Research on Intelligent Brake Assist System Based on Motor Drive and ECU Control

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Abstract. Autopilot is divided into three parts: they are perceptual positioning, planning decision and execution control. In this project, we study its implementation control part, the intelligent brake boosting system. The intelligent brake boosting system is the most advanced intelligent braking system in the world. It is an essential and key component for autonomous driving and driverless driving. At the same time, it is the inevitable trend and the best solution for the next generation braking system of automobiles. This project describes the composition, functions and advantages of the intelligent brake boosting system, and analyzes the key component controllers, electric brake actuators and product performance.

1. Intelligent Brake Boost System
Figure 1 is a composition diagram of an intelligent brake boosting system. A motor-driven and ECU-controlled intelligent brake boosting system including a controller (1), an electric brake actuator (5), and a vehicle stabilization aid (9). The controller (1) is connected to an electric brake actuator (5), which is also connected to the vehicle stabilization aid (9).

The motor-driven and ECU-controlled intelligent brake boosting system is driven by a motor, controlled by an ECU, and can be mounted on an autonomous driving vehicle, which is a future development trend.
1. Controller; 2a. Output port one; 2b. Output port two; 3a. Output port three; 3b. Output port four; 4. Oil cup output port one; 5. Electric brake actuator; 7. Output port six; 8. Oil cup output port two; 9. Vehicle stability auxiliary device;

Figure 1. Intelligent brake boost system components

1. controller; 5. electric brake actuator; 10. electric drive assembly; 11. master cylinder assembly; 12. oil cup; 13. pedal master cylinder; 14. pedal force simulator; 15. ECU;

Figure 2. Controller and Electric brake actuator components
2. Intelligent Brake Boost System Function

2.1. Controller, electric brake actuator structure

The controller (1) is mainly composed of a pedal master cylinder (13), a pedal force simulator cylinder (14), and an ECU (15). The electric brake actuator (5) is mainly composed of an electric drive assembly (10), a master cylinder assembly (11), and an oil cup (12).

2.2. System working principle

A method for operating a motor-driven and ECU-controlled intelligent brake boosting system. The method comprising the steps of:

Step S1: The controller (1), the electric brake actuator (5) and the vehicle stability assisting device (9) are connected by a hydraulic circuit formed by a hose or a pipe.

The chamber II output ports 2a, 2b of the controller (1) and the chamber ii output port of the electric brake actuator (5) are coupled to point c, and then connected to the vehicle stabilization aid (9). The chamber I output ports 3a, 3b of the controller (1) are connected to the cavity i output port of the electric brake actuator (5) at point d, and are then connected to the vehicle stabilizing aid (9).

The pressure sensor Pm and the normally open solenoid valve A2 are sequentially connected to the connecting line of the chamber II to the output ports 2a and 2b, and the normally open solenoid valve A2 is in the open position when the power is not supplied.

A normally open solenoid valve A1 is sequentially connected to the connecting line of the cavity I to the output ports 3a, 3b, and the normally open solenoid valve A1 is an open position and a pressure sensor Pp when the power is not supplied;

The chamber I is in communication with the chamber V, and a normally closed solenoid valve A3 is mounted on the connecting line thereof the closed solenoid valve A3 is in a closed position.

![Figure 3. Principle of intelligent brake boost system](image-url)

1. Controller; 2a. Output port 1; 2b. Output port 2; 3a. Output port 3; 3b. Output port 4; 5. Electric brake actuator; 9. Vehicle stability auxiliary device; 12. Oil cup; Small oil cup; 17. Hall displacement sensor;
Step S2: When the pedal is depressed, the Hall displacement sensor (17) mounted on the cylinder detects the change of the magnetic field of the magnetic ring, and transmits the signal to the electronic control unit (ECU), and the output signal of the electronic control unit (ECU) controls each component work;

At the same time, when the brake pedal is depressed, since the cavity I is connected to the cavity V, the brake fluid of the cavity I is pressed to the cavity V. The device inside the cavity V is transmitted to the brake pedal by applying a reaction force. The deeper the reaction is depressed, the greater the pedal force experienced by the operator.

Step S3: The electronic control unit (ECU) outputs a control signal to the motor M. The rotation of the motor M drives the pinion gear mounted on the output shaft to rotate, and the pinion gear rotates to drive the large gear that meshes with the gear, and the large gear and the ball screw pass. The screw nut is pressed into the assembly, the rotation of the large gear drives the ball screw to move to the left to contact the piston one, and at the same time compresses the cavity i, the cavity i is gradually compressed, and the cavity i brake fluid is pressed out to the vehicle stability auxiliary device (9); When the piston is compressed, the spring assembly installed between the piston 1 and the piston 2 is compressed, and the spring force is increased. When the pressure on the right side of the piston 2 is greater than the left side, the piston 2 gradually compresses the cavity II to the left, and the cavity II brakes. The liquid is forced out to the vehicle stabilization aid (9).

