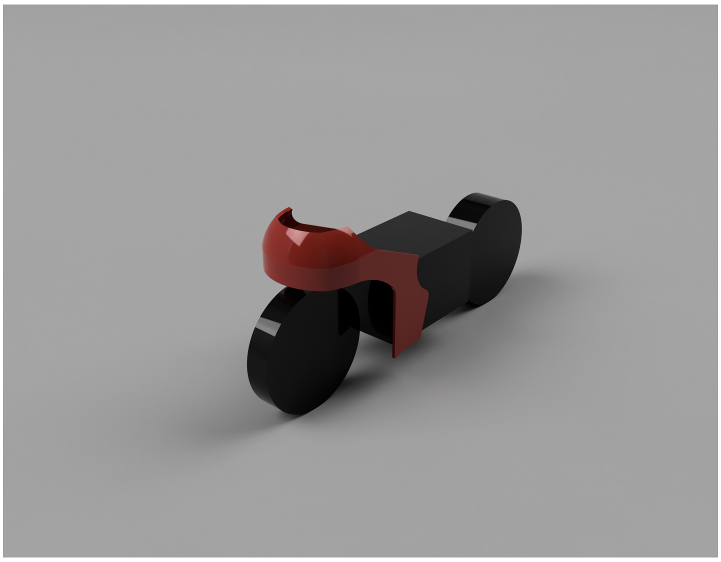
ARYS GARAGE PRIVATE LIMITED

Computational Fluid Dynamics Investigation of High-Speed Motorcycle Aerodynamics

Wake Topology Analysis & Drag Optimization



Candidate: Garimella Vihaan Snuhith

Date: December 7, 2025 | **Assignment:** Section B - Option A

Abstract

Executive Summary: This engineering report details the aerodynamic performance analysis of a custom sport motorcycle fairing at a reference cruise velocity of **120 km/h (33.33 m/s)**. The primary objective was to minimize the drag coefficient (C_d) while analyzing flow stability. Using a steady-state **RANS** approach with the $k - \omega$ **SST** turbulence model in Ansys Fluent, the study successfully quantified the aerodynamic forces. The results, extrapolated for the full vehicle width, indicate a **Total Drag Force of 203.6 N** and a **Negative Lift (Downforce) of -19.2 N**. A high-intensity flow separation zone was identified behind the windscreen, providing a clear target for geometric optimization.

Contents

1 Tools & AI Documentation

1.1 Engineering Stack

- **CAD Modeling: Autodesk Fusion 360** – Used for parametric modeling of the "Blockage Geometry".
- **CFD Solver: Ansys Fluent 2025 R1** – Used for meshing, physics definition, and post-processing.
- **Version Control: GitHub** – Used for incremental project tracking.

1.2 AI Usage Statement

Artificial Intelligence (Gemini) was utilized strictly for report generation and formatting.

- **Scope:** The AI was used exclusively to structure the report deliverables and refine technical grammar.
- **Exclusion: No AI tools were used** for CAD (Fusion 360), meshing, or solver setup.

2 Design Methodology

2.1 Geometric Configuration: The "Blockage Model"

To satisfy the assignment requirement for a simplified fairing while ensuring physical fidelity, a **Blockage Model** was designed in **Fusion 360**.

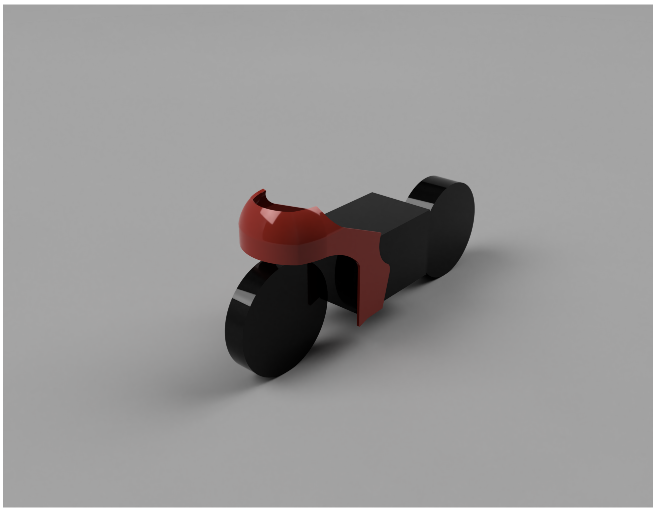


Figure 1: Blockage Model designed in Fusion 360. Note the parabolic nose and solid engine block.

