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Analysis Research of Control Method Model on Automobile Brake Test Rig

Abstract. *This paper, firstly in accordance with the engineering design method, PID controller are used to control the current loop and speed loop common on double closed-loop DC converter, and build dual-loop PID control model, and Matlab's emulation to model, as well as analysis and evaluate the structural of the simulation. Because conventional PID control can not meet the parameters of the controlled object changes and lack of non-linear characteristics, the fuzzy self-tuning PID can overcome the uncertainty and nonlinear objects, furthermore the fuzzy self-tuning PID has more flexibility and adaptability, so this paper putting to use fuzzy self-tuning PID controller for dual-speed loop in the closed-loop system to transform, so that it has not or less affected by the object model, you can achieve high performance, robustness and other advantages.*

Streszczenie. *W artykule opisano metodę testowania system hamulcowego w pojazdach samochodowych. Ay uniezależnić wyniki testu od parametrów układu sterowania zaproponowano ulepszony kontroler PID z automatycznym strojeniem i wykorzystaniem logiki rozmytej. (**Analiza metody sterowania układem hamulcowym pojazdów samochodowych**)*

Keywords: Brake test, Double closed-loop, Electrical simulation, PID control, Fuzzy self-tuning PID, MATLAB simulation
Słowa kluczowe: testowanie układu hamulcowego, kontroler PID

Introduction

Car brake is an important part of the car, it makes car parking a short distance when driving and keep driving the direction of the stable, its performance has a direct impact on vehicle safety performance. The brake test, complete te st-bed vehicle brake control method, to evaluate its overall performance strengths and weaknesses, improve brake pe rformance as an integral part. Therefore, in the automotive brake units to develop a simulation test performance, test the brake test bench with high precision is necessary, shou ld be tested to simulate the effect of the brake control the si tuation and the actual work of car brake line.

Conventional PID control often can not meet the control object parameters change and the lack of nonlinearity, and fuzzy self-tuning PID control process controls to overcome the uncertainty of the object and non-linear factors, but also has better flexibility, adaptability, not or less affected by the object model, can achieve high performance, robustness etc.

Test bench of power simulation system model designed

Power analog systems mainly through the speed control system to control the motor speed, so that electrical inertia system is under load the dynamic characteristics and mechanical inertia of the system dynamic characteristics of the same, which is to ensure the original inertial system speed variation, to achieve inertia simulation [1]. Electrical simulation system is a DC motor as the core control system.

DC motor speed control system, is currently widely used speed and current double closed-loop speed control system, dual-loop speed regulation system performance, the static properties of strong, non-steady-state error, fast dynamic response, the starting time is short, anti-interference ability and other characteristics, its speed and control theory has matured, engineering design method is simple and practical.

This speed DC motor control system will use the main drive motor, through the speed and current double closed-loop speed control system test bed system to achieve speed control. Speed and current double closed-loop speed control system shown in Figure 1.

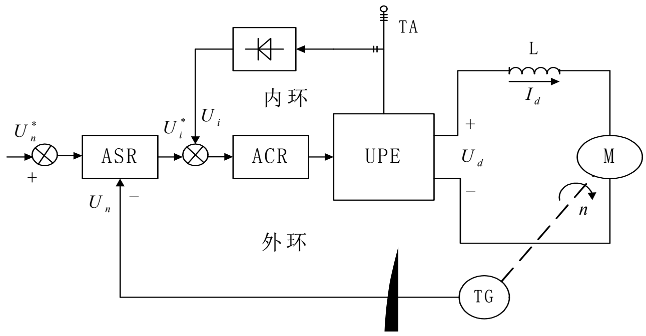

Fig.1. Speed, current double closed-loop speed control system

ASR - speed regulator, ACR - Current Regulator, UPE - power electronic converter, TG - engine speed, TA - CT - speed for a given voltage, U_n* - Speed feedback voltage, U_n - current for a given voltage, U_i* - Current feedback voltage.

In order to speed and current work were two kinds of negative feedback in the system set up two regulator, adjust the speed and current, respectively, between the two using a cascade connection shown in Figure 1. This closed-loop structure from the point of view, the current adjustment ring on the inside, known as the inner; regulator called the ring current regulator, with the ACR to represent. Speed control loop out and called the outer ring, the ring modulator as speed regulator, with the ASR said.

