The design of Self-adaptive Fuzzy PID Controller in Magnetic Suspension Systems

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Keywords: Self-adaptive; PID Controller; Magnetic Suspension Systems

Abstract. This paper introduces self-adaptive fuzzy PID controller to improve static and dynamic performance of magnetic suspension systems aiming at the characteristics of nonlinearity, hysteresis and uncertain model of the systems. The simulation results demonstrate that this fuzzy self-adaptive PID controller is more precise and less time-consuming for convergence, when uncertain parameters and disturbances exist at the same time, the system obtains better robust and stronger anti-interference ability.

Introduction

Magnetic suspension system is a typical linearity, hysteresis, model uncertainty system. By controlling the current to adjust the suspension coil gap, the whole suspended process is in a dynamic adjustment process, so that the system does not have a stable operating point, therefore the dynamic and static performance requirements for magnetic suspension systems are very high[1-3]. Conventional PID control principle is simple, easy to implement, no static error steady. However, the traditional PID control is mainly linear control process with the exact model. Moreover, dynamic performance of fuzzy control is better, but the input of controller only has error and error rate of variables, or the steady-state performance is bad[4-6]. Thus, for the PID control and fuzzy control of their own characteristics, scholars have used different methods to combine fuzzy control and PID control to develop a variety of fuzzy PID control to meet the requirements of complex systems.

In view of the requirements for the magnetic suspension system and a variety of intelligent control features, we use a method of self-adaptive fuzzy PID control. The controller's study accuracy and convergence rate is investigated, which is applied to the magnetic suspension system Simulation results show that the performance of the control system is significantly changed.

Self-adaptive Fuzzy PID Controller Design

Parameter self-adaptive fuzzy PID control is based on the conventional PID controller to choose the error e and error change rate e_c as input, and use fuzzy rules to adjust parameters K_p K_i , K_d to meet different e and e_c for the different requirements of the controller parameters, in order to make the controlled object have a good dynamic and static performance. This would constitute a self-adaptive fuzzy PID controller, and the structure is shown in Fig.1.

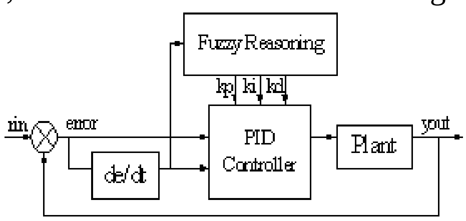

Fig. 1 The structure of self-adaptive fuzzy PID controller

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Conventional PID controller control formula is:

$$u(t) = K_p[e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d \frac{de(t)}{dt}] \tag{1}$$

Where $e(t)$ is the error, $e_c(t)$ is the changing rate of error, they can be used as input linguistic variables for fuzzy systems, K_p is a proportionality factor, $K_i = K_p / T_i$ is the integral action coefficient, $K_d = K_p * T_d$ is derivative action coefficient, after a certain mathematical processing , these can be used as the output variables for fuzzy systems.

Set $K_p \in [K_{pmin}, K_{pmax}]$, $K_d \in [K_{dmin}, K_{dmax}]$,

$$\Delta K_P = \frac{K_p - K_{p\min}}{K_{p\max} - K_{p\min}} \quad , \quad \Delta K_d = \frac{K_d - K_{d\min}}{K_{d\max} - K_{d\min}} \tag{2}$$

Input linguistic variables e and e_c are the domain {-6, -5, -4, -3, -2, -1,0,1,2,3,4,5,6}, using a single-valued fuzzy production device, its membership function is shown in Fig. 2, the membership functions of output linguistic variables ΔK_p and ΔK_d are shown in Fig. 3, the membership function of a is shown in Fig. 4.

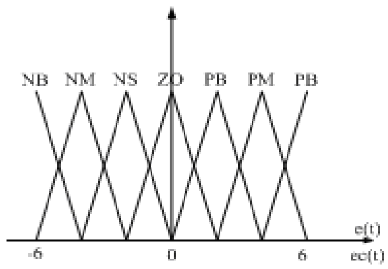

Fig. 2. The membership function of e and e_c

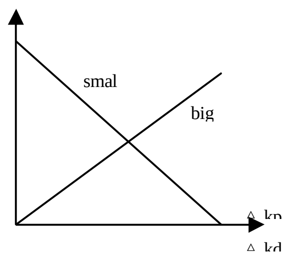

Fig.3. The membership function of ΔK_p and ΔK_d

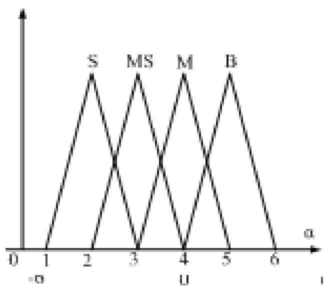

Fig.4. The membership function of a

Based on the above parameters K_p, K_i , K_d impact on the system output characteristics, we can obtain parameters self-tuning principle at different e and e_c .