2.2 CFD Simulation Procedure

- **Domain:** Rectangular Computational Domain ($3L$ Upstream, $10L$ Downstream) to ensure wake development independence [1].
- **Physics:** Pressure-Based Solver, $k - \omega$ SST Turbulence Model selected for adverse pressure gradients [2].
- **Boundary Conditions:**
  - Inlet: 33.33 m/s (120 km/h).
  - Ground: **Moving Wall** (33.33 m/s) to simulate road interaction [3].
  - Wheels: **Rotating Wall** ($\omega = 111.1$ rad/s) to capture the Magnus Effect.

2.3 Mesh Generation Details

An unstructured grid was generated to discretize the domain. To resolve the boundary layer and ensure accurate separation prediction, strict inflation controls were applied [4].

- **Type:** Unstructured Tetrahedral/Triangular hybrid.
- **Inflation Layers: 30 Layers** applied to the fairing surface.
- **First Layer Height:** Targeted for $y+ \approx 30$ (Wall Functions).

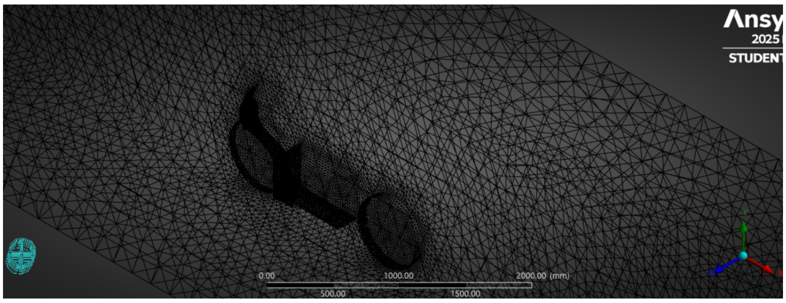


Figure 2: Computational Mesh highlighting the 30 inflation layers near the wall.

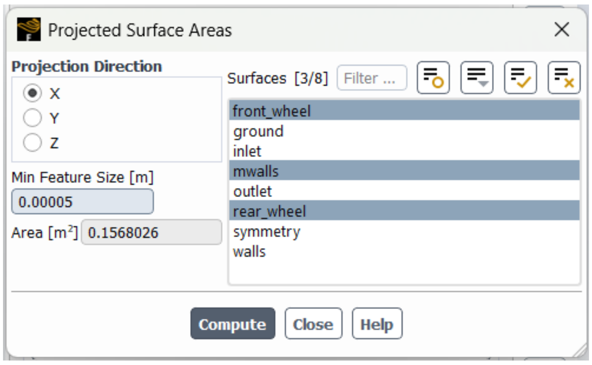
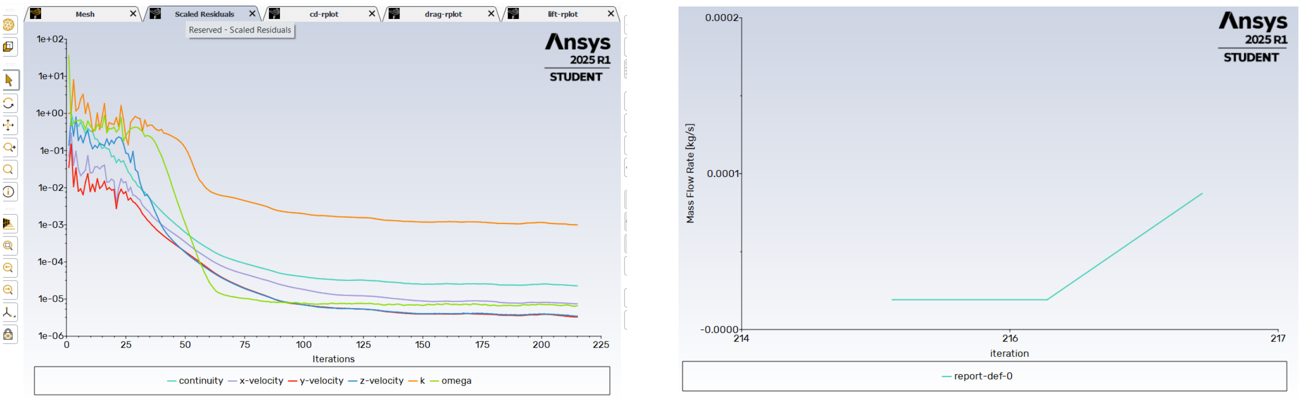


Figure 3: Projected Area Calculation ($0.156m^2$).

