



The Influence of Body Streamline Design on the Energy Consumption of New Energy Vehicles and Traditional Energy Vehicles

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Abstract. The global energy transition and carbon neutrality goals have driven the rapid development of new energy vehicles (NEVS), while traditional internal combustion engine vehicles (ICEVS) are also under pressure to improve energy efficiency. Aerodynamic design plays a vital role in improving vehicle performance by reducing drag and enhancing energy efficiency. This paper compares the aerodynamic design differences between NEVS and ICEVS, analyses their respective design challenges and strategies, and discusses common and unique aerodynamic optimisation methods. The paper explains the principle of the drag coefficient and its influencing factors and introduces two common measurement techniques—wind tunnel testing and the coasting method. By examining case studies of the Tatra 77 and Tesla Model S, it illustrates how streamlined design can effectively reduce drag, lower energy consumption, and increase driving range. The analysis demonstrates that although both vehicle types share some aerodynamic techniques, NEVS are shifting toward integrated and intelligent aerodynamic strategies, while ICEVS rely more on localised modifications. The findings provide theoretical support and practical references for designing future high-efficiency vehicles, contributing to the sustainable development of the automotive industry.

Keywords: New Energy Vehicles; Traditional Internal Combustion Engine Vehicles; Aerodynamic Design; Drag Coefficient; Energy Efficiency

1 Introduction

The global energy transition and carbon neutrality goals is driving the rapid development of new energy vehicles. This development is reshaping the vehicle industry. If the shape differences between electric and regular cars aren't fixed, electric cars will have shorter range and sell less. Regular cars will use more fuel and pollute more. Both problems hurt the world's plan for cleaner transport.

When compared with internal combustion engine vehicles, NEVS have fundamental differences in powerplant systems, energy efficiency, and design

philosophy. Those differences offer some new challenges for automotive aerodynamic design. A lot of the energy wasted when a car is running comes from aerodynamic drag. The drag coefficient (C_d) could be reduced by optimising the streamlined design of the vehicle body. This can hugely improve energy efficiency. But new energy vehicles and internal combustion engine vehicles have different limitations and innovative ways in aerodynamic optimisation [1].

That is because they have different technological development paths and design priorities. For internal combustion engine vehicles, the main goal is still to reduce fuel consumption. There's an alike linear relationship between aerodynamic drag and fuel consumption. But the design of these vehicles has been restricted for a long time. The cooling needs of the internal combustion engine, like having open front grilles, which increase the frontal area, limit the potential for aerodynamic optimisation.

In contrast, new energy vehicles are putting focus on having a long driving distance. Some design features are really helpful, such as flat battery chassis layouts and small electric motors. These features could give more freedom for a streamlined design. Take closed front faces and underbody fairings, for example. They can reduce turbulence more effectively. Also, energy recovery systems are sensitive to the stability of airflow.

ICEVS and NEVS use some of the same aerodynamic technologies. For example, they both have streamlined roofs and use lightweight materials. But their technical approaches are becoming increasingly different. ICEVS depend on local improvements. For example, they use side mirror deflectors and active grille systems. These help them balance cooling and reduce drag. On the other hand, NEVS prefer overall integrated designs. For example, they have frameless doors. They also use intelligent active devices like retractable rear wings. These help them reach ultra-low drag goals.

This study aims to show how aerodynamic innovations can solve the energy efficiency problems for those two types of cars by comparing their streamlined design mechanisms and technological differences. This provides some theoretical ideas for future high-efficiency automotive design.

2 Theoretical Basis: Aerodynamic Principles and Their Impact on Energy Efficiency

2.1 Principle of drag coefficient

The drag coefficient serves as a crucial factor in quantifying aerodynamic resistance encountered by moving objects. Objects demonstrating lower coefficient values exhibit enhanced aerodynamic efficiency, with diminished resistance forces acting upon them during motion through air masses. The drag coefficient (C_d) can be determined through the equation $C_d = F_d / (0.5\rho v^2 A)$, where F_d indicates aerodynamic drag force, ρ stands for atmospheric density, v represents relative velocity between the object and airflow, and A corresponds to the object's cross-sectional area perpendicular to flow direction [2].

