Matlab-Simulink Automobile ABS Modeling and Simulation Analysis.

Songqin Jiang

School of Automotive and Mechanical Engineering College, Chong Qing Jiao Tong University, Chongqing400074, China.

1019122250@qq.com

Abstract

The ABS system installed on the vehicle is related to the stability of the vehicle during the braking process and the safety of the occupants, so the performance of the ABS system is very important. The model of single wheel vehicle is taken as the object of study. The simplified model of automobile ABS system is established by Matlab/Simulink, and the model is simulated and analyzed by ID control method. The simulation curves of slip rate, vehicle speed, wheel speed and braking distance with time are obtained by simulation when braking the vehicle without ABS system. The simulation results show that the vehicle slip ratio can be effectively controlled near the expected value, and the braking distance and braking time can be effectively shortened when the vehicle with ABS system is in emergency braking. It is proved that the ABS system has good braking performance and directional control, and can achieve ideal braking effect.

Keywords

Slip ratio, tire model, PID control.

1. Forward

The anti-lock Braking System (ABS) is an important device for vehicle Braking and driving safety. With the increase of car ownership and popularization, the safety performance of automobile is getting more and more attention. As an important part of automobile safety performance, the stand or fall of automobile braking performance is directly related to the driver and the passengers' personal safety, thus increase the efficiency of the automobile brake has been an important direction in the field of automotive research. When the car is braking, if the front wheel is locked, the driver can't control the direction of the wheel, which is prone to crash. If the rear wheel of the car dies first, there will be a side slip, a tail, and a normal driving lane [1]. ABS can prevent the rear wheel braking when it is fully locked, thus improving the stability and steering ability of the vehicle in the braking process, shortening the braking distance and preventing excessive tire wear. In this paper, we establish a real vehicle single wheel dynamic model, adopt PID control method, and simulate the vehicle ABS through matlab/simulink. The simulation results show that the ABS system adopts PID method to achieve good braking effect in the automobile braking process, so this paper is of great reference significance to the control research of ABS system.

2. ABS System

2.1 Automobile ABS System.

The ABS system is composed of three parts.The brake controller, data sensor and actuator are respectively [2]. The ABS system is connected to an organism through the vehicle-mounted circuit, forming a vehicle braking control system which aims at controlling the slip rate. As a tool for signal acquisition and transmission, the data sensor is normally installed on the automobile axle or brake disc, and is responsible for transferring the relevant information of the wheel to the brake controller. As the brain of ABS, the brake controller is mainly composed of input amplifying circuit, operation circuit, voltage stabilizing power supply and solenoid valve control loop. With the rapid development of electronic technology, the integration and control precision of brake control system are greatly improved. It is mainly responsible for the calculation and processing of basic information transmitted by data sensors, and calculates the real-time slip rate. Controller according to road conditions and sliding rate a brake actuator motion commands to the system, the system will be done the best braking torque automobile brake actuator process, so as to meet the requirements of vehicle braking under different road condition.

2.2 Working Princple of ABS System.

For automobile brake system, the most ideal job is to work in different road conditions and circumstances, to maintain good braking effect, thereby reducing the braking distance and braking time, ensure the safety of the vehicle. At the beginning of the braking process, the brake pressure rises sharply and ACTS on the wheels. The speed and wheel speed are reduced simultaneously, and the acceleration of the wheel becomes negative. When the wheel speed is much less than the speed, the vehicle has a tendency to cling to death and slide. At this point, ABS gives the command to reduce the braking torque and release part of the braking force. As the acceleration of the wheel falls, the wheels start to roll normally, and when the wheels are stabilized, they hold the same braking force for a while. If at this time through the brake pedal, and continue to reduce the pressure of the brake, which reduces the effect on the braking torque on the wheels, the wheels and the surface adhesion will decrease greatly, vehicles lose proper braking effect; If the brake pedal is adopted at this time, the braking pressure will be increased, and the braking acceleration will be increased, so that the wheel can be re-entered into the sliding state. Both ways lose a certain amount of power. So, as shown in Fig.1, when the vehicle braking measures, ABS braking controller will according to receive the wheel angular velocity signal, after the analysis of the data processing, calculate the discriminant car wheel angular acceleration, wheel speed, slip rate, and then using alternating pressure relief way, adjust the size of the braking force, keep the vehicle as long as possible on the best adhesion coefficient range work, in order to gain the best braking effect [3].

