Research on Anti-lock Braking System of Electro-mechanical Braking Vehicle Based on Feature Extraction

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Abstract. With the increase of vehicle speed, the increase of road traffic density and people's higher requirements for vehicle safety, the Anti-lock Braking System (ABS) has become an important safety device on vehicles. It not only has the braking function of the common braking system, but also can prevent the wheels from locking. Automobile ABS is an important device that affects the safety of automobile braking system and driving safety. It can shorten braking distance and improve directional stability and operability during braking. Electro-mechanical braking control system adopts advanced electro-mechanical braking technology and is applied to automobile braking control system together with anti-lock braking system. Emb (electro-mechanical brake) uses electric energy as the energy source of the braking system, and uses the motor to drive the actuator to generate braking force, which responds quickly and can effectively improve the active safety of automobiles. In this paper, based on feature extraction algorithm, the brake pressure estimation method of EMB actuator is proposed, and the anti-lock braking control algorithm of automobile is analyzed.

Keywords: ABS; EMB; mechanical braking; control system

1. Introduction
Automotive electro-mechanical braking has incomparable advantages over traditional hydraulic braking, such as simple structure, fast response, high braking efficiency, low assembly and maintenance difficulty [1]. Automobile anti lock braking system (ABS) is an important device that affects the safety of automobile braking system and driving safety. It can shorten the braking distance, improve the directional stability and operability during braking, and is an important safety guarantee to ensure that the automobile does not swing tail and deviate from the predetermined Lane in the process of emergency braking [2]. As an active safety device, ABS adopts electronic control mode to automatically adjust the braking torque of the wheel according to the "vehicle road" condition in the braking process, so as to achieve the purpose of preventing the wheel from locking [3]. Drivers pay more and more attention to the safety performance of automobile driving, and the loading rate of ABS system is higher and higher. Most drivers think that the self-test function of ABS can check all its faults, but they don't know that this self-test can only detect electrical faults such as open circuit and short circuit [4]. Whether the ABS system works normally or not directly affects the safety performance of automobile driving [5]. Statistics show that most of the road traffic accidents are caused by the vehicle's departure from the predetermined track or tail flick at the moment of braking.
Therefore, improving the braking performance and ensuring the effectiveness and reliability of the braking system performance are important measures to reduce traffic accidents [6].

The function of ABS is to prevent the wheels from locking and sliding on the road, improve the directional stability, steering control ability and shorten the braking distance in the braking process, so as to make the vehicle braking safer and more effective [7]. It is the most advanced braking device with the best effect on the automobile at present. The fault diagnosis of equipment generally refers to the technology of using certain technical methods to judge the state of the equipment, diagnose the fault of the equipment and estimate its development and change according to the accumulated experience and data without the equipment disintegration [8]. Due to the different structure of ABS system in different vehicles, the detection methods are not the same. Therefore, when checking the system, it should be carried out according to the maintenance and testing technical data provided by various manufacturers [9]. Traditional ABS is generally equipped with self diagnosis system, including the diagnosis of short circuit and open circuit fault of motor. Once the fault is detected, ABS will stop working and the fault light will be on [10]. However, with the structure of automobile braking system becoming more and more complex, the traditional fault diagnosis based on electrical test is far from being able to meet the monitoring of ABS system [11]. As a branch of linear control, EMB (electrical brake) uses a unique braking concept compared with traditional hydraulic braking [12]. It uses electric energy as the energy source of the braking system, and uses the motor to drive the actuator to generate braking force, which can effectively improve the vehicle active safety [13]. Based on the feature extraction algorithm, this paper proposes the estimation method of EMB actuator braking pressure, and analyzes the anti lock braking control algorithm.

