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Lateral stabilization of a four wheel independent drive electric vehicle on slippery roads

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ABSTRACT

In this paper, a new controller is proposed for lateral stabilization of four wheel independent drive electric vehicles without mechanical differential. The proposed controller has three levels including high, medium and low control levels. Desired vehicle dynamics such as reference longitudinal speed and reference yaw rate are determined by higher level of controller. Moreover, using a neural network observer and a fuzzy logic controller, a novel reference longitudinal speed generator system is presented. This system guarantees the vehicle's stable motion on the slippery roads. In this paper, a new sliding mode controller is proposed and its stability is proved by Lyapunov stability theorem. This sliding mode control structure is faster, more accurate, more robust, and with smaller chattering than classic sliding mode controller. Based on the proposed sliding mode controller, the medium control level is designed to determine the desired traction force and yaw moment. Therefore, suitable wheel forces are calculated. Finally, the effectiveness of the introduced controller is investigated through conducted simulations in CARSIM and MATLAB software environments.

1. Introduction

In the recent years, electric vehicle technologies have become one of the most important fields of research and investment for the automotive companies leading to creating various structures of electric and hybrid electric vehicles [1] among which, the 4 Wheel Independent Drive (4WID) vehicles with 4 independent electric motors, each designed to drive one wheel, is one of the absorbing ones. According to this structure that can be used for almost all types of electric vehicles and series hybrid electric vehicles, the electric motors, known as in-wheel motors, can be placed in the inner space of the wheels [2].

In spite of all advantages, balancing such a vehicle with 4 independent 4-wheel motors, especially in corners and fault conditions, which needs a coordinated motor controller, can be the most challenging problem that the designers confront [3–5]. For solving the problem, an efficient controller along with independent control of each wheel can be used, that can enable the driver to keep the vehicle in the correct direction and also enhance the stability.

In electric differentials, used for path tracking in the vehicles with no mechanical differential, first the motor speed is measured by an observer, and then speed references are generated to drive the motors. Some of these electric differentials have been proposed in [6–9]. In normal driving conditions these proposed methods can perform well, but critical conditions such as driving on slippery roads, severe steering angle changes, and an unskilled driver can endanger the stability of the vehicle.

A fuzzy yaw rate and an independent wheel slip controllers for 4WID electric vehicle stability control with an artificial network yaw rate reference generator are proposed by [10–13]. A three-layered vehicle dynamic controller for a 4WID vehicle with DC in-wheel motors is presented in [14]. In this method, a fuzzy logic controller is used to define the desired wheel slips; then a sliding mode controller drives the DC motors. In [15], the desired yaw moment is achieved by minimizing a cost function. This cost function is defined by using yaw rate and body sideslip angle. [16] uses a fuzzy method to control the motor and hydroelectric brakes to ensure the lateral stability in a through the road (TTR) hybrid electric vehicle with an engine in the front axle and an electric motor in the rear axle.

In recent years, fault-tolerant controllers have been considered in various studies for 4WID vehicle stability applications [17–19]. A hybrid fault-tolerant controller, which combines the linear-quadratic control method and Lyapunov function technique to ensure proper 4WID electric vehicle path-tracking, is proposed in [17]. [18] presents an adaptive control-based passive fault-tolerant control approach for 4WID electric vehicles. The controller is

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