Diesel Engine Common Rail Pressure Control Based on Neuron Adaptive PID

Shijie An, Limin Shao
College of Naval Architecture and Power
Naval Univ. of Engineering
Wuhan, China
Fly-bird@hb165.com

Abstract—**The overflow control method of pressure in common rail has been studied through theory and experiment. The single neuron adaptive PID controller has been designed, and the corresponding control program has been worked out under the Labview environment. The experimental study was performed in the experimental platform, and the results have been compared against those from experiment with common PID controller. The comparison shows that the effect of single neuron PID control is superior to that of common PID control, in addition, single neuron adaptive PID controller has smaller error.**

Keywords—**Common rail, Neuron, PID control, Pressure valve**

I. INTRODUCTION

With the increasing strict in emission regulation and intensity of energy sources, the demand for fuel economy and emission performance of diesel engine is becoming higher, common rail system[1] has high flexible control performance, so it has become one of the important developing direction of modern diesel engine. The stabilization of the pressure in common rail will directly influence the performance of common rail system, so it is very important to find out a control strategy with good practical effect. In this paper, mainly aiming at the control method of the backpressure of overflow valve, the single neuron control and PID control method have been researched through experiment, and the corresponding software was worked out, through analyzing the experimental result, the single neuron PID can be proved effective.

The typical common rail system is shown in Figure 1, the high-pressure pump generates high pressure fuel and supplies them to the common rail, the pressure in rail is kept by the control valve, and the electronic control injectors inject the correct amount of fuel into the combustion chambers. The Electronic Control Unit (ECU) controls extremely precisely all the injection parameters – such as the pressure in the Rail and the timing and duration of injection. In the common rail system, keeping the stabilization of common rail pressure is the precondition to ensure injectors inject fuel accurately according to the inject rule[2]. The control of common rail pressure can be realized through controlling the pressure control valve's open and close. The main content discussed in this paper is how to control the pressure-control-valve effectively so that it can ensure the pressure in common rail fluctuates slightly.

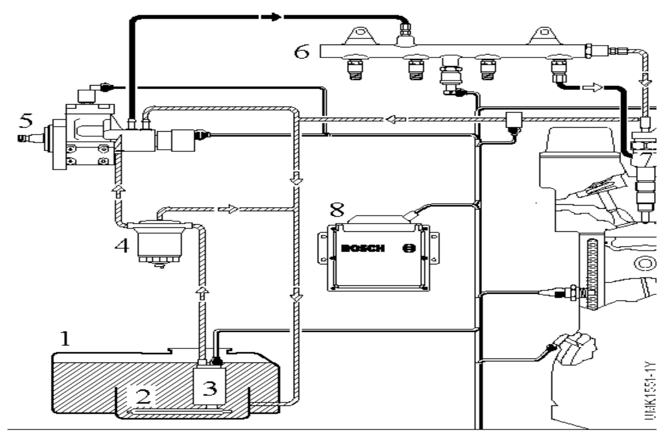

Figure 1. Typical CR fuel injection system

1 Tank; 2 Pre-Filter; 3 Pre-supply Pump; 4 Filter; 5 High-Pressure Pump; 6 Common Rail; 7 Injector; 8 ECU

II. PID CONTROL BASED ON SINGLE NEURON

A. The model of Adaptive Neuron

It is the abilities of self-learning and self-adapting and the multi-input structure for simple Single neuron. Its characters of input and output are shown as:

$$y = K\sum_{i=1}^{n} w_i x_i - \theta \tag{1}$$

Where: K-proportion coefficient;

x_i -parameters of input;

y -parameter of output;

θ -liminal value;

w_i -the weights.

The work principle of this adaptive neuron is shown in Figure 2.

The adaptive neuron can self-learning through modifying the inputs weights. The self-learning rule of adaptive neuron is :

$$w_i(t+1) = (1-c)w_i(t) + dp_i(t) \qquad (2)$$

Where, $c, d > 0$, and d is the learning rate.

For the adaptive neuron in Figure2, its learning rule can be given:

$$p_i(t) = Z(t)S(t)x_i(t) \qquad (3)$$

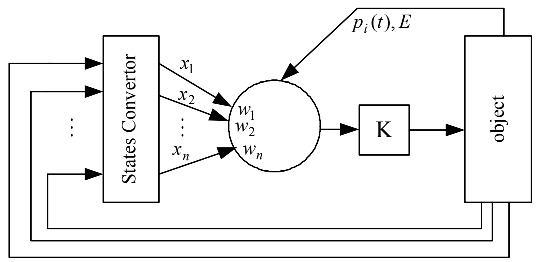

Figure 2. The Work Principle of adaptive Neuron

B. Single Neuron Adaptive PID Control

PID control is used wildly in engineering fields. It can eliminate the error of steady state in control system, make the system response of steady state tracking the target value accurately[3,4]. But when it is applied in practice, because of the existence of practice output breadth limit, usually makes the integral effect overly accumulating, and it results in oscillating of the control system.