2. Function analysis and structure design of ABS fault simulation system

2.1. Structure and working principle of ABS system

Generally speaking, the automobile braking system with ABS includes two parts: the basic braking system and the braking force adjusting system. The basic braking system is composed of brake master cylinder, brake wheel cylinder and brake pipeline, which is used to realize the conventional braking of automobiles, while the braking force adjustment system is a hydraulic control system composed of sensors, ABS controllers, ABS actuators, etc., which is used to ensure that the wheels never lock up during braking. The wheel speed signal of ABS is measured by sensors, and the calculation process of wheel speed is completed by control software. In these two processes, the sensor parameters determine the lowest wheel speed that it can measure, while the software parameters determine the lowest wheel speed that it can calculate. The lowest wheel speed of ABS is determined by these two lowest wheel speeds. The function of the wheel speed sensor is to convert the wheel speed signal into an electrical signal and output it. The ABS electronic control unit detects the wheel speed by detecting the frequency of the sensor output signal. If there is no ABS system, when the driver brakes quickly in an emergency, it will cause the wheels to lock. At the same time, if the steering wheel is turned sharply, it will cause the car to skip its tail and cause accidents. ABS system is an active safety system of automobile, which plays a vital role in preventing wheel locking. The wheel speed sensor is the key part of ABS system, and the accuracy of the output signal from the sensor directly affects the performance of ABS. Therefore, if the wheel speed sensor fails, it will affect the correct control strategy of ABS [14]. In the process of high-speed driving, if the car encounters an emergency, it will usually brake urgently and turn the steering wheel urgently. In addition, the complicated driving conditions will easily lead to the car rollover leading to a car accident. ABS system is an auxiliary braking system designed to overcome this problem.

It can be seen from Figure 1 that ABS ECU, as the central control unit of ABS system, receives the information provided by sensors to make a control strategy, and adjusts the brake pressure by controlling the hydraulic adjustment module.
The main task of the traditional ABS electronic control unit is to process the signal output by the wheel speed sensor, calculate the wheel speed, estimate the vehicle speed, run the ABS control algorithm, drive the actuators such as valves and pumps to act correctly, and realize the ABS function. Automobile ABS system is mainly composed of conventional braking part and anti-lock control part, in which conventional braking part is composed of brake pipeline, brake master cylinder and brake wheel cylinder, while anti-lock control part is composed of ABS controller, actuator and wheel speed sensor. ABS actuator is hydraulic control unit, also known as hydraulic regulator, which mainly includes solenoid valve, return pump motor and reservoir. The actuator is installed between brake master cylinder and brake wheel cylinder, receives control instructions from electronic control unit, and automatically adjusts brake pressure of brake wheel cylinder. ABS actuator, also known as oil pressure regulator, is installed between brake master cylinder and brake wheel cylinder, and is composed of oil inlet valve, oil return valve, liquid storage tank and hydraulic pump. Among them, the oil inlet valve and oil return valve components play a major role. The electromagnetic elements of the oil inlet valve and the oil return valve receive the adjustment command sent by the control unit ECU and automatically open or close.

2.2. Functional requirements of ABS fault simulation system

Sensor failures mainly include electromagnetic wheel speed sensor failure, Hall wheel speed sensor and wheel cylinder pressure sensor failure, instead of only simulating one sensor failure, because Hall wheel speed sensor has a tendency to replace electromagnetic wheel speed sensor, and wheel cylinder pressure sensor is gradually integrated into hydraulic braking system. The ECU of ABS system mainly receives and processes wheel speed signals from wheel speed sensors, and then calculates real-time wheel acceleration, slip rate, vehicle speed and other information according to the control strategy set in the ECU, and then judges the working mode of the system, and sends control commands to the oil inlet valve and oil return valve of hydraulic regulating components. Electro-mechanical braking control system based on anti-lock braking system mainly consists of two parts: actuator and control system. The hardware cost of brake control system is mainly the use of sensors. Saving the use of sensors can reduce the hardware cost of the system and save the space of the system. The electro-mechanical brake control system can be better integrated in the structure of the car. There are generally four wheel speed sensors, and each sensor has its own gear ring. As the wheel rotates, there will be a changing sinusoidal signal output. Only when the signal of the wheel speed sensor is input
into the ECU can the ABS system be controlled to correctly select among its four working modes for precise control and precise hydraulic adjustment.

