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INTEGRATED CONTROL OF DIFFERENTIAL BRAKING AND ACTIVE AERODYNAMIC CONTROL FOR IMPROVING HIGH SPEED STABILITY OF VEHICLES

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ABSTRACT−In this paper, an integrated control strategy (ICS) is proposed to improve high speed dynamics stability of the vehicle by the integration of active aerodynamic control (AAC) and differential braking control (DBC). Two aerodynamic surfaces are attached to the roof of the vehicle and servo-controlled separately in real-time. A hierarchical control structure is used to design the proposed scheme, which is composed of an upper and a lower controller. In the upper controller, the additional yaw moment required for stability control is determined by sliding mode control with the consideration of driver inputs, vehicle dynamic and the limitation of road adhesion. In the lower controller, a control strategy is designed to coordinate differential brake and active aerodynamic control, and an optimal control allocation algorithm is adopted to distribute the brake pressure of each wheel. A simplified magic formula tire model is used to describe the nonlinearity of the tires. Two double lane change tests on dry and wet road performed to study the effectiveness of the control algorithm in CarSim/Simulink Co-simulation. The results show the proposed control strategy can effectively improve the vehicle dynamics stability and tire workload usage.

KEY WORDS : Vehicle dynamics stability, Active aerodynamic control, Differential braking control, Control allocation, Tire workload

1. INTRODUCTION

As an active safety technology, vehicle dynamics stability control plays a vital role in improving driving performance. It has always been the focus of automotive safety research, resulting in a rich literature.

To improve vehicle stability performance, three types of stability control systems have been proposed and developed (Rajamani, 2012). Differential braking systems, which utilize the hydraulic brake system on the vehicle to generate an additional yaw moment by imposing uneven brake forces on right-side and left-side wheels, have received the most attention from researchers and automobile manufacturers (Goharimanesh and Akbari, 2017; Yakub *et al*., 2017; Zhu and He, 2017). Active front steering systems, which overlay a steering torque or a steering angle by a DC motor, have gradually received attention from academic researchers in the past decades (Song, 2016; Diao *et al*., 2017; Wang *et al*., 2017; Wu *et al*., 2018). Active torque distribution systems, which utilize active driving /braking torque control technology to independently control the torque distributed to each in-wheel motor, has been extensively studied in the recent past with the improvements on electric motor and motor controller (Goodarzi and Mohammadi, 2014; Li *et al*., 2015; Zhao *et al*., 2015; Nahidi *et al*., 2017). To realize the optimal control of the vehicle, a number of integrated vehicle dynamics control system have been developed (Yim, 2015; Ren *et al*., 2016; Jalali *et al*., 2017; Ni *et al*., 2017).

However, these control systems adjust vehicle's dynamics or trajectory by changing the tire forces. One major problem arise from this: tire forces are at the risk of saturation, especially under critical conditions.

In the last decade, advances in electromechanical technology and decreases in the cost of actuators have made it possible to provide a new path to improve vehicle dynamics under high speed condition. The active aerodynamic surfaces (AASs) control is a new and effective method to solve the problem of tire saturation (Corno *et al*., 2016).

In the past, the use of active aerodynamic surfaces for improving vehicles' performance have investigated by scholars and automotive manufacturers. In academic research, Savkoor has conducted a series of pioneering studies on the use of active aerodynamics surfaces in

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