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Antiskid Control System of Construction Machinery Drive Based on Fuzzy PID Control

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Abstract: With the increase of car ownership year by year, the driving safety and operating stability of cars have been paid more and more attention and become important performance indexes of cars. The drive anti-skid control (DASC) system is an important part of the automotive electronic control system, which can effectively restrain the vehicle from skidding under bad road conditions. This paper mainly studies the design of antiskid control system of construction machinery drive based on fuzzy PID control. In this paper, several existing anti-skid control algorithms are analyzed first, and the fuzzy PID control algorithm is designed by combining fuzzy algorithm and PID algorithm. In this paper, the simulation model of each module is established under the SIMULINK simulation environment, and the control effect of fuzzy PID algorithm is analyzed. The simulation results show that the algorithm can effectively improve the driving force of vehicles on two roads.

1. Introduction

With the rapid development of the domestic economy, cars have been rapidly popularized in every household, and the number of private car ownership has been increasing year by year. At the same time, with the increase of car ownership, traffic facilities, road facilities, laws and regulations are increasingly perfect today, the number of traffic accidents has been high [1]. The safety performance requirements of automobiles are also constantly improving. The stability and safety of automobiles have become the key performance indicators of automobiles. Various safety control systems and equipment of automobiles have now become an important part of automobiles [2]. Safety technologies related to automobiles are usually divided into two types: passive and active safety technologies. Among them, passive safety technology is the safety measures to reduce the consequences of the accident after the accident, including safety body, seat belt, airbag and so on. Active safety technology is a safety measure to prevent accidents, including automobile electronic stability control system, chassis integrated control system, intelligent safety auxiliary system, etc.

[3-4]. Compared with passive safety technology, automobile active safety technology can prevent accidents in advance and avoid the loss of people and property, which is of high practical significance [5]. The DASC system belongs to the category of automobile active safety technology, which can not only enhance the vehicle's drive anti-slip and escape ability under bad road conditions, improve the handling and stability under starting and accelerating, but also improve the vehicle's riding comfort and reduce the risk of accidents [6]. The DASC system is increasingly applied to middle and high-end cars and sports vehicles, such as Benz, Volkswagen, BMW, Honda, Audi, Land Rover and other international famous brands [7].

With the technological innovation, the drive anti-slip system has been more and more widely used in advanced bridge vehicles, and the current ASR technology has been gradually applied to ordinary bridge vehicles, and a more ideal control mode is also under further study [8]. As early as the early 20th century, there have been driving anti-slip control methods [9]. By the nineteen thirties, mechanical anti-lock braking systems were in use on trains and airplanes. In the middle of the 20th century, ASR technology was only applied in automobiles, so people began to study and expand its scope of use. However, the effect of DASC in this period was not very ideal and could not reach the expected effect [10]. In the late 20th century, ASR technology has achieved rapid development, and the control accuracy of the control method has also improved a lot. Toyota has successfully developed a new type of DASC system, which can not only adjust the size of the throttle opening of the engine, but also not interfere with the braking force. The advantages of this system are relatively low cost; much reduced noise and vibration, and improved the operation stability of the vehicle on the separated road surface [11]. At the beginning of the 21st century, more than half of automobile companies have been equipped with ASR system. With the successful development of more and more driving anti-skid products, ASR technology will also set off a new round of research climax [12].

In foreign countries, the research on the DASC system is more in-depth, and has formed a mature product chain, which is in the technical monopoly position. Domestic DASC is still in the stage of theoretical research, most of the products are purchased from abroad and matched with vehicles, further improve the level of domestic independent research and development.

2. PID - Based DASC System

2.1. Drive the Anti-Slip Control Algorithm

(1) PID control

PID control is common in the field of automatic control. The main task of this method is to design PID controller. The control principle of the controller is relatively simple, that is, the difference between the feedback value and the target value set to the controller is taken as input of the controller and the controller calculates the difference to obtain the output value, which acts on the controlled object. For the DASC, the feedback value is the slip rate (SA) calculated by the sensor, the target value is the set slip interval, and the output value is the motor output torque [13-14]. The working principle of the controller is shown in FIG. 1, where r(t) is the sliding rate interval of the drive wheel set in the controller, Y (t) is the actual sliding rate calculated through the information collected by the sensor, E (t) is the difference between the actual sliding rate and the set sliding rate, and U (t) is the torque command output by the PID controller.

