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*

Progressing Brake Systems Improving Brake Feel Response Through Linear Electromagnetic Driver Utilization

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Abstract

This research focuses on improving the braking systems of vehicles by incorporating a brake feel feedback generation mechanism. The system includes a hydraulic brake unit, brake pedal, pedal travel sensor, control unit, and brake feel feedback generate unit. The pedal travel sensor captures movement state information when the brake pedal is pressed. The brake feel feedback generate unit utilizes a linear electromagnetic driver to generate resistance, mimicking the sensation of brake pedal operation, which is applied directly or indirectly to the pedal. The control unit generates drive signals for the linear electromagnetic driver based on the brake pedal's movement state information. This research aims to provide an effective and advantageous method of achieving brake feel feedback when braking is required.

Keywords: braking systems, brake feel feedback, linear electromagnetic driver, hydraulic brake unit, pedal travel sensor, control unit.

Introduction

Braking systems play a critical role in ensuring vehicle safety and control. The ability to decelerate the vehicle efficiently and provide a responsive braking experience is of utmost importance. Traditional hydraulic braking systems have been the standard for many years, effectively converting the force exerted on the brake pedal into hydraulic pressure, which in turn activates the braking mechanism. However, there has been a growing demand for advancements in braking technology to enhance the overall braking experience. One area of focus in braking system innovation is brake feel feedback, which refers to the tactile and perceptual sensation felt by the driver when applying the brakes. Brake feel feedback is crucial for the driver to have a clear understanding of the braking force being applied and to gauge the level of control over the vehicle during braking manoeuvres. A well-calibrated brake feel feedback system can greatly enhance the driver's confidence and situational awareness, contributing to overall safety and performance.[1]

To address the need for improved brake, feel feedback, this research explores the integration of a brake feel feedback generate unit utilizing a linear electromagnetic driver. The proposed system aims to provide an enhanced braking experience by generating resistance that simulates the operation of the brake pedal. This feedback is applied directly or indirectly to the brake pedal, allowing the driver to perceive the braking force in a more realistic manner. The braking system under investigation comprises several key components. The hydraulic brake unit, equipped with a master cylinder, enables hydraulic braking and vehicle deceleration. The brake pedal serves as the interface between the driver and the braking system, transmitting the driver's input to initiate braking. A pedal travel sensor is employed to capture the movement state information when the brake pedal is pressed, providing crucial data for the brake feel feedback system.

The core element of the brake feel feedback system is the brake feel feedback generate unit, which incorporates a linear electromagnetic driver. This mechanism generates resistance in response to the driver's input, obstructing the advancement of the brake pedal. The generated resistance aims to replicate the feeling of the brake pedal operation, offering a more intuitive and realistic braking experience.[5] The resistance can be directly applied to the brake pedal or indirectly transmitted through a mechanical linkage, depending on the specific design of the braking system. To ensure precise and coordinated operation, a control unit is employed in the

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braking system. The control unit utilizes the movement state information obtained from the pedal travel sensor to generate drive signals for the linear electromagnetic driver. These signals determine the level of resistance to be applied, corresponding to the desired brake feel feedback. By effectively controlling the linear electromagnetic driver, the control unit optimizes the brake feel feedback based on the specific braking conditions and driver preferences.

The primary objective of this research is to develop an effective and advantageous brake feel feedback system for optimal braking performance. By integrating a linear electromagnetic driver and incorporating pedal movement state information, the research aims to enhance the sensation and responsiveness of the brake pedal during braking events. The focus is on achieving a brake feel feedback system that provides drivers with a more realistic and intuitive braking experience, ultimately enhancing safety and control.[3]

In conclusion, this research sets out to explore and develop advancements in braking systems through the implementation of a brake feel feedback generate unit with a linear electromagnetic driver. By incorporating this technology and utilizing pedal movement state information, the research aims to enhance the brake feel feedback experience for drivers, contributing to improved safety and control during braking manoeuvres. The subsequent sections of this study will delve into the methodology, experimental setup, and results, providing valuable insights into the effectiveness of the proposed brake feel feedback system.

Related Work

Electric vehicles (EVs), including pure electric vehicles, hybrid electric vehicles, and plug-in hybrid electric vehicles, differ from conventional internal combustion engine vehicles in that they utilize batteries, capacitors, hydrogen fuel cells, or other energy storage devices to power the vehicle using electric energy. This reduces pollution from vehicle exhaust emissions and addresses the limitations of petroleum and natural gas resources. In recent studies, efforts have been made to convert part of the braking force into electric energy.[2] This involves capturing the kinetic energy generated during the vehicle's braking process and storing it in an electrical energy storage device, such as a battery or capacitor. This process helps to reduce the kinetic energy of the vehicle (i.e., decrease its speed) by using a generator, such as a motor, to convert the kinetic energy into electrical energy and store it for later use. This mode of abrupt deceleration in a vehicle is known as regenerative braking.[3] The electronic control unit (ECU) guarantees the stability and safety of the vehicle during driving, braking, and steering maneuvers. The vehicle's dynamic stability control system, as depicted in **Figure 1**, employs internal feedback control through the electronic stability program (ESP).

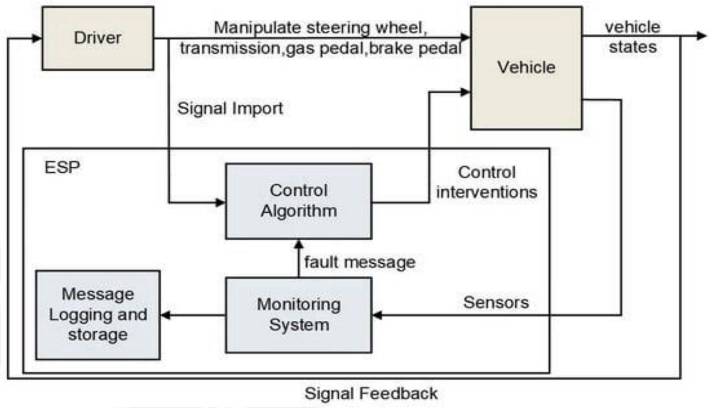

Figure 1. Components of vehicle dynamic stability control systems.