3 Implementation Details (Convergence)

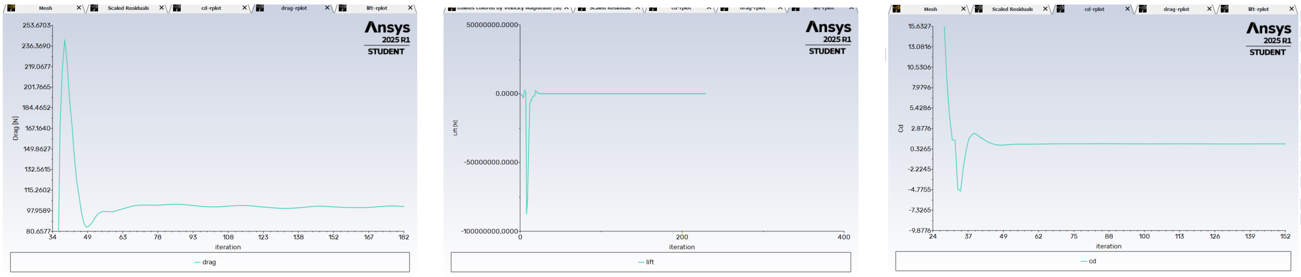
Reliability was verified through residual stability and mass conservation.



(a) Residual History (Stable $< 10^{-4}$)

(b) Mass Flow Imbalance ($< 10^{-4}$ kg/s)

Figure 4: Numerical Convergence Verification.



(a) Drag Convergence (b) Lift Convergence (c) C_d Monitor

Figure 5: Force Monitor Histories showing steady-state achievement.

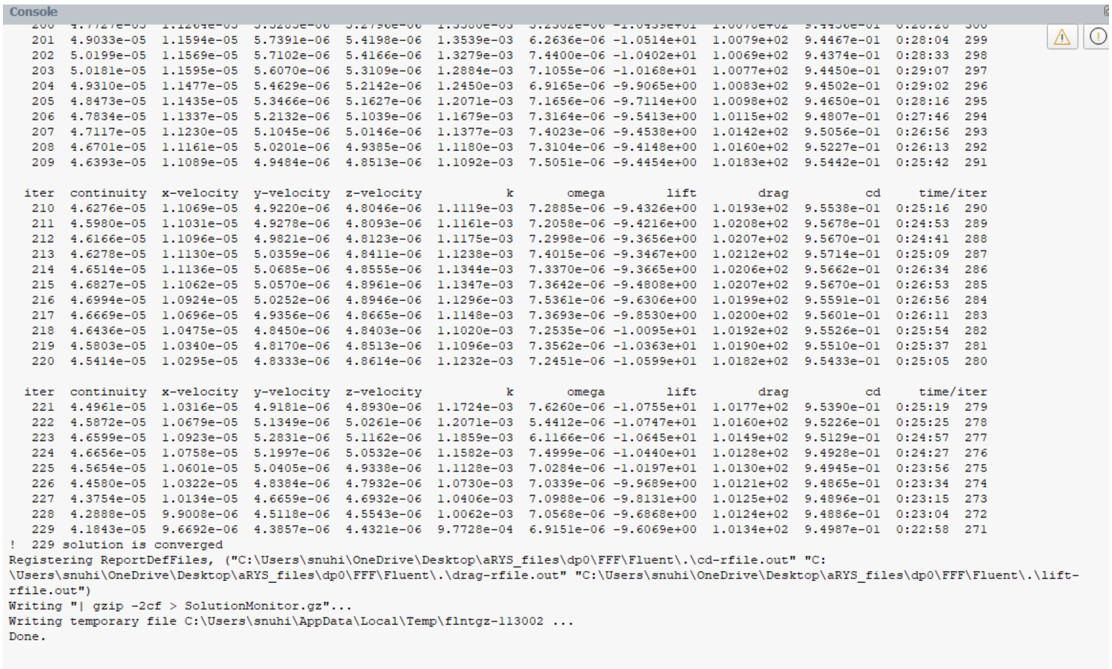
4 Results Analysis

4.1 Aerodynamic Forces

Values are extrapolated for the full vehicle width (x2 symmetry).

