DESIGN OF POROUS MEDIA BURNER CONTROL SYSTEM BASED ON ARM EMBEDDED PROCESSOR

by

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Because the traditional porous media burner control system has the problems of low control accuracy and long control time, a porous media burner control system based on Advanced RISC Machines (ARM) embedded processor is designed. The hardware of the system is designed through ARM embedded processor, FPGA data acquisition card, power supply circuit, reset circuit and audible and visual alarm module, and the system software is designed based on it. According to the structure of fuzzy controller, fuzzy control rules, assignment table of fuzzy variables, fuzzy control table, and defuzzification, the fuzzy controller is used to fuzzy control the porous media burner. The simulation results show that the designed system has the highest precision and the shortest control time

Key words: ARM, embedded processor, porous medium, burner, control system

Introduction

At present, the combustion of gaseous fuel in the field of industrial heating in China is mainly atmospheric combustion characterized by free flame. It is a traditional combustion mode with low combustion efficiency. The combustion process emits a large amount of NO_x and Co, which seriously pollutes the environment. In recent years, countries around the world have increasingly stringent standards for the content of exhaust pollutants (NO_x, Co, SO_x). International advanced combustion equipment companies have shifted their research and development focus from improving combustion efficiency to improving combustion efficiency and reducing pollutant emissions [1]. From the perspective of global and national development strategies, vigorously carry out energy conservation and emission reduction, promote the technological revolution of gas fuel combustion and develop new combustion equipment are the technical trends of future development. Porous media combustion (PMC) technology is a new combustion mode developed in the international combustion field in recent ten years. The preheating zone is small pore porous medium, and the combustion zone is large pore porous medium [2]. After the gas and air are fully mixed in the premixing chamber, they flow through the preheating zone and then enter the porous medium combustion zone for combustion. Its advantages are:

– The combustible gas is fully mixed with air, which improves the combustion efficiency, reduces CO emission and reduces fuel consumption.

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– Uniform combustion avoids local high temperature, reduces the emission of thermodynamic NO_x, and makes the work piece heated evenly.
– The heat transfer form dominated by high temperature solid radiation avoids the problem of *frequency band Window* of high temperature flue gas radiation, improves the heating efficiency and saves the heating time.
– The self-reflux of heat contributes to the stable combustion of low calorific value fuels (such as blast furnace gas, converter gas, organic waste gas, *etc*.) [3].

Therefore, this technology is a combustion technology of *energy conservation and emission reduction*. At present, in Japan, Germany, the USA and other countries, PMC technology has been successfully applied to some gas combustion equipment in metallurgy, machinery, chemical industry, ceramics, food and other industries. In order to ensure the normal and reliable operation of the boiler, a porous media burner control system is designed to effectively predict and prevent tempering, adapt to the combustion of gases with different calorific values, monitor and diagnose the use of porous media materials in real time [4].

Huang *et al*. [5] designed a porous media burner and its control system for the field of medium and high temperature heating, which can realize the efficient and clean combustion of gases with different calorific values, and has the functions of preventing tempering and flame monitoring. Combustion tests were carried out on several porous media materials with different materials (Al_2O_3, SiC, SiC-Al_2O_3 composite materials). The results show that different materials have different time to achieve stable combustion, and SiC is the fastest, Al_2O_3 material is the slowest. The maximum surface temperature of porous media is the same when the three materials are stable combustion [6]. The volume fraction of NO_x and CO in flue gas is low during stable combustion, but it also shows some differences due to different materials. The volume fraction of NO_x in flue gas of SiC material is slightly higher than that of the other two materials, and the volume fraction of CO is significantly higher than that of the other two materials. Wu [7] designs the air distribution parameter control system of aggregate drying pulverized coal burner, selects the pulverized coal burner of LB2000 asphalt mixing plant as the research object, aims at constant flame temperature, combustion economy and safe operation of the burner, and takes air volume and pulverized coal quantity as the main control quantities to control the flame temperature and flue gas oxygen content of the pulverized coal burner. The main research contents of this paper are:
– Based on the engineering requirements of aggregate drying process on the flame temperature of pulverized coal burner, the mathematical model of flame temperature control is established, and the flame temperature control system of pulverized coal burner is established by using MATLAB software. Through comparison, it shows that the adaptive fuzzy PID plays a significant role in flame temperature control, which can reduce the flame fluctuation of pulverized coal combustion and enhance the anti-interference ability.
– Controlling the ratio of air volume and pulverized coal will affect the oxygen content and flame temperature of flue gas at the same time. The oxygen content of flue gas is an important indicator of combustion efficiency and pollutant emission. Because the pulverized coal burner is a multivariable control system, the fuzzy decoupling control algorithm is used to analyse the simulation results through SIMULINK platform, which weakens or even eliminates the correlation between flue gas oxygen content and flame temperature, and effectively controls the flue gas oxygen content.
– According to the general requirements of pulverized coal burner, the control system of pulverized coal burner is determined. Combined with the working environment of high temperature and high radiation of pulverized coal burner, current sensor is often used to