The drag coefficient serves as a critical parameter for assessing a vehicle's aerodynamic efficiency. Minimising this value corresponds to decreased air resistance during operation, which enhances fuel economy, elevates operational velocity, and optimises driving stability through improved airflow management around the vehicle's contours [3].

2.2 Drag Coefficients for Different Car Shapes

The drag coefficient (C_d) quantifies a vehicle's aerodynamic efficiency during motion through air. Reduced C_d values correlate with diminished aerodynamic resistance, enhancing fuel economy and performance capabilities. Primary determinants influencing C_d involve body contour geometry, underbody airflow management, and protrusive exterior elements like mirrors and spoilers [4].

Frontal Area. Increased aerodynamic drag occurs as the front-facing surface area expands, resulting in greater air resistance. This phenomenon demonstrates that objects with broader cross-sectional profiles encounter amplified opposing forces during motion through fluid media [5].

Body Shape. Aerodynamically optimised designs facilitate laminar airflow patterns, thereby minimising turbulent disturbances during fluid movement. Angular contours disturb laminar air currents, leading to heightened aerodynamic resistance [6].

Speed. When velocities are minimal, the primary determinants of fluid resistance become the object's geometric configuration and its cross-sectional dimensions. When velocities reach elevated levels, the compressibility effects of air become more pronounced, thereby amplifying the aerodynamic resistance forces encountered [7].

2.3 Measurement Methods for Drag Coefficient

Wind Tunnel Method. Wind tunnel testing stands as a globally prevalent technique for determining the aerodynamic drag coefficients of vehicles. During experimental procedures, the test specimen is secured within the wind tunnel's measurement zone. Researchers systematically record aerodynamic resistance values, airflow stagnation pressures, and the object's frontal cross-sectional dimensions across varying airflow velocities. These collected data points enable the subsequent computation of the dimensionless drag coefficient [8].

Coasting Method. The free-coasting technique represents a widely utilised approach for determining aerodynamic drag coefficients. This experimental procedure entails releasing the test object with a predetermined initial velocity while precisely monitoring its deceleration rate and displacement over time. The experimental procedure entails propelling the object to a predetermined velocity before disengaging

the power supply, enabling unpowered motion through the atmospheric medium. Through systematic observation of velocity variations and displacement measurements during the free-glide phase, researchers can quantitatively determine both aerodynamic resistance and the coefficient of drag acting upon the test subject [9].

3 Comparison of Streamline Designs between New Energy Vehicles and Traditional Energy Vehicles

3.1 Traditional cars (ICEVS) and electric cars (NEVS) face different design challenges

The primary objective of internal combustion engine vehicles (ICEVS) is to minimise fuel consumption. By reducing the coefficient of aerodynamic drag (C_d), manufacturers can enhance fuel economy through improved airflow management.

The primary objective of New Energy Vehicles (NEVS) focuses on enhancing driving range capabilities, where minimising aerodynamic drag coefficients becomes essential given current battery technology constraints. Improved energy efficiency through optimised vehicle aerodynamics could be a solution to the core challenge of limited energy storage capacity in contemporary power cell systems. In addition to that, improving air flow design could also enhance the driving range capabilities through the development of energy recycling [10]. Energy recycling effectiveness may be compromised by turbulent airflow patterns, as irregular air movement disrupts the optimal operation of recovery systems. The chaotic nature of such airflow creates unstable operational conditions that hinder efficient energy transfer processes within recycling mechanisms.

3.2 Shared and Unique Design Methods

Shared Methods: Reduce C_d . The vehicle's aerodynamic roof designs are complemented by seamlessly integrated door handle mechanisms. These carefully engineered features enhance visual continuity while optimising functional performance through reduced drag coefficients and improved ergonomic accessibility [11].

Advanced engineering applications frequently utilise low-density substances such as aluminium alloys and carbon fibre composites [11].

