An Improved Nonlinear PID Control Method for a Class of Servo

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Abstract. For the second order simplified model of servo system, the traditional PID control method is used to design the feedback controller of the servo system, and the PID control parameters are adjusted to make the output stable and smooth without chatter. On this basis, an improved nonlinear PID control method is introduced, which makes the response speed of the servo system faster and the output not overshoot or flutter, in line with the needs of engineering applications.

Introduction

The servo system is a heading automatic control system to ensure the flight of missiles and other aircraft in a given course. The performance of the servo system directly affects the safety performance, economic performance and military performance of the aircraft [1-3]. PID control is a widely used control method in servo systems for many years [2-5]. The traditional PID control is realized by proportional, integral and differential control of the deviation between the desired signal and the actual output. However, the linear mapping becomes a defect of its control, such as the contradiction between dynamic performance and static performance, control performance and robust performance. Therefore, many scholars proposed to use fuzzy control, variable structure, neural networks and other methods of control [6-8], while these algorithms can achieve better control in the simulation results, but the practical application of system reliability is difficult to guarantee. Therefore, this paper designs a nonlinear PID control algorithm based on PID control, which can be applied to the typical model of missile servo system. The simulation results show that the nonlinear PID control algorithm can obviously improve the performance of the servo system.

Model Description

A simplified model of a missile servo system can be described as a differential equation 1[9-10].

$$\dot{y}_a = -\frac{1}{T} y_a + \frac{1}{T} u$$
$$\dot{y} = y_a \tag{1}$$

Where T is the inertial time constant, and $T = 0.06s$, u is the control input, y_a is the rotational angular velocity, y is the output. The correlation between y_a and u can be described as the transfer function 2.

$$\frac{y_a}{u} = \frac{1}{TS + 1} \tag{2}$$

Where S is the differential Operators in transfer Function.

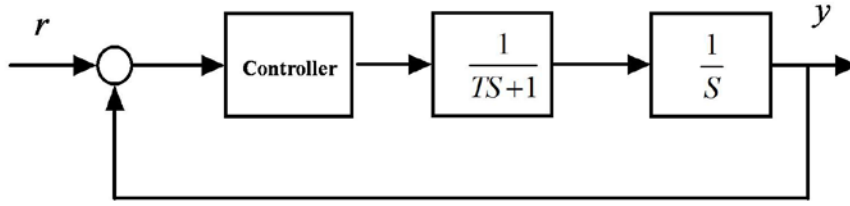So the whole servo system model can be described as follows figure 1.

Figure 1 Schematic diagram of servo system

The control objective is to design the controller such that the output position signal y of the servo system tracks the desired signal r [11].

PID Controller Design

Define the error variable $e = r - y$, and design the PID controller as the formula 3.

$$u = k_1 e + k_2 \dot{e} + k_3 \int edt \qquad (3)$$

Where k_1, k_2, k_3 are the proportion, differential and integral coefficient respectively, $\dot{e}$ is the derivative of error, and $\int edt$ is the integration of error. Generally suppose r is the constant step signal, and $r = 5/57.3$, then we get the formula 4.

$$\dot{e} = \dot{r} - \dot{y} = -y_a \qquad (4)$$

Simulation Results of PID Control

Set the control parameters as k1=5, k2=0.2, k3=0.5. Simulation result is shown in figure 2.
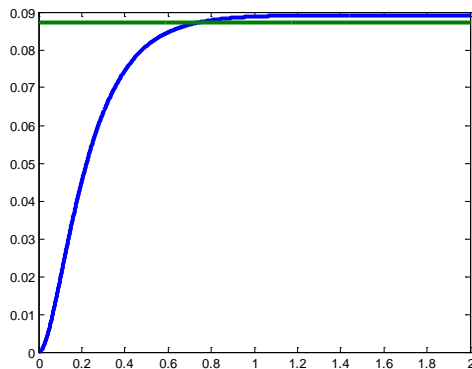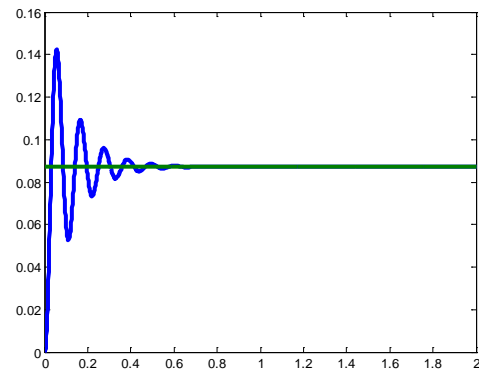