According to the above principle PID tuning parameters and expertise, we can get $\Delta \boldsymbol{K}_p$, $\Delta \boldsymbol{K}_i$, tuning rules $\Delta \boldsymbol{K}_d$ Table 1, Table 2, Table 3:

Table 1 ΔK_p △ Kp tuning rules

e	e_c						
	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

Table 2 ΔK_i tuning rules

e	e_c						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Table 3 ΔK_d tuning rules

e	e_c						
	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

With adaptive fuzzy rules, the adjustment of controller parameters can be summarized as: According to some actual load value, the initial value of various parameters for PID controllers is obtained. At the same time, according to the error and error rate of change, the changed value of PID controller is calculated. Finally, the parameters of the PID controller at time k can be calculated by the formula (3) - (5):

$$K_p(k) = K_p(k-1) + \Delta K_p(k) \quad (3)$$

$$K_i(k) = K_i(k-1) + \Delta K_i(k) \quad (4)$$

$$K_d(k) = K_d(k-1) + \Delta K_d(k) \quad (5)$$

fuzzy self-tuning PID control simulation

We use MATLAB / SIMULINK block to establish fuzzy PID control system simulation model The simulation model is shown in Fig. 5. The entire model is consist of fuzzy controller module, PID module, control input and output objects and other components.

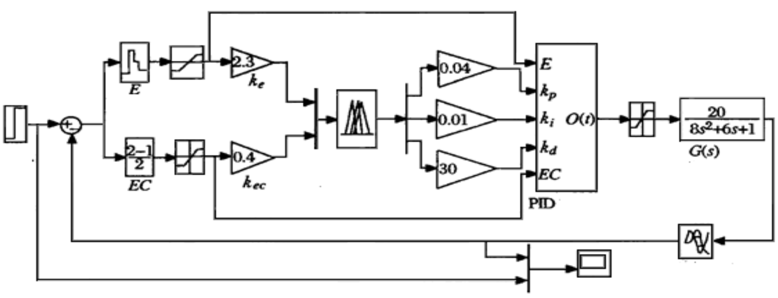

Fig5. Self-adaptive Fuzzy Control systems

The mathematical model of magnetic suspension systems is:

$$G(s) = \frac{20}{(2s+1)(4s+1)} e^{0.5s} \quad (6)$$

System input signal is a step signal. After the system is running, you can take advantage of the oscilloscope to observe the situation of system output. The response curve of the conventional PID control system and the response curve of self-adaptive fuzzy PID control system are shown in Fig6 and Fig 7, respectively. From Fig. 6 and Fig .7, it can be seen that the self-adaptive fuzzy PID control than the conventional PID controller improves the system more significantly.

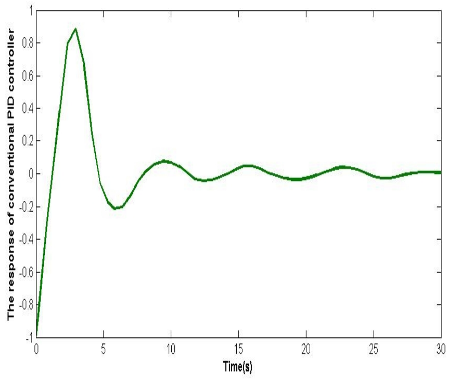

Fig.6. The response of conventional PID controller

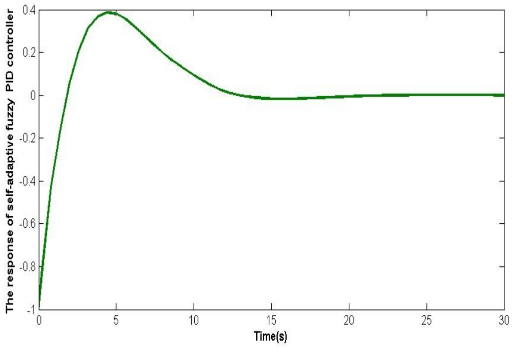

Fig.7. The response of self-adaptive fuzzy PID controller

Conclusion

In this paper, Magnetic Suspension Systems for dynamic and static characteristics of the performance requirements are very high, the fuzzy adaptive tuning PID control algorithm in which the control system, full use of the adaptive PID controller little fuzzy control theory rules, the system is simple and transparent and a strong theoretical advantages of adaptive self-learning ability, adaptive capabilities.

Acknowledgments

This work is partially supported by the National Nature Science Foundation of China (Grant No.61104106, Grant No.61473195, Grant No. 61402088, Grant No. 61203329), Fundamental Research Funds for the Central Universities(Grant No. N130423013), Higher Educational Science and Technology Program of Hebei Province (Grant No. QN20132011), Science Research Foundation of Northeastern University at Qinhuangdao (Grant No.XNK201502), and Program Funded by Liaoning Province Education Administration (Grant No. L2014480, Grant No. L2015360).

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