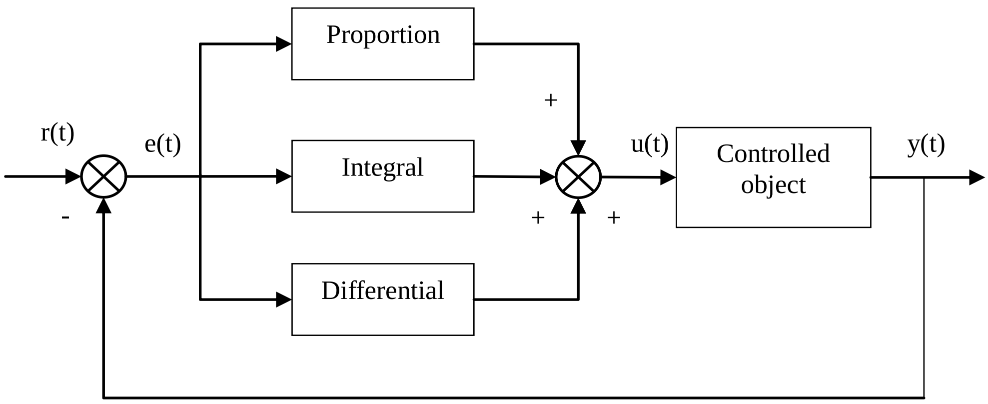

Figure 1. PID control principle

The input of the controller is:

$$e(t) = r(t) - y(t) \tag{1}$$

Its control rule is:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \tag{2}$$

(2) Synovial control

The variable slip mode structure control also takes the deviation between the feedback value and the expected value as input of the system, and outputs relevant variables to the controlled object through the sliding mode controller [15]. FIG. 2 shows the sliding mode variable structure control schematic.

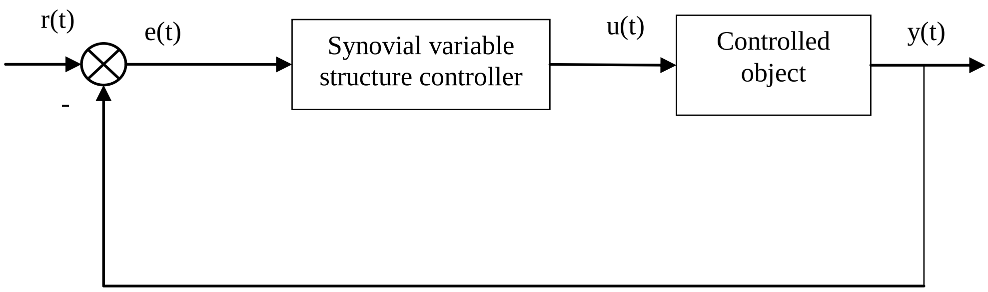

Figure 2. Sliding mode variable structure control principle

Sliding mode variable structure control is not sensitive to system parameter changes, has strong adaptability to external environment changes, and can quickly respond to input deviation [16]. But in order to obtain better control effect, the mathematical model of the control system needs to be accurately modeled. If the inertia of related components is large in the control process, chattering phenomenon will occur in the system.

(3) Fuzzy control

Blurred control is a kind of intelligent control. Its control principle is about the same as other control methods. It takes the difference between the feedback value and the expected value as a system input, and calculates the output value through the blurred controller as input of the actuator. Fuzzy controller makes corresponding rules according to the relation between input and output. For example, when the input of the fuzzy controller is the difference between the feedback value and the expected value, and the output is P, I and D, the fuzzy control rules should be formulated by PID regulation rules. When the deviation is large, the PID value can be adjusted appropriately to reduce the deviation quickly; when the deviation is small, the PID value can be output to prevent the system from overshooting and other phenomena [17].

For vehicle motion slip control, blurred control can be added to the control algorithm. The control input is the SA difference set by the calculated SA of the current road, and the output can be the output torque of the machine. When the current expected value is greater than the feedback value, increase the engine's output torque, increase the SA, and improve the vehicle's acceleration performance. When the current expected value is less than the feedback value, reduce the engine output torque to prevent wheel slipping [18].

2.2. Fuzzy PID Driving Anti-Slip Control Algorithm

Considering the real-time and nonlinearity of the object system, the influence of PID parameters on the whole system should be comprehensively analyzed in the process of tuning PID parameters to avoid one-sidedness when considering separately. Generally speaking, increasing the proportionality factor KP can speed up the system response, but also make the system overshoot and reduce the system stability. In order to reduce the overshoot and improve the stability, the integral coefficient KI should be increased. The differential coefficient KD has a leading control function, which can eliminate the deviation before it occurs and reduce the adjustment time. But it can amplify the noise and is not conducive to the anti-interference of the system. Therefore, the three parameters should be considered comprehensively. Generally, KD and KI should be set to 0 first, and then KI should be added to make the deviation close to 0 after adjusting KP to make the system meet the basic performance requirements. Finally add KD, repeated debugging, to achieve better results.