It has the ability of self-learning and self-adapting of single neuron, and it has the characters of structure simpleness and calculate expedience and calculating easiness and adjusting parameters contact tightly with engineering target. Combing the adaptive neuron with traditional PID controller, the problems can be solved such as can not online adjust parameters easily and have difficulty in controlling the complex process and the system of parameters changed slowly for time effectively [5,6].

In this paper, the adaptive neuron theory was introduced on the base of classical PID theory, and the PID controller based on adaptive neuron was established. The structure diagram of adaptive PID control is shown in Figure 3.

The inputs of neuron $x_i(t)(i=1,2,3)$ are:

$$x_1(t) = e(t)$$

$$x_2(t) = \sum_{i=0}^{t} e(i)T \qquad (4)$$

$$x_3(t) = \Delta e(t)/T$$

The output of controller is：

$$u(t) = u(t-1) + K\sum_{i=1}^{3} w_i(t)x_i(t) \qquad (5)$$

$$u_g(t) = U_{\max}\frac{1-e^{-u(t)}}{1+e^{-u(t)}} \qquad (6)$$

Where: $U_{\max}$ is the maximum controlling value.

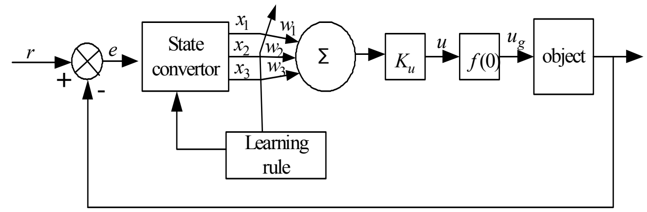

Figure 3. The Principle of Single Neuron Adaptive PID

III. CONTROL SIMULATION

Based on the principle of Single Neuron Adaptive PID, the simulation program is established by using the MATLAB SIMLINK. And the controlled pressure of common rail in common rail injection system are studied. Figure4 shows the simulation result. The comparing of control pressure about Single Neuron Adaptive PID and common PID are shown in Figure5 and Figure6.

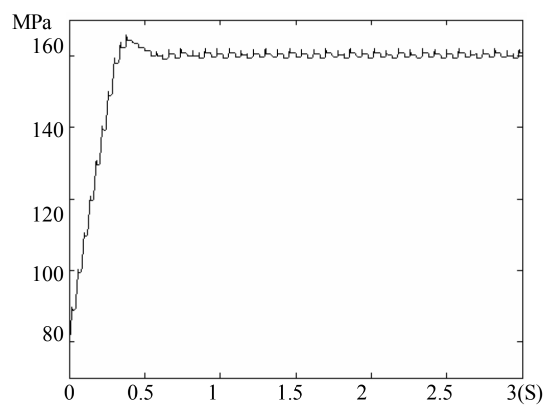

Figure 4. The simulation of Single Neuron Adaptive PID

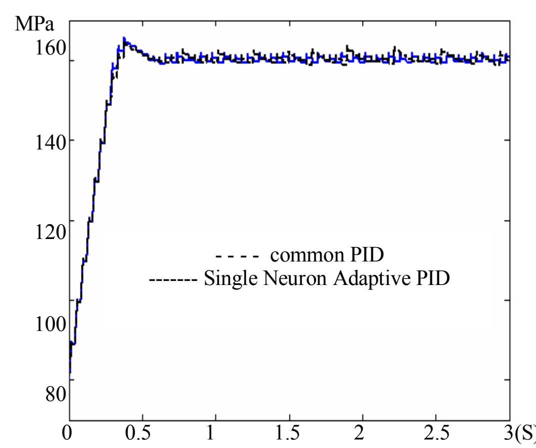

Figure 5. The comparison of Single Neuron Adaptive PID and common PID

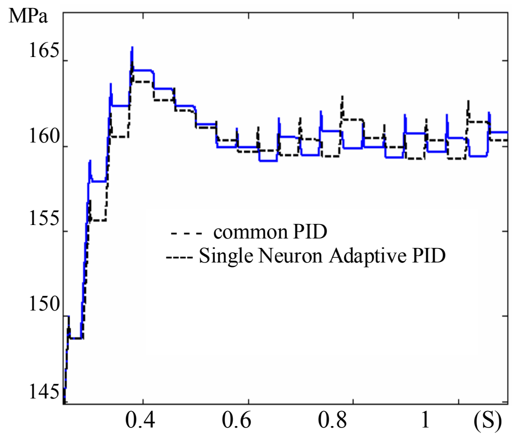

Figure 6. The part of comparison result

Through the part of control pressure, it is shown that responding speed of two methods are same, but the static error of Single Neuron Adaptive PID is more small.

IV. EXPERIMENTAL STUDY

To validate the performance of single neuron adaptive PID controller, experiment has been done on the common rail system experimental setup, and the corresponding control program was worked out under the Labview programming environment [7]. The control program can setting target pressure and sampling period expediently through man-machine interaction interface. The experimental platform is composed of high pressure source, common rail, pressure sensor, overflow valve, computer and multi-function A/D board, as shown in Figure 7.

