Simulation and Optimization of a Prototype Active Rear Spoiler for Enhanced Vehicle Dynamics and Efficiency in Electric CSUVs

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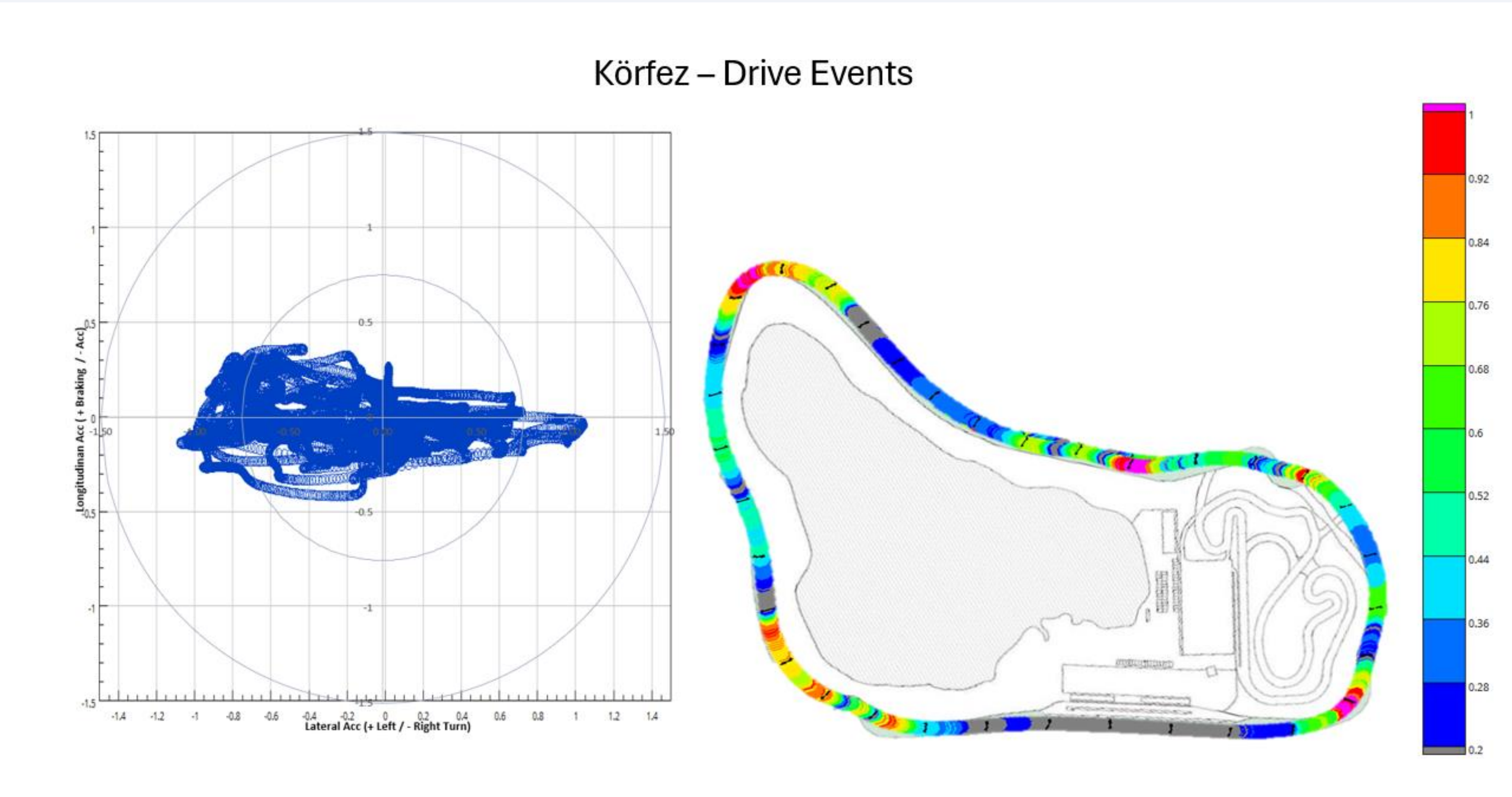
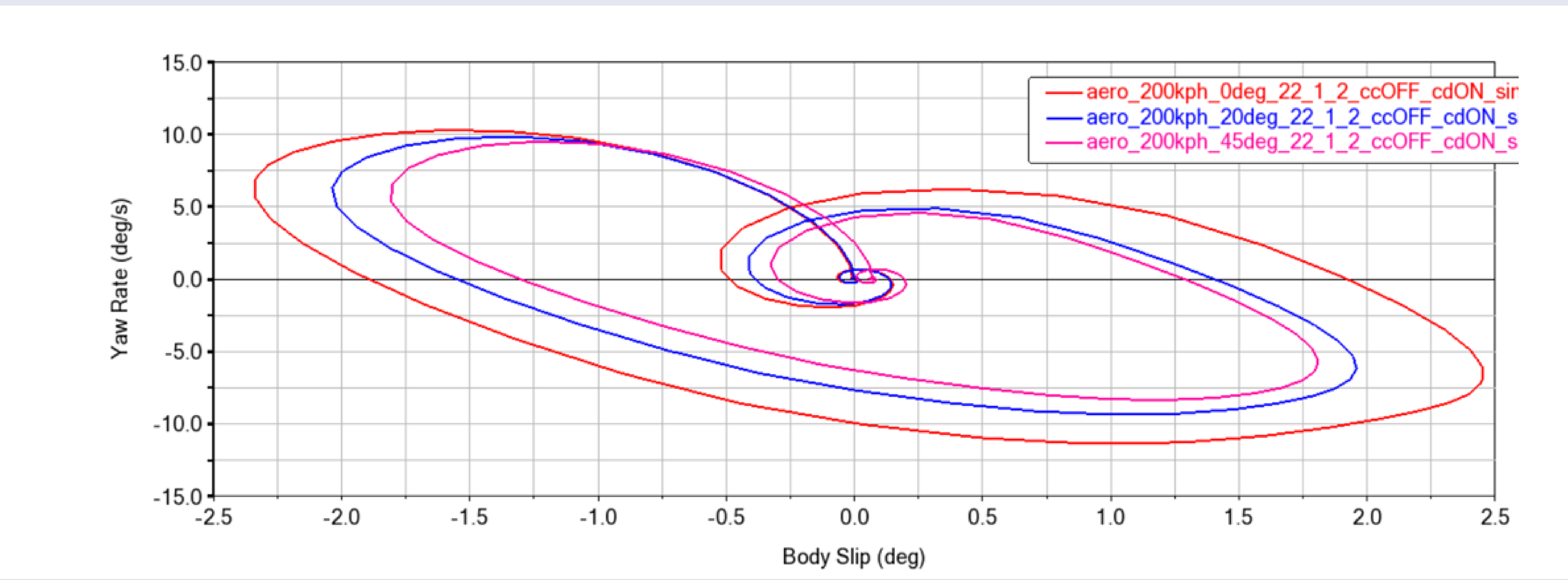
ABSTRACT