Shown in Figure 1, the motor drive system, the introduction of speed feedback method is to install a shaft of the motor tachometer generator TG, which leads to be transferred with the amount of negative feedback voltage U_n proportional to speed, and speed for a given voltage U_n* comparison to be bias voltage through the amplifier to produce the control voltage triggering device, to control motor speed. DC full voltage starting, if not limiting measures, will have a greater impact on the current. This is not only the motor commutation is very unfavourable for high SCR is not overload, it is not permissible, restrictions must be automatically part of the armature current, so the introduction of current feedback to maintain current essentially the same, so it does not exceed the permissible value [1] [5].

Armature current feedback measured by the current transformer TA. Double-loop speed control system dynamic structure Figure 2.

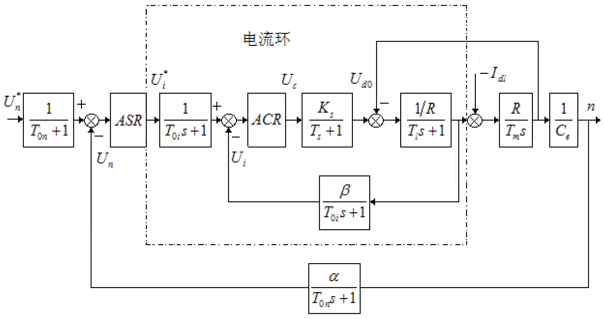

Fig.2. Double-loop speed control system block diagram of the dynamic

Design multi-loop control system is a general principle: starting from the inner ring, a ring and gradually spread. That is: start with the inner current loop start, the first current regulator design is good, and then the entire current loop speed control system as a part of, and then design the outer ring speed regulator.

Test the pid control simulation system power

1). PID control principle

PID control principle is based on the amount of the system is adjusted to set the value of the measured value and the deviation between the use of deviation proportional, integral, differential aspects of the different combinations of three to calculate the amount of the controlled object of control [7]. Conventional PID control system block diagram shown in Figure 3. Conventional PID control system consists of PID controller and charged objects. Figure 3, r (t) is a given value, y (t) is the system's actual output value, set point and the actual output value constitutes the control deviation e (t).

(1) $$e(t) = r(t) - y(t)$$

e (t) as a PID control input, u (t) as the output of the PID controller and the controlled object input.

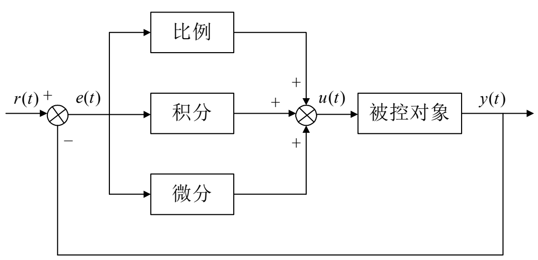

Fig.3. Block diagram of conventional PID control system

2). Current design of the PID regulator ACR

From the dynamic requirements of point of view, the actual armature current system does not allow the role of control in sudden there is too much overshoot, dynamic process to ensure that current does not exceed the allowable value, while the grid voltage fluctuation of the role of a second-time immunity to factors, for current loop should follow the performance-based, its transfer function:

(2) $$W_{ACR}(s) = K_i \frac{(\tau_1 s + 1)(\tau_2 s + 1)}{\tau_1 s}$$

K_i - current regulator proportional coefficient;

τ_1, τ_2 - Ahead of the current regulator time constant.

3). PID speed controller design for ASR

In order to achieve speed without steady-state error, load disturbance in the point must be preceded by an integrator, it should be included in the speed controller ASR, it is now back at the point of disturbance has been an integral part of, the speed loop open-loop transfer function should be There are two integral aspects. The transfer function is:

(3) $$W_{ASR}(s) = K_n \frac{(\tau_1 s + 1)(\tau_2 s + 1)}{\tau_1 s}$$

K_n - Speed regulator proportional coefficient;

τ_1, τ_2 - Speed controller lead time constant.