The control goal of anti-slip driving is to ensure that the SA of the steering wheels is close to the optimal SA. The control method is to adjust the output torque value of the drive motor. Therefore, the input parameter of the self-tuning vague controller is the deviation value of the SA of the wheel driver, and the output parameter is the torque adjustment value of the driving motor. Finally, the controller produces the torque correction value in the motor controller as a steering wheel.

The range of deviation of input parameter SA is [-2.5,8], and the range of deviation change rate is [-5,5]. The domain of the output parameter is finally determined as [-1,1], [-0.5,0.5], [-3,3] after many adjustments. According to the language name, the fuzzy segmentation is carried out, and the fineness of the control and the completeness of the model are considered at the same time. Finally, the fuzzy set is divided by multiple trial and error.

The sharpening process is also calculated by the weighted average method which is widely used. Finally, the adjustment values of the three parameters of PID controller, Δkp, Δki and Δkd, are calculated according to the following formula:

$$\begin{cases} k_p = k_{p0} + \Delta k_p \\ k_i = k_{i0} + \Delta k_i \\ k_d = k_{d0} + \Delta k_d \end{cases} \quad (3)$$

Where, Kp0, ki0 and Kd0 are parameters of the original PID controller. The parameter values of self-tuning PID after fuzzy inference can be obtained.

3. Establishment of Simulation Model

Computer simulation technology is a quantitative analysis method, using the computer to dynamically imitate the system structure, with the rapid development of computer technology, computer simulation technology is widely used in automation control, automobile control and other fields. Compared with the traditional physical test, the computer simulation technology can greatly improve the efficiency, reduce the development cycle and development cost.

SIMULINK is the most important dynamic simulation tool in MATLAB software. It provides an integrated environment for dynamic simulation, modeling and analysis. SIMULINK has a large number of modules with characteristic functions, which can reduce the workload of users to write code repeatedly, so this paper will use SIMULINK simulation tools to analyze the fuzzy PID driven anti-slip control algorithm.

In this document, blurred control algorithm model is established and dynamic vehicle simulation model box is used to simulate the operating conditions of vehicles under different road conditions and carry out the dynamic simulation. Vehicle system simulation frame with electronic slip limit and differential speed is shown in Figure 3:

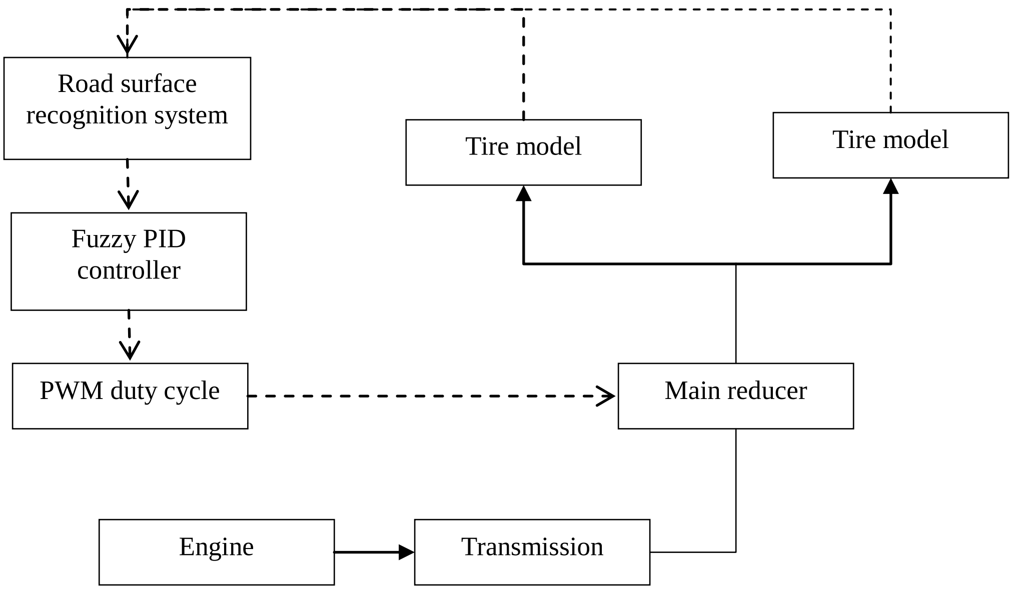

Figure 3. Vehicle system simulation framework

The motor output torque is transmitted to the electronic differential limited slip housing through the gearbox and main reducer, and the electronic differential distributes torque to the left and right drive wheels according to the limited slip torque. The tyre model can calculate the SA of the driving wheel in real time. At the same time, the real-time SA is compared with the optimal SA of the current road situation estimated by the road identification system, which provides a crisis basis for the blurred conclusion of the blurred PID controller. The vague controller determines the control parameters according to the difference between the optimal SA and the real-time SA, and the final output is the task cycle of the wave. According to the different cycles of duties, the slip torque required by the electronic limited slip differential is adjusted so that the driver's SA is controlled close to the optimal SA, so as to achieve the purpose of anti-slip.

