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Research on Boiler Water Supply Control System Based on AT89C55 and Fractional order PID Algorithm

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Abstract

In order to improve the controlling effect of temperature and pressure of industrial boiler and ensure the safety of it, the AT89C55 and fractional order PID controller are applied in it. Firstly, mathematical model of water supply system of boiler is studied. Secondly, the water supply controlling system of boiler based on AT89C55 is designed. Thirdly, basic theory of fractional order PID algorithm is put forward, and the improved genetic algorithm is used to optimize the parameters of it. Finally, controlling simulation analysis of temperature and pressure of boiler water supply is carried out, results show that the novel method has better controlling effect.

Key words: Boiler water supply control system; AT89C55; Fractional order PID algorithm

1. Introduction

The industrial boiler has large demand and extensive use, which has been applied in many industrial sectors, such as power generation, manufacturing and chemical industry. The industrial boiler is also one of important equipments in heat source power. Supplying steam required for load can ensure normal operation of boiler, the process parameters of each link should be controlled strictly. The main controlled variables of boiler system conclude drum water level, superheated steam temperature, superheated steam pressure, combustion air ratio, furnace negative pressure. Boiler feed water, lukewarm water flow and lukewarm water flow are main controlling variables. Currently, automatic controlling system of industrial boilers in China is not quite good, some boiler has also been controlled

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based on experience of boiler worker, and the combustion condition has not been controlled automatically. The working quality of boiler can not be ensured, and boiler accident may happen. Therefore it is necessary to apply an advanced technology to control the water supply system of boiler. The AT89C55 is used to control water supply of boiler, and fractional order PID algorithm is applied to control water supply of boiler, then the better of water supply of boiler can be obtained [1].

2. Mathematical Model of Water Supply System of Boiler

The water supply boiler is defined by $\hat{P}$, which has n thermal loads $\hat{Q}_i$, $i=1,2,\cdots,n$, The outlet temperature of boiler is defined by T_o, the outlet pressure of boiler is defined by P_o. The inlet pressure of $\hat{Q}_i$ is defined by P_i, $i=1,2,\cdots,n$. The flow of $\hat{Q}_i$ is defined by $\overline{V}_i$, $i=1,2,\cdots,n$. Every section flow in main pipe is defined by V_i, $i=1,2,\cdots,n$. The following equations can be satisfied [2]:

$$V_i - V_{i+1} = \overline{V}_i ,\ \ i=1,2,\cdots,n-1 \tag{1}$$

$$V_n = \overline{V}_n \tag{2}$$

The flow resistance in every section is defined by f_i, and inlet pressure of each branch is calculated by

$$P_i = P_{i-1} - f_i ,\ \ i=1,2,\cdots,n \tag{3}$$

The temperature in general pipeline is defined by $T(x,t)$, which satisfied the following expression:

$$c\frac{\partial T}{\partial t} + cV(x)\frac{\partial T}{\partial t} = \beta_0 (T_e - T) \tag{4}$$

$$T(0,t) = T_0(t) \tag{5}$$

$$T(x,0) = T_e(x) \tag{6}$$

where c denotes the heat capacity of fluid, T_e denotes the environmental temperature, β_0 denotes the heat exchange coefficient between fluid in general pipeline and environmental temperature.

$$V(x) = \begin{cases} u_1, x \in (0, x_1) \\ u_2, x \in (x_1, x_2) \\ \cdots\cdots \\ u_n, x \in (x_{n-1}, L) \end{cases} \tag{7}$$

The space where the branch is located is y axis, and the length of every branch is defined by L_j, temperature distribution of each branch is defined by $T_j(y,t)$, and the load temperature is defined by $T_{Lj}(y,t)$, and the following expressions can be obtained [3]:

$$c_L \frac{\partial T_{Lj}}{\partial t} = \alpha_j (T_j - T_{Lj}) + \beta_j (T_e - T_{Lj}) \tag{8}$$

$$T_j(0,t) = T(x_j, t) \tag{9}$$

$$T_j(y,0) = T_e(y) \tag{10}$$

$$T_{Lj}(y,0) = T_e(y) \tag{11}$$

where $j = 1,2,\cdots,n$, $y \in (0, L_j)$, c_L denotes the heat capacity of load object, α_j denotes the heat exchange coefficient between T_j and T_{Lj}, β_j denotes the heat exchange coefficient between T_{Lj} and T_e.