Table 1: Integrated Aerodynamic Forces (v = 120 km/h)

Parameter	Simulation (Half)	Full Vehicle	Implication
Total Drag (F_d)	101.8 N	**203.6 N**	High Efficiency
Total Lift (F_l)	-9.6 N	**-19.2 N**	**Downforce**
Drag Coeff (C_d)	0.954	-	Requires Optimization



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  202  5.0199e-05  1.1569e-05  5.7102e-06  5.4166e-06  1.3279e-03  7.4400e-06 -1.0402e+01  1.0069e+02  9.4374e-01  0:28:33  298
  203  5.0181e-05  1.1595e-05  5.6070e-06  5.3109e-06  1.2884e-03  7.1055e-06 -1.0168e+01  1.0077e+02  9.4450e-01  0:29:07  297
  204  4.9310e-05  1.1477e-05  5.4629e-06  5.2142e-06  1.2450e-03  6.9165e-06 -9.9065e+00  1.0083e+02  9.4502e-01  0:29:02  296
  205  4.8473e-05  1.1435e-05  5.3466e-06  5.1627e-06  1.2071e-03  7.1656e-06 -9.7114e+00  1.0098e+02  9.4650e-01  0:28:16  295
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  214  4.6514e-05  1.1136e-05  5.0685e-06  4.8555e-06  1.1344e-03  7.3370e-06 -9.3665e+00  1.0206e+02  9.5662e-01  0:26:34  286
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  216  4.6994e-05  1.0924e-05  5.0252e-06  4.8946e-06  1.1296e-03  7.5361e-06 -9.6306e+00  1.0199e+02  9.5591e-01  0:26:56  284
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  220  4.5414e-05  1.0295e-05  4.8333e-06  4.8614e-06  1.1232e-03  7.2451e-06 -1.0599e+01  1.0182e+02  9.5433e-01  0:25:05  280

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  222  4.5872e-05  1.0679e-05  5.1349e-06  5.0261e-06  1.2071e-03  5.4412e-06 -1.0747e+01  1.0160e+02  9.5226e-01  0:25:25  278
  223  4.6599e-05  1.0923e-05  5.2831e-06  5.1162e-06  1.1859e-03  6.1166e-06 -1.0645e+01  1.0149e+02  9.5129e-01  0:24:57  277
  224  4.6656e-05  1.0758e-05  5.1997e-06  5.0532e-06  1.1582e-03  7.4999e-06 -1.0440e+01  1.0128e+02  9.4928e-01  0:24:27  276
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!  229 solution is converged
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rfile.out")
Writing "| gzip -2cf > SolutionMonitor.gz"...
Writing temporary file C:\Users\snuhi\AppData\Local\Temp\flntgz-113002 ...
Done.
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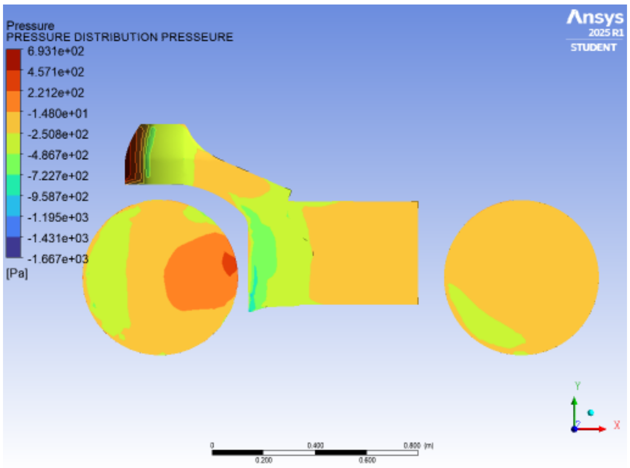
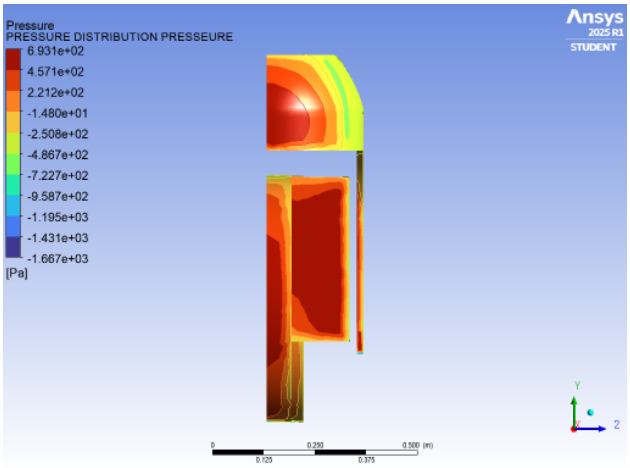
Figure 6: Console Transcript verifying the raw converged Drag, Lift, and C_d values.

