

Research on a Kind of Adaptive Fuzzy Control Method and Its Application in Feeding System of CNC Honing Machine

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Abstract. Controller design for industrial processes with large time delay still remains challenging at present. On the basis of brief introduction to the processing of honing machine, then the control system was conducted by using the tool of Simulink. The simulation result showed that the correction by using fuzzy controller, to numerical control honing machine feeding system for real-time control, system stability improvement at the same time, response speed, feed system and raises the comprehensive performance. Through the experiment simulation, the feasibility and validity of the adaptive fuzzy control in this paper are proved.

1. Introduction

The mathematical model of controlled object of CNC servo control system is generally unknown. Aiming at multi axis CNC servo control system, Lanzhou Industry and Equipment Co. Ltd, Lanzhou University of technology researchers [1-21] proposed an NURBS algorithms which based on real-time interpolation and compensating error. When using modern control theory and intelligent control to control, it is necessary to know the mathematical model of the system accurately.

Hengmoji, as an important equipment in the production of metal processing industry, began to expand to heavy cutting and rough machining direction, which also led to the improvement of honing processing speed, which also put higher requirements on the control system [22, 23]. As the key link of honing machine control, the reciprocating position control of honing machine directly affects honing machine's ability and quality [24]. For equipment such as honing machines, precise location accuracy is required in machining, especially in processing blind whole parts. Due to the limited size of the cutting slot, it is required that the overshoot should be as small as possible [25]. It is better to have no excess. Because of the existence of excess, a modified and effective control method must be chosen to reduce the excess [25-29]. Fuzzy control can improve the stability of the system, the overshoot is zero, the response speed is accelerated and the performance of feed system is improved synthetically.

In the paper, A kind of adaptive fuzzy control method and its application in feeding system of CNC honing machine is introduced. In the design of this adaptive fuzzy control, the controller and parameter updating strategy are designed with the recognition of the model set and the controlled object as a whole when the adaptive model set is adopted, which effectively guarantees the system stability. Through the experiment simulation, the feasibility and validity of the adaptive fuzzy control in this paper are proved.



2. Modeling of reciprocating motion of honing machine

2.1. Establishment of model of reciprocating motion control system

Servo control system has the characteristics of high positioning accuracy and good stability, so servo control system is used in some important situations. The control voltage is u in figure. $y(s)$ Is the output displacement of the hydraulic cylinder; k_{sv} is servo gain coefficient; k_a for servo amplifier gain coefficient, $k_a = 0.775 \text{ A/V}$ [8].

The mathematical model of the electrohydraulic servo valve available according to the instructions provided by the manufacturer is as follows:

$$G_v(s) = \frac{4444}{\frac{s^2}{500^2} + \frac{2 \times 0.85}{500}s + 1} \quad (1)$$

In this paper, the hydraulic cylinder, we should give $\omega_h = 544.7, \xi_h = 0.15$, can be derived that the transfer function of the hydraulic cylinder is:

$$G_h(s) = \frac{0.0406}{s(\frac{s^2}{544.7^2} + \frac{2 \times 0.15}{544.7}s + 1)} \quad (2)$$

Above all, the mathematical model of the reciprocating motion control system of the honing machine can be obtained, as shown in Figure 1.

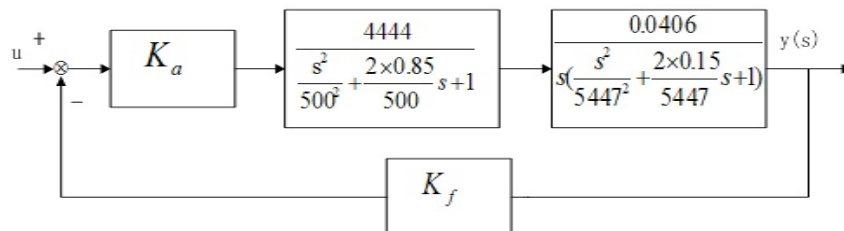


Figure 1. Frame diagram of electrohydraulic servo position control system.

2.2. Analysis of Overtone (Time Domain) [7]

Using MATLAB software to simulate the step response of servo control system. The fixed step h (Fixed-step), $H=0.001$, and the algorithm ode 4 (longue-kuta) are used in the design. The unit step response curve of the closed-loop transfer function can be drawn by MATLAB software. As can be seen from Figure 2, maximum overshoot $\sigma = 15.142\%$; Time adjusted $t_s = 0.015s$; $s=0$, as shown in Figure 2.