replace voltage sensor in the selection of pulverized coal burner hardware. In order to overcome the characteristics of large energy consumption and low control sensitivity of the damper, frequency conversion speed regulation of primary air and secondary air volume, as well as the selection of flame temperature and flue gas oxygen content detector under high temperature conditions are selected. Although the previous two systems have realized the control of porous media burner, the control accuracy is low and the control time is long.

In view of the problems existing in the previous system, this paper designs a porous media burner control system based on ARM embedded processor, and through simulation experiments, it is verified that the system can control the porous media burner quickly and accurately, which provides the necessary guarantee for the safe and efficient operation of the control system.

Design of porous media burner control system based on ARM embedded processor

System hardware design

The ARM embedded processor

In 1985, the first ARM prototype was born in ACOM Computer Co., Ltd. in Cambridge, UK, and was manufactured by San Jose VLSI technology company in California, USA. In recent years, ARM has become a very influential microprocessor designer in embedded systems. It authorizes its technology to many famous semiconductor, software and OEM manufacturers in the world [8]. At present, a total of 30 semiconductor companies have signed hardware technology license agreements with ARM, including large companies such as Intel, IBM, LG semiconductor, NEC, and Sony. As for the partners of software systems, they include a series of well-known companies such as Microsoft, Shengyang, and MRI. The ARM architecture is the first RISC microprocessor designed for low-cost market. Its main features are:

– Adopt fixed length instruction format.
– A large number of registers are used. Data processing instructions only operate on registers. Only loading and storing instructions can access the memory, so as to improve the execution efficiency of instructions.
– Single cycle instruction is used to facilitate pipeline operation and execution.
– The loading and storage instructions can be used to transmit data in batches to improve the transmission efficiency of data.
– In the loop processing, the increase or decrease of address is used to improve the operation efficiency [9].

Based on the aforementioned functions, this paper selects the ls1043a processor of NXP as the main controller, because this processor can provide enough hardware and software resources and save a lot of development process. The ls1043a processor is a quad core 64-bit ARM processor launched by NXP. It supports flexible I/O package with fan free design. It can run with only 6 W power and up to 1.6 GHz. It perfectly combines the advantages of high performance and high energy efficiency. In addition, it optimizes the BOM for the economical low-end PCB and reduces the hardware cost. The JTAG, UART, and 3 pcie2 are reserved in the self-designed data acquisition system based on ls1043a processor 0 interface, 2 usb3 0, and one 10g and one 1000m Ethernet interface, and the interface between ls1043a and FPGA adopts pcie2 0 interface, and 2 PCIe interfaces that can be used are reserved [10]. The design framework of ls1043a processor is shown in fig. 1.

