

Maximization of Total Tangential Force Based on Rear-Front Driving Torque Distribution Control

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Maintaining optimal total tangential torque is crucial for AWD vehicles on varying road surfaces. Although tangential force control focusing on the slope of the friction coefficient μ with respect to slip velocity v_s (μ -Rate) on unknown roads has been proposed, existing approaches are limited to single-wheel driving systems. This paper proposes a μ -Rate-based tangential force control for AWD vehicles using modal space theory.

By defining the operational states of the front and rear wheels as $^R x$ and $^F x$, these states are transformed into a common-mode state $^C x$ and a differential-mode state $^D x$, as shown in Eq. (1). The common-mode tangential torque $^C \tau_d = ^R \tau_d + ^F \tau_d$ represents the total vehicle tangential torque (instead of linear force), and tracking its command $^C \tau_d^{cmd}$ is the control objective.

$$^C x = ^R x + ^F x, \quad ^D x = ^R x - ^F x \quad (1)$$

Fig. 1 shows the overall structure of the proposed method, which regards tangential force control as a real-time modal-space slip velocity search problem. The system consists of a command generator that determines modal-space slip velocity commands from observer estimates, and a modal-space slip velocity control system that achieves these commands, thereby realizing $^C \tau_d^{cmd}$ tracking on unknown road surfaces.

In simulations under driving conditions with unknown roads and discontinuous front-and-rear friction variations, the proposed method achieved tracking of the command. Furthermore, even when $^C \tau_d^{cmd}$ exceeded the physical adhesion limit $^C \tau_d^{lim}$, it was confirmed that the proposed method maximized the tangential torque up to $^C \tau_d^{lim}$ while suppressing wheel slip.

In this study, by converting the two degrees of freedom of the front and rear wheels in an AWD vehicle into common and differential modes, and controlling them in an integrated manner in the modal space, the μ -Rate-based tangential force control was extended to the entire vehicle. Upon examination, it was demonstrated that robust total tangential force control can be achieved under unknown road variations. Furthermore, the potential utilization of redundant degrees of freedom inherent in achieving the required torque was confirmed.

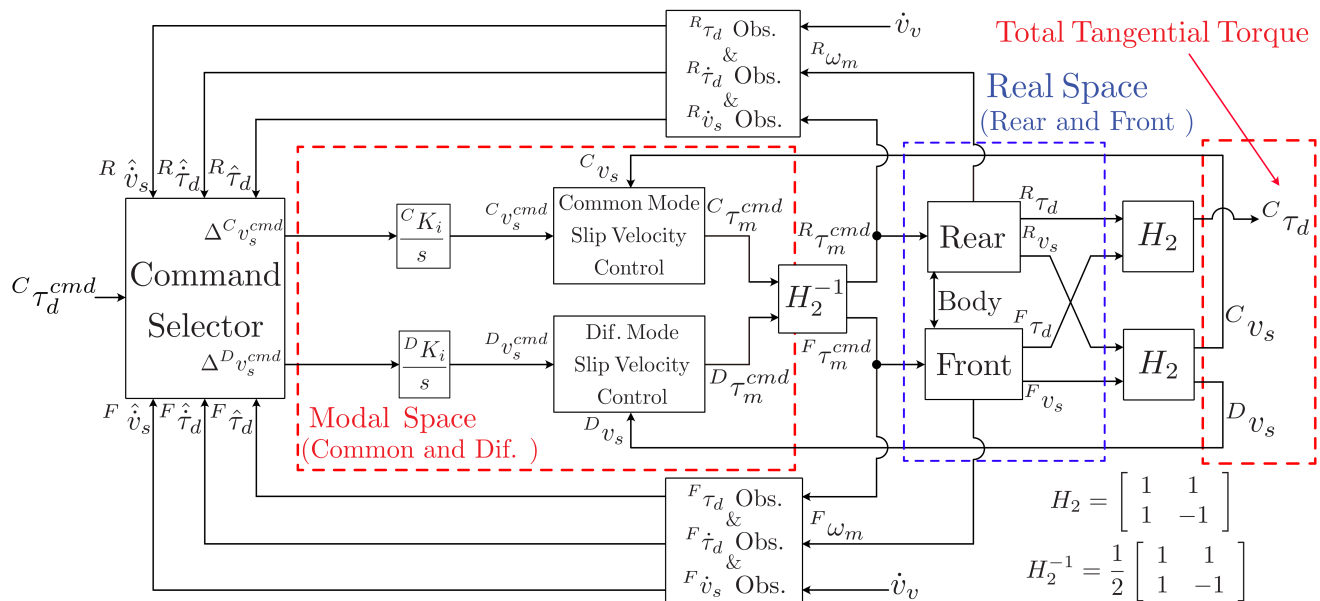


Fig. 1. Proposed Method Block Diagram