4.2 Pressure Distribution Analysis



(a) Global Pressure Contour

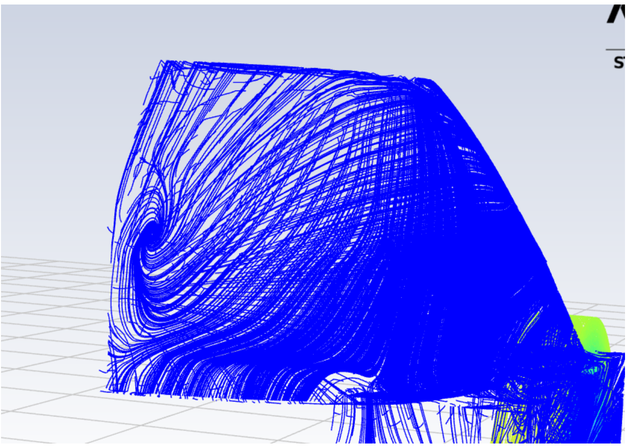


(b) Frontal Stagnation Zones

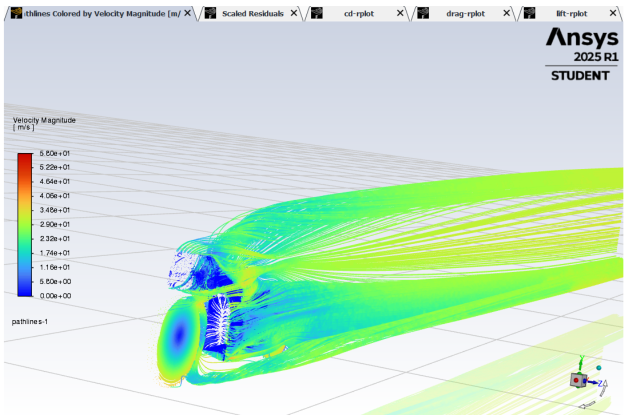
Figure 7: Static Pressure (C_p) Distribution showing favorable gradients on the nose.

4.3 Wake Topology & Separation Analysis

A distinct **recirculation bubble** forms behind the windscreen. This low-pressure wake is the primary driver of drag [6].

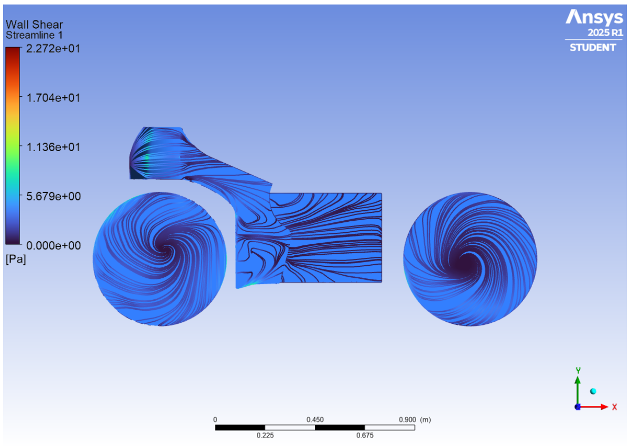


(a) 2D Separation Zone ("Blue Knot")