3. Water Supply Controlling System of Boiler Based on AT89C55

The water supply system of boiler is used to connect the input and output, and provide the input and output interfaces. The system can accept the signals from key, package water level sensor, feed water flow sensor, steam flow sensor, and feed water pressure sensor. The opening degree of solenoid valve is driven after the signals are processed. The water supply flow and drum water level can be controlled. The system can also display working parameters and give an alarm. The water supply controlling system of boiler is shown in figure 1.

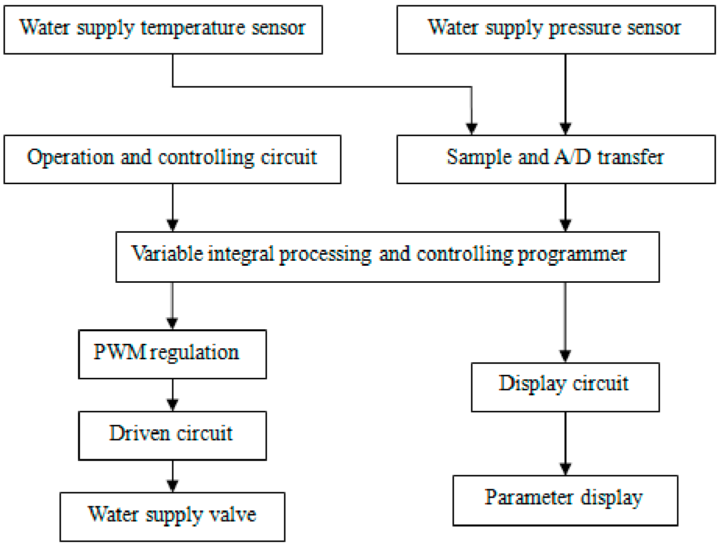

Figure 1 Diagram of water supply system of boiler

The water supply controlling system of boiler uses AT89C55 as core to monitor and control the working procession of boiler. The AT89C55 is developed by ATMEL company, which has storage with 20k bit and RAM with 256 Bit. In addition, AT89C55 extend the programmer storage 24C256 to store the data and programmer. 8155 is used to extend I/O interface. It also has the functions of keyboard entry, LCD display and input and out of analog quantity. The controlling system based on AT89C55 is shown in figure 2.

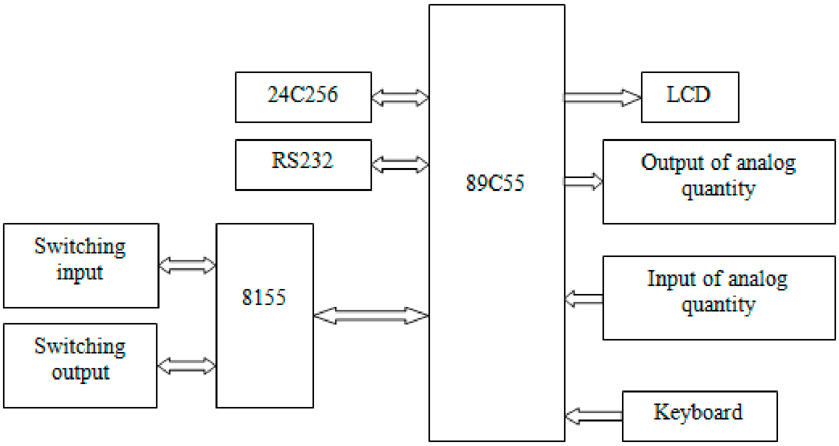

Figure 2 Diagram of water supply controlling system of boiler based on AT89C55

he controlling system design the 1285LCD liquid crystal display, which can online display the temperature and pressure of supply water of boiler, LED can display the monitoring data, the buzzer can give an alarm. The driven circuit is a integrated circuit that amplify the PWM signal, and the input and output of chip are PWM pulse.

4. 3Basic Theory of Fractional order PID Algorithm

The fractional order PID controller should optimize the parameters K_P, K_I, K_D, λ and μ. The five parameters mutually restraint, and the optimal combination of parameters can be obtained through searching optimal solution. And then the controlling effect of fractional order PID controller can be improved.

Theory diagram of fractional order controlling algorithm is shown in figure 3.