This Project focuses on the design, simulation, and optimization of an adaptive active rear spoiler for an electric compact SUV (CSUV) to improve stability, reduce drag, and boost energy efficiency. The spoiler dynamically adjusts to driving conditions to enhance handling, particularly at high speeds and during cornering—key for SUVs with high centers of gravity.

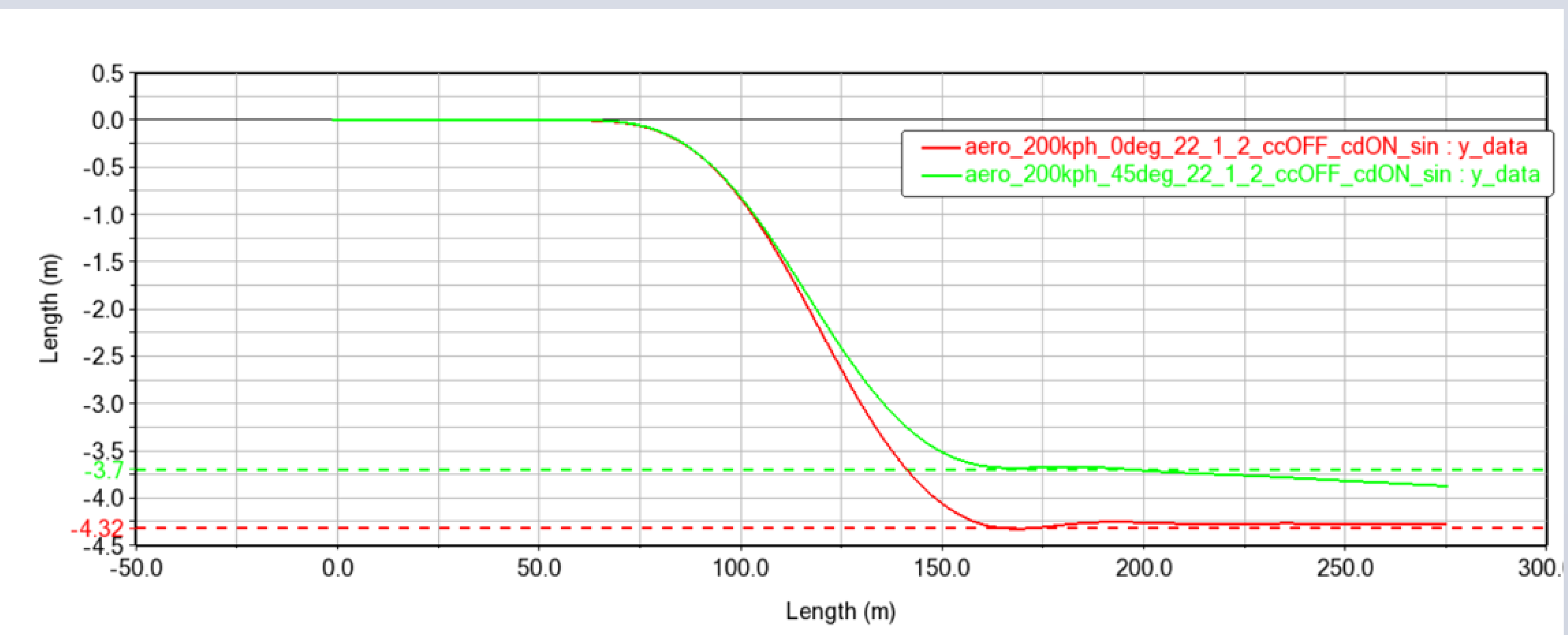
By lowering aerodynamic drag, the spoiler helps extend EV driving range and reduce energy consumption. CFD and simulation tools are used to optimize performance across scenarios, balancing downforce and drag for measurable gains in stability and efficiency. The