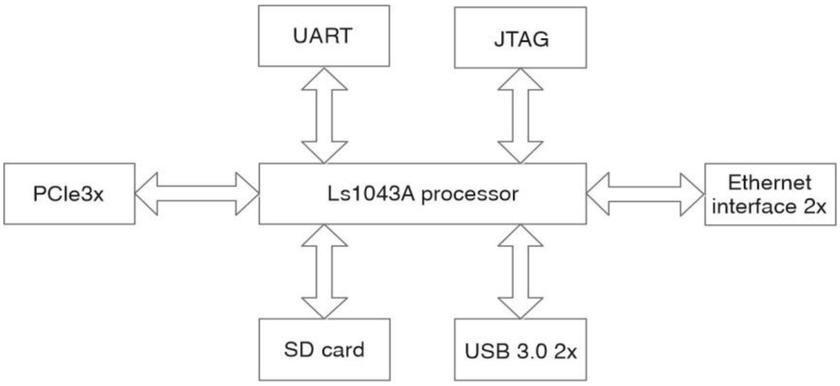

Figure 1. The Ls1043a processor design framework

The FPGA data acquisition card

The FPGA data acquisition card is designed based on Xilinx artix-7 series xc7a200t chip, mainly including DMA data transmission controller, PCIe controller, ADC module, IP core, interrupt control mechanism, address decoding, and mapping mechanism, *etc*. The FPGA data acquisition card supports PCIe 2.0 function, which can realize the framing coding, decoding and demodulation functions of LTE protocol physical layer, and meet the interpolation, extraction, filtering and other functions required in general signal processing [11]. The functional block diagram of FPGA data acquisition card is shown in fig. 2.

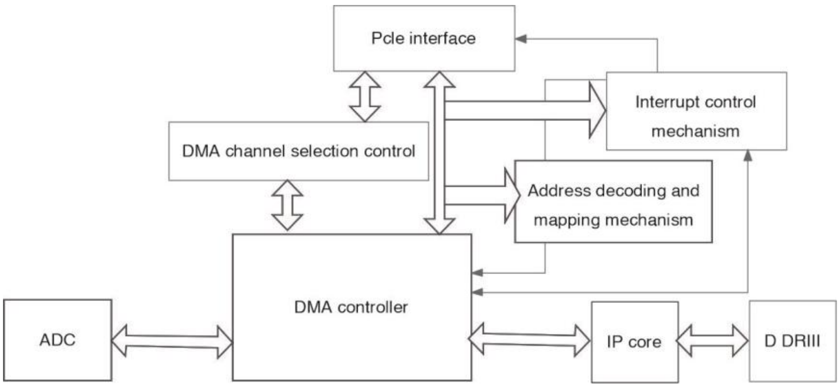

Figure 2. The FPGA design block diagram

The data acquisition system implemented in this paper needs high-speed data transmission between FPGA and arm through PCIe bus. Because DMA bypasses CPU for data transmission, it is conducive to improve data transmission performance, so DMA controller is integrated in the hardware design of FPGA data acquisition card [12]. In addition, the IP core in the FPGA data acquisition card realizes the reading and writing of DDRIII memory. When the ARM controller writes the data to the DMA buffer, it will send an interrupt to the FPGA. After the FPGA identifies the interrupt through the interrupt control mechanism, the DMA controller reads the DMA buffer data into FIFIO, and then puts the data in FIFO into DDRIII after processing by the IP core. On the contrary, when FPGA sends data to ARM, it also checks the reading of DDRIII through IP, sends the data to DMA buffer through PCIe bus, and then the interrupt control mechanism sends interrupt to ARM to make ARM read the data in DMA buffer.

Power circuit

As the power source of the system, the power supply plays a vital role in the performance of the whole system, so it is very important to design a good power circuit for the system. The system requires two different power supplies, 5 V and 3.3 V, respectively. Among them, the power supply voltage of ad controller and CPLD is 3.3 V, and the power supply voltage of operational amplifier and some other common chips is 5 V. The design of 5 V source is relatively mature, and there is a ready-made 5 V power adapter; In order to obtain 3.3 V, 5 V conversion methods is generally adopted. The voltage conversion chip used in this system is AMS1117 series power conversion chip AMS1117-3.3 provided by AMS company (the world's leading power management IC design company). The AMS1117-3.3 can provide stable 3.3 V output. The maximum line adjustment rate and maximum load adjustment rate are 0.2% and 0.4%, respectively, with stable performance [13]. The 5 V to 3.3 V conversion circuit of the system is shown in fig. 3.

