論文の内容の要旨

General Approach to Traction Control for Electric Vehicles Based on Maximum Transmissible Torque Estimation

（最大伝達可能トルク推定にもとづく電気自動車の一般的なトラクション制御に関する研究）

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This dissertation deals with traction control for electric vehicles. A new control method is proposed which makes full use of the inherent advantages of electrical traction systems to provide a novel general approach to the traction control of electric vehicles.

Due to growing concern about global environmental problems and shrinking non-renewable energy sources, research on electric vehicles and hybrid electric vehicles is gaining more and more attention. Meanwhile, significant improvements in power electronics, energy storage and control technology have made electric vehicles fully feasible, also paving the way for the introduction of innovative technologies that will give them an even greater advantage. In particular, the realization of practical in-wheel motors will allow for some revolutionary changes in the design of electric vehicles, with new topologies not only contributing to the energy efficiency and freedom of vehicle design, but also providing considerable benefits to the controllability of electric vehicles.

On the other hand, active safety control performs a very important role in modern vehicles. However, its core technology, traction control, is still problematic. Conventional traction control in internal combustion engine vehicles, which is dependent on the slip ratio

reference, is limited in effectiveness and adaptability by the fact that chassis velocity and road conditions cannot be measured or detected in a practical, reliable way. For this reason, much research has been applied to controllers for electric vehicles, seeking to make use of their advantages to overcome the obstacles of calculating chassis velocity and detecting road conditions in real time to perform traction control. However, these control designs, which are based on compensation, compromise performance for system stability, and the compensation gain is tuned for some specific tire-road conditions, also limiting the practicability of these methods.

Therefore, this dissertation, making use of the advantages of electric vehicles, focuses on development of a core traction control system based on a proposed concept called Maximum Transmissible Torque Estimation, which requires neither chassis velocity nor information about tire-road conditions. In this system, use is made of only the torque reference and the wheel rotation to estimate the maximum transmissible torque to the road surface, then the estimated torque is directly applied to antislip control.

Chapter 1 introduces the research background, particularly the history and the advantages of electric vehicles, as well as the importance of traction control in vehicles. Chapter 2, using Anti-lock Braking Systems as an example, reviews conventional traction control and analyzes the difficulties it faces. Chapter 3 presents the novel topology of traction control and uses an equivalent model to provide the stability analysis of the control system. Chapter 4 describes the experimental electric vehicle used as a test-bed and presents the simulations and experiments performed on it to evaluate the proposed control system. Comparative experimental results and additional simulation results are then followed by a detailed discussion and analysis. Finally, Chapter 5 discusses the extension of the proposed traction control to a two-degree-of-freedom vehicle motion control system. Simulation results on an example system are followed by a detailed discussion of its effectiveness.

Based on thorough experimental tests and simulations, and supported by detailed theoretical analysis as well as wide acceptance in both domestic and international conferences and authoritative journals, the author firmly believes in the advantages of the proposed control topology. The controller not only has better antislip performance and higher adaptability in different tire-road conditions than previous controllers, but also has greater robustness to perturbations in vehicle mass and disturbances in driving resistance, which also demonstrates the high practicality of the method. From the viewpoint of implementation, only torque and wheel rotation are used as the input variables to the controller, which contributes not only to lower cost, but also higher reliability and greater independence from driving conditions.

These advantages qualify the proposed control method as a general approach for traction control, as well as a basis for more sophisticated and advanced motion control in electric vehicles. Moreover, the control philosophy implied in the proposed control topology merits further investigation and can be expected to find application as a general approach to a wider class of control problems.