4. Analysis of Simulation Results

At an initial speed of 10km/h, the vehicle starts to accelerate linearly from the road surface, the throttle opening is 40%, and the transmission gear is 2. After 5S, the vehicle enters the dual road surface. The changes of driving wheel sliding rate and vehicle longitudinal speed under the action of different driving anti-skid control algorithms were observed.

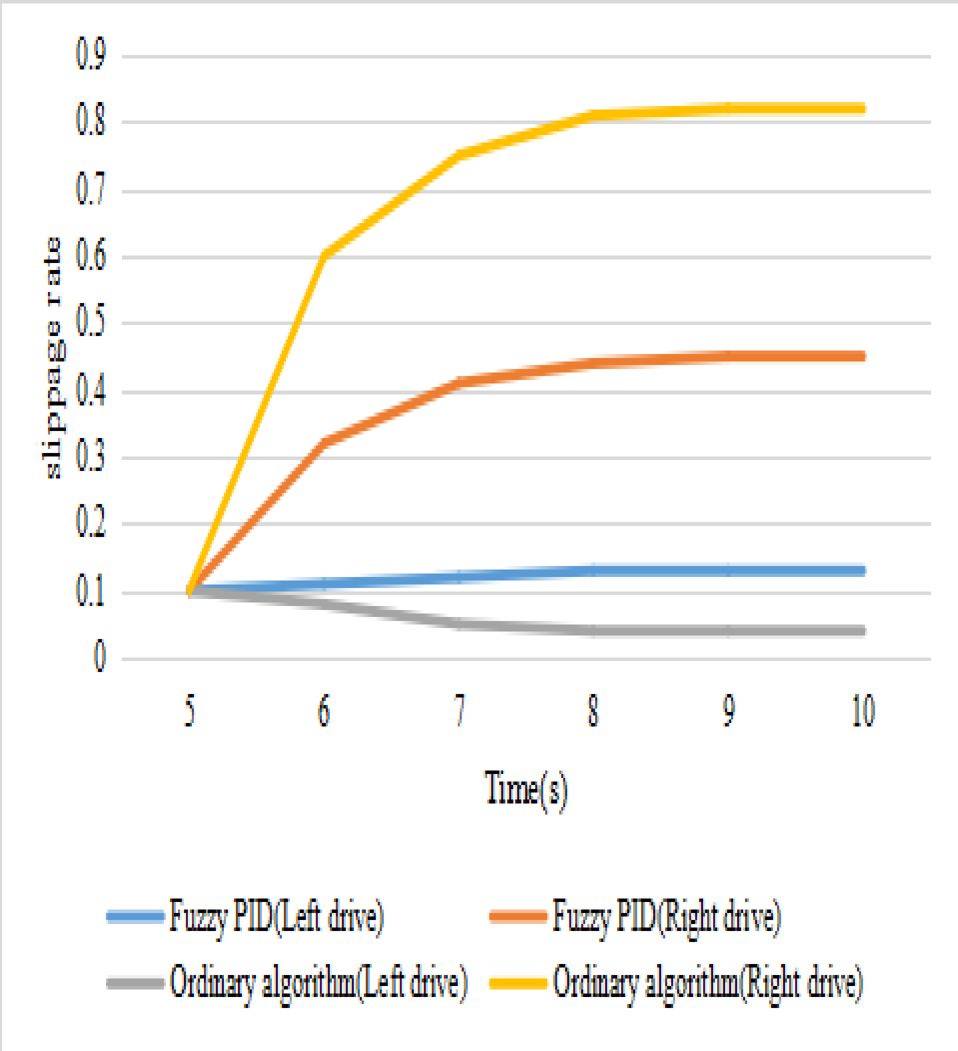

Figure 4. Slippage rate changes

When the vehicle is initially driven on a uniform road surface with a high coefficient of traction, the SA of the steering wheels is very low and the stability of the vehicle is high. After 5S, the vehicle enters the uniform road surface, and the vehicle equipped with the common algorithm will have excessive slippage on the right drive wheel on the low adhesion road surface, and the slippage rate of the right drive wheel will rise rapidly. When the vehicle equipped with fuzzy PID algorithm enters the dual road surface, the sliding rate of the right drive wheel located on the low adhesion road surface will also increase, but the rise is more slow, and the rise range is smaller than that of the ordinary algorithm. Under the action of fuzzy PID controller, the slippage rate of the left driving wheel on the high adhesion road surface rises rapidly and stabilizes near the target slippage rate.