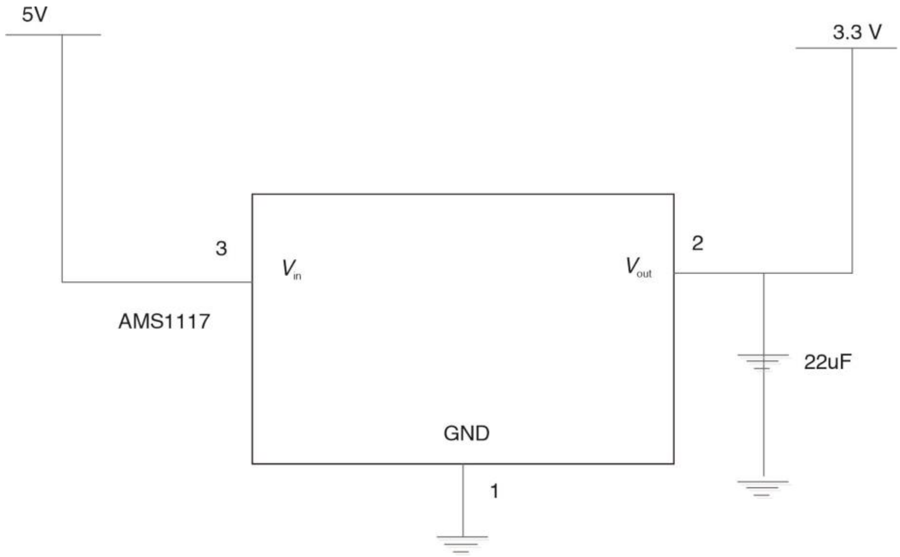

Figure 3. Power circuit design

In addition, in order to obtain a stable 3.3 V output, the voltage output must be filtered, and the filter circuit is shown in fig. 4.

Reset circuit

The reset device of the main controller ensures that the main controller is reset in a known and safe state. During power on, power down or power saving, reset will send a reset signal to prevent code execution errors. Due to the characteristics of high speed, low power consumption, and low working voltage ARM chip has low noise tolerance, which puts forward higher requirements for power ripple, transient response performance, clock source stability, power monitoring reliability and so on. The reset circuit of the system uses a special microprocessor power monitoring chip max809r, which improves the reliability of the system [14]. The Max809r is a single function microprocessor reset chip, which is used to monitor the power supply voltage of microcontroller and other logic systems. It can provide reset signals to microcontroller under power on, power off and power saving conditions. When the voltage is lower than / reset threshold voltage (the typical value of max809r is 2.63 V), the

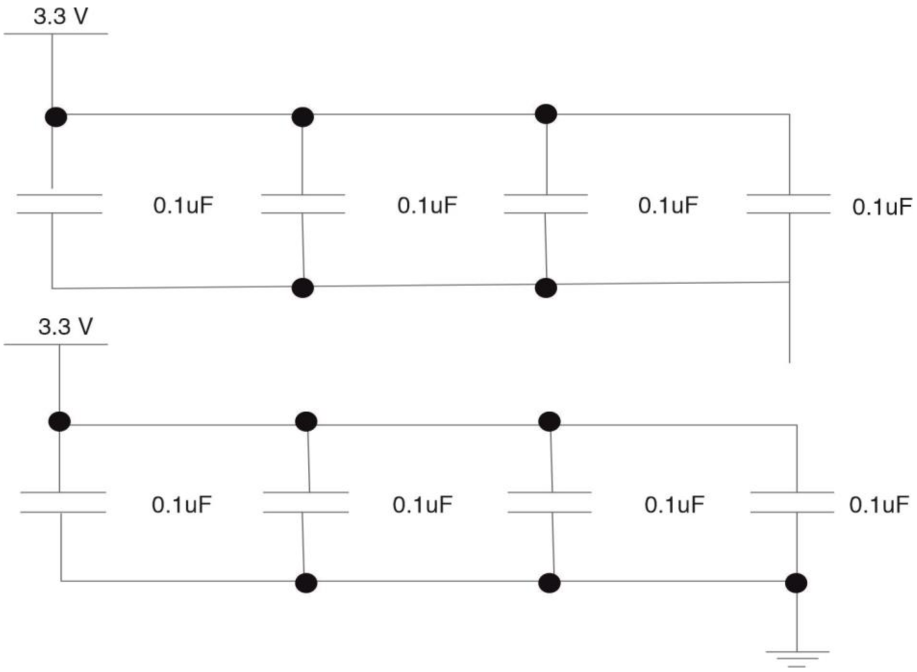

Figure 4. Power filter circuit

monitoring circuit will continue to generate reset signal to reset the CPU and peripheral interface. This reset signals will remain until the reset signal is released after the power supply voltage is higher than the threshold voltage for at least 140 ms. This delay time helps to ensure effective reset signal in case of unstable power supply voltage and avoid accidents caused by abnormal operation. The Max809 has push-pull output stage, so there is no need to pull up [15]. The reset circuit is shown in fig. 5.

