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Study on Vehicle Electronic Stability Program Control Algorithm under Electronic Mechanical Braking

Zhen Wang, Zhehao Hong, Yumeng Wang, Jinjun Zheng*

College of Automobile Engineering, Jilin University, Changchun 130012, China
wangzhen@jlu.edu.cn

This paper aims to understand the vehicle electronic stability program control algorithm under electronic mechanical braking. Methods: ADAMS/Flex is used for research. The simulation results are analyzed, and the process and model of vehicle braking are analyzed. The results show that the design is effective. Through the analysis of the process and model, it is proved that the motor speed is up to 1125deg/s in a short time. It is basically consistent with the rated motor speed 190r/min of the motor, which shows the validity and correctness of this design.

1. Introduction

Automobiles are one of the most important tools for people to travel in modern society. At present, most automobiles are driven by the electronic mechanical brake system. This system is mainly used as a brake actuator, and its main core is the motor drive component. However, the emergence of electro mechanical braking system has replaced the traditional hydraulic or pneumatic braking mode, which has effectively improved the shortcomings of traditional vehicle braking methods. In order to better understand the electronic mechanical braking system, on the basis of previous theoretical research, the control algorithm of the electronic stability program under electronic mechanical braking is studied.
The research ideas of this paper are as follows: First of all, the simulation analysis of the braking performance of the EMB rigid flexible coupling system is carried out mainly by the combined simulation technology of ADAMS and ANSYS, and the stability of the braking of the EMB system is studied emphatically, and the test bench is built to verify and analyze the EMB system. In this regard, it has a guiding significance for the development of the EMB system. Secondly, according to the analysis and comparison of the representative EMB implementation scheme, the optimized EMB actuator structure is selected for a certain sample model, so as to realize the type selection design of the concrete structure, and complete the dimension modeling and assembly according to the specific parameters. In addition, in order to verify the effectiveness of the design in this paper, a rigid flexible coupling dynamic simulation model of the EMB system is established, and the effect of the brake disc and brake block deformation on the braking performance is considered, and the equivalent model of the flywheel is established. The moment of rotational inertia of the whole vehicle is equivalent to a single wheel, and the dynamic model of a single brake is simulated.

2. Literature review

With the rapid development of the automobile industry and the continuous improvement of the road traffic facilities, the automobile has gradually become a step tool for people. People are enjoying the comfort and convenience of the car and put forward higher requirements for the safety performance of the car. Research by the Zang and others showed that, according to the German Insurance Association and the automotive safety association, the analysis of the causes of serious traffic accidents showed that 60% of the death traffic accidents were caused by the side crash, and 30%-40% was caused by overspeed, sudden change or operation (Zang et al., 2017). Automobile safety, energy saving and environmental protection are the main direction of the development of the automobile industry. With the development of the society and the progress of automobile technology, the traffic and transportation industry present the trend of high speed, nonprofessional and dense traffic, and how to improve the safety is one of the important topics of modern automobile research. The safety of the car includes active safety and passive safety. Active safety refers to how to minimize or avoid the occurrence of traffic accidents through the design of the vehicle. Passive safety means that the vehicle is designed to minimize the damage to the crew in the event of an accident. In the study, Gong and others pointed out that the brake system of the car is the key to determine the vehicle's active safety. How to design the brake system and make it have a good braking performance is always an important issue for the vehicle researchers. In recent years, due to the progress of vehicle technology and the improvement of vehicle speed, this importance is becoming more and more obvious (Gong et al., 2015).

At present, the research on vehicle braking mainly focuses on braking control, including the theory and method of braking control, and the adoption of new control technology (Zhai et al., 2016). The anti-lock braking system (ABS) adjusts the brake pressure according to the attachment characteristics of the tire and ground at different slip rates to prevent the wheel from locking in the car. By making full use of the ground adhesion coefficient, the high ground braking force can be obtained, the braking distance of the car is shortened, the direction stability of the automobile braking is improved and the tire wear is reduced. This technology has played an important role in improving vehicle safety and reducing accident losses. It is one of the most important active safety technologies in the automotive industry.