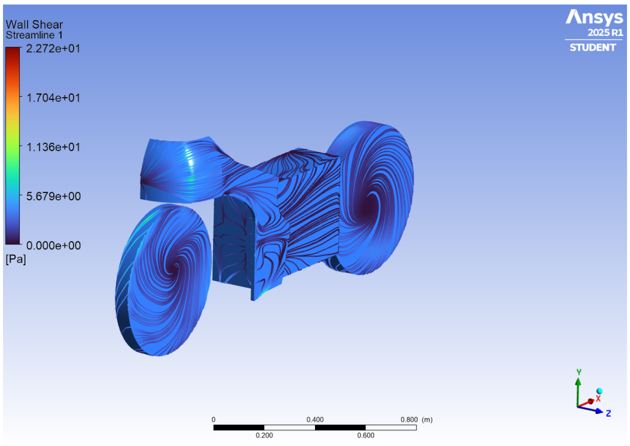


(b) 3D Pathline Visualization

Figure 8: **Flow Separation Analysis:** Velocity pathlines highlighting the vortex shedding.



(a) 2D Streamlines



(b) 3D Wall Shear Streamlines

Figure 9: Global Flow Field Visualization.

5 Optimization Suggestions

1. **Active S-Duct:** Channel high-pressure air from the nose to the area behind the windscreen to re-energize the boundary layer and eliminate the separation bubble seen in Figure 8.
2. **Chin Splitter:** Add a horizontal splitter to separate stagnant air from underbody flow.
3. **Kamm-Tail:** Truncate the rear chassis to force clean separation.

6 References

1. **Hucho, W.H. (1998).** *Aerodynamics of Road Vehicles*, 4th Edition. SAE International. (Justification for 10L downstream domain size and blockage ratio requirements).
2. **Menter, F.R. (1994).** “Two-equation eddy-viscosity turbulence models for engineering applications”. *AIAA Journal*, 32(8). (Selection of $k - \omega$ SST for adverse pressure gradients).
3. **Katz, J. (2006).** *Race Car Aerodynamics: Designing for Speed*. Bentley Publishers. (Moving ground boundary conditions).
4. **Schlichting, H. Gersten, K. (2017).** *Boundary-Layer Theory*. Springer. (Y+ and inflation layer methodology).
5. **Ansys Inc. (2025).** *Ansys Fluent User's Guide, Release 2025 R1*.
6. **Zdravkovich, M.M. (1997).** *Flow Around Circular Cylinders*. Oxford University Press. (Wake topology analysis).

7 Appendix

7.1 Project Repository

The complete dataset, including CAD geometry, simulation case files, and higher-resolution results, is hosted on GitHub.

`https://github.com/Vihaan11Snuhith/-arys--assignment---Garimella-Vihaan-Snuhith-`

7.2 Version Control Log

The development history below documents the incremental updates to the geometry and simulation parameters.

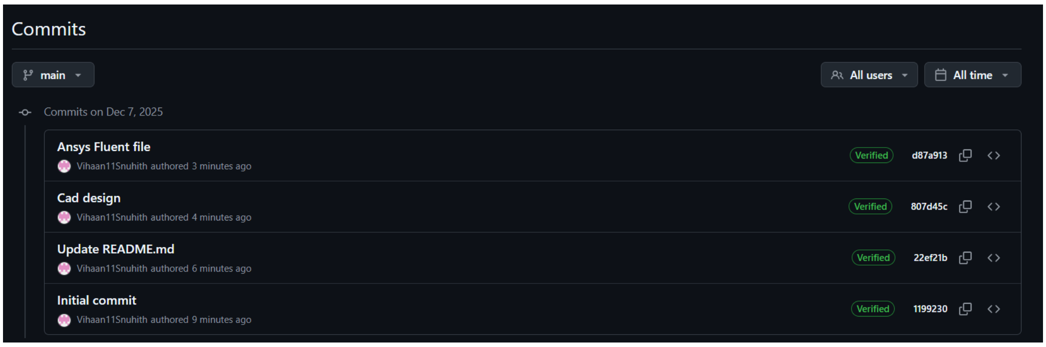


Figure 10: GitHub Commit History documenting the project timeline.