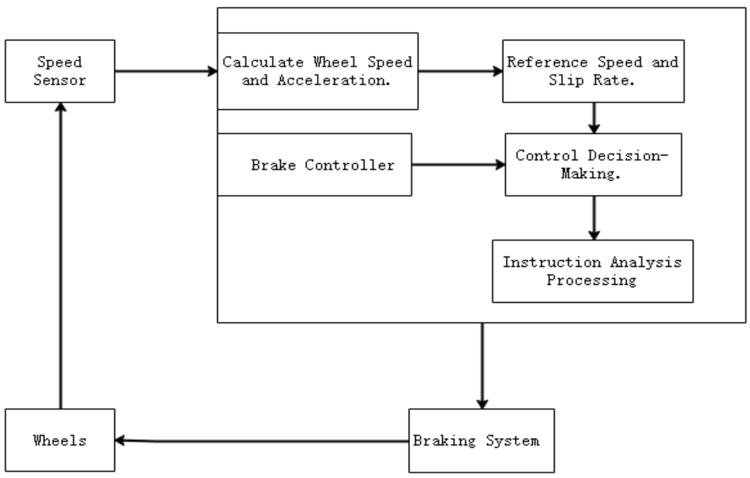

Fig.1 Car ABS control schematic

3. Establishment of ABS System Model

The automobile itself is an extremely complex system, therefore, the study of the automobile must have an accurate and simplified mathematical model, which needs to be realized by modeling [4]. For the auto ABS system theory analysis and simulation, we want to automotive anti-lock braking system modeling, must be accurate and reaction of the proposed model of the actual working condition, otherwise, we in the subsequent simulation process, the related calculation and reliability will be affected. Simulation mathematical model of the car with the vehicle model, the two-wheeled vehicle model and single wheel vehicle model are three types, their essence is the same, according to the specific situation respectively applied in different research direction and field. In this paper, the function of ABS system is studied, and the control strategy of ABS system is discussed, including braking distance, slip rate, braking deceleration speed and so on. A single - wheeled vehicle model is considered in this paper.

3.1 Vehicle Dynamic Model

In the process of driving, the tire will be combined by two forces, longitudinal and transverse, which have a great influence on the safety of the braking process. When the car breaks down suddenly, the wheel speed is equal to the speed of the car before the braking process begins. The wheel speed is less than the speed of the vehicle from the beginning of the brake pedal to the end of the braking. When braking, automobile wheel mainly caused by dynamic disk and static disk friction braking torque and the road to the reaction of the tire the effects of the two torque moment F, direction and wheel rotating in opposite directions, use is to make the wheel speed increasing, speed decreases, and motion model is shown in Fig.2.

In the automobile movement, the wheel force is more complicated. Because the single wheeled vehicle model is chosen as the research object, it can be assumed that the wheel load is constant. Ignore windward resistance and wheel rolling resistance [5].

Thus, the vehicle dynamics equation can be obtained:

Vehicle motion equation:

$$Ma = -F \tag{1}$$

Wheel motion equation:

$$I\alpha = FR - T_b \tag{2}$$

Longitudinal friction of vehicle:

$$F = \mu N \tag{3}$$

In the formula, the unit is the mass of 1/4 vehicle; For vehicle speed, the unit is m/s; For longitudinal friction, the unit is; For the moment of inertia of the wheel, the unit is; For wheel angular velocity, the unit is rad/s; Is the radius of the wheel, the unit is m; For brake torque, unit is; Is the longitudinal attachment coefficient; N is ground support, unit is.

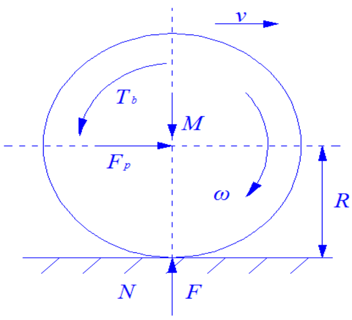

Fig.2 Force analysis diagram of vehicle

3.2 Calculation Model of Slip Ratio.

During braking, the wheel may slip relative to the road surface. With the increasing of the braking strength, the components of the wheel rolling will become less and less, and the components of the wheel sliding will become more and more [6]. The proportion of slippage in the longitudinal motion of the wheel can be characterized by slip ratio, and the slip rate of the wheel can be determined by the following formula:

$$\lambda = \frac{v - \omega r}{v} \times 100\% \tag{4}$$

In the formula, is the speed of wheel center; Is the rolling radius of the wheel; Is the angular velocity of the wheel.