The automobile anti-skid control system (Anti Slip Regulation) is called ASR for short, also known as Traction Control System (TCS) (Ko et al., 2014). It is an electronic control system applied to wheel skid resistance following ABS. Its function is to control the slip ratio within a certain range when the vehicle accelerates, thus to prevent the driving wheel from sliding rapidly. Its function is to increase traction; the two is to maintain the stability of the vehicle. Driving on a slippery road, the driving wheel is easy to skid without ASR's car acceleration; if the rear driven-vehicle is easy to tail, it is easy to get out of control in the direction of the front drive. When ASR is used, it will not or can alleviate this phenomenon when the car accelerates. When turning, if the wheel skidding occurs, the whole vehicle will shift to one side. When ASR is used, the vehicle will follow the correct route. Electronic Stability Program controls the system (Moon et al., 2014) for short ESP. The ESP system, which appeared in the middle of the 90s, is another major leap in automotive active safety following the anti-lock braking system of the automobile and the anti-skid control system of the automobile (Yim, 2015). The ESP system is used to control the dynamic performance of vehicles and wheels under the critical condition of reaching the adhesion limit between the tire and the road surface. ESP will greatly improve the stability of the wheels and vehicles when the vehicle is in full braking or partial braking, sliding, driving, engine drag and braking, shift transition and transition from drive to brake. By controlling and distributing the longitudinal and lateral forces of the tire, the vehicle will travel as much as possible along the driver's desired path, reduce the risk of vehicle slip, improve the handling and stability of the vehicle, and establish a predictable vehicle behaviour system adapted to the experience of the driver.

Gao and others think that with the continuous development of vehicle chassis dynamics control, integrated control is the direction of future development (Gao et al., 2014), Brake by wire system BBW (brake-by-wire) arises at the historic moment. The wire brake system is different from the traditional brake system. It cancels the mechanical connection between the brake pedal and the brake actuator, and completely gets rid of the limitations of the traditional brake system. At present, the BBW has been applied to medium and high-class cars. The concept of wire control technology originated from aviation field and was first applied to aircraft manufacturing. People call it "wire-controlled flight control technology". Line control flight control technology has been successfully run on military and commercial aircraft for more than 20 years after its rigorous test of security, reliability and maneuverability. At present, it is also applied to high-tech land warfare equipment. Aviation and military applications have proved that wire control technology (X-by-Wire) is reliable and efficient. With the further development and wide application of electronic technology, this concept has been introduced into the field of vehicle manufacturing, and the application of line control steering, linear control throttle and line control technology on vehicles has emerged. With its superior performance, wire control technology is becoming more and more popular among the world's major auto manufacturers. This technique can emancipate the driver from a variety of tedious operations in the driving car and assist the driver in handling emergencies in a critical time, thus improving the handling stability and safety of the vehicle. This technology is listed as one of the ten new technologies of automobile in 2000. The technology of line control will bring a revolution to the automobile industry (Fang, 2017). It will become the core of the future development of intelligent vehicle technology. The line controlled BBW system, which is formed by the line control technology and the automobile brake system, has gradually replaced the traditional hydraulic and mechanical systems as the trend of the development of braking technology. A linear brake system is a multi-functional braking system, such as the brake antilock system ABS (Antilock Braking System), the electronic braking force distribution EBD (Electronic Brakeforce Distribution), the vehicle stability control ESP (Electronic Stability Program) or the ESC (Electronic Stability Control). The traction control system TCS (Traction Control System) and other existing braking system functions, and through the vehicle wired network, each system is organically

integrated into a complete functional system. The emergence of the brake by wire system has brought great changes to the design of vehicle braking characteristics, providing the conditions for future intelligent vehicle control.
To sum up, the above research work has done a deep research on vehicle braking control, but there are few researches on integrated control. Therefore, based on the above research status, this paper mainly studies the electronic stability program control algorithm under electronic mechanical braking. The characteristics of the high-speed switch valve of the important hydraulic components in the hydraulic regulator of the EHB system are discussed in depth. The hydraulic regulator of the electronic hydraulic brake system EHB (Electronic Hydraulic Brake System) is modelled and the dynamic characteristics of the hydraulic system are simulated and analysed by AMESim. To prove the validity and rationality of the vehicle stability control algorithm, the vehicle stability control algorithm is simulated by using open loop control and closed loop control respectively by using AMESim, CarSim and matlab/Simulink simulation environment.

3. Methods

ADAMS/Flex is used to input the brake disc and the modal neutral files of the brake block flexible body generated by ANSYS into ADAMSF/View, and move it to the appropriate position, as shown in Figure 1.

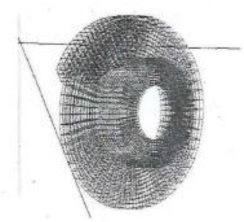

Figure 1: Import of brake disc and brake block flexible body in Adams

It is necessary to verify whether the brake disc and brake block flexible body are distorted after being introduced into A. The correctness of the model is verified by obtaining the mass, the moment of inertia and the center of mass of the brake disc and the flexible body of the brake block flexible body.
This paper is a dimensional model of the actuating mechanism of the electronic brake system for vehicles built in the CATIA environment. By using the simdesign interface module, its 3D model can be imported into the ADAMS to complete the assembly between the rigid body and the flexible body. The EMB rigid flexible coupling system after assembly is shown as shown in Figure 2 below.