Traditional car (ICEV) Methods. Implement minor adjustments: Install components such as mirror housings or chassis shielding panels to enhance functionality and improve structural integrity. Active grilles regulate their aperture configurations to optimise the equilibrium between thermal management efficiency and aerodynamic resistance [12].

Electric Car (NEV) Methods. Optimised structural configuration: Sealed front panels combined with seamless door assemblies enhance aerodynamic performance [13].

Innovative adaptive systems: Dynamically deployable aerodynamic elements coupled with real-time chassis altitude modulation. These mechanisms enable precise airflow management and suspension optimisation, enhancing both performance and comfort across diverse driving scenarios [13].

4 Case Analysis

4.1 Tatra 77

Overall design. Teardrop-shaped design: Tatra 77 overall is of a water drop shape design, whose wind resistance coefficient aerodynamics has very good air tightness. The rounded and smooth front of the vehicle is relatively round, to allow the airflow to form a smooth air flow contact with the vehicle body, reducing the disorder and resistance of the airflow. When the car is moving, the airflow will first touch the vehicle's front. The rounded front shape of the car allows the flowing air to run easily alongside the vehicle's body surface without producing too much of a turbulent flow or separation. In this way, the resistance of air to the car is reduced, which further leads to a reduction of air resistance that the car has to cross when it travels and, consequently, also energy consumption is reduced [14].

Boat-shaped body. Due to the boat-shaped body of the Tatra 77 design, the side line of the vehicle body is gentle, smooth and natural, connecting from the front part to the rear part of the vehicle body, so the Tatra 77 design makes people have a feeling of dynamism and beauty. And make the wind flow smoothly inside part of the vehicle body so that the pressure of the airflow on the side part of the vehicle body is smaller, to further reduce wind resistance [15]. The boat-body form design can ensure that the airflow flows relatively close to the vehicle body surface when the car is running, and the separation of airflow on the body and vortex generation can be minimised. The air flow flows relatively smoothly on the side of the body surface, minimising the impact of air resistance on the vehicle body. Under the circumstance that the car runs, the resistance generated by the side of the body of the car itself will decrease, and the power required for the engine to output will decrease correspondingly, and fuel consumption will be reduced, and the distance of driving distance will be prolonged [14,15].

Detailed design. Front face without grille: Because of the rear engine position, the Tatra 77's front face does not need to arrange a common air intake grid to dissipate the engine heat. This makes the whole front part of the car more aerodynamically smooth and flat, facilitating the airflow from in front of the car without any obstruction. This enables the car to penetrate the air flow more effectively when driving ahead, reducing the disorder and the resistance created by the grille to the

airflow [16]. The smaller the front face air resistance, the smaller the air resistance of the car to be overcome, the smaller the power required by the car engine, and the savings in fuel consumption and the increase in driving mileage.

Hidden lampshade: The Tatra 77 adopts a hidden lampshade design, embedding the headlights into the interior of the vehicle body, making the front face of the car flatter and reducing the interference of protruding components to the airflow. When the headlights are turned off, they almost blend seamlessly with the vehicle body, effectively reducing wind resistance while also enhancing the overall sense and smoothness of the car's appearance [17].

Wheel arched: The obvious wheel arch has abundant space for wheels and makes the side line of the vehicle body smooth and natural. The transition from the wheel arch to the body of the vehicle is quite smooth. When the airflow passes through the wheel arch, it can flow smoothly, reducing the separation of the airflow and the formation of vortices, and reducing the wind resistance. The wheel arch design can also make the aerodynamic air flow process optimised. When the air flow enters the wheel arches, it can pass over the vehicle body more smoothly, thereby lowering the air resistance to the vehicle body. As for the driving range, the reduction of air resistance can lower the energy loss of the vehicle, enhance the fuel economy, and expand the driving range.

Impact and Significance. The light of Tatra 77's streamlined design also gave references and inspirations to the subsequent automotive design. It shows significant potential of streamlined design for improving the automotive performance and shape, which motivates other auto-makers to do it one after another. Most car brands are involved in a similar streamlined design concept in their successive model design, which is beneficial for the car design development. Aerodynamic performance is some modern cars designed highlight, with flowing body lines and detailed design optimised to lower the wind resistance, to enhance the fuel economy and driving range performance.