Traditional ABS adds a control system to prevent wheel locking on the basis of ordinary braking system, so that the braking system becomes a closed-loop control system with negative feedback. The control structure of ABS is shown in Figure 2.

![Figure 2 ABS control structure](image)

The cost of system debugging is determined by the system module algorithm. Therefore, on the premise of normal operation of the brake control system, the complexity of the algorithm should be simplified, and the realizability of the algorithm should be improved in software programming, thus reducing the design cost of the system. Conventional braking means that when the driver brakes normally, it is not enough to trigger the ABS system, and the electromagnetic valve is in the default mode. When the driver steps on the brake pedal during driving, the oil in the brake master cylinder enters the brake wheel cylinder along the brake pipeline. Once the pressure of the brake wheel cylinder increases, the brake disc will be clamped, and the wheel speed will be reduced until stopping. In the schematic diagram of electromechanical brake control, we can see that in the process of braking, after the brake pedal is trampled, the signal is sent to the central controller through the sensor of the brake pedal, and the central controller carries out braking analysis after receiving the signal, and makes correct braking output according to the real-time speed and other parameter information of the vehicle. After the wheel speed signal output by the wheel speed sensor is input into the ABS control unit, the ABS system control unit will control the solenoid valve to act when the wheel is about to lock, the oil return valve will open to facilitate the oil in the wheel cylinder to flow out, and the oil inlet valve will close to prevent the oil from continuing to enter the wheel cylinder for decompression.

### 3. Implementation technology of ABS fault simulation system

In automobile brake system, sensors provide accurate wheel speed information and pressure information for brake control system, so as to realize accurate control of brake pressure. Therefore, the accuracy of sensor output information directly affects the correctness and effectiveness of control instructions of control system. When an automobile is braked urgently, it is easy to cause the wheels to lock up. At this time, ABS enters the working state, and the braking pressure of each wheel is adjusted timely and accurately to avoid the wheels from locking up. When braking, ABS must be able to adapt to various complicated road conditions, effectively resist various road interference factors, and respond quickly in an extremely short time. When brake an automobile, if only that movement of wheels include locking sliding and rolling are consider, when the brake pedal force is relatively small and the friction force of the braking system is not large, the friction force between the road surface and the tire is enough to overcome the braking force of the braking system, thus meeting the conditions of rolling driving of wheels.

Electro-mechanical braking control system based on anti-lock braking system integrates anti-lock braking technology and electro-mechanical braking control technology, and has better safety than traditional braking control system. Electro-mechanical braking control system based on anti-lock braking system has fast response speed and higher braking efficiency. Figure 3 shows the framework of automobile comprehensive performance inspection and maintenance system using dense disparity variance technology.
Figure 3 The framework of the vehicle's comprehensive performance detection and maintenance system using dense parallax variance technology

In order to verify the reliability of the fault diagnosis method studied, it is not only costly to conduct destructive experiments with actual sensors, but also unable to reproduce faults repeatedly. Therefore, it is necessary to build an ABS fault simulation system to simulate sensor faults. Stable operation of ABS requires a set of mature and reliable real-time control methods. If the algorithm is too simple, it can meet the real-time requirements, but its reliability and stability cannot be guaranteed. The transmission medium of the mechanical brake control system is mainly electrical signal, which shortens the time between stepping on the brake pedal and starting the brake. When the brake system is in emergency braking, the anti-lock brake system gives the maximum adhesion coefficient to the tire, which makes the car decelerate in the shortest time and stop running in the shortest distance. The ground braking force of automobile depends on the braking force of braking system at first, but it is limited by the ground adhesion condition at the same time. Therefore, only when the automobile has enough braking force of braking system and the ground can provide high adhesion, can it obtain enough ground braking force. The application of electro-mechanical braking control system reduces the mass of automobile, which can reduce the fuel consumption of automobile and improve the safety of automobile. Lightening the whole mass of automobile can reduce the energy loss when braking.