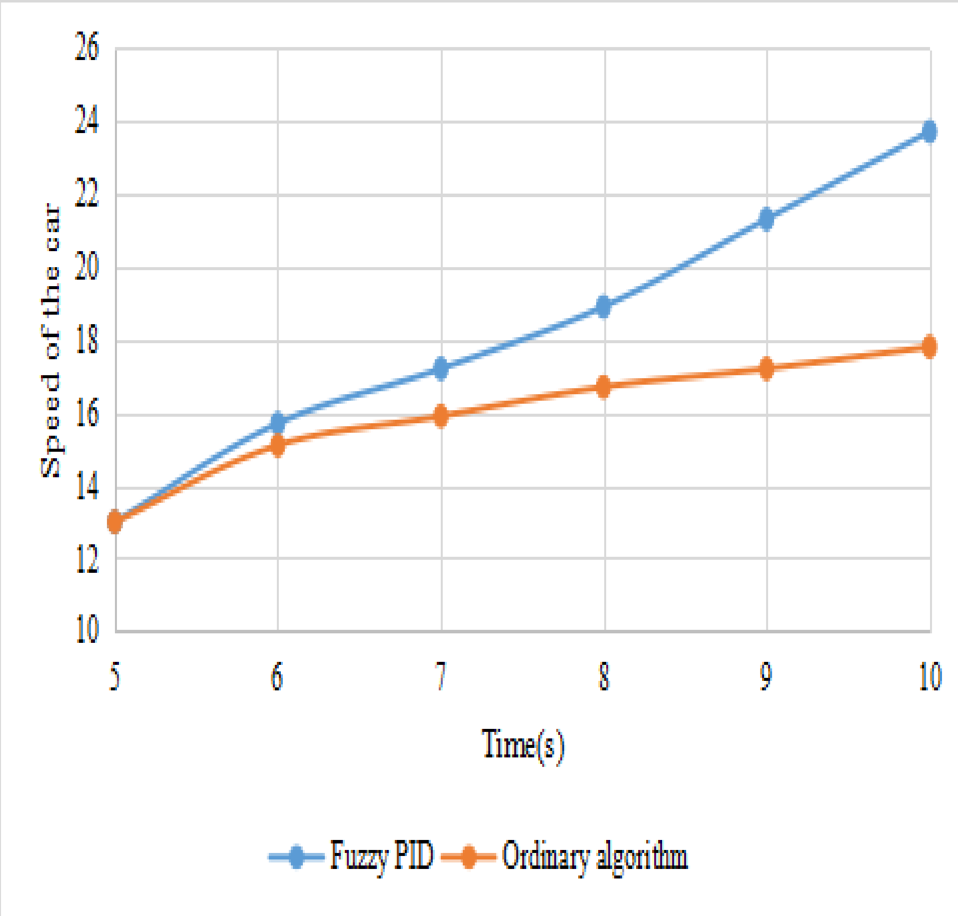

Figure 5. Longitudinal speed change

The vehicles equipped with the common algorithm and fuzzy PID algorithm have the same acceleration when driving on a uniform road surface. After entering the split road, the acceleration of the vehicle equipped with the pass algorithm gradually decreases, and finally the acceleration approaches 0. At the end of the simulation, the vehicle speed is about 17km/h. After the vehicle equipped with fuzzy PID algorithm enters the split road, although the overall acceleration drops slightly, the speed still maintains a rapid upward trend, and the speed is about 24km/h at the end of the simulation.

5. Conclusion

This paper takes vehicle driven by wheel machine as research object, and studies anti-slip control strategy to improve vehicle dynamic performance and ensure linear acceleration performance. Based on the standard control algorithm and the fuzzy algorithm, this paper designs an anti-slip control strategy to control the SA to meet the requirements of anti-slip control. The output torque of the four-wheel edge motor is controlled through simple torque distribution to ensure the vehicle's in-line driving capability. In this paper, there are still some problems in the following aspects for the study of driving anti-skid control of driving vehicles, which need to be further improved: As this paper only focuses on the control of vehicle longitudinal dynamics, the system simulation only selects the most basic road conditions under linear conditions, and the study of more complex conditions (turning, mountain road, climbing, etc.) still needs to be further discussed.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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