(1) When the wheels are pure rolling on the road, the longitudinal velocity of the center of the wheel is entirely due to the rolling of the wheel. At this time, $v = \omega r$,there is no slip between the wheels and the road surface, so the slip rate $\lambda = 0$;

(2) When the wheel is braking until the pure slippage is made on the road surface, the longitudinal velocity of the center of the wheel is completely caused by the wheel slip, at this time, $\omega = 0$, the slip rate $\lambda = 100\%$;

(3) When the wheels rolling on the road side slip, wheel center part of the longitudinal velocity is generated due to wheel rolling and the other part is due to wheel slip, at this point, $v > \omega r$, so the slip rate, $0 < \lambda < 100\%$.

Therefore, the size of slip ratio reflects the proportion of sliding components in the process of wheel motion. The larger the slip ratio, the more the components of the wheel move during the movement of the wheel.

ABS simulation model to establish the theory basis of the vehicle braking process of adhesion is changing with movement of the vehicle driving road conditions, the adhesion coefficient is directly affect the parameters of vehicle braking performance [7]. Now the tire adhesion coefficient is divided into longitudinal adhesion coefficient and lateral adhesion coefficient. Vertical adhesion coefficient -- the ratio of ground adhesion to vertical load; Peak adhesion coefficient - the maximum value of longitudinal adhesion coefficient; Lateral adhesion coefficient -- the ratio of the lateral force of the tire to the vertical load of the tire. According to the curve of FIG. 4, in order to obtain the larger lateral adhesion coefficient, the slip rate is easier to realize, namely, the ability of the tire to prevent sideslip and keep steering is better. In the process of braking, in order to obtain a larger longitudinal adhesion coefficient and a higher lateral adhesion coefficient, the slip rate should be kept at a lower value, which is called a stable region. The role of the anti-lock braking system is to ensure that the car in the process of braking, the pressure regulator by adjusting the wheel cylinder pressure control the size of the brake force on the ground, keep the slip rate is around 20%, as long as the slip rate within the range of the nearby, brake wheel in higher longitudinal adhesion coefficient can also obtain larger lateral adhesion coefficient, so it can dramatically improve the braking efficiency, braking and improve the directional stability.

3.3 Tier Model

Is car tire contact with the ground of the only parts, but also is the ultimate stress of the ground braking force make automobile brake parts, because we in simulation of automobile ABS system, must choose the right tire model, simulate the real situation. The tire model is usually expressed as a function relation of the tire adhesion coefficient and various parameters. The factors affecting the adhesion coefficient are many, including the material of the road, the condition of the road, the structure of the tire, tread pattern, material and the speed of the car. But in practice, it is difficult to draw the variety of the relation between the variables effect on adhesion coefficient, and is more practical and reasonable way is to consider only the adhesion coefficient of influential factors, the calculation expression of adhesion coefficient is established. To this end, experts and scholars have put forward a variety of tire models, hoping to establish accurate simulation of tire dynamic characteristics. Commonly used in the research process is the magic formula model formula, Burckhardt model and bilinear model, but the magic formula model and Burckhardt model is difficult to get the meaning explicit analytical solution, so this article choose the characteristic curve for the modeling process of linear fitting, double linear tire model [8]. 19/5000 Mathematical expressions of bilinear tire model can be derived:

$$\mu = \frac{\mu_H}{\lambda_T} \times \lambda \quad \lambda < \lambda_T \tag{5}$$

$$\mu = \frac{\mu_H - \mu_G \times \lambda_T}{1 - \lambda_T} - \frac{\mu_H - \mu_G}{1 - \lambda_T} \times \lambda \quad \lambda > \lambda_T \tag{6}$$

Where, μ is the attachment coefficient; μ_H Is the peak attachment coefficient; μ_G Is the coefficient of adhesion when the slip rate is 100%; λ_T, It's the best slip rate.

