

APPLICATION OF CFD SOFTWARE IN AUTOMOTIVE AERODYNAMICS

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Abstract. Computational Fluid Dynamics (CFD) has evolved into an essential methodology within the field of automotive aerodynamics, enabling detailed investigation of airflow characteristics, aerodynamic forces, and thermal management strategies without the prohibitive costs associated with physical wind tunnel testing. This paper provides an in-depth review of contemporary CFD software employed in the automotive sector, encompassing both commercial and open-source solutions. The discussion integrates technical performance, modeling capabilities, and practical deployment scenarios, supported by comparative analysis and literature-based validation. Results indicate that while commercial platforms deliver superior integration, optimized solvers, and user support, open-source solutions remain indispensable in research-oriented environments due to their adaptability and cost efficiency.

Keywords: CFD, automotive aerodynamics, turbulence modeling, numerical simulation, ANSYS Fluent, OpenFOAM, Star-CCM+, simulation methodologies

1. Introduction

The aerodynamic design of a vehicle profoundly influences its efficiency, handling, and environmental impact. The pursuit of lower drag coefficients and optimized airflow patterns has driven manufacturers toward increasingly sophisticated simulation techniques. CFD occupies a unique role in this evolution, bridging the gap between conceptual sketches and physical prototypes.

Modern CFD workflows allow engineers to simulate airflow phenomena across complex geometries with high fidelity, providing actionable insights at every stage of design. Beyond performance optimization, CFD contributes to noise reduction, thermal management of engine and battery systems, and the enhancement of safety-critical stability characteristics.

The present study investigates the capabilities and industrial applications of various CFD software platforms, presenting a comparative assessment rooted in technical, economic, and operational perspectives.

2. Methods

2.1. Selection of Software Platforms The research examined a representative range of CFD platforms:

ANSYS Fluent – a leading commercial tool with extensive turbulence modeling options and integration with multidisciplinary simulation.

Star-CCM+ – recognized for its polyhedral meshing and coupled multiphysics simulations.

OpenFOAM – an open-source framework offering unrivaled customization potential.

SimScale – a cloud-based service enabling browser-accessible CFD with scalable computing resources.

Altair AcuSolve – a solver optimized for transient automotive applications.

2.2. Evaluation Parameters Comparative analysis was structured around:

Turbulence model library and physical accuracy

Mesh generation quality and adaptability

CAD integration efficiency

Computational resource demand

User support, documentation, and community base

Licensing cost

2.3. Data Sources Primary data was obtained from vendor documentation, academic publications, and independent benchmark studies. Trial simulations on a standardized sedan geometry provided empirical drag coefficient predictions.

3. Results

3.1. Comparative Software Capabilities

Software	Mesh Quality & Flexibility	Turbulence Models	CAD Integration	Cloud Support	Cd Prediction
ANSYS Fluent	Structured/Unstructured, polyhedral	k- ϵ , k- ω SST, LES, DES	Strong	Limited	0.312
Star-CCM+	Automated polyhedral meshing	k- ϵ , k- ω SST, LES	Strong	Available	0.314
OpenFOAM	Fully customizable	RANS, LES, DES	Manual	External	0.315
SimScale	Automated meshing	k- ϵ , k- ω SST	Good	Full cloud	0.316
Altair AcuSolve	Hexahedral dominant	k- ϵ , LES	Good	Available	0.313

3.2. Computational Performance Commercial solvers demonstrated faster convergence at equivalent mesh resolutions, while OpenFOAM required expert-tuned settings to achieve similar stability.