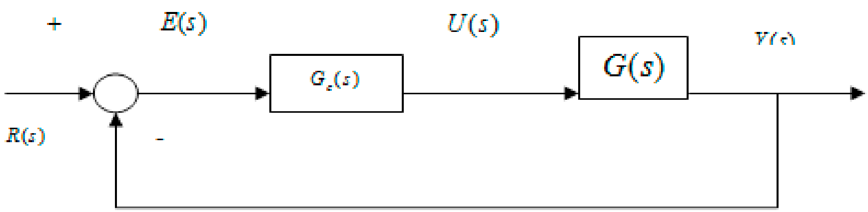

Figure 3 Diagram of fractional order controlling system

Transfer function of fractional order PID controller is listed as follows:

$$G_c(s) = \frac{U(s)}{E(s)} = K_P + K_I s^{-\lambda} + K_D s^{\mu} \tag{12}$$

Transfer function of fractional order closed loop control system is expressed as follows [4]:

$$G_s(s) = \frac{Y(s)}{R(s)} = \frac{G(s)G_c(s)}{1+G(s)G_c(s)} = \frac{\sum_{j=0}^{m}\beta_j s^j (K_P + K_I s^{-\lambda} + K_D s^{\mu})}{\sum_{j=0}^{n}\alpha_j s^j + \sum_{j=0}^{m}\beta_j s^j (K_P + K_I s^{-\lambda} + K_D s^{\mu})} \quad (13)$$

The characteristic equation is expressed by

$$\sum_{j=0}^{n}\alpha_j s^j + \sum_{j=0}^{m}\beta_j s^j (K_P + K_I s^{-\lambda} + K_D s^{\mu}) = 0 \quad (14)$$

In order to effectively optimize the five parameters of fractional order PID controller, an effective intelligent should be chosen. Genetic algorithm is put forward based on duplication, crossing and variation in genetic process. The random population is used as start point to carry out selection, interaction and variation procession, and then the population with higher adaptability can be generated. And then continuous optimization in searching space can be achieved. In order to improve optimal precision of parameters, the chaos theory is introduced into the genetic algorithm, and the improved genetic algorithm is constructed. The improved genetic algorithm uses chaos series as the original population, and the searching speed of optimal solution is enhanced. One hand, the population diversity can be ensured, on the other hand, the global solution can be obtained. The improved genetic algorithm is applied in optimization of fractional order PID controller parameters, and the optimal parameters K_P, K_I, K_D, λ and μ can be obtained. The basic framework of fractional order PID controller based on improved genetic algorithm is shown in figure 4.

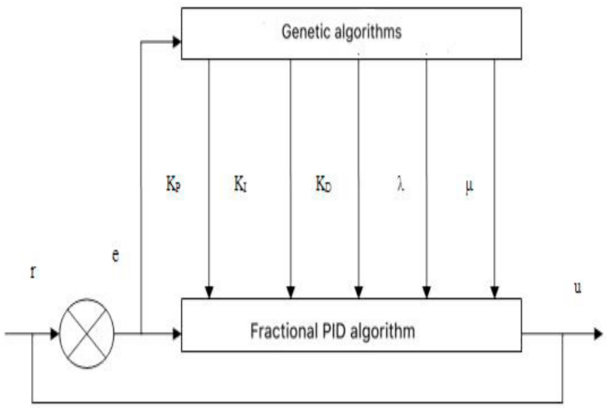

Figure 4 Principle diagram of fractional order PID controller based on improved genetic algorithm

The algorithm procedure of improved genetic algorithm is listed as follows:

Step 1: The size of population is defined by N, the maximum iteration times of improved genetic algorithm is defined by $I_{\max}$, and the chaos optimal controlling paramters are defined by χ and ψ respectively.

Step 2: let evolution generations $I = 0$, chaos initial population is defined by H_g, and the chaos optimal model is expressed by [5]

$$\phi_{i,j} = \lambda\phi_{i,j}^0(1-\phi_{i,j}^0) \quad (15)$$

Where, $\phi_{i,j}$ denotes the chaos vector, $\phi_{i,j}^0$ denotes the initial value, $i=1,2,\cdots N-1$, $j=1,2,\cdots,m$, m denotes the dimensions of decision vector. The chaos variables are mapped into the decision vectors, and the range of it is defined by $(x_{j\min}, x_{j\max})$, which satisfies the following expression:

$$x_{i,j} = x_{j\min} + (x_{j\max} - x_{j\min})\phi_{i,j} \tag{16}$$

Step 3: The non dominated sorting is carried out for population H_g, and the non dominated level is the fitness degree corresponding to the different solutions. And then the next generation population S_g with same size is generated through selection, crossover and mutation operations.

Step 4: The intersection of upper and next generation populations are selected, that is $C_g = H_g \bigcup S_g$. The non dominated sorting is used to generate the front surface of C_g, which is defined by $U=(U_1, U_2, \cdots)$.

