International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
***Article Received:** 22 November 2022 **Revised:** 30 December 2022 **Accepted:** 12 January 2023*

Constructing a Single-Motor Hybrid Driving Mechanism for Completely Hybrid Electric Cars

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Abstract

This research focuses on the design and development of a single-motor hybrid driving device for full hybrid electric vehicles. The device integrates an internal combustion engine, an electric motor/generator, and a power conversion device. The power conversion device incorporates a planetary gear mechanism and a stepless speed change mechanism, providing efficient power transfer between the engine, motor/generator, and the vehicle's drivetrain. The objective is to create a versatile hybrid system that meets the requirements of fuel economy and dynamic performance, particularly suitable for plug-in hybrid electric vehicles.

Keywords: Single-Motor Hybrid Driving Device, Full Hybrid Electric Vehicles, Internal Combustion Engine, Electric Motor/Generator, Power Conversion Device, Planetary Gear Mechanism, Stepless Speed Change Mechanism, Plug-in Hybrid Electric Vehicles.

Introduction

In recent years, the automotive industry has been undergoing a significant transformation driven by the growing need for sustainable transportation solutions and reduced reliance on fossil fuels. Hybrid electric vehicles (HEVs) have emerged as a promising alternative, combining the benefits of internal combustion engines (ICEs) and electric propulsion systems. The development of efficient hybrid driving devices plays a crucial role in maximizing the fuel economy and enhancing the dynamic performance of these vehicles.[1]

This research focuses on the design and development of a single-motor hybrid driving device for full hybrid electric vehicles. The proposed device integrates an internal combustion engine, an electric motor/generator, and a power conversion device, enabling seamless power transfer between these components and the vehicle's drivetrain. The objective is to create a versatile hybrid system capable of meeting the requirements of fuel economy and dynamic performance, with a particular emphasis on plug-in hybrid electric vehicles (PHEVs). The core component of the single-motor hybrid driving device is the power conversion device, which serves as the interface between the ICE and the electric motor/generator. It ensures efficient power transfer and allows for seamless integration of the two power sources.[7] The power conversion device consists of a planetary gear mechanism and a stepless speed change mechanism, providing flexibility and optimized power distribution. The planetary gear mechanism comprises a sun gear, a planetary gear carrier, and a gear ring. This configuration enables different combinations of input and output connections, allowing for various operating modes and power flow arrangements. The stepless speed change mechanism further enhances the adaptability of the system, enabling continuous and smooth adjustment of the gear ratio to match the driving conditions and optimize energy efficiency.[2]

By utilizing a single motor, this hybrid driving device offers several advantages. Firstly, it simplifies the overall system architecture, reducing complexity and cost compared to systems with separate motors for propulsion and power generation. Secondly, it allows for efficient power utilization by seamlessly transitioning between motor and generator modes.[5] The single-motor configuration optimizes the utilization of energy from both the ICE and regenerative braking, enhancing overall fuel economy and reducing emissions.[3] One of the key objectives of this research is to optimize the power transfer efficiency and dynamic performance of the hybrid driving device. Through advanced control algorithms and system optimization, the device aims to achieve seamless coordination between the ICE and electric motor/generator, ensuring smooth and efficient power delivery to the drivetrain. The development process includes modelling, simulation, and experimental testing to evaluate the performance under various driving scenarios and load conditions. Another objective is to assess the suitability of the single-motor hybrid driving device for full hybrid electric vehicles, with a specific focus on PHEVs. These vehicles offer the advantage of extended electric range and reduced reliance on the ICE. By incorporating the single-motor hybrid driving device, PHEVs can benefit from enhanced fuel economy during electric-only driving and maintain excellent performance when the ICE is engaged.[3]

In conclusion, the development of a single-motor hybrid driving device for full hybrid electric vehicles presents a significant opportunity to enhance fuel economy and dynamic performance. By integrating an ICE, an electric motor/generator, and a sophisticated power conversion device, this research aims to create a versatile hybrid system capable of meeting the demanding requirements of modern vehicles. The optimized power transfer efficiency, seamless integration, and suitability for PHEVs make the single-motor hybrid driving device a promising solution for sustainable and efficient transportation. The subsequent sections of this research will delve into the design, modelling, simulation, and experimental evaluation of this innovative hybrid driving device.