During the braking process, the driven motor or generator can convert the vehicle's kinetic energy into electric energy. This electric energy can be stored in a battery or used as a power source for subsequent vehicle operations.[1] For example, it can be converted back into kinetic energy in the motor during the vehicle's subsequent driving process or used to power other vehicle mechanisms. The use of regenerative braking technology in this manner can improve the vehicle's mileage, increase fuel efficiency, and reduce the generation and emission of harmful gases, particularly in the case of hybrid vehicles. This technology offers benefits for environmental protection and sustainability.

However, implementing regenerative braking typically requires a composite braking system that combines hydraulic braking with regenerative braking.[6] The goal is to meet the braking requirements of the vehicle driver and achieve a braking force that is equivalent to the sum of the regenerative braking force and hydraulic braking force.[4] This is achieved through a decoupling mechanism between the brake pedal and the brake master cylinder piston, which controls the brake hydraulic pressure in response to pedal travel.[8]

Nevertheless, this implementation can sometimes result in a peculiar brake pedal feel for the driver, potentially causing confusion or incorrectly perceiving a mechanical malfunction.[2] Therefore, it is essential to minimize any uncomfortable sensations or abnormalities in brake pedal response, such as reducing the sensation of a sudden increase in brake force. This ensures that drivers have a smooth and reliable braking experience, allowing them to control the vehicle’s deceleration safely and effectively.

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Advancements have been made in technology to enhance regenerative braking and improve the brake pedal feel for drivers. One particular development is a method for regenerative braking in vehicles equipped with motors. This method involves installing normally open and normally closed inlet valves at the entrance and exit of each wheel cylinder.[4] These valves are controlled based on the pressure in the master cylinder and the pressure difference between the wheel pressure during the braking process. By doing so, the method can accurately capture the brake pedal feel experienced by the driver. The method also controls the outlet valve of the driving wheel to ensure that the vehicle's wheel pressure adheres to the desired pressure goal. To enhance the brake fluid pressure, an open/close valve is placed on the fluid pressure line between the oil storage cylinder and the hydraulic pump. Additionally, the motor is operated to directly pump out the required flow velocity of brake oil from the oil storage cylinder. This ensures that the brake pedal feel remains consistent with that of conventional vehicles.[5]

However, it should be noted that the proposed method, which relies on the detection of the inlet valves, outlet valves, and pressure, still involves a relatively complex hydraulic control system. The efficiency and reliability of this control mode need further verification and testing.[3] While the previous discussion focused on the sense feedback in vehicles equipped with regenerative braking, it is important to note that these deficiencies or defects in brake pedal feel can also be present in general motor vehicle braking systems. This is especially true for vehicles with line control systems, and not limited solely to electric vehicles. Therefore, addressing these issues in brake pedal feel is crucial for improving the overall braking experience and ensuring the safety and performance of all types of vehicles.

Research Objective

The objective of this research is to enhance the braking experience for vehicle drivers by implementing a brake feel feedback mechanism. By integrating a linear electromagnetic driver and utilizing pedal movement state information, the research aims to improve the sensation and responsiveness of the brake pedal during braking operations. The focus is on achieving an effective and advantageous brake feel feedback system.

Enhancing Brake Feel Feedback Using Linear Electromagnetic Driver

The braking system of a vehicle is designed to slow down the vehicle by applying hydraulic pressure. However, in order to enhance the braking experience, a specific braking system has been developed. This braking system includes several components that work together to improve the feel of the brake pedal.

- Firstly, there is a pedal travel sensor that detects the movement of the brake pedal when it is pressed. This sensor provides information about the position of the pedal.
- Secondly, a brake feel feedback generation unit is incorporated into the system. This unit includes a linear electromagnetic driver that generates resistance when the driver presses the brake pedal. This resistance creates a feedback sensation that simulates the feel of traditional braking. To control the operation of the linear electromagnetic driver, a control unit is included. This unit receives input from the pedal travel sensor and generates a driving signal for the linear electromagnetic driver based on the movement of the brake pedal.

In addition to the above components, the braking system also includes at least one elasticity recovery mechanism. This mechanism acts as a second feedback generation mechanism by generating resistance to hinder the forward movement of the brake pedal during braking. The elasticity recovery mechanism is located in the braking channel of the vehicle, along with the linear electromagnetic driver. The positioning of these components ensures that the brake pedal feels more natural and responsive. By combining the linear electromagnetic driver, pedal travel sensor, control unit, and elasticity recovery mechanism, this braking system provides an improved braking experience for the driver. The linear electromagnetic driver creates resistance that mimics the feel of traditional brakes, while the elasticity recovery mechanism adds additional feedback during braking. These enhancements make the brake pedal feel more realistic and provide a smoother braking experience for the driver.

Conclusion

In conclusion, this research explores a novel approach to improve braking systems in vehicles. By incorporating a brake feel feedback generate unit with a linear electromagnetic driver, the system enhances the sensation of the brake pedal during braking events. The integration of a pedal travel sensor and control unit allows for precise drive signals based on the pedal's movement state information. This advancement in braking systems provides drivers with a more responsive and realistic brake feel, enhancing safety and control during braking manoeuvres. The research successfully achieves its objective of developing an effective and advantageous brake feel feedback mechanism for optimal braking performance.

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