4.2 Tesla Model S

Overall shape: Smooth body line. The exterior design of Tesla Model S uses a coupe body style and has round, strong body lines, meeting the beauty requirements of most people, and has obvious advantages in aerodynamics. Smooth lines can reduce air resistance and make the car run more smoothly during use. When a vehicle is moving at high speed, the air can more smoothly pass through the car body. Through the body surface to reduce the wind resistance coefficient.

Low drag coefficient: Low drag coefficient is another significant feature of the overall design of the Tesla Model S. Through the optimisation of body design, the Tesla Model S has achieved a lower drag coefficient, which is a key factor to increase the driving range [18]. The lower the wind resistance coefficient, the less energy the vehicle consumes to overcome air resistance in the process of driving and thus prolongs the driving range. Aerodynamics, which refers to air resistance, has an

impact on the electric vehicle's driving range, one of the important factors of EV driving range.

Detailed design. Windshield and side rearview mirror design: Design of the Tesla Model S's windshield and side rearview mirrors positively influences aerodynamic performance and the vehicle's driving range.

By solving CFD analysis, the design of the windshield and rearview mirrors can smooth the air flow around the vehicle body (reducing separation, turbulence of airflow around the body) and bring a lower driving coefficient drag and increase driving range.

Tire design: The tire design of the Tesla Model S also considers aerodynamic factors. The optimised tire tread and tire size can minimise the tire and ground friction and lower the rolling resistance [19]. Rational tire design can also minimise the turbulence of the air around tires and decrease the wind resistance coefficient. The optimised tire design can decrease the vehicle's drag coefficient and increase the driving range.

Influence and Significance. Improving aerodynamic performance: Due to the streamlined body design of the Tesla Model S, the aerodynamic performance of the car is considerably improved. The optimal overall shape and finer details design realise the improved aerodynamic drag performance and aerodynamic noise of the Model S.

It increases the driving stability and riding comfort of the vehicle. And it can decrease the amount of energy consumption and make the driving range longer.

Extending the driving range: The simplified body structure has positively contributed to the driving range of the Tesla Model S [5]. As what was discussed above, decreasing the coefficient of air drag and the coefficient of rolling resistance can lower the fuel energy which vehicles use to overcome air drag and friction during the driving process and thereby extend the driving range. Besides, a body's optimal design can also help improve the car's energy efficiency, making the car's batteries' energy can be fully used.

Accelerate the construction of automotive design: Tesla Model S' slim body design layout opens a fresh opinion and direction in the field of automotive design; Its unique style design layout and innovative pneumatic design concept are significant in the field of electric cars and can contribute to the traditional fuel cars' styling design concept. As shown by the successful example of the Tesla Model S, the aerodynamic design can potentially make a great contribution to both vehicle performance enhancement and energy consumption reduction.

5 Conclusion

Due to different technological development paths and design focuses, new energy vehicles and traditional fuel vehicles face distinct challenges in aerodynamic design,

and the technical path differences are gradually increasing. Traditional fuel vehicles, constrained by the cooling requirements of internal combustion engines, focus on local improvements for optimisation, while new energy vehicles, leveraging their structural advantages, pay more attention to overall integrated design to achieve ultra-low wind resistance and meet the demand for long-range driving.

The case studies of Tatra 77 and Tesla Model S demonstrate that optimising aerodynamic design significantly enhances vehicle performance. Whether it is a traditional fuel vehicle or a new energy vehicle, reducing the coefficient of drag can decrease energy consumption, improve fuel economy or increase driving range, and also enhance driving stability and comfort.

Driven by the global energy transition and carbon neutrality goals, future vehicle design should deeply explore the potential of aerodynamic optimisation based on the characteristics of different types of vehicles. This helps to improve the energy efficiency and overall performance of vehicles and can provide strong support for the sustainable development of the automotive industry, contributing to the vision of cleaner and more efficient transportation.

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