3.4 Braking System Model.

The braking system includes two parts: the transmission mechanism and the brake. The transmission mechanism mainly refers to the hydraulic transmission system, and its modeling is mainly considering the relationship between brake pressure of the power regulator and the current change of the electromagnetic valve. In order to simplify the system, the nonlinear factors of the solenoid valve spring and the delay of pressure transfer are ignored, and the hydraulic transmission system is simplified as an electromagnetic valve and an integral part [9]. The transfer function is expressed as:

$$G(S) = \frac{100}{s \cdot (0.01s + 1)} \tag{7}$$

The model of brake model is the relationship between brake moment and brake fluid pressure. In order to facilitate the study of the control algorithm, it is assumed that the brake is the ideal element in the simulation and ignores the effect of lag. Therefore, the brake equation is:

$$T_b = k_p \cdot p \tag{8}$$

in the formula, T_b is brake torque of brake, unit is N·m; k_p For brake coefficient, the unit is N·m/kPa; p For brake fluid pressure, the unit is kPa.

3.5 PID Control Model.

In the current control system, PID control is a control method that is known to be widely applied and mature in technical theory. PID control is the combination control of the proportion, integral and differential of deviation. It is characterized by the explicit physical meaning of each parameter, the independence of control parameters, simple algorithm, good robustness and high reliability. The greatest advantage of PID control is that it can control the control [10-12] of the mathematical model or model of precise controlled object. Therefore, the mathematical model of anti-lock braking system for complex automobile is very suitable for PID control. By setting sliding rate difference between the actual value with the theoretical value for the optimization goal, according to the experience of the online or offline method of ABS controller parameters setting, in order to gain a better braking coefficient [13].

This paper focuses on designing a car single wheel vehicle model, through the PID algorithm to control the car sliding rate, deviation signal can be used to draw a specific proportion, integral and differential value, so that it can be used to control some parameters, and according to the given value of artificial and the actual input values formed between the corresponding error, namely

$$u(t) = k_p \cdot e(t) + \frac{1}{T}\int_0^t e(t)d\tau + T_d \frac{de(t)}{dt} \tag{9}$$

The rule of PID control is:

$$u(t) = k_p \cdot e(t) + \frac{1}{T}\int_0^t e(t)d\tau + T_d \frac{de(t)}{dt} \tag{10}$$

The corresponding transfer function is:

$$G(S) = \frac{U(S)}{E(S)} = K_P + \frac{K_I}{S} + K_D S \tag{11}$$

Type: K_P is proportional coefficient and $\frac{1}{T}$ is integral coefficient, T_d is differential coefficient, these three values can be different effects on the PID controller, we can according to these three values, to make corresponding change, make whole PID controller to work within the effective range [14 -15]. To install the controller in automobile ABS, is actually the target slip ratio and the numerical difference between the reference slip ratio as control target, control of automobile brake output brake pressure, keeping the car on the target slip ratio.

4. ABS Modeling and Simulation Analysis.

4.1 Modeling of Automobile ABS System.

Simulink is a new kind of graphical modeling tool in Matlab, which can be used for dynamic simulation as well as the design of control system. Using Simulink to simulate the advantage of vehicle braking condition control system and mechanical braking system of organic soluble in an organic whole, at the same time with graphics easy to express the control system of signal flow and logical switch control. In the simulation model, the braking system model by using the simplified first-order model, its dynamic characteristic in the characterization by PID controller to adjust of braking force, maintain the best sliding rate, in order to obtain the best braking efficiency and stability of the (16-17). The simulation parameters of single wheel vehicle model are shown in Table 1.

Table 1 Simulation parameters of single wheel vehicle model

Name and Symbol	TheNumerical
1/4 Automobile mass M.	300Kg
Initial Speed of Braking V	25 m/s
Wheel Moment of Inertia I.	213
Wheel Radius R.	0.35m
Initial Braking Torque	1500N

Fig.3 shows the simulation model of ABS system using PID controller on Matlab/Simulink platform.