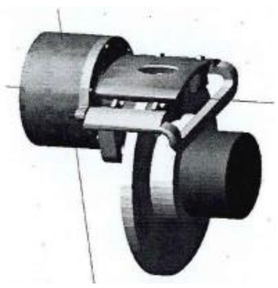

Figure 2: EMB rigid flexible coupling system

The EMB system executor is a rigid flexible coupling system composed of several rigid bodies and flexible bodies. In order to simulate the real motion situation of the EMB system during the braking process, the motion relationship between components should be abstracted as the corresponding kinematic pair in ADAMS. Through these identified kinematic pairs, the independent components of the EMB system are linked together to form an integrated system.
When the driver's brake signal is received by the EMB system, the DC torque motor decelerated by rotor output torque through planetary gear reducer, and the rotational motion of the low speed and high torque is converted into the straight motion of the nut, and the nut pushes one side of the brake block to press the brake disc. The counteraction of reaction of the lead screw acts as a driving force to drive the subject into the opposite direction.

In ADAMS/View, loads mainly include the external load, the internal load and the special load. The external load is mainly the force applied to the system, the moment and the gravity. The internal load is mainly the flexible connection between the parts, such as the spring, the buffer, etc. The special load refers to the contact force and the friction force on constraints. This paper focuses on the special loads such as EMB system applied gear to W, Contact force between the brake disc and brake module.
When two construction surfaces are exposed, a special contact force is produced in the position of contact. The contact force mainly includes intermittent contact and continuous contact of two kinds. In the case of continuous contact, the system defines contact as a form of nonlinear spring, the resistance of material is taken as the energy loss, and the elastic modulus is regarded as spring stiffness. In ADAMS, there are two kinds of methods of calculating the contact force, namely, the compensation method and the impact function method. The compensation method needs to determine the penalty coefficient and the compensation coefficient. The penalty coefficient indicates the depth of the two components that contact each other. The greater the penalty coefficient is, the greater the contact stiffness is. The less the depth of a component entering another component is, the greater the penalty coefficient is, and the computation result may not converge. If penalty coefficient is too small, it cannot reflect the real contact between two components of F. The compensation coefficient represents the loss of energy between two components. When the contact force is defined by the impact function method, the Impact function is used to calculate the contact force. The unilateral collision force is approximately calculated by the nonlinear spring resistance method. When two components enter into each other, they will produce elasticity, and the relative speed between the two components will produce resistance.
In this paper, the contact type of brake disc and brake block is set as flexible body to flexible body.In addition to axial contact force and tangential friction in process of flexible body contact between brake disc and brake block, tangential friction realizes the braking effect by producing braking torque.
The contact parameters are defined as follows,
Spring force stiffness factor K=100000
Nonlinear force field index e=3
Maximum damping coefficient c=1
Penetrationdistance d=F0.001.
The rigid-flexible coupling model of EMB system actuator with load and constraint is shown in figure 24 as below.

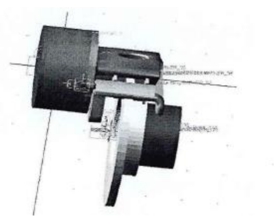

Figure 3: the rigid flexible coupling model of EMB system actuator is applied to load and constraint

3.1 The calculation on equivalent rotational inertia of the whole vehicle

In this paper, as the whole vehicle model has not been built, if it needs to act real vehicle braking process in the simulation analysis, the rotational inertia of the rotating parts and motion translational inertia of the whole vehicle should be equalized as inertia flywheel applied to brake disc. As the inertia flywheel and brake disc are fixed connected and coincident, with the changes upon rotational inertia of inertia flywheel, the simulation of actual driving conditions under different load could be realized.

3.2 Results and analysis

After the establishment of EMB system rigid flexible affinity model in the ADAMS, the braking performance such as braking force, brake response time, braking distance require simulation analysis, and verification on the rationality of the selection design on simulation should be carried out through comparing the theoretical calculation results and national standard brake laws and regulations. In addition, with the test bench setup for EMB system actuator braking performance, the braking force produced by locked-rotor state of torque motor and parameter of elimination on brake clearance time of actuators are tested to suggest the rationality of the scheme selection and the selected design results through the simulation analysis and experimental validation.
After point C, the car begins to generate braking force and decelerate. From point C to point C is the time required for braking force growth of disc brake EMB system, namely the braking action time. And from point e

to point f is the braking duration of T3 of EMB system brake, the braking force and deceleration speed remain unchanged. And then from point f to point g is the braking force eliminating period. The braking response process of automobile is shown in figure 4.