Figure 2 Servo output response curve

Figure 3 Servo output response curve

In order to make the system response faster and steady-state error smaller, we increase the control coefficient and the system response curve is shown in figure 3. In this case the system oscillates more, so we can increase the damping coefficient and system response curve is shown in figure 4.
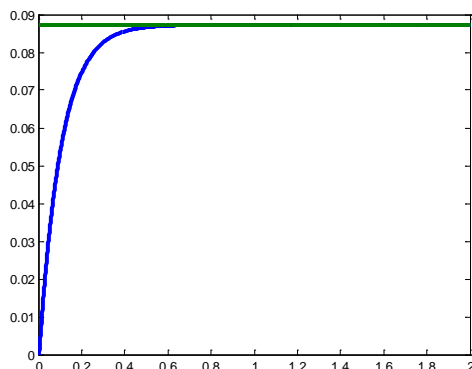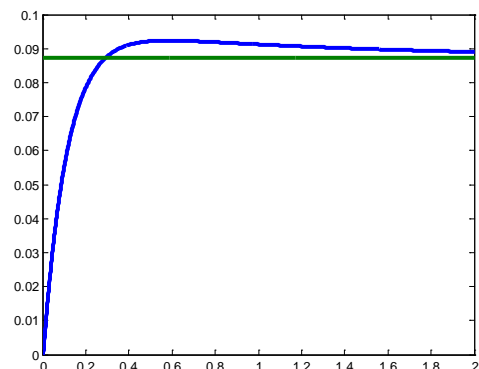

Figure 4 Servo output response curve

Figure 5 Servo output response curve

As shown in figure 4, the system response speed is still not fast enough, so try to increase the integral coefficient, and the system response curve is shown in figure 5.

Nonlinear PID control algorithm

Nonlinear PID control algorithm is proposed as the formula 5, based on the above PID control.

$$u = k_1 e + k_2 \dot{e} + k_3 \int edt + k_4 e^{3/5} + k_5 e^{5/3} \tag{5}$$

Set the parameters as k1=200, k2=20, k3=150, k4=50, and simulation results are shown in figure 6 and figure 7.
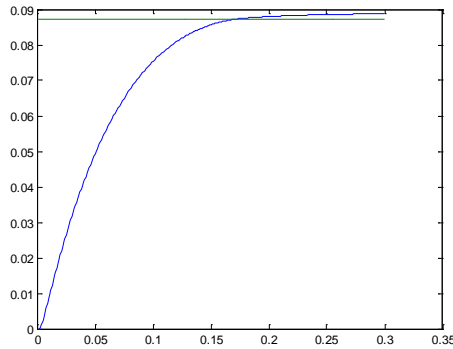
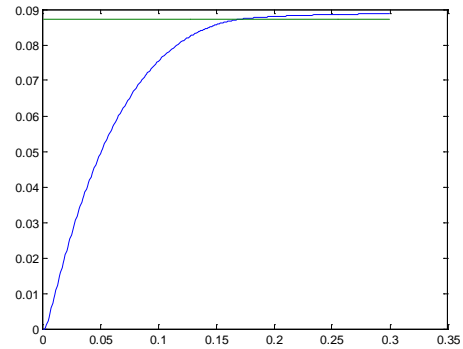|	
Figure 6 Servo output response curve	Figure 7 Control value response curve

From the simulation results, it can be seen that the improved nonlinear PID control algorithm makes the servo response speed from 25ms to 15ms. At the same time the control volume of the servo system is also very smooth with no flutter, in line with engineering needs.

Conclusions

In this paper, the PID control is designed and simulated for a simplified model of servo system is. Then an improved nonlinear PID control method is used to control and simulate the servo system. It can be concluded from the simulation curves that the nonlinear PID control algorithm can improve the response speed of the system and improve the smoothness of the system.

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