Step 5: The crowding distance of non dominated front surface is calculated, and the intersection of them is taken, $H_{g+1} = H_{g+1} \bigcup U_i$, $i=i+1$. The end condition of iteration computation is set as $|H_{i+1}| + |U_i| \le N$. The sorting is carried out according to crowding distance of U_i, and the top $(N-|H_{g+1}|)$ solutions are selected.

Step 6: Confirm whether the optimal population is obtained. When individual number of population with non inferiority level of 1 is equal to size of population, the chaos refine method is used to find out top 10% of next generation population, and the searching space is defined by $(x'_{j\min}, x'_{j\max})$, and the relationship is expressed by [6]

$$\begin{cases} x'_{j\min} = x^*_{i,j} - \kappa(x_{j\max} - x_{j\min}) \\ x'_{j\max} = x^*_{i,j} + \kappa(x_{j\max} - x_{j\min}) \end{cases} \tag{17}$$

where , κ is the searching optimization factor, κ is equal to 0.35 in this research.

If $x'_{j\min} < x_{j\min}$, and then $x'_{j\min} = x_{j\min}$; If $x'_{j\max} > x_{j\max}$, and then $x'_{j\max} = x_{j\max}$.

The chaos variable $x'_{i,j}$ can be obtained after mapping. And then the linear computation is carried out for chaos variables $x'_{i,j}$ and $x_{i,j}$ [7]:

$$x''_{i,j} = (1-\gamma)x'_{i,j} + \gamma x_{i,j} \tag{18}$$

where, γ denotes the regulation coefficient.

The Step 3- Step 5 are executed circularly. When the end condition is satisfied, return to Step 7.

Step 7: The optimal solution collection is output, and the calculation is over.

5. Controlling Simulation Analysis of Water Supply System of Boiler

In order to verify the effectiveness of ATC89C55 and fractional order PID controlling algorithm, controlling simulation analysis of water supply system of boiler is carried out based on traditional PID algorithm and fractional order PID algorithm respectively, and the parameters of improved genetic algorithm are set as follows: size of population is 1500, the maximum iteration times is 160, $\chi = 1.5$, $\psi = 1.2$, $\gamma = 0.4$.

The temperature and pressure of boiler are required to be 480K and 1.2MPa respectively, and the controlling simulation curves are shown in figures 5 and 6 respectively.

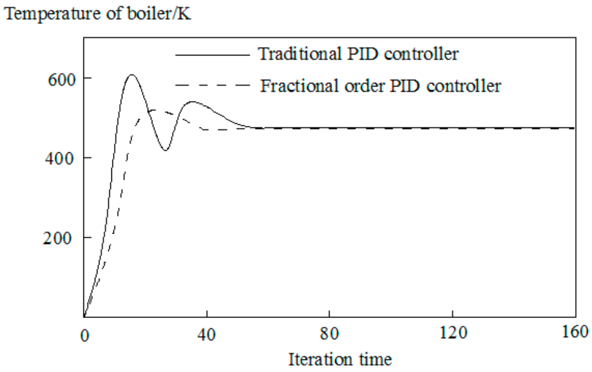

Figure 5 Controlling simulation curve of temperature of boiler

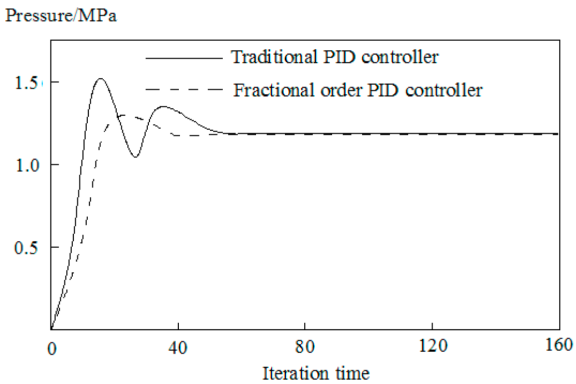

Figure 6 Controlling simulation curve of pressure of boiler

As seen from figures 5 and 6, the fractional order PID controller has quicker response speed and less overshoot than traditional PID controller. Therefore the controlling effect of temperature and pressure of boiler has been improved obviously, and then the working reliability of boiler can be ensured.

6. Conclusions

The AT89C55 is applied in controlling the industrial boiler, and the water supply temperature and pressure can be ensured to be stable. The AT89CC55 can run stably. Controlling simulation analysis is carried out, and results shown that the fractional order PID controlling algorithm can obtain better controlling effect than traditional PID controller. The water supply system of boiler based on AT89C55 and fractional order PID controller has lower cost, stronger anti-interference ability, and better controlling performance. Therefore the new system can be applied in controlling water supply system of boiler in further.

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