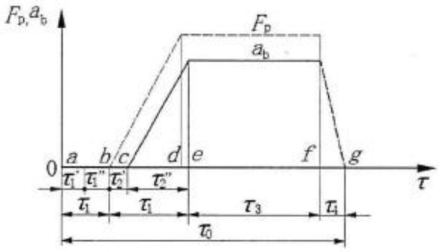

Figure4: Vehicle braking response process

The whole braking process of EMB system includes four processes, namely the reaction time of the driver receiving brake signal, the action time of the brake, the braking force continuity and brake elimination. Braking distance refers to the vehicle movement distance start from driver beginning to contact with the brake pedal to the car stop, which determined by the main factors of the action time of the brake and maximum braking deceleration.

The electromechanical actuator is one of the most important parts of the which is distinguished from the hydraulic brake. The dynamic response of the EMB braking system is faster than that of the hydraulic braking system because the motor could directly drive the gear reducer in electromechanical braking system. In the rigid flexible affinity model in ADAMS, in order to be able to accurately predict the braking efficiency of EMB system, the motor rotor in dynamic model requires the initial conditions of simulation. The motor approximately works under no-load speed at the eliminating brake clearance stage, and as the brake block contact with the brake disc, motor speed quickly reduces to completely blocked, and to regulate output torque through changing armature voltage. The DC motor mathematical model is set up to drive the motor before the start of the simulation conveniently.

In this paper, the driving motor of the EMB system is the permanent magnet DC torque motor, and its equivalent circuit diagram is shown in figure 5.

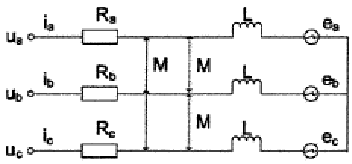

Figure 5: Equivalent circuit of rare earth permanent magnet DC torque motor

When actuators in EMB system are in the eliminating brake clearance stage, the brake clearance of disc brake is generally between 0.1 and 0.3 imnPq as reference, thus in this paper the brake clearance time on both sides of brake disc is set of 0.1 mm, with the motor starting voltage of 24 v and the simulation time of 0.1 s. FIG. 6 shows the simulation results of eliminating brake clearance time in EMB system.

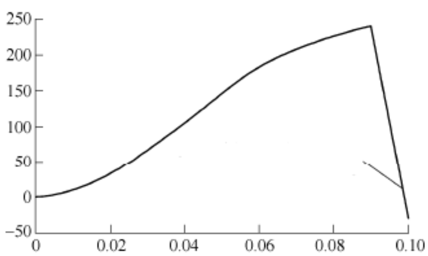

Figure 6: Clearance time

As you can see in the above figure, the torque motor start running at the approximate no-load speed, and the inside brake block near the screw nut contacts with brake disc at 0.044 s, and then the inside brake block is resistant, thus axial reaction force of screw rod act on the misprinted with bearing thrust, which lead to the italic displacement along sliding pin to drive the lateral brake block move to brake disc, finally the clamping of brake disc is completed at the time of 0.078 s that the brake housing drives the lateral brake block contact with the brake disc. The motor reaches the no-load speed within a very short time after starting, so the clearance time of the lateral brake clearance is shorter than that of the inner one. After 0.085s, the brake clearance is completely eliminated, and the inner and outer brake block act on the brake disc simultaneously to generate the brake clamping force, which meets the design requirements of automobile braking clearance elimination. The motor speed reaches 1125deg/s in a short time, which is basically consistent with the rated no-load speed of 190r/min of the motor.

4. Conclusion

In order to understanding for automotive electronic mechanical brake system, ADAMS/Flex is applied to input the neutral file in brake disc and brake block in flexible body modal generated by ANSYS into ADAMSF/View, and then move it to the right location and expound the adjustment results. Later it will also import and assemble the rigid body in ADAMS, then calculation of the restrictions of EMB coupling system with rigid and flexible, applied load of EMB coupling system, the definition of contact parameters of brake disc and brake block, the equivalent rotational inertia of the vehicle could be carried out. Finally in order to demonstrate the validity of this study, that the process and model of simulation and the analysis of the process and model proves that the motor rotation speed could reach 1125 deg/s in a short period of time, which is basically consistent with the rated no-load speed of 190r/min of the motor, thus it illustrates the validity and correctness of the design in this paper.

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