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Editorial

Advanced X-by-Wire Technologies in Design, Control and Measurement for Vehicular Electrified Chassis

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1. Introduction

Advanced X-by-wire technologies for vehicular electrified chassis play an essential role in developing new energy-intelligent vehicles, which is the inevitable choice for intelligent vehicles in the future. This technology is involved in mechanical engineering, electronic and electrical engineering, computer technology, control engineering, signal processing, and artificial intelligence. Advanced electrified chassis control technology transmits control signals through cables and acts directly on the actuator to implement its corresponding actions. The application of X-by-wire technologies for vehicular electrified chassis has changed complex mechanical connections among actuators and hydraulic and pneumatic equipment in the past, significantly promoting energy efficiency, integration, and intelligence.

This Special Issue focuses on advanced X-by-wire technologies in durable reliability design, modeling, integration control, thermal management, energy management, fault diagnosis, and fault-tolerant control with the vehicular electrified chassis. Therefore, this Special Issue aimed to solicit recent advanced X-by-wire technologies for vehicular electrified chassis.

The topics of interest included but were not limited to:

➢ Modeling, analysis, control, and management of electrified chassis;
➢ Coordinated control of integrated chassis;
➢ Highly integrated design technology of electronic control suspension, steering by wire, braking by wire;
➢ High-efficiency motor drive control, thermal management, electric drive system design;
➢ Autonomous driving and intelligent linearization control technology;
➢ Testing and signal analysis technology of electrified chassis;
➢ Vibration and noise suppression;
➢ Reliability design and evaluation;
➢ System operation condition monitoring and fault diagnosis technology;
➢ Highly reliable fault-tolerant control technology.

A total of 15 papers (from 17 submitted) were published. These papers can be loosely categorized into four sections: (1) Suspension System; (2) Trajectory Planning and Control; (3) Vehicle Torque Distribution; (4) Motor Control Review. In this article, we provide a brief overview of the published papers.

2. Overview of Contribution

2.1. Suspension System

Reference [1] studies using a mechatronic inerter to enhance vibration isolation in vehicle seat suspensions by introducing it into a half-vehicle model and optimizing the seat suspension layout parameters using the particle swarm optimization algorithm. Numerical simulations show that the mechatronic inerter improved the vibration isolation performance of the suspension compared to a passive suspension and increased the transfer

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function-order of the external electrical network further by reducing seat acceleration and pitch acceleration RMS values. Reference [2] proposes a design method for vehicle ISD (Inerter Spring Damper) suspension systems that utilize the fractional-order electrical network structure of a mechatronic inerter. This method used the inerter's external electrical network to simulate the corresponding mechanical network structure equivalently. A 1/4 dynamic model of the suspension was constructed, and the improved oustaloup filtering algorithm was used to simulate fractional-order components. The optimal fractional electrical network structure and parameters were obtained through the structure-immittance approach and an optimization algorithm. Reference [3] proposes a new active suspension control strategy that combines a fuzzy neural network and a proportional-integral-derivative (PID) controller to improve vehicle comfort and smoothness and reduce the vibrations caused by uneven road surfaces. The main optimization target was body acceleration, and the PID controller parameters were adjusted in real-time. An offline optimization and online fine-tuning method for fuzzy neural network parameters were proposed using a particle swarm optimization algorithm and gradient descent method. Reference [4] focuses on developing a mechatronic inerter consisting of a ball-screw inerter and permanent magnet electric machinery. The study proves the feasibility of using electrical element impedances to simulate corresponding mechanical elements. The impedance characteristics of the bridge and series-parallel electrical networks were introduced, and their effectiveness in improving the vibration isolation performance of the mechatronic inertial suspension was compared. The advantages of the bridge network were demonstrated, and a real vehicle test shows that the mechatronic inertial suspension based on the bridge network is superior to the passive suspension. Reference [5] proposes a fault diagnosis design method for the solenoid valve in the electronically controlled air suspension (ECAS) system based on multiple extended Kalman filter banks (EKFs). The fault model of the solenoid valve was built by the fault tree analysis of the ECAS system and considered the correlation between the duty cycle and flow rate of the air spring solenoid valve. An adaptive threshold was used for fault diagnosis, and an active fault-tolerant control was carried out based on an analytical model. The real controller based on d2p rapid prototyping technology and the vehicle model based on AMESim were tested on the hardware-in-the-loop (HiL) simulation platform.

