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Hybrid Power Car Controller: Device and Process for Simulation and Testing

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Abstract

This research presents a device and procedure for simulating and testing the finished car controller of a hybrid power car. The device utilizes a PCI interface and a microprocessor for communication, resulting in improved reliability, high data transmission rate, and excellent expandability. By employing a mathematical model of the power unit, the system achieves cost reduction. The device includes a microprocessor unit, a PCI bus processing unit, a display unit, and an interface board card. Through connections between these components, convenient configuration of the finished car's structure, power unit parameters, operation spectrum, road spectrum, and interface board attributes are achieved, enhancing the system's versatility. When applied to testing hybrid power car controllers, this device and procedure reduce test duration and cost, while providing stable and accurate test results.

Keywords: hybrid power car, car controller, simulation, testing device, microprocessor, PCI interface, reliability, cost reduction, accuracy

Introduction

With the increasing popularity of hybrid power cars, it has become crucial to develop efficient and reliable testing procedures for their finished car controllers. The finished car controller plays a vital role in managing the complex interactions between the internal combustion engine and the electric motor, ensuring optimal performance and efficiency. To address this need, this research focuses on the development of a device and procedure for simulating and testing the finished car controller of hybrid power cars (Z. Zhao et al. 2019).

The proposed simulation and testing device stands out due to its utilization of a PCI interface and a microprocessor for communication. This choice offers several advantages, including enhanced reliability, high transmission rates of data, and excellent expandability. By incorporating a mathematical model of the power unit, the system achieves significant cost reduction compared to traditional testing procedures. This reduction in system cost allows for more cost-effective testing procedures without compromising accuracy (Wanbang Zhao et al. 2019). The simulation and testing device comprises essential components, including a microprocessor unit, a PCI bus processing unit, a display unit, and an interface board card. These components are interconnected to facilitate seamless communication and convenient configuration of the finished car's structure, power unit parameters, operation spectrum, road spectrum, and interface board attributes. This flexibility and generality make the system adaptable to different hybrid power car configurations, enhancing its usability and practicality (Nadeau, Micheau, and Boisvert 2018; Wanzhong Zhao et al. 2019).

By employing this device and procedure in testing hybrid power car controllers, several benefits can be achieved. Firstly, the test period is significantly shortened, leading to improved efficiency in the testing process (Z. Zhao et al. 2019). Moreover, the reduced system cost contributes to overall cost savings in testing operations. Most importantly, the test results obtained using this device exhibit high stability and accuracy, ensuring reliable performance of the finished car controller. In summary, the development of

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this simulation and testing device for hybrid power car controllers addresses the growing need for efficient and reliable testing procedures in the automotive industry (Wanbang Zhao et al. 2019). By combining the advantages of a PCI interface, a microprocessor, and a mathematical model of the power unit, the device offers enhanced reliability, cost reduction, and accurate test results. The subsequent sections of this research will delve into the details of the device's design, implementation, and performance evaluation, providing valuable insights into the field of hybrid power car controller testing. Figure 1 is displaying the flow-chart of this research.