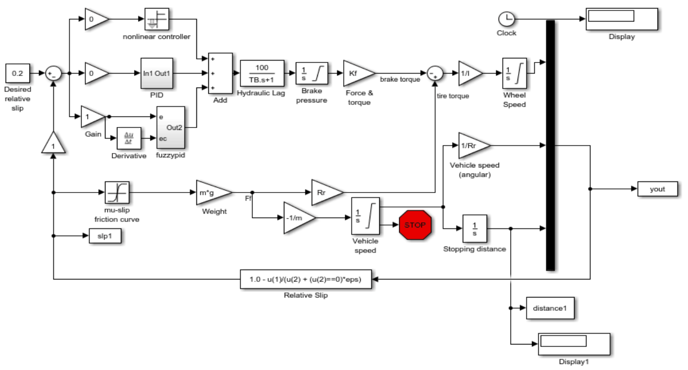

Fig.3 Simulation model of automobile ABS system

4.2 Simulation Analysis

When A=1, the system is equipped with ABS; When A=0, the system is non-abs. When A=1 and A=0 are simulated, the slip rate curve, speed and wheel speed curve and braking distance curve can be obtained, as shown in the figure below.

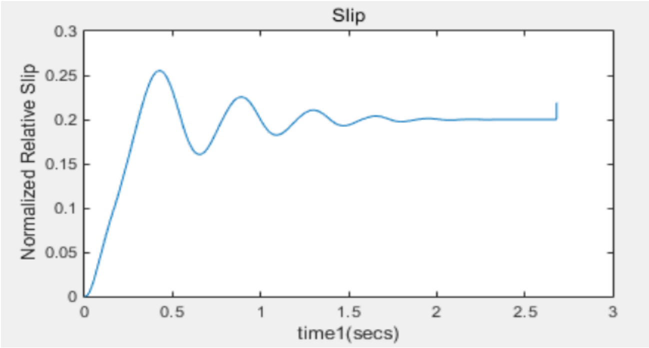

Fig.4 Slip rate simulation curve with ABS system

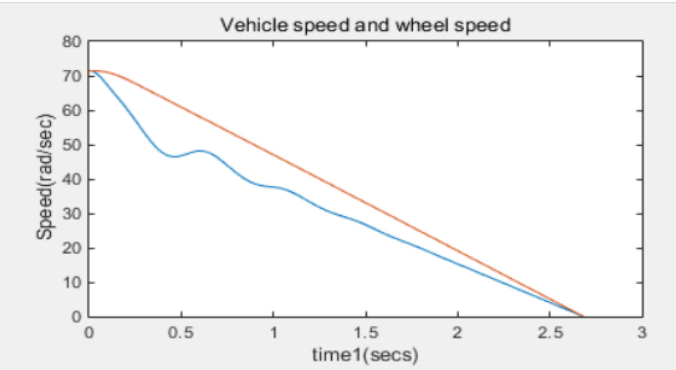

Fig.5 Simulation curves of vehicle speed and wheel speed in ABS system

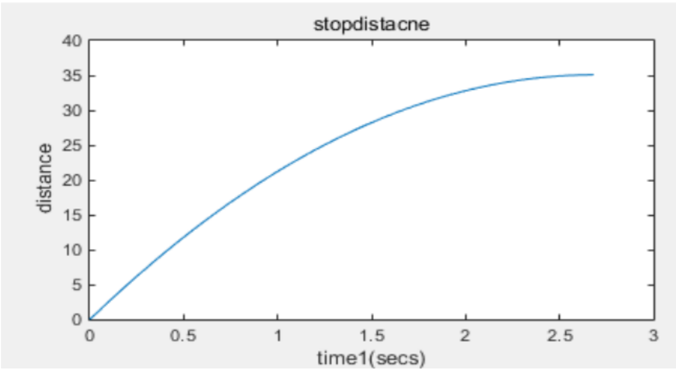

Fig.6 Simulation curve of braking distance with ABS system

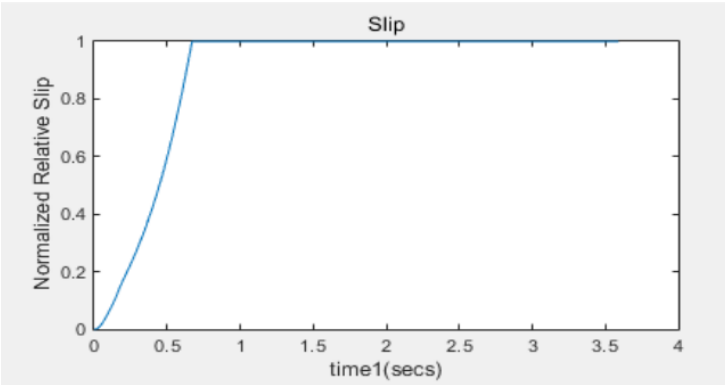

Fig.7 Slip rate simulation curve without ABS system

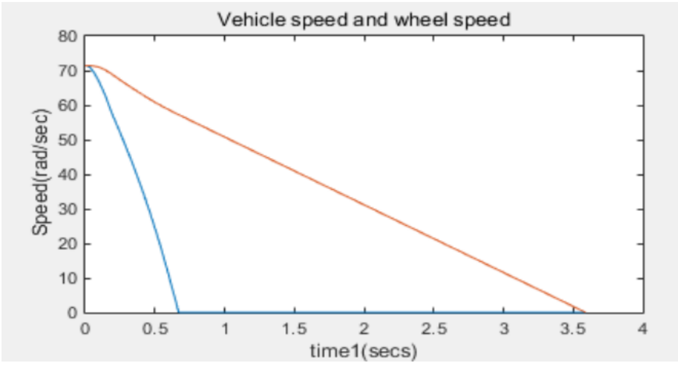

Fig.8 Simulation curves of vehicle speed and wheel speed without ABS system

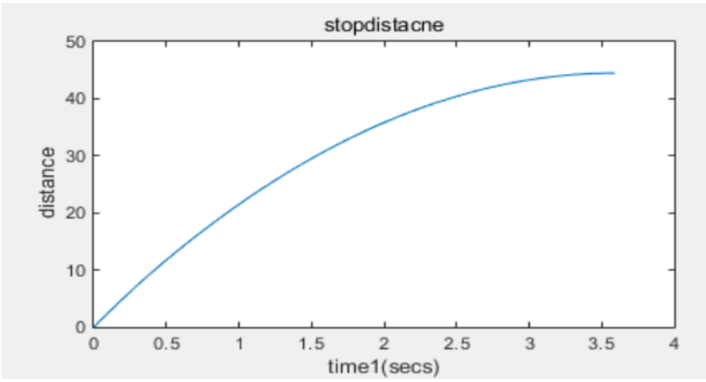

Fig.9 Simulation curve of braking distance without ABS system

Can be seen from the Fig.4 , there is car in the brake process of ABS system, the sliding rate after a short oscillation remain near the ideal sliding rate (0.2), ensure that the wheel is in a state of edge piping slippery, can achieve the best braking effect; Fig.7 shows that when the vehicle is not equipped with ABS, the slip rate of the wheel will increase rapidly to 1.Fig.5 , you can see that the car braking process, due to the effect of ABS, the vehicle's speed smoothly down, the speed of the wheel and evenly with the decreasing of the speed slow down, to ensure the vehicle braking stability, enhance the driving safety of the vehicle; Fig.8 shows that the wheel speed becomes zero when the ABS system is not available, that is, the death of the wheel can seriously affect the safety of vehicle driving. From Fig.6 and Fig.9 , the braking time of the ABS system is 2.7s and the braking distance is 35m. When the car without ABS is completely stopped, the braking time is 3.7s and the braking distance is 45m. The simulation results show that the ABS system can play to the role of the anti-lock, greatly reduce the braking distance and braking time, and ensure the car in the braking process has good maneuverability and stability.

5. Conclusion

Based on the establishment of a single wheel vehicle dynamics model, the PID control method is adopted, and the simulation results are analyzed based on Matlab/Simulink platform. According to the simulation results, the vehicle with no ABS system is prone to the death of the wheel when braking, causing the vehicle braking stability to become worse and prone to accidents; The slip rate of the vehicle equipped with ABS can be maintained in the vicinity of 0.2, effectively preventing the wheel from being locked and ensuring the safety of the vehicle braking. The comparison also shows that the braking distance and braking time of ABS equipped with ABS are significantly shortened, which indicates that the ABS system has good directional stability and braking effect.

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