2.2. Trajectory Planning and Control

Reference [6] proposes an automatic driving trajectory-planning method using a variable Gaussian safety field to improve planning efficiency and safety. This method used a time series bird's-eye view as the input to extract features of the surrounding traffic environment and the policy gradient algorithm to generate the planned trajectory. The variable Gaussian safety field improved the safety of the reinforcement learning vehicle tracking algorithm. The simulation results demonstrated the method's excellent trajectory planning ability in highway scenes with high safety and precision tracking control. Reference [7] presents a trajectory-tracking control algorithm for X-by-wire electric vehicles based on a hierarchical control architecture. The algorithm consists of three layers: trajectory tracking, tire force distribution, and actuator control. The trajectory tracking layer used the model predictive control algorithm to control the vehicle and follow the desired trajectory. The tire force distribution layer solves the tire force distribution problem using quadratic programming with constraints. The actuator control layer obtained longitudinal and lateral forces of each tire and calculated the vehicle's steer angle and driving torque. Simulation results show that the proposed algorithm could accurately track the desired trajectory under different driving conditions. Reference [8] proposes a path-tracking controller for distributed drive electric vehicles to achieve safe obstacle avoidance. The path planning was based on a sixth-degree polynomial with anti-collision and anti-rollover conditions. The Model Predictive Control (MPC) controller outputs the front wheel steering angle and additional yaw moment, while the torque distribution controller distributes the wheel torque. The obstacle avoidance path-tracking control was achieved through the additional yaw moment and the vertical force ratio of the wheel. Reference [9] proposes an adaptive robust control framework for the path-tracking control of X-by-wire autonomous vehicles. The non-singular fast terminal sliding mode control algorithm was used to formulate the control law, and the radial basis forward neural network was introduced to estimate system uncertainty in real time. The dynamic model of an active front steering system was established, and the model reference control algorithm was applied to the steering torque control. Reference [10] proposes a multi-agent coordinated control system for active collision avoidance in intelligent vehicles. This system uses hierarchical control and blackboard model methods to handle conflicts between different agent decisions and achieve multi-decisions and planning simultaneously. The fuzzy sliding mode control theory was used to ensure accurate path tracking in lateral collision avoidance.

2.3. Vehicle Torque Distribution

Reference [11] proposes an anti-roll and anti-rollover control strategy to improve the roll stability of distributed drive electric vehicles (DDEV). The control strategy used the active control of wheel torque adjustment to achieve an effect similar to active suspension. This strategy decoupled roll motion and yaw motion and used the LQR algorithm and sliding mode variable structure to calculate the direct yaw moment and additional rolling moment, respectively. Reference [12] proposed a regenerative-braking torque optimization method for dual-motor electric vehicles (EVs) that integrated energy recovery and braking stability. This method used the genetic algorithm theory and considered the state of charge (SOC), vehicle speed, and braking intensity to design an energy recovery-dominated regenerative braking torque distribution rule. Reference [13] proposes a torque distribution method for four in-wheel motor drive (4IWMD) electric vehicles that aim to optimize torque distribution and energy efficiency. The dynamic programming (DP) control algorithm was used to distribute the torque between the front and rear in-wheel motors for optimal torque distribution and energy efficiency. Reference [14] proposed an acceleration slip regulation (ASR) control strategy based on nonlinear model predictive control (NMPC) for front and rear dual-motor four-wheel drive electric vehicles (4WD EVs). The ASR controller tracks reference speed or optimal slip rate, including intervention and exit mechanisms. The motor output torque was determined according to the wheel with the increased slip rate to enhance the passibility of split road surfaces. Simulation experiments on different road conditions demonstrated that the proposed controller exhibited better dynamic performance and stability than the PID control, particularly under low speed and low adhesion road conditions, and met robustness requirements.

2.4. Motor Control Review

Reference [15] reviews the position's sensorless compound control technology for permanent magnet synchronous motors (PMSMs). This technology improved motor reliability, reduced costs, and expanded the speed range of PMSMs. The article elaborated on the compound control technology of PMSMs without a position sensor and summarized the existing problems and development trends of sensorless compound control technology.

3. Final Thoughts

The Special Issue covers advances in the design, control and measurement of X-by-Wire technologies. The Guest Editorial Board hopes that this Special Issue provides state-of-the-art research in the field of vehicular electrified chassis. This Special Issue also presents various innovative approaches with promising results to address the challenges in vehicular electrified chassis. The Guest Editorial Board also hopes that more researchers will enter into this interesting field to promote respective research in the near future.

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