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DEVELOPMENT OF REAL-TIME ESTIMATOR ON MAXIMUM AND PRESENT TIRE GRIP FOR DIRECT YAW MOMENT CONTROL

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ABSTRACT–This study proposes a method for estimating the maximum and present tire grips of a driving vehicle in real time. Direct yaw moment control (DYC) based on detecting wheel slip does not significantly affect general driving due to wheel slip at medium and low speeds. However, during the high-speed driving of a high-performance vehicle or driving within a racing track, frequent wheel slips have a significant adverse effect on the driving performance. This is because a tire that loses grip cannot generate additional driving and steering forces. Therefore, if the tire operating force of each wheel can be estimated in real time and the tire friction saturation limit can be precisely calculated, the driving performance can be significantly improved compared to control for wheel slip regulation. In this study, a precise tire friction limit model was developed to improve the limit driving handling performance through DYC, and the reliability of the estimation of the present tire grip was verified through actual vehicle measurements.

KEY WORDS : Friction saturation limit, Wheel slip inhibition control, Direct yaw moment control (DYC), Torque-vectoring (TV), Wheel position sensor, Wheel force transducer

NOMENCLATURE

F_{yf}, F_{yr}	: lateral forces of the front and rear tires
l_f, l_r	: distances from the CG to the front axle and rear axle
α_f, α_r	: tire slip angle of the front and rear wheels
C_f, C_r	: cornering stiffness of the front and rear tires
β	: side slip angle of the vehicle
μ	: friction coefficient of the road
v	: vehicle velocity
m	: mass of the vehicle
t_w	: wheel tread of the vehicle
L	: wheel base of the vehicle
h_{RC}	: height of COG
γ, ψ	: yaw rate and yaw angle
δ_f	: steering angle of the front tire
I_{zz}	: yaw moment of inertia on the vehicle
r_{eff}	: effective rolling radius of tire

1. INTRODUCTION

The grip performance of the tires of a vehicle is a key factor that influences its handling performance. The vehicle motion is determined by the longitudinal and lateral forces generated by the tires to produce traction and handling performance. Tires have the frictional properties of polymer materials. In Al-Bender *et al*. (2008), the frictional force increases in proportion to the vertical force on the upper face. The frictional force on an object is characterized using the static and kinetic friction coefficients. In the absence of relative motion (static friction), the frictional force between an object and a surface is greater than that in the presence of relative motion (kinetic friction). Safety systems for driving vehicles have been developed to utilize these characteristics for maximizing the tire grip. In Bhandari *et al*. (2011), the anti-lock brake system (ABS) is mentioned as a typical example. Braking pressure is generated in the form of a pulse to restore the braking force lost by locking the brake. This facilitates the instantaneous restoration of a low kinetic frictional force to a high static frictional force.

As mentioned in De Novellis (2014, 2015), a recently developed vehicle handling control system includes a torque-vectoring (TV) system. In Shibahata *et al*. (1993), the TV system creates a yaw moment for turning the vehicle by generating a difference between the longitudinal forces of the left and right tires. Therefore, when the vehicle is turned by the steering and TV systems, lateral and longitudinal forces of the tire are simultaneously generated. This type of handling control is called direct yaw moment control (DYC). In the current trend of EVs weighing over 2 tons, the frictional force of the tires must be maximized to

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