4). Detcermination of controller parameters

Double closed-loop DC drive systems, the basic data are as follows:

DC motor:

Rated voltage $U_N = 220\ V$,
rated current $I_{dN} = 136\ A$,
rated speed $n_N = 1460\ r/\min$,
motor potential factor $C_e = 0.132\ V \bullet \min/r$,
that allows multiple overload $\lambda = 1.5$,
thyristor devices amplification system $K_s = 40$,
three-phase bridge circuit $T_s = 0.0017\ s$,
the average uncontrolled time $T_s = 0.0017\ s$,
the total armature circuit resistance $R = 0.5\Omega$,
the electromagnetic time constant $T_l = 0.03\,s$,
electrical and mechanical time constant $T_m = 0.18\,s$,
speed filter time constant $T_{on} = 0.01\,s$,
the current filter time constant $T_{oi} = 0.002\ s$,
speed feedback coefficient $\alpha = 0.007\ V\ \min/r$,
the current feedback factor $\beta = 0.05\ V/A$.

By the combination of the above parameters and (2) have current loop transfer function:

(4) $$W_{ACR}(s) = 1.013\,\frac{(0.03s + 1)(0.002s + 1)}{0.03s}$$

By the combination of the above parameters and (3) have speed loop transfer function:

(5) $$W_{ASR} = 11.7\,\frac{(0.087\ s + 1)(0.01s + 1)}{0.087\ s}$$

Test bench of power simulation fuzzy self-tunin control

1). Fuzzy self-tuning PID control principle

Fuzzy control part of the conventional PID control and fuzzy reasoning of two parts, a fuzzy reasoning part of the essence of the fuzzy controller, but its input is the error e and error change rate ec, the output is ΔK_p、 ΔK_i、 ΔK_d.

PID parameter self-tuning fuzzy controller structure shown in Figure 4.Seen from Figure 4, PID self-tuning fuzzy parameters is to identify the three PID parameters and deviation e and error change rate ec fuzzy relationship between the operation and through ongoing testing e ec, according to the fuzzy control theory to the three parameters on-line modified to meet different when e and ec the different requirements of the control parameters, leaving the controlled object has a good dynamic and static performance.

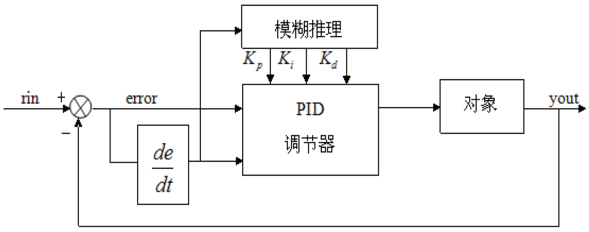

Fig.4. PID parameter self-tuning fuzzy controller structure

2). Fuzzy self-tuning PID controller design

As needed, the input linguistic variables E and EC is divided into seven fuzzy sets, respectively, the value of language The positive largest (PB), middle (PM), positive small (PS), zero (ZE), negative small (NS), negative in (NM), negative big (NB) to represent their membership function is Gaussian, the output linguistic variables, with the linguistic values small positive largest (PB), middle (PM), positive small (PS), zero (ZE), negative small (NS), negative middle (NM), negative big (NB) to represent the membership function is triangular.

Select the error e and error change rate ec fuzzy set domain are 7,they respectively are e = {-6, -4, -2,0, +2, +4, +6}, ec = {-6, - 4, -2,0, +2, +4, +6}; k_p, k_i, k_d on the domain is [0,15], the fuzzy subset of e, ec, k_p, k_i, k_d = {NB, NM, NS, ZE, PS, PM, PB}. Let e, ec and k_p、k_i、k_d are subject to normal distribution, thus obtained the fuzzy subset of the membership, according to the fuzzy subset of the parameters of the membership assignment and fuzzy control model using fuzzy reasoning design synthesis parameters of PID correction fuzzy matrix to identify correct parameters into the following equation [7]

(6) $$K_p = K_p' + \{e_i, ec_i\}_p$$

(7) $$K_i = K_i' + \{e_i, ec_i\}_i$$

(8) $$K_d = K_d' + \{e_i, ec_i\}_d$$

Operation, the control system through the processing of fuzzy logic rules, look-up table and computing, to complete online tuning PID parameters.

Matlab Simulation

1).Simulation model of the conventional PID control

In the two-loop speed control system based on the dynamic structure, through the current loop and speed loop PID design, combined with the basic parameters of the simulation, the establishment of simulink simulation model shown in Figure 5.

