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Independent wheel torque control of 4WD electric vehicle for differential drive assisted steering

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ABSTRACT

In-wheel motors have tremendous potential to create an advanced all-wheel drive system. In this paper, a novel power assisted steering technology and its torque distribution control system were proposed, due to the independent driving characteristics of four-wheel-independent-drive electric vehicle. The first part of this study deals with the full description of the basic theory of differential drive assisted steering system. After that, 4-wheel-drive (4WD) electric vehicle dynamics model as well as driver model were built. Furthermore, the differential drive assisted steering control system, as well as the drive torque distribution and compensation control system, was also presented. Therein, the proportional–integral (PI) feedback control loop was employed to track the reference steering effort by controlling the drive torque distribution between the two sides wheels of the front axle. After that, the direct yaw moment control subsystem and the traction control subsystem were introduced, which were both employed to make the differential drive assisted steering work as well as wished. Finally, the open-loop and closed-loop simulation for validation were performed. The results verified that, the proposed differential drive torque assisted steering system cannot only reduce the steering efforts significantly, as well as ensure a stiffer steering feel at high vehicle speed and improve the returnability of the vehicle, but also keep the lateral stability of the vehicle.

1. Introduction

All-wheel-independent-drive systems have been recognized as a break-through concept that will have a major impact on future electric and hybrid vehicle design, as their power source have some advantages, such as packing flexibility, all-wheel-independent-drive, space-saving, fast drive train response, etc. [1,2]. Furthermore, another potential advantage being developed in this paper is that the accurate control of the driving forces on the steering wheels can function as power steering. In this way, the traditional engine-driven or electrical direct driven power steering system may become unnecessary. Thus the system can be simplified and the energy consumed in traditional power steering can be saved.

Several prior researches have investigated the technology of steering or assisting steering by driving forces. Francis Hoogterp and Meldrum [3] firstly named skid-steering of wheeled combat vehicles as differential torque steer, this application is the tradeoff between the running speed and cross-country mobility. But the key point is that the combat vehicle does not have steerable wheel for space-saving, so it is still skid-steering. Li et al. [4] proposed a measure of assist steering based on integrated steering and traction/braking system. His idea is also derived from skid-steering of tracked vehicle, and applied to four non-steerable wheel-drive electric vehicle with independent wheel torque control. His simulation results showed that this type vehicle steered with this method can have similar moving trajectory to conventional vehicle with steerable front wheels. But when moving on large curvature path, due to priority of stability compensator, the vehicle's cornering radius leads bigger than conventional vehicle. Shuang et al. [5] also gave us an good application of skid-steering on wheeled vehicle. But none of them mentioned above utilized the differential drive torque between two sides to supply assist force to steer the vehicle when conventional steer linkages remains. Thacher [6] applied for a patent on an assisted steering system operated by controlling the speed of inner rear wheel to improve front axle steering maneuverability, when the rear axle of the utility off-road vehicle has large load distribution. Besselink [7] has proposed an integration of steering system and traction system, which was also about how to utilize differential drive torque of rear axle to assist steering and improve vehicle's steering performance. Some other researchers such as Jang et al. [8], Nozaki [9] and so on, also have proposed the measure of utilizing differential braking torque to correct steering maneuver. All of them mentioned above discussed the assisted steering measure using differential traction/braking

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