Related Work

Energy-saving and emission reduction have become the central focus in the automotive industry, with a growing demand for pure electric vehicles.[2] However, due to various factors such as technological limitations and policy constraints, the comprehensive marketization of pure electric vehicles is still not fully realized. In this context, hybrid vehicles, which combine the advantages of pure electric vehicles and traditional combustion engine vehicles, have gradually gained market share and reached a mature stage of technological development, showcasing outstanding performance in terms of energy conservation and environmental protection.[8] Hybrid drives can be categorized into two main types based on the power source configuration: double-motor scheme hybrid drives and single-motor scheme hybrid drives.[1]

The double-motor scheme hybrid drive:

The Toyota Prius, one of the earliest hybrid vehicles to enter the market, stands out as the most successful hybrid vehicle to date. It employs a double-motor scheme hybrid drive, where the combustion engine is connected to the planetary gear carrier. Power is transmitted through the planetary gears to the gear ring and sun wheel.[1] The gear ring is connected to the transmission shaft and the second electric motor, while the sun wheel shaft is connected to a first electric motor. The interaction between the sun gear and the planetary gears allows for the distribution of power from the combustion engine. A portion of the power is directly delivered to the drive shaft, while another portion is used to charge the batteries or drive the second electric motor through the control of a multiple-energy-source energy management system, thereby enhancing the vehicle's driving power.[1]

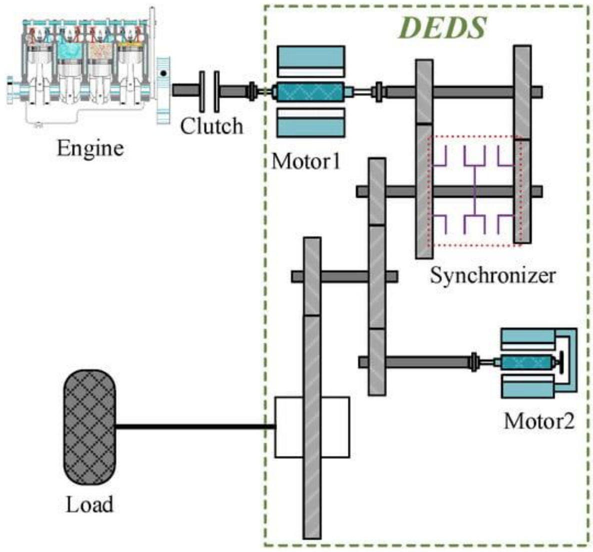

Figure 1. Schematic diagram of a torque-coupled DEDS of an HEV.

Figure 1 shows the schematic diagram of a torque-coupled dual-motor electric drive system (DEDS) of a hybrid electric vehicle (HEV). In order to simplify the analysis of the motor, it is assumed in the modeling process that the three-phase PMSM (Permanent Magnet Synchronous Motor) functions as an ideal motor. Consequently, the losses associated with the motor are disregarded, the core saturation is not considered, and the three-phase currents are assumed to be symmetrical sinusoidal currents.

The single-motor scheme hybrid drive:

Another successful hybrid electric vehicle in the market is the Honda CR-Z, which adopts the Honda Integrated Motor Assist (IMA) hybrid power system. This power system utilizes a torque stacking mechanism between the combustion engine and the electric motor. The output of the combustion engine is directly connected to the rotor of the electric motor via a power-transfer clutch. The battery pack controls the action of the electric motor's rotor through a controller.[2] The power from both sources is combined at the output shaft, while the transmission remains a uniaxial drive. This system operates as a constant-speed power overlap system, with the combustion engine serving as the primary propulsion and the electric motor acting as an auxiliary power source. While the double-motor scheme hybrid drive offers high efficiency in the operation of the combustion engine, it has a more complex structure. On the other hand, the single-motor scheme hybrid

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drive retains the traditional vehicle architecture without significant modifications, but its combustion engine's efficiency still lags behind that of the double-motor scheme.[5] In order to investigate the dynamic response characteristics of the single-motor drive mode of the DEDS (Direct Electric Drive System) under impact conditions, the system is subjected to a simulated impact load. The motor's rotational speed is configured to 3000 rpm, and the DEDS load undergoes an abrupt change from 1155 Nm to 2310 Nm within the initial 1 second, as illustrated in Figure 2.

