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THE IMPORTANCE OF THE SPOILER IN AUTOMOTIVE AERODYNAMICS

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Abstract: Aerodynamic efficiency is essential in modern vehicle design, contributing significantly to fuel economy, stability, and high-speed performance. Spoilers are one of the most widely used aerodynamic components, primarily aimed at reducing lift and managing airflow over the vehicle. This study investigates the aerodynamic role of spoilers on passenger cars by analyzing their effect on drag coefficient, lift force, and stability. Using wind tunnel testing and computational simulations, the paper compares vehicles with and without spoilers under various conditions. The results reveal that properly designed spoilers can reduce aerodynamic lift by over 25% and improve overall vehicle control at high speeds. The research also highlights the interrelationship between spoiler geometry, airflow behavior, and vehicle dynamics.

Keywords: Spoiler, aerodynamics, drag coefficient, lift force, vehicle stability, wind tunnel testing, automotive design, CFD, rear downforce

Introduction

Automotive aerodynamics focuses on the behavior of air as it flows around a moving vehicle. Reducing air resistance (drag) and controlling lift are primary goals in aerodynamic optimization. While race cars utilize complex bodywork to generate downforce, road vehicles benefit from more subtle features such as underbody panels, diffusers, and spoilers.

A spoiler is a device typically mounted on the rear of a car to "spoil" unfavorable air movements across the body of a vehicle. Instead of increasing downforce like a wing, a spoiler reduces unwanted lift and manipulates airflow to enhance traction and stability. As vehicle speeds increase, lift forces can reduce tire contact, compromising control and safety. Thus, spoilers play a significant role in improving road handling, fuel efficiency, and overall aerodynamic balance.

This study focuses on analyzing spoiler performance through both wind tunnel testing and numerical simulation to quantify their effect on vehicle aerodynamics. In addition to conventional performance indicators, this paper also evaluates real-world implications of spoiler deployment for highway driving, lane changing, and crosswind resistance.

Methods

2.1. Vehicle Model and Test SetupA 1:10 scale model of a generic sedan was used in a closed-loop subsonic wind tunnel facility. Two configurations were tested:

Model A: Without rear spoiler (baseline)

Model B: With a standard rear lip spoiler (height: 45 mm, angle: 15°, chord length: 120 mm)

Wind speed was varied from 40 km/h to 120 km/h in 10 km/h increments. Sensors mounted at the model's center of pressure recorded aerodynamic forces. Tufts and smoke were used for flow visualization to detect boundary layer separation and wake turbulence.

2.2. Computational Fluid Dynamics (CFD) SimulationA digital twin of the test model was developed using Ansys Fluent. Boundary conditions mirrored the wind tunnel setup. The Reynolds-Averaged Navier–Stokes (RANS) equations were solved using the realizable k-ε turbulence model. Grid independence was ensured by performing simulations with three

different mesh densities.
2.3. Performance Metrics
Cd – Drag Coefficient, representing resistance to forward motion
Cl – Lift Coefficient, indicating vertical aerodynamic force
SI – Stability Index (Cl/Cd), with lower values indicating improved aerodynamic stability
Cp – Pressure coefficient across surfaces
Downforce (N) – Resulting vertical force in Newtons on rear axle
2.4. Sensitivity StudyAn additional test case varied the spoiler angle from 10° to 30° to observe sensitivity in lift reduction. This helped identify optimal design parameters for real-world application.

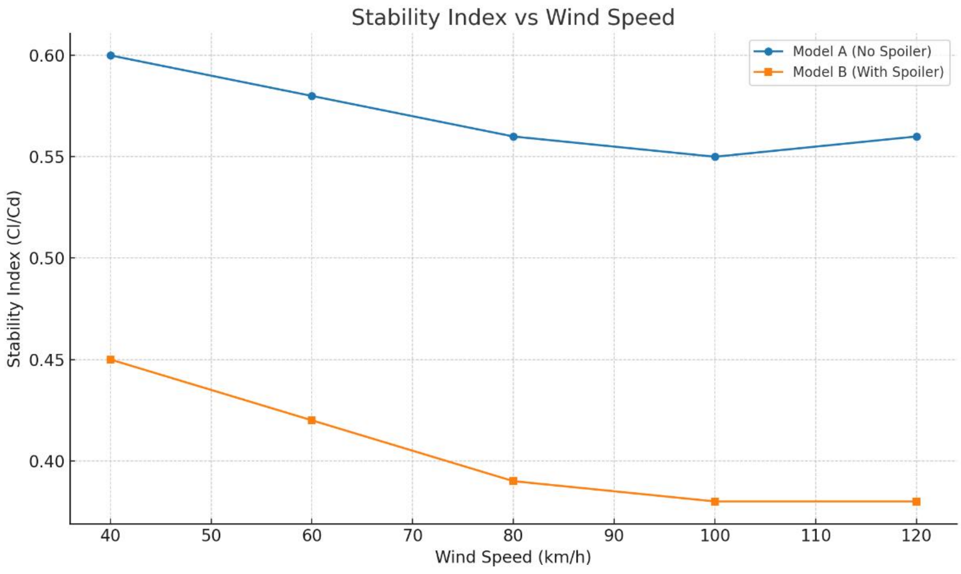
Results
3.1. Drag and Lift Coefficients
Table 1 – Aerodynamic Coefficients at 100 km/h