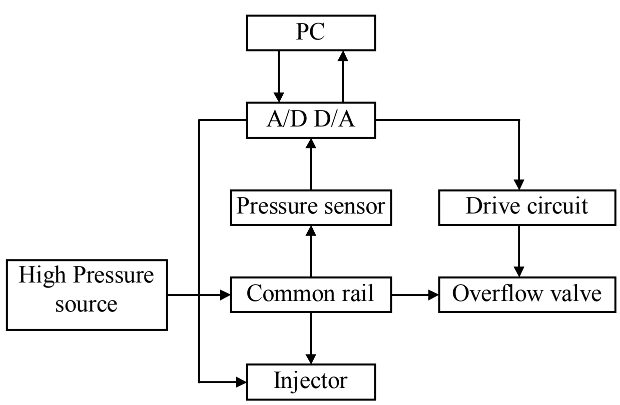

Figure 7. Basic composition of experiment platform

The control step response of pressure in common rail experiment has been performed using the experiment setup above, the test result of single neuron adaptive PID control is shown in Figure 8. Figure 8 shows that the experiment obtained better effect, and the response speed is quick as well as the overshoot is little.

In order to compare with the single neuron adaptive PID control, the common PID experiment was performed as well as the single neuron adaptive PID control, the effect of control response is shown in Figure 9. Figure 9 shows that some slightly oscillate existed in control process. To illustrate this problem, the error values of the two control method were quantified, and the method was that calculated the summation of the absolute value of warp between calculated response curve and target value in the steady-state phase with 500ms as a unit, the results are shown in Figure 10.

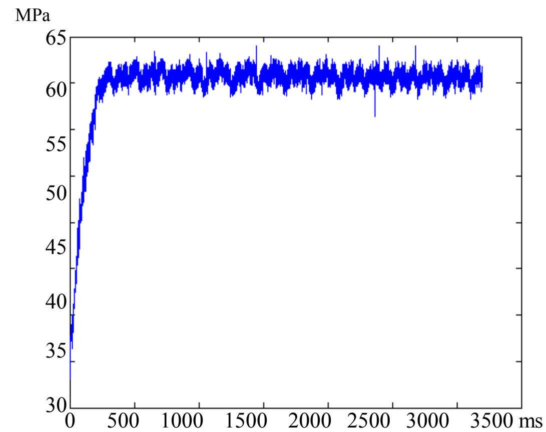

Figure 8. The Response Curve of Single Neuron Adaptive PID

As shown in Figure 10, the control error of common PID is bigger than it of single neuron adaptive PID in the same period. Due to the single neuron has the ability of self-learning and self-adapting, it can reduce the control error, thus it improves the control effect.

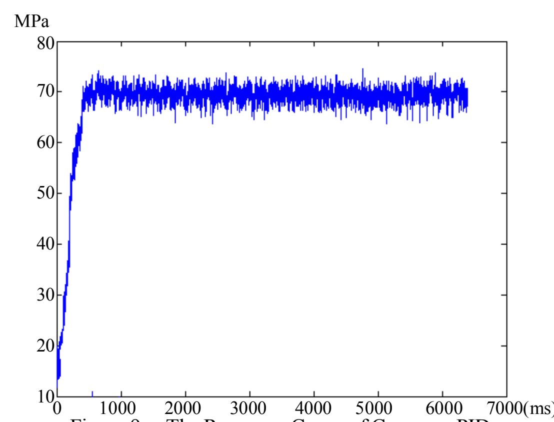

Figure 9. The Response Curve of Common PID

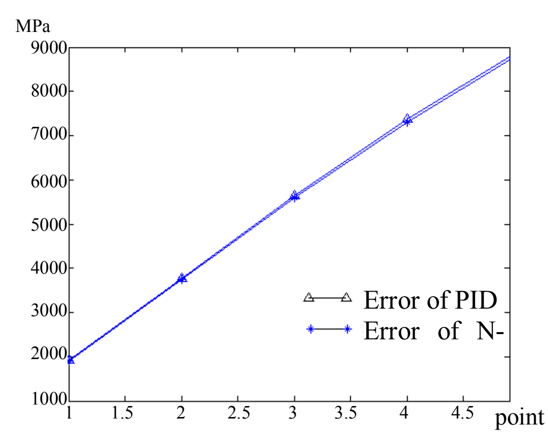

Figure 10. Comparison of the errors of two kinds of control method

V. CONCLUSIONS

From the analysis above the following conclusions can be drawn.

(1) The designed single neuron adaptive PID controller used to control electromagnetism valve of common rail system reserves the characteristics of simple-structure and adjusting expediently, in addition, it solves the problem of setting parameters during the time of displaying, so it is feasible.

(2) Labview provides good platform of man-machine interaction and many kinds of control experimental study can be performed expediently based on this environment.

(3) The experimental results show that single neuron adaptive PID control can improve the response speed of the pressure in common rail, thus decreasing the fluctuation of pressure.

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