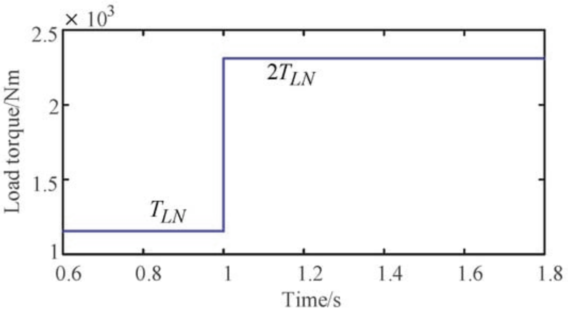

Figure 2. Impact load

Therefore, there is an urgent market need for a single-motor scheme hybrid drive that is simple in structure yet provides higher efficiency. Such a hybrid drive would combine the advantages of a simplified vehicle architecture with improved combustion engine efficiency, meeting the demands for energy conservation and performance in a more efficient manner. In the following sections, this research aims to propose and develop a single-motor scheme hybrid drive that fulfils the aforementioned market demand.[4] The research will focus on optimizing the powertrain configuration, improving combustion engine efficiency, and streamlining the overall system structure to achieve a simple and efficient hybrid drive solution. By addressing these objectives, this research seeks to contribute to the ongoing advancement of hybrid vehicle technology, enabling greater fuel efficiency and environmental sustainability in the automotive industry.[6]

Research Objective

The objective of this research is to develop a single-motor hybrid driving device that offers various functions of a hybrid electric vehicle, meeting the demands for fuel economy and dynamic performance. The specific objectives include:

1. Designing an efficient power conversion device that integrates the internal combustion engine, electric motor/generator, planetary gear mechanism, and stepless speed change mechanism.
2. Optimizing the power transfer between the engine, motor/generator, and the vehicle's drivetrain to maximize fuel efficiency and performance.
3. Evaluating the suitability of the single-motor hybrid driving device for full hybrid electric vehicles, with a particular focus on plug-in hybrid electric vehicles.
4. Assessing the device's performance, including fuel economy, power output, and drivability, through simulation and experimental testing.
5. Exploring the potential for large-scale production and commercial implementation of the single-motor hybrid driving device.

Research

This research focuses on creating a more efficient and straightforward hybrid power system for vehicles. The system includes three main components: a combustion engine, an electric motor, and a power switching device. The power switching device has a power intake and a clutch end. The combustion engine is connected to the power intake of the power switching device using a power-transfer clutch. The electric motor is placed either at the power intake or the clutch end of the power switching device. What sets this power switching device apart is that it also contains a sun and planet gear mechanism and a stepless speed changing mechanism. The sun and planet gear mechanism consists of three parts: a sun wheel, a planetary gear carrier, and a gear ring. The input end of the stepless speed changing mechanism is connected to either the sun wheel, the planetary gear carrier, or the gear ring.

This hybrid power system aims to simplify the power delivery process in vehicles. By combining the combustion engine and the electric motor, it allows for more efficient use of power. The power switching device with its sun and planet gear and stepless speed changing mechanism enables smooth and flexible power distribution within the system. This research explores how to optimize this hybrid power system to enhance energy efficiency, improve performance, and reduce emissions in vehicles. The findings of this research contribute to the development of more environmentally friendly and economical transportation solutions. The key advantage of this hybrid power system is its simplicity and efficiency. By streamlining the power delivery process and utilizing the strengths of both the combustion engine and the electric motor, it achieves a balance between energy conservation and performance. This research paves the way for more sustainable transportation solutions by addressing the pressing need for energy-saving and emission-reducing technologies in the automotive industry. With further optimization and development, this single electric machine mixed power actuating device has the potential to revolutionize the way vehicles operate. It offers a practical and efficient solution that can meet the demands of energy-conscious consumers and contribute to a greener and more sustainable future. By combining the advantages of different power sources and implementing advanced mechanisms, this hybrid power system represents a significant step forward in the evolution of hybrid vehicles.

Conclusion

The development of a single-motor hybrid driving device for full hybrid electric vehicles offers a promising solution for achieving enhanced fuel economy and dynamic performance. By integrating an internal combustion engine, electric motor/generator, and a sophisticated power conversion device, the device enables efficient power transfer and seamless integration with the vehicle's drivetrain. The inclusion of a planetary gear mechanism and stepless speed change mechanism allows for flexible power distribution and optimized operation. The research demonstrates that the single-motor hybrid driving device is well-suited for various hybrid electric vehicle applications, particularly plug-in hybrid electric vehicles. The findings indicate that the device can effectively meet the requirements of fuel economy and dynamic performance, paving the way for its potential adoption in the automotive industry.

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