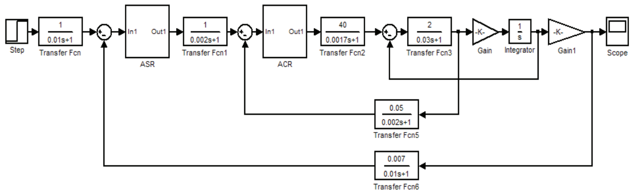

Fig.5.Control Simulation Model

Simulation model diagram of PID ACR package sub-module shown in Figure6.

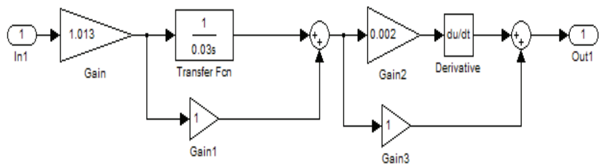

Fig.6. ACR PID control sub-module map

ASR simulation model diagram of PID sub-module package shown in Figure7.

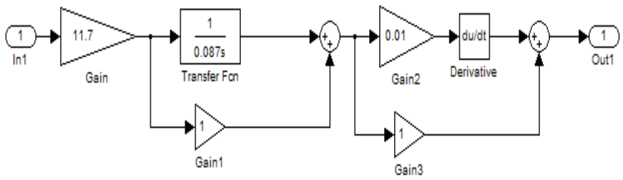

Fig.7. ASR sub-block diagram of PID control

2). Fuzzy self-tuning PID control simulation model

ASR will speed loop fuzzy self-tuning PID control, current loop ACR still using conventional PID control. Speed Ring ASR fuzzy self-tuning PID control sub-module shown in Figure 8.

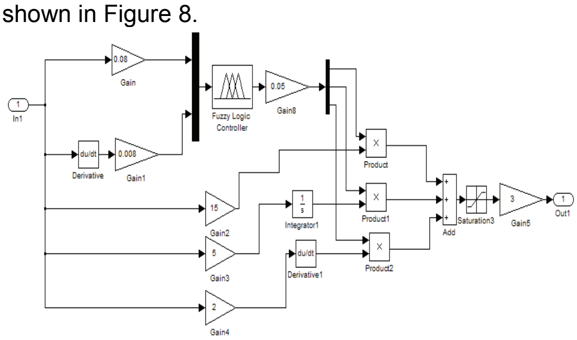

Fig.8.ASR fuzzy self-tuning PID control sub-module

3). Simulation results

Through the establishment of Simulink simulation, two kinds of control methods from the waveform on an oscilloscope as comparisons of waveform Figure 9.

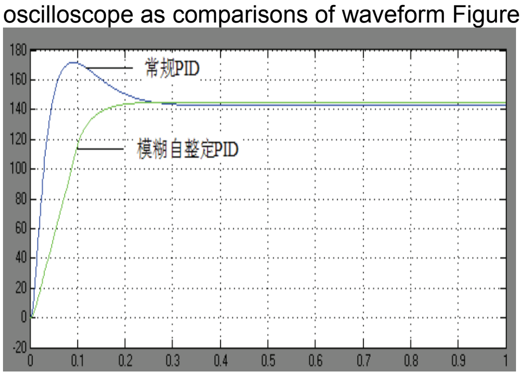

Fig.9. Waveform compare two control methods

Graphics from the simulation shows that fuzzy parameter self-tuning controller to control the overall performance superior to conventional PID controller. Compared with the conventional PID, fuzzy self-tuning PID control does not require a precise mathematical model, has not or less affected by the object model parameters, can achieve high performance, robustness, and small overshoot or no overshoot, etc. advantages.

Conclusion

In this paper, a large number of books and access to relevant information for automotive brake test rig control system features closed-loop DC drive the bi-simulation system. First, conventional PID control theory is applied to the current loop and speed loop. Then the fuzzy parameter self-tuning PID controller loop speed the transformation. Through the application of MATLAB to conventional PID controller and fuzzy self-tuning PID controller parameters of the simulation study, the fuzzy parameter self-tuning controller to control the overall performance superior to conventional PID controller. First, the fuzzy parameter self-tuning PID controller dynamics better, not only the fast response and small overshoot; Second, the fuzzy parameter self-tuning PID controller has good dynamic quality, steady-state process does not shock; Finally, fuzzy parameter self-tuning PID controller system, to enhance anti-interference ability, with good non-linear and time-varying, greatly improve the control effect.

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