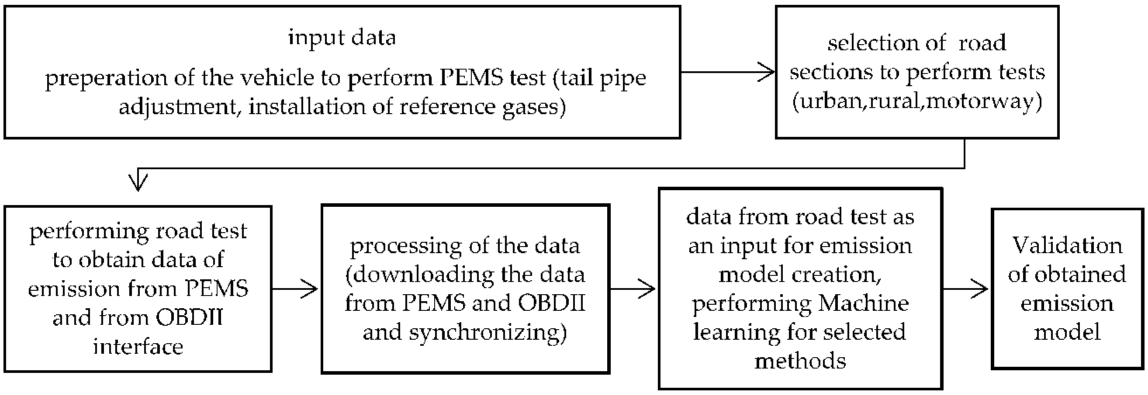

Figure 1. *Flow chart of research.*

Related Work

The increasing demand for environmental sustainability and the need to balance power network loads in urban areas have driven the rapid growth of hybrid vehicles. As a result, numerous domestic automobile manufacturers, parts enterprises, schools, and research institutions are actively engaged in research on hybrid vehicles (Wanbang Zhao et al. 2019).

The whole-control system serves as a critical component responsible for executing driver commands, managing the operation of each power component, and overseeing the network management of the vehicle's load. It acts as the central nervous system of the hybrid vehicle, ensuring the stability and reliability of the vehicle's performance. The effectiveness of the full-vehicle control algorithm directly impacts the vehicle's emission behavior, power performance, and overall economic efficiency. Considering that hybrid vehicles are still in the developmental research stage, it is essential to emulate and test the control algorithm of the whole-control system to achieve performance optimization. In order to address the challenges associated with system emulation and testing, several common approaches have been employed. These include building specialized emulation and testing platforms or using real steering vectors for testing purposes (Bazhynova 2019).

While the procedures enable basic emulation and testing of the whole-control system, they also possess significant limitations. Firstly, the equipment required for specialized emulation and testing platforms is prohibitively expensive, making it difficult for many enterprises and research institutions to afford. Secondly, these procedures often entail lengthy test periods, resulting in higher testing costs. In order to overcome these challenges, there is a need for a more cost-effective and time-efficient approach to emulate and test the whole-control system of hybrid vehicles. This research aims to develop a device and procedure that addresses these shortcomings, providing a practical and economical solution for the emulation and testing of the whole-control system. By doing so, it will contribute to the advancement of hybrid vehicle technology and facilitate the development of more efficient and environmentally friendly vehicles (Liangang 2020). An illustrative update hybrid electric vehicle (HEV) for this study is depicted in **Figure 2**. During low velocities (under 50 km/h) when solely relying on electric power, the coupling mechanism connecting EM1 and EM2 is disengaged, and the car operates in a series hybrid setup. In this mode, the vehicle is solely propelled by the second motor, EM2. The transition from the

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series mode to the parallel mode will occur at high speeds (above 50 km/h) by engaging the friction clutch between EM1 and EM2. EM1 will initiate the Internal Combustion Engine (ICE) to propel the vehicle. Once the ICE is started, EM1 will be deactivated. If necessary, EM2 can be activated as an electrical generator to recharge the vehicle batteries. In situations of excessive load and under the driver's control, both EM1 and EM2 can be simultaneously activated to assist the ICE in operating the vehicle under challenging driving conditions. Our research focuses on the development of dependable control strategies that can govern the speeds of these two propulsion system components and effectively synchronize them using a friction clutch. This aims to achieve rapid and seamless clutch engagement, minimize driveline jerk, and enhance driving comfort (Ščasný, Zvěřinová, and Czajkowski 2018). A typical upgraded hybrid electric vehicle (HEV) utilized for this study is illustrated in Figure 2. It originates from a widely used parallel HEV design system developed by Daimler Chrysler, specifically known as the P12-Configuration unveiled at the 2004 Detroit Motor Show. The conceptual model features a single (1) traditional internal combustion engine (ICE) and two (2) EM1 and EM2 units. A conventionally adjustable friction clutch serves to divide the drivetrain of the model into two (2) segments: Part 1 comprises the ICE with EM1, while Part 2 consists of EM2 and the remaining powertrain transmission components. The EM1 functions as an electrical starter and a supplementary electrical generator. This configuration does not incorporate a torque converter. The rear wheel of this model is designated as the driven wheel and is connected to a standard automated transfer gearbox and a conventional differential gearbox(Bazhynova 2019).

