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TRACTION CONTROL USING A DISTURBANCE OBSERVER FOR HYBRID ELECTRIC VEHICLES

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ABSTRACT−This paper presents a practical approach designing a traction controller based on disturbance observer (DOB) in hybrid electric vehicles (HEVs). To conduct the traction control of HEVs, the proposed control scheme estimates disturbances in a specific frequency range caused by wheel-slips and reduces driving force in accordance with the estimated disturbance. A band pass filter is employed to the DOB to extract the disturbance in a specific frequency range causing wheel slip. In addition, a proportional-integral (PI) type regulator is applied to effectively reject the disturbances. To validate the proposed control algorithm, actual vehicle tests are performed using a C-segment HEV sport utility vehicle (SUV). The test results show that the proposed control algorithm achieved more enhanced energy efficiency as well as better ride comfort with maximizing traction force than the conventional control algorithm.

KEY WORDS : Traction control, Disturbance observer, Hybrid electric vehicle

1. INTRODUCTION

The history of traction control systems (TCS) begins with a limited slip differential in high-torque rear-wheel drive cars, which is a pure mechanical system. The first electronic TCS was introduced by Buick in 1971 with the name Buick (1971), which detects wheel spin and modulates engine power to provide the most traction. Since then, many studies have been carried out, and it has been available in non-performance cars as well as performance cars for a safety feature and a performance enhancement. Despite the abundant research of TCSs, it is still an important topic in the automotive industry due to powertrain electrification.

Recently, powertrain electrification has been booming in the vehicle industry as an effective solution to reduce energy consumption and emissions (Wang *et al*., 2020; Yang *et al*., 2020). An electrified powertrain also provides high acceleration performance when a vehicle launches due to motor characteristics with high initial torque or additional power with an internal combustion engine (ICE) in HEV mode. However, the torque characteristics of the electrified powertrain can cause the wheels to slip at vehicle start-up, resulting in driveline vibration and unnecessary power loss (Nam *et al.*, 2015). Therefore, electric vehicles (EV) and hybrid electric vehicles (HEV) require more precise and frequent traction control than conventional ICE vehicles even on high friction road surfaces.

In existing literature, many approaches to traction control have been proposed to prevent wheel-slip. In general, TCSs have been conducted based on vehicle velocity. Some studies (Schinkel and Hunt, 2002; Fuji and Fujimoto, 2007) try to realize the optimal slip ratio controls according to the Magic Formula (Pacejka and Bakker, 1992) based on the vehicle velocity. Usually, the vehicle velocity is approximated by the non-driven wheels in two wheel drive vehicles. In four-wheel drive systems, other sensors such as an accelerometer and optical (Saito *et al.*, 2002) and magnetic (Fujimoto *et al*., 2004) sensors are used for estimating the vehicle speed. However, they are too sensitive to the environment or too expensive to be applied in real vehicles. To overcome the shortcomings of the vehicle velocity based control methods, intelligent control theories are applied. The fuzzy logic outputs the optimal slip velocity reference (Kwon *et al.*, 2004) and compensates for the abrupt change in the driving environment (Li *et al.*, 2012) according to fuzzy rules. A wavelet denoising method (Huang *et al.*, 2007) is used to recognize slip characteristics. However, these intelligent methods need a large amount of data and computation, so they require a high-performance processor to guarantee real-time results.

In contrast, a model based traction control system is simple and easy to apply because there is no need to approximate the vehicle velocity to calculate the slip ratio and it works near the peak traction force by adjusting the powertrain torque based on the nominal model. As one of the

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