study provides both data and a working prototype to advance adaptive aerodynamic technology for electric CSUVs.



OBJECTIVES

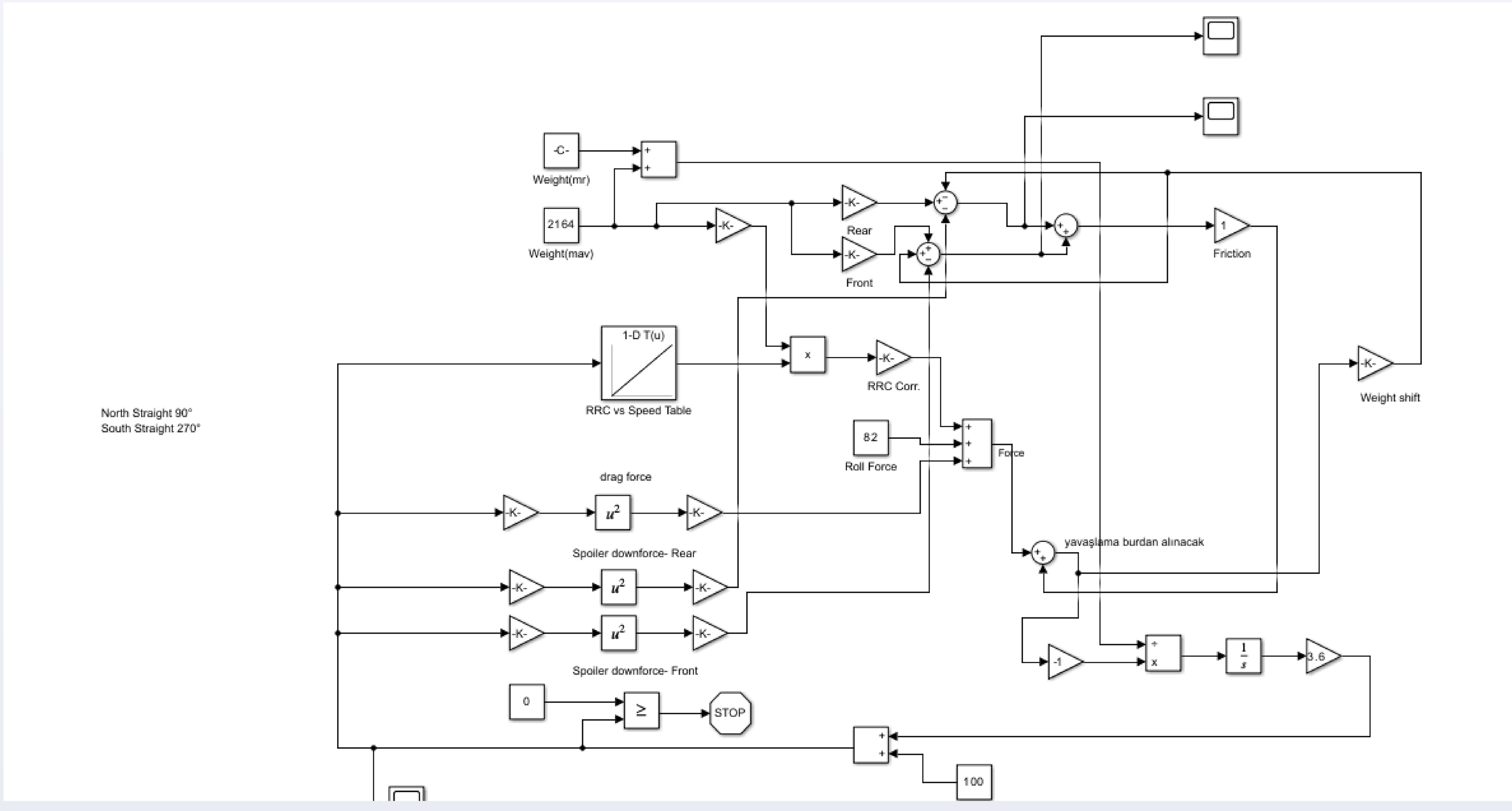
Aerodynamic analysis, dynamic modeling, energy efficiency assessment, structural testing, design optimization, and thorough validation are all part of the structured, multidisciplinary methodology used in the development and evaluation of the adaptive active rear spoiler system for an electric compact SUV (CSUV). Through simulation-driven design and iterative testing, this process guarantees that all crucial elements—performance, safety, efficiency, and durability—are thoroughly investigated.