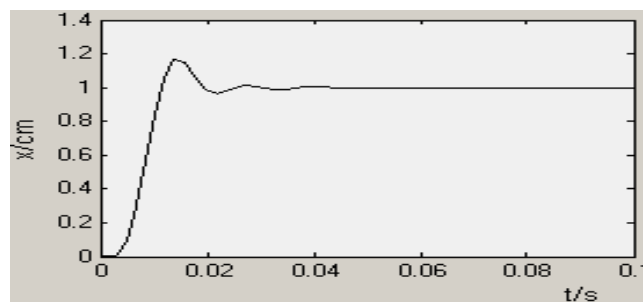


Figure 2. The Step Response Curve of Closed Loop System.

For this system, the error at the command input speed $v = 25m/min$ is

$$e_v = \frac{v}{K} = \frac{25/60}{136.2} = 0.003m \quad (3)$$

When there is interference input will cause the position error, the system is the equivalent of θ -type. The system has a position error of.

$$e_p = \frac{-f}{k_a k_f} = \pm \frac{0.02 \times 300 \times 10^{-3}}{0.755 \times 1} = \pm 0.008cm \quad (4)$$

This position error is an estimate [8], the existence of zero drift factors are different with the working conditions.

From the error judgement, because of the existence of the error position, the NC honing machine in the processing of deep hole location, the need for accurate location, so it is best not to overtune the amount, but from the response curve data can be seen that the system does not meet the requirements, needs to be corrected, so the use of fuzzy control correction to meet the requirements.

3. Calibration of fuzzy control

In order to facilitate sensitivity control and fuzzy rule analysis, we apply quantization factor K_e and K_{ec} to quantify the error and its error change $ES(k)$, map it to the fuzzy set universe, and finally act on the control system. The fuzzy domain is divided into 7 language variables, such as large NB, negative medium NM, negative small NS, zero ZE, positive small PS, middle PM and Zhengda PB, and so on. The fuzzy control block diagram and flow chart are shown in figures 3 and 4.

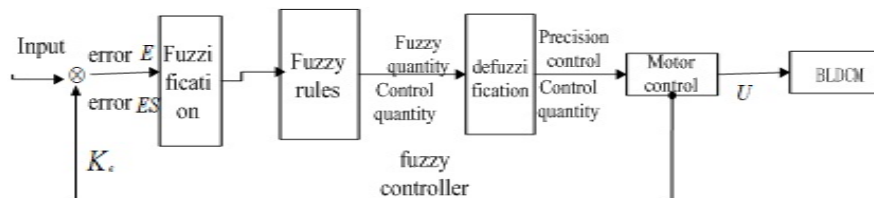


Figure 3. Block diagram of fuzzy control.

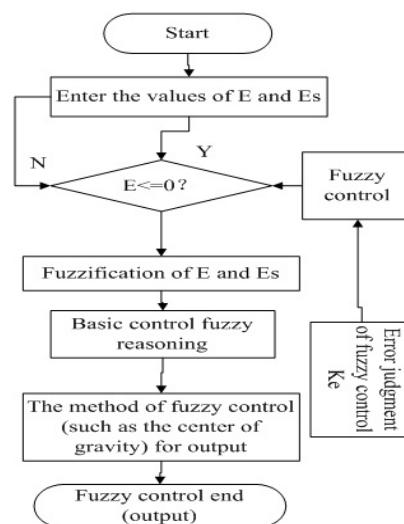


Figure 4. Flow diagram of fuzzy control for model reference.

4. Design of Fuzzy Control

4.1. Design of Fuzzy Control

The fuzzy control designed in this paper uses real-time fuzzy control such as fuzzy operation, fuzzy reasoning, and fuzzy solution, also known as fuzzy logic control [9]. Compared with the traditional method of fuzzy table control, this method is convenient to adjust the parameters of membership, control rules and proportional factors. The fuzzy control block diagram and flowchart are shown in Figure 3 and 4.

In fuzzy control, we select the error signal E and the error change signal ES as the input variables of the fuzzy controller, and the output variables are the control variables U and gain K_e of the servo amplifier. Theoretically speaking, the enlargement of K_e is equivalent to narrowing the basic field of error, increasing the control function of error variables, resulting in shorter rise time, but overshoot makes the transition time of the system longer.

4.2. Establishment of membership functions

The subject's subordinate editor is shown in Figure 5. The domain of E , ES in the fuzzy control system is $[-6, 6]$ (NL, NM, NS, ZO, PS, PM, PB).

