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ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, TRANSMISSION AND DRIVELINE, VEHICLE DYNAMICS AND CONTROL

Development of Coordinator for Optimal Tireforces Distribution for Vehicle Dynamics Control Considering Nonlinear Tire Characteristics

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Abstract
The Vehicle Dynamics Control (VDC) system is designed to enhance vehicle stability by effectively applying corrective yaw moments through differential brake forces during severe maneuvers. The VDC configuration primarily comprises two essential components: the supervisor and coordinators. The supervisor is responsible for determining appropriate corrective yaw moments, while the coordinators decide the tire forces necessary to achieve the desired corrective yaw moments. In modern times, various control schemes, such as model predictive controls, h-infinity controls, and relative controls, have been extensively investigated for the supervisors. However, in contrast, research concerning the coordinator component has not received much attention, resulting in relatively low research numbers. Most of the research has focused on the utilization of VDC coordinators that decide tire forces solely in proportion to corrective yaw moments. This approach leads to significant errors due to assumptions that do not account for the nonlinear characteristics of tires. In this research analysis, a coordinator considering nonlinear tire characteristics, such as the friction ellipse effect is presented. This crucial method of considering tire's nonlinear characteristics significantly enhances the accuracy of achieving the corrective yaw moment. Overall, the developed coordinator was validated through both simulations and experiments.

Keywords Vehicle Dynamics Control · Optimal tire force distribution · Friction ellipse effect · Tire force nonlinearity

List of Symbols

δ_{f}	Average front steer angle
C_{f}	Lumped cornering stiffness of front tires
C_{r}	Lumped cornering stiffness of rear tires
μ	Tire-road friction coefficient
F_x	Tire longitudinal force
F_{yf}	Front axle lateral tire force
F_{yr}	Rear axle lateral tire force
l_{f}	CG-front axle distance
l_{r}	CG-rear axle distance
I_z	Vehicle yaw moment of inertia
m	Vehicle mass
v_x	Vehicle longitudinal speed
M_z	Corrective yaw moment
τ_{b}	Time constant for lag of differential braking
h	Height of mass center of gravity

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1 Introduction

Vehicle safety demands have consistently grown since the advent of automotive vehicles. In the early stages, safety systems primarily comprised passive measures effective post-crash. Studies investigating airbags, seat belts, and dynamic human body models, coupled with numerous crash tests, were conducted to assess vehicle safety. As electronic technologies advanced and became more reliable, active safety systems, aimed at crash prevention, began entering the automotive market. After Following Robert Bosch GmbH's introduction of the first Antilock Braking Systems (ABS) in 1978, various active safety systems have entered