In feature extraction, features mainly refer to resources that cannot meet the production demand, which hinders the flow and output of the whole automobile production and maintenance system. The characteristics of the production system can be judged by the following formula:

\[ \beta_i = \frac{\sum_{j=1}^{n} T_i}{T} \quad (1) \]

In the formula, \(\beta_i\) is the load rate of a certain resource; \(T_i\) is the operation time of a single product; \(n\) is the production batch; \(T\) is the available capacity of resource 1.

According to the relationship between the overall buffer time and the processing time, a proportional value R can be determined, so the buffer value can be calculated by the following formula:

\[ t_{bi} = (1 + R)\sum_{j=1}^{m} t_{ij} \quad (2) \]
In the formula, $I_{ij}$ is the buffer time of processing task $i$ before its characteristic resources, $R$ is the buffer coefficient, and the parameter value can be set according to the actual situation, $I_{ij}$ is the sum of the operation time of processing task $i$ on process $j$ and the production preparation time, $m$ is the total processing quantity of the buffer.

Line fault refers to the open circuit and short circuit of the signal output line of the sensor, resulting in no signal output. Non-line fault mainly refers to the fault of abnormal output of wheel speed signal caused by missing teeth of gear ring and excessive gap between sensor head and gear ring in electromagnetic wheel speed sensor and Hall wheel speed sensor. Electro-mechanical braking control system has strong expansibility, and it also improves the fault diagnosis ability of braking control system. In electro-mechanical braking control system, auxiliary control systems can be easily integrated into the whole control system, and the application of computer network in vehicles can improve the fault detection ability of various parts of vehicles. In the process of automobile running, ABS control unit monitors the wheel speed information sent from wheel speed sensor all the time, and processes and analyzes it through the built-in control algorithm, so as to determine the appropriate working process, such as pressurization process and decompression process [15]. All these are based on the premise that the wheel speed sensor works normally and the wheel speed signal can be transmitted accurately. During braking, ABS collects various parameters such as wheel speed and braking force through sensors, calculates the best target braking pressure signal according to the vehicle safety control algorithm, and adjusts the braking pressure in real time through EMB actuator to keep the wheel slip rate in a certain range. The electromagnetic induction wheel speed sensor will output a sine wave with varying amplitude and frequency when the car is running. The magnitude of wheel speed can be inferred from the frequency amplitude of output wheel speed signal. The larger the signal frequency and amplitude, the larger the wheel speed, the smaller the signal frequency and amplitude and the smaller the wheel speed signal.

4. Conclusions
ABS system, as one of the important devices that affect the braking safety and driving safety of automobiles, requires not only highly reliable hardware design technology, but also reliable fault diagnosis capability. In the process of automobile running, ABS control unit constantly monitors the wheel speed information sent from the wheel speed sensor, and processes and analyzes it through the built-in control algorithm, so as to determine the appropriate working process. Vehicle electro-mechanical braking system (EMB) is sensitive and efficient, and can achieve braking performance that conventional hydraulic braking system can't achieve, which is the development direction of vehicle braking system in the future. The emergence of EMB is a milestone in the development of automobile braking system, which not only effectively eliminates the disadvantages brought by traditional hydraulic braking, but also facilitates the integration of various advanced safety control functions of automobile chassis, and promotes the integration of integrated control of chassis. Due to the influence of manufacturing process, the current EMB actuator has large gap, low transmission efficiency, large friction force and residual braking pressure. When improving the structure of EMB actuator, we should combine the performance requirements of EMB with the current manufacturing process, change the idea that the higher the design performance, the better, and take practicality as the standard. The development and application of electromechanical brake control system is beneficial to the development of automobile industry.

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