PROJECT DETAILS



This study evaluates and optimizes the performance of an adaptive aerodynamic spoiler system under various driving and climatic conditions using a thorough simulation-driven methodology. Its objectives are to increase stability, range, and mechanical reliability through the use of ANSYS Fluent for thorough aerodynamic analysis, MSC ADAMS for vehicle dynamics simulations, AVL Cruise M for energy efficiency modeling, and Abaqus for structural durability evaluations. Through an iterative optimization process, the spoiler design and control logic are refined to meet goals for energy consumption, fatigue life, drag reduction, and downforce. Comprehensive documentation and reporting are used to assure repeatability and clarity, and integrated simulations and fault analysis are used to evaluate the finished system.

PROJECT DETAILS II



Simulation Insights (ADAMS):

- Spoiler angle significantly affects lateral stability and yaw dynamics.
- Higher angles (e.g., 45°) increase rear stability but cause understeer and route overshoot.
- At 0°, the car experiences high yaw rates and slow recovery.

Aerodynamic Analysis:

- Increased spoiler angle raises rear downforce (rcz), reduces front downforce (fcz).
- This shifts the aerodynamic center rearward, contributing to understeer.

Track Testing (Körfez):

- Fixed-angle prototype showed superior initial braking vs. Hyundai IONIQ 5N.
- Structural issues and brake fade observed under sustained rear stress.
- Full-lap performance remains uncertain.

Simulink Braking Models:

- Rear downforce improves straight-line braking and mitigates rear lockup during weight transfer.
- Especially beneficial for rear-heavy EVs.

CONCLUSIONS

This project's main goal was to examine how a prototype active rear spoiler system affected aerodynamics and dynamic performance, with an emphasis on high-speed stability, brake dynamics, and overall vehicle handling. Through empirical comparison, simulation-based research, and early on-track testing, the initial goals were mostly achieved. Through the project, the effects of different spoiler angles on braking dynamics, aerodynamic load distribution, yaw behavior, and lateral stability were clearly understood. The theoretical advantages of the system were validated by simulations, which showed that raising rear spoiler angles greatly improves rear-end grip and directional control.

Real-world testing constraints, however, led to certain departures from the initial goals. Specifically, the prototype vehicle's inadequate braking system hindered a thorough dynamic investigation of the active aero system's capabilities during coupled acceleration and deceleration events. As a result, even though the fixed-angle 45° design demonstrated obvious advantages in simulations, its full potential in real-world situations could not be fully demonstrated due to the lack of an adaptive or responsive control mechanism. In spite of this, the project can be deemed satisfactorily finished in terms of system evaluation and technical insight.

By offering a data-driven comprehension of the trade-offs inherent in fixed-angle aerodynamic design and emphasizing the necessity of front-to-rear aero balance in high-performance applications, it significantly advances the state-of-the-art. Additionally, the suggested combination of structural optimization and adaptive control creates a framework for further study in active vehicle aerodynamics, marking a significant breakthrough above the static aerodynamic systems now in use.