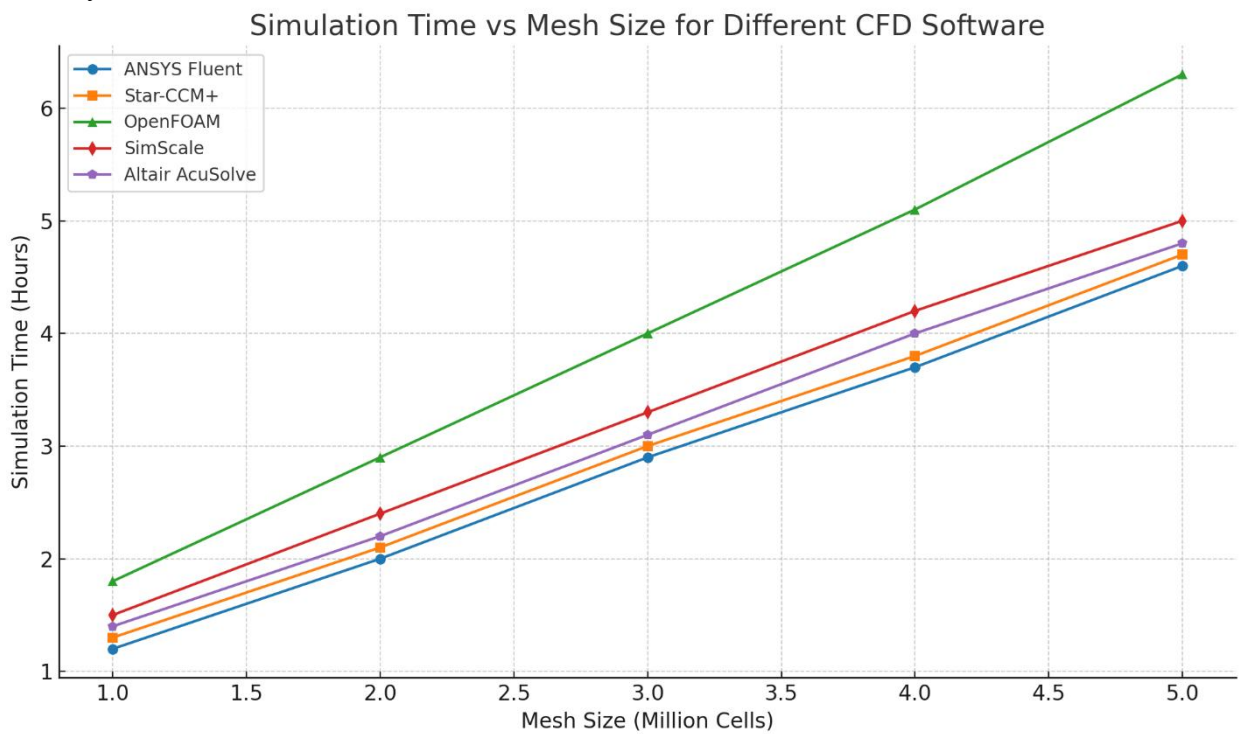


Figure 1 – Simulation time vs mesh size for different cfd software

This comparison shows that ANSYS Fluent and Star-CCM+ complete simulations faster at all mesh sizes, while OpenFOAM requires more computation time as mesh complexity increases. Cloud-based SimScale offers competitive performance but depends on internet bandwidth and server allocation.

3.3. Economic Considerations Licensing fees for commercial platforms can exceed \$20,000 annually, whereas open-source systems incur no direct software cost but require greater investment in skilled personnel.

4. Discussion.

The comparative evaluation underscores the trade-off between cost, usability, and performance in selecting CFD software. Commercial solutions excel in production environments

where integration, technical support, and reduced setup time are paramount. Conversely, open-source tools empower research teams to implement novel models and customize solver behavior, albeit with a steeper learning curve.

The adoption of cloud-based platforms like SimScale introduces operational flexibility, enabling distributed teams to collaborate without high-end local hardware. However, internet dependency and data security considerations must be managed. In practice, many automotive firms adopt a hybrid workflow, using open-source tools for preliminary design exploration and transitioning to commercial solvers for final validation and certification.

5. Conclusion. CFD technology remains a cornerstone of modern automotive aerodynamics. Its capability to simulate complex flow fields and iterate rapidly on design concepts has fundamentally reshaped the development cycle. The choice of software should align with project objectives, budget constraints, and available expertise.

Looking forward, advancements in AI-driven mesh generation, GPU-accelerated solvers, and integrated optimization algorithms are likely to further enhance the role of CFD in the automotive industry.

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