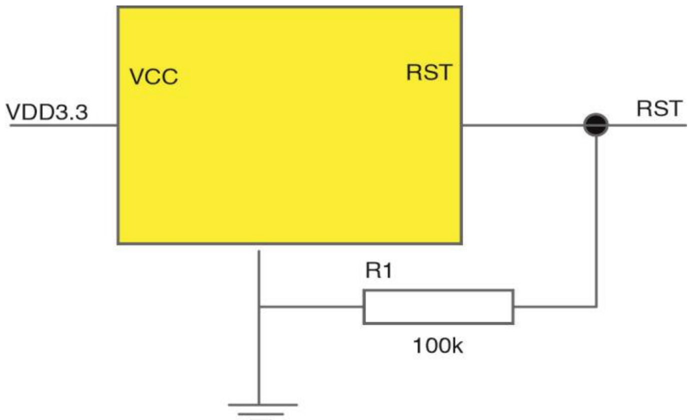

Figure 5. Reset circuit of main controller

Audible and visual alarm module

The audible and visual alarm module is composed of a buzzer and a plurality of light-emitting diodes. Through the different combination states of LED and buzzer, it indicates the overrun of porous media burner parameters and system failure, so as to remind the operator to deal with them accordingly. In this paper, a buzzer and two light-emitting diodes LED1 and LED2 are used to simulate the audible and visual alarm. The two LED are directly connected with the 4th and 5th bits of microprocessor port B, and the buzzer is directly connected with the third bit of microprocessor port E. When the system works normally, LED1 on indicates that the temperature exceeds the upper limit, LED2 on indicates that the temperature exceeds the lower limit, LED1 and LED2 on indicate that the humidity exceeds the lower limit, and the buzzer will sound when the system fails and the parameters exceed the limit [16]. Figure 6 shows the buzzer circuit.

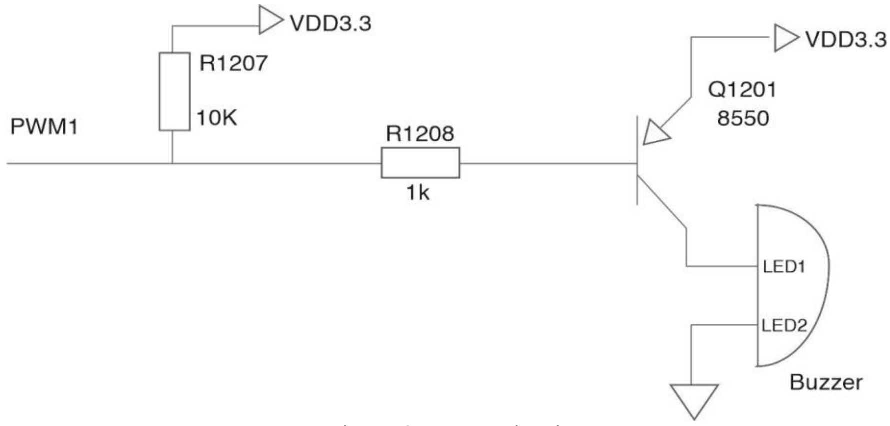

Figure 6. Buzzer circuit

Fuzzy control algorithm of porous media burner

Fuzzy control method is to imitate people to use language variables to describe the fuzzy concept in controlling complex objects, so as to realize the control of complex controlled objects. This is precisely an important feature that fuzzy control is different from traditional control. Traditional control uses numerical variables. Fuzzy control is a kind of nonlinear intelligent control, which does not require the controlled object to establish a high-precision mathematical model. It usually forms a digital control system with feedback channel and closed-loop structure with microcomputer. In this paper, the fuzzy controller is designed for the fuzzy control of porous media burner, including the structure of fuzzy controller, fuzzy control rules, assignment table of fuzzy variables, fuzzy control table and defuzzification [17]:

- Determine the structure of fuzzy controller

The structure design of fuzzy controller refers to determining the specific input and output fuzzy set and its universe of fuzzy controller. The 1-D fuzzy controller that only uses error, *E*, as the input variable, the 2-D fuzzy controller that uses error, *E*, and error change rate, *EC*, as the input variable, and the 3-D fuzzy controller that uses error, *E*, error change rate, *EC*, and error change rate as the input variable. In general, the most common structural form is univariate 2-D fuzzy controller [18].