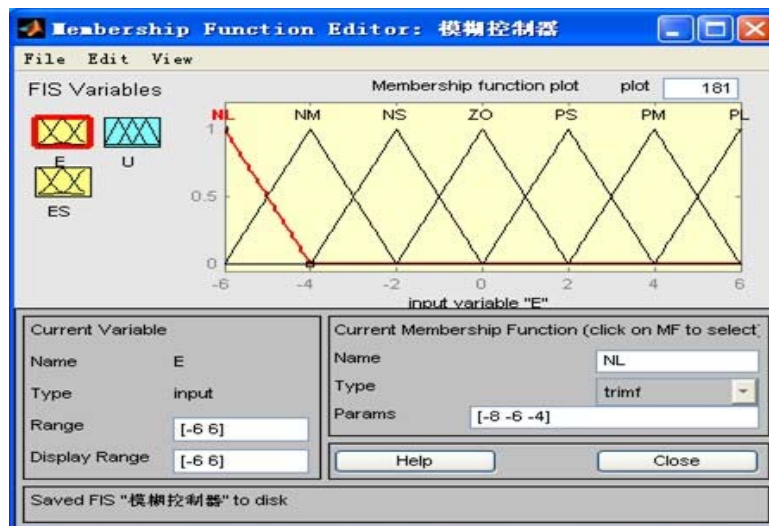


Figure 5. Affiliation Function Editor.

4.3. Fuzzy control rules

The control rules are shown in Table 1. Enter these 49 control rules in the Rules Editor window. For example, If E is NB and EC is PS then U is PM table.

Table 1. Fuzzy Control Rule Table.

Control quantity		Variation rate of input variable deviation ES						
		NL	NM	NS	ZO	PS	PM	PL
Input deviation E	NL	PL	PL	PL	PL	PM	ZO	ZO
	NM	PL	PL	PL	PL	PM	ZO	ZO
	NS	PM	PM	PM	PM	ZO	NS	NS
	ZO	PM	PM	PS	ZO	NS	NM	NM
	PS	PS	PS	ZO	NM	NM	NM	NM
	PM	ZO	ZO	NM	NL	NL	NL	NL
	PL	ZO	ZO	NM	NL	NL	NL	NL

5. Simulation and Analysis of Fuzzy Control System

5.1. Simulation of Fuzzy Control System

The model is built for system simulation in Matlab, as shown in Figure 6.

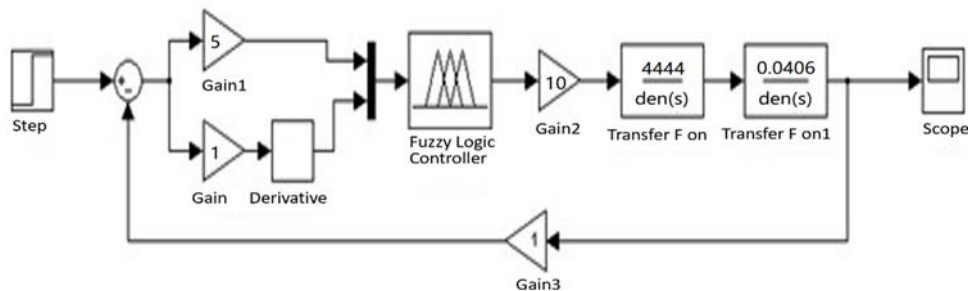


Figure 6. System simulation.

We use the CNC honing machine tool servo testing machine to do the fuzzy control experiment of the servo testing system, which: CNC honing machine servo testing machine, as shown in Figure 6:

The results of Simulink's general control simulation and fuzzy control simulation are shown in Figure 8, 9.



Figure 7. CNC honing machine servo testing machine

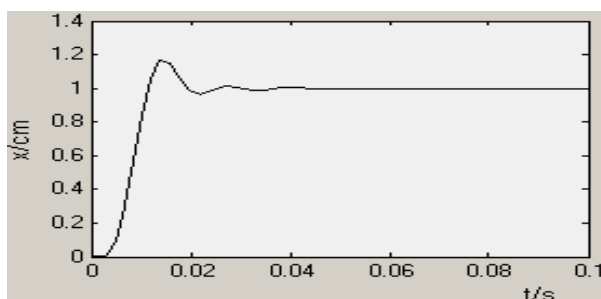


Figure 8. General control simulation curve

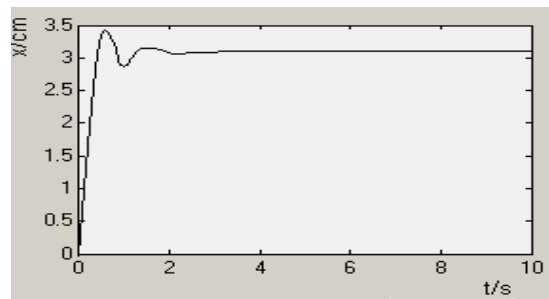


Figure 9. Simulation diagram of response curve of fuzzy control unit function

5.2. Fuzzy Control System Analysis

Through Simulink software simulation, it can be concluded from the analysis of Figure 7 that the fuzzy control system has no overtone and can meet the requirements of honing industry.

6. Summary

1) After the fuzzy control method is adopted, the curve rises gently before the system reaches stability, and there is no shock.

2) Using fuzzy control to control the input system of logarithmic honing machine, the stability of the system is improved, the response speed is accelerated and the comprehensive performance of the feed system is improved.

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