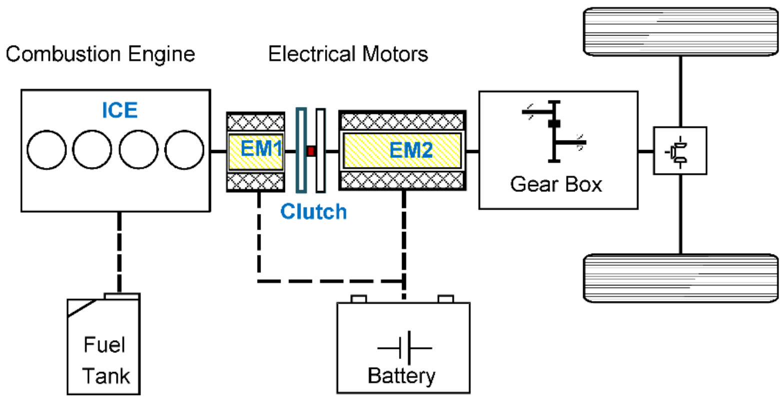

Figure 2. Configuration of the parallel hybrid powertrain.

The increasing concerns surrounding environmental pollution and the need for sustainable energy solutions have propelled the rapid development and adoption of hybrid vehicles. As a result, various stakeholders, including automobile manufacturers, parts suppliers, academic institutions, and research organizations, are actively involved in researching and advancing hybrid vehicle technology. One of the critical components of a hybrid vehicle is the whole-control system. This system plays a pivotal role in interpreting driver commands, coordinating the operations of different power components, and managing the overall load of the vehicle. It acts as the nerve center, ensuring the stability and reliability of the vehicle's performance. The efficiency and effectiveness of the full-vehicle control algorithm employed in the whole-control system directly impact the vehicle's emission behavior, power performance, and overall economic efficiency (Liangang 2020).

Given that hybrid vehicles are still in the early stages of development, there is a crucial need to thoroughly emulate and test the control algorithm implemented in the whole-control system. By conducting comprehensive simulations and tests, researchers and engineers can fine-tune and optimize the system's performance (Nadeau et al. 2018; Wanzhong Zhao et al. 2019). This step is vital to ensure that hybrid vehicles meet the desired objectives of reduced emissions, improved power efficiency, and enhanced driving experience.

Traditionally, there have been two common approaches to emulate and test the whole-control system. The first involves constructing specialized emulation and testboard bays, which provide a controlled

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environment for testing various scenarios and parameters. However, this procedure often incurs high equipment costs, making it financially challenging for many enterprises and research institutions to adopt. The second approach involves utilizing real steering vectors, where the vehicle is subjected to real-world driving conditions to assess the performance of the whole-control system. While this procedure offers a more realistic evaluation, it also comes with drawbacks. The testing process can be time-consuming, requiring lengthy test periods, and it can result in higher overall testing costs.

To address these limitations, there is a growing need for a more cost-effective and time-efficient approach to emulate and test the whole-control system of hybrid vehicles (Łukasik, Kozyra, and Kuśmińska-Fijałkowska 2018; Yanxin et al. 2013). This research aims to develop a device and procedure that overcome these challenges and provide a practical and economical solution. The proposed device will enable accurate emulation and testing of the whole-control system, allowing for quicker evaluation of performance, reduced testing costs, and improved stability and accuracy of test results. By developing an efficient emulation and testing procedure, this research contributes to the advancement of hybrid vehicle technology. It facilitates the development of more sophisticated control algorithms, enhances the overall performance and efficiency of hybrid vehicles, and ultimately accelerates the transition to a greener and more sustainable transportation system (Yanxin et al. 2013).