For example, for the input variable error, *E*, the error change rate, *EC*, and the output control variable, *u*, the language variable word set contains seven words: negative large, negative medium, negative small, zero, positive small, and positive large. The corresponding English abbreviations are: Nb, NM, NS, O, PS, PM, Pb, the corresponding domain of error, *E*, and error change rate, *EC*, is {–3, –2, –1, 0, 1, 2, 3} and the domain of control variable, *u*, is {–4.5, –3, –1.5, 0, 1.5, 3, 4.5}.

– Establish fuzzy control rules

Fuzzy control rules can be summarized into three rules: one is the rule of rapid response to large errors, the other is the damping rule to prevent overshoot, and the third is the steady-state rule that the error maintains a small change near zero.

The fuzzy control rule for eliminating systematic errors according to the trend of error, E, and the rate of change of error, EC, has the form:

If the error is A and the change of error is B, the control quantity is C and it is expressed in the conditional statement composed of Related words as:

$$\text{If } E = A \text{ and } EC = B \text{ then } u = C$$

Fuzzy control rules are a summary of the actual control experience of personnel, and still follow the basic principles of feedback control. The fuzzy model of the controlled process is formed by the description of many fuzzy control rules, such as the relationship between feed water and heating and the water level of the boiler, the relationship between the motor excitation and the rotational speed, the relationship between the yaw angle and the heading of the aircraft, *etc*. If the control objects are different, the corresponding meanings of the error, E, the rate of change of the error, EC, and the control quantity, u, in the conditional statement are also different [19].

– Determine the assignment table of fuzzy variables

After determining the fuzzy set universe of fuzzy variable error, E, error change rate, EC, and control variable, u, it is necessary to determine the membership degree of the elements in the universe to the fuzzy linguistic variable, that is, to determine the membership function for the fuzzy linguistic variable, also called as fuzzy variable assignment. The assignment of fuzzy variables is determined according to the specific conditions of different objects, and is usually given in the form of an assignment table [20].

– Establish a fuzzy control table

The fuzzy control rules described above can be represented by a fuzzy control rule table. The relationship between the fuzzy conditional statements of fuzzy control is OR, and the control rules determined by the conditional statements can calculate the fuzzy control set, u, of the control quantity. The control rule determined by the first sentence can calculate, u_1, and similarly the other sentences can obtain, u_1, u_2, u_3,…, u_{49}, respectively, then the fuzzy control set, u, can be expressed as:

$$u = u_1 + u_2 + u_3 + ... + u_{49} \tag{1}$$

– Defuzzification

The previously obtained through fuzzy reasoning is the fuzzy quantity, but the actual control must be the precise quantity. Therefore, the task of defuzzification calculation is to convert the fuzzy quantity of the fuzzy quantity, u, into the precise quantity. The choice of the defuzzification method is very important, which affects the accuracy of the control quantity. It is required that the calculation result of the membership function can be accurately expressed and output. The most common and concise and accurate method is the weighted average method. The idea of this method is to use each element x_i(i = 1,2,…, n) in the universe as the weighting coefficient of the membership degree, $u(i)$, of the output fuzzy set, that is, to calculate the sum of the membership degrees of the products, $x_i u(i)$ and $\sum_{i=1}^{n} x_i u(i)$. The mean x_0, that is:

$$x_0 = \frac{\sum_{i=1}^{n} x_i u(i)}{\sum_{i=1}^{n} u(i)} \tag{2}$$

The average value, x_0, obtained by the weighted average method is the decision result of the fuzzy set. Finally, the actual value of the control quantity is obtained by multiplying the output quantization factor by x_0 to meet the control requirements.