Step S4: The vehicle stability assisting device (9) further implements the braking function by calculating the brake device that distributes the brake fluid to each wheel of the vehicle.

Step S5: The brake pedal is released, and the brake is released. The control system rotates the motor in reverse according to the signal of the Hall sensor, and drives the pinion gear mounted on the output shaft of the motor to rotate, and the pinion rotates to drive the large gear that meshes with the rotation. The ball screw is axially right-sliding; at this time, the cavity i and the cavity ii of the electric brake actuator (5) are gradually released, and the brake fluid of the vehicle stabilization auxiliary device (9) is returned to the cavity i and the cavity ii. Eventually the electric brake actuator (5) is returned to its original state.

At the same time, the cavity I of the controller (1) is gradually released, and the brake fluid in the cavity V is gradually returned to the cavity I to restore the initial state.

Steps S1 - S5 are sequentially performed.

When the electric brake actuator (5) fails, the device acts as a safe hydraulic brake actuator. At this time, the normally open solenoid valve A1, the normally open solenoid valve A2, and the normally closed solenoid valve A3 are all in a power off state.

The normally open solenoid valve A1 is turned on, and the controller (1) output ports 3a, 3b output brake fluid to the vehicle stability assisting device (9).

The normally open solenoid valve A2 is turned on, and the controller (1) output ports 2a, 2b output brake fluid to the vehicle stability assisting device (9).

At this time, the normally closed solenoid valve A3 is closed, and the pedal force simulator cylinder (14) has no brake fluid input and does not function.

The motor-driven and ECU-controlled intelligent brake boosting system is composed of a line-controlled brake system and a conventional hydraulic brake system. The line-controlled brake system is used as a normal time, and the hydraulic brake system is used. Used as a fail-safe. The system is composed of a controller (1), an electric brake actuator (5) and a vehicle stability assisting device (9). The controller is a device that input the control signal when the operator operates the brake pedal, then the electric brake actuator receives the control signal to generate brake hydraulic pressure.

3. Advantages of intelligent brake boosting system
The motor drive and ECU controlled intelligent brake boosting system have the following positive effects:
3.1. With motor drive, the response speed is fast, the response time is about 120 milliseconds to 150 milliseconds, which is 200 to 300 milliseconds shorter than the response time of the ESP module.

3.2. The system adopts motor drive, ECU control, and can be installed on the auto-driving car, which is a future development trend.

3.3. Compared with the traditional vacuum booster system, the structure is compact, the units are highly integrated, the component cost is reduced, and the size and weight are also reduced, which is in line with the current trend of automobile development.

3.4. The DC brushless motor used in this system is designed with a parameter-adaptive fuzzy PID control strategy. Overcoming the parameters of the traditional motor itself and the parameters of the drag load will change during the operation, so that the PID control of the fixed parameters The device does not allow the system to maintain the shortcomings of the design performance specifications under various operating conditions.

3.5. The system is designed with a simulator structure. When the brake pedal is depressed, a reaction force is applied to the brake pedal through the simulator piston, the brake fluid and the master cylinder piston. The deeper the reaction force is, the greater the reaction force is. Give the operator the feeling of braking force generated by the pedaling force.

3.6. This system realizes the change of hydraulic pressure almost without the influence of pedal force through special structural design, which realizes the decoupling between hydraulic pressure and pedal force. The first half of the motor does not work, the pedal force increases, and the hydraulic pressure increases very little; the second half of the motor acts, the hydraulic pressure fluctuates, and the pedal force remains unchanged.

4. Conclusion
The intelligent brake booster system is an electromechanical servo booster that does not rely on a vacuum source to meet the requirements of modern brake systems. The intelligent brake boost system can be used in all power systems, especially for hybrid and electric vehicles. Modern internal combustion engines and electric vehicles do not provide sufficient vacuum for the vacuum booster, so mechanical or electric vacuum pumps must be relied upon to supplement the vacuum. The vacuum required for the operation of a conventional vacuum assist system is obtained through fuel consumption, while the intelligent brake boost system does not require a vacuum source at all. This means that a vacuum pump is no longer needed. In terms of removing the vacuum pump itself, it means saving fuel consumption and reducing carbon dioxide emissions. In addition, various fuel-saving technologies (such as the start/stop or coasting function of the engine temporarily closed) can be more fully utilized.

The successful application of this product also helps to improve the safety of vehicle operation and protect the safety of passengers and pedestrians. In addition to the importance of maintaining the safety of vehicle operation, it also plays a huge role in the improvement of product quality and test R&D of automotive electronic brake parts manufacturers, and is conducive to improving the overall competitiveness of China's automobile production enterprises and parts enterprises.

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