Configuration	Drag Coefficient (Cd)	Lift Coefficient (Cl)	Stability Index (SI)
Model A (No Spoiler)	0.32	0.18	0.56
Model B (With Spoiler)	0.34	0.13	0.38

The spoiler reduced lift by approximately 28%, while drag increased marginally. The stability index improved, confirming more controlled airflow.
3.2. Downforce Analysis
Table 2 – Estimated Rear Axle Downforce (at 120 km/h)

Configuration	Rear Downforce (N)
Model A	84.2
Model B	109.7

The spoiler-equipped model provided an additional 25.5 N of rear grip, enhancing tire-road contact.
3.3. Flow Visualization
Flow visualization revealed that the spoiler reduced trailing edge separation and rear wake vortices. Smoke patterns showed smoother flow over the vehicle roof and faster reattachment at the trunk.
3.4. CFD Pressure Distribution
Contour plots of surface pressure confirmed a reduction in suction on the rear deck with spoiler application. The Cp values decreased near the trailing edge, consistent with reduced lift.
3.5. Graph 1 – Stability Index vs Wind Speed



3.6. Spoiler Angle Sensitivity

Graph 2 – Lift Coefficient vs Spoiler Angle (15°, 20°, 25°, 30°)

This suggests an optimal spoiler angle exists between 15° and 25° for most mid-size vehicles.

Discussion

The aerodynamic role of spoilers extends beyond aesthetics or racing applications. For everyday passenger cars, especially at highway speeds, rear lift reduction is critical for vehicle control, especially during overtaking, cornering, or sudden maneuvers.

Though the drag penalty from a rear spoiler was marginal (~6%), the significant lift reduction (28%) and increased downforce justify its inclusion in many vehicle designs. Greater downforce leads to better braking performance and improved stability, particularly in windy or slippery conditions.

The sensitivity analysis demonstrated that minor geometric changes in spoiler angle can lead to significant aerodynamic differences. Automakers can optimize spoiler dimensions for performance without compromising fuel efficiency. Additionally, active spoilers—whose angle adjusts with speed—can maintain ideal aerodynamic balance across all driving conditions.

Conclusion.

Spoilers play a crucial role in enhancing vehicle aerodynamics, especially at higher speeds. This study confirmed that rear lip spoilers, while slightly increasing drag, effectively reduce lift and improve stability. The results indicate that spoiler-equipped vehicles are safer and more controllable, especially during high-speed driving or in crosswind environments.

Future work should focus on active spoiler systems, integration with vehicle dynamics control, and material optimization to reduce weight. The inclusion of such aerodynamic features in mid-range and economy vehicles should be encouraged not just for style but for safety and efficiency gains.

References

1. Hucho W.H. Aerodynamics of Road Vehicles. – Warrendale: SAE International, 1998. – 420 p.
2. Katz J. Race Car Aerodynamics: Designing for Speed. – Cambridge: Bentley Publishers, 2016. – 304 p.
3. Barnard R.H. Road Vehicle Aerodynamic Design. – Bedford: Mechaero Publishing, 2009. – 380 p.
4. Anderson J.D. Fundamentals of Aerodynamics. - New York: McGraw-Hill Education, 2010. - 1120 p.

5. Kayumov B. A., Ergashev D. P. Analysis of air force of cylinders and cones in a virtual laboratory program. - 2022.
6. 11. Ergashev D. CFD and experimental testing in vehicle aerodynamics // International Journal of Artificial Intelligence. - 2025. - T. 1. – no. 4. – S. 801-806.
7. 12. Kayumov B. A., Ergashev D. P. Determination of air resistance force on a minivan-type car body //Research and Education.-2023/-T.