Research Objective

The objective of this research is to develop a device and procedure for simulating and testing the finished car controller of a hybrid power car. The focus is on utilizing a PCI interface and a microprocessor for communication, reducing system cost through the use of a mathematical model of the power unit, and achieving improved reliability, data transmission rate, and expandability. The research aims to create a versatile system that allows convenient configuration and testing of hybrid power car controllers, leading to shortened test periods, reduced costs, and high stability and accuracy of test results.

Simulation and Testing Device and Procedure for Hybrid Power Car Controller

The simulation and testing procedure for the whole-car controller of a hybrid electric car involves using a specialized device. This device consists of a microprocessor unit, a PCI bus processing unit, a display unit, and an interface board. The display unit and the PCI bus processing unit are connected to the microprocessor unit. The interface board, connected to the PCI bus processing unit via a PCI bus, interfaces with the whole-car controller being tested.

The interface board is equipped with various interfaces, including analog-to-digital interfaces, digital-to-analog interfaces, switch signal collection interfaces, switch signal output interfaces, pulse duration frequency signal acquisition interfaces, pulse duration frequency signal output interfaces, and CAN interfaces. These interfaces allow for the exchange of signals and data between the microprocessor unit and the whole-car controller. The microprocessor unit, specifically an S3C2460ARM9 microcontroller, generates control signals that are transmitted to the interface board. The interface board then sends these signals to the whole-car controller for testing. Once received, the whole-car controller responds by sending back steering commands to the interface board, which in turn forwards them to the microprocessor unit. The microprocessor unit converts these steering commands into input parameters for the mathematical model of the power components. The simulation process generates status data, which is sent back to the tested whole-car controller through the interface board. The microprocessor unit also calculates the car speed using a car speed model. The data from the entire simulation and testing process is displayed on the display module.

The display unit includes various modules, such as a manual input module, a drivetrain structural allocation module, a power component parameter setting module, a whole-car parameter setting module, an operation spectrum/road spectrum setting module, an interface board port arrangement module, and a result output module. These modules enable convenient configuration of the whole-car structure, power component parameters, operation scenarios, and interface board attributes, making the system highly versatile.

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The simulation and testing process involve using a pilot model to simulate the driver's behavior. The output signals from the pilot model include the accelerator position, gear selection, key signals, brake signals, parking brake signals, emergency signals, and driving mode signals. These signals are used to drive the simulation and testing of the whole-car controller. The mathematical models of the power components include models for the engine, main motor, ISG motor, transmission, clutch, moment coupling mechanism, and speed reduction unit. These models utilize input signals such as engine start/stop signals, throttle signals, torque signals, rotational speed signals, and torque direction signals to generate output signals representing the engine speed, motor speed, clutch state, driving torque, and more.

By employing this simulation and testing procedure, the performance of the whole-car controller of a hybrid electric car can be accurately evaluated. It reduces the testing time, lowers the overall testing costs, and improves the stability and accuracy of the test results. This procedure contributes to the development and optimization of hybrid electric car technology, enabling improved control algorithms, enhanced power performance, and increased fuel efficiency.

Conclusion

The developed simulation and testing device for hybrid power car controllers, utilizing a PCI interface and a microprocessor, provides several advantages including enhanced reliability, high data transmission rate, and excellent expandability. The incorporation of a mathematical model of the power unit significantly reduces system cost. The device consists of a microprocessor unit, PCI bus processing unit, display unit, and interface board card, enabling convenient configuration and testing of the finished car controller. The application of this device and procedure in testing hybrid power car controllers leads to reduced test durations, cost savings, and reliable and accurate test results. Overall, this research contributes to the advancement of simulation and testing techniques for hybrid power car controllers.

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