The intelligent PID control method based on the porous media burner control system proposed in this paper is composed of two parts: intelligent control and PID control. Using the intelligent control method, the parameters of the PID controller can be adjusted on-line to meet the requirements of the control object (porous media burner control system) for high-precision control [21].

The inputs of the fuzzy adaptive PID controller are *e* and *ec*, respectively, namely the error, *e*, between the actual steam pressure and the set pressure and the rate of change, *ec*, of the error. The output variable is ΔK_P, ΔK_I, ΔK_D, which is the adjustment amount of the PID controller parameters. On-line tuning of PID parameters is realized according to fuzzy control rules.

In the fuzzy control algorithm, the basic domain is the actual range of the input quantity. According to the system characteristics, the basic domain of *e* is taken as [–60, 60], and the basic domain of *ec* is [–8, 8]. Let the fuzzy domain of the deviation *e* and the deviation change rate *ec* be {–6, –5, –4, –3, –2, –1, 0, 1, 2, 3, 4, 5, 6}. In order to carry out fuzzy reasoning, the basic universe of discourse must be discretized into the fuzzy universe of fuzzy subsets, which is achieved by the quantization factor K_e, K_{ec}:

$$K_e = \frac{n}{e} = \frac{6}{60} = 0.1 \tag{3}$$

$$K_{ec} = \frac{m}{ec} = \frac{6}{8} = 0.75 \tag{4}$$

where *m, n* are the fuzzy universe value and *e, ec* are the basic universe value.

For the control object of this paper, after repeated experiments, the combination of normal membership function and triangular membership function is ideal for the input quantities *e* and *ec*. The normal type membership function can properly represent the fuzzy correspondence, and the fuzzification results are accurate, while the triangular membership function requires less computation and is easy to adjust. The membership function combining the two can make full use of its advantages. When the input variable value is large, the normal distribution membership function is relatively stable, which ensures the stability of the system. When the input variable value is small, the triangular membership function compares steep, high system resolution [22, 23].

Taking the fuzzy domain value of the output ΔK_P, ΔK_I, ΔK_D of the fuzzy controller as {–3, –2, –1, 0, 1, 2, 3} the membership function of the fuzzy language value is the same as that of *E*. In this paper, the weighted average method is used to de-fuzzify the output. which is:

$$c = \frac{\sum_{i=1}^{l} c_i u(i)}{\sum_{i=1}^{l} u(i)} \tag{5}$$

where c is the exact value of the output, c_i – the fuzzy domain value of the output, and $u(i)$ – the membership degree corresponding to c_i in each fuzzy subset. To convert the precise quantity into the basic domain of PID parameters is the real PID parameter adjustment quantity. The desired adjustment can be obtained by multiplying the output of the fuzzy controller by the scaling factor. Let the scale factor, G, be defined as:

$$G = \frac{u}{l} \tag{6}$$

where $[-u,u]$ is the basic domain of discourse and l – the number of quantization files. Generally, the larger the value, the faster the system response, but if it is too large, the system will be unstable. Therefore, the basic domain of ΔK_P set in this paper is [–0.4,0.4], the basic domain of ΔK_I is [–0.06,0.06], the basic domain of ΔK_D is [–3,3], and the corresponding scale factor is $G_P = 4/30$, $G_I = 0.02$, and $G_D = 1$.

The calculation method for on-line adjustment of the parameters of the PID controller is as:

$$\Delta K_P = \Delta K'_P + G_P \Delta K_P \tag{7}$$

$$\Delta K_I = \Delta K'_I + G_I \Delta K_I \tag{8}$$

$$\Delta K_D = \Delta K'_D + G_D \Delta K_D \tag{9}$$

where K_P, K_I, K_D are the PID controller parameter, K'_P, K'_I, K'_D – the initial parameter value of the PID controller, ΔK_P, ΔK_I, ΔK_D – the adjustment amount, and G_P, G_I, G_D – the scale factor.

For the control system of the porous medium burner, the burner is kept within the allowable error range of the set value by adjusting the heat released by the combustion. The fuzzy controller designed in this paper makes decisions through the pressure error, e, and its rate of change, ec. Since the output of the fuzzy controller is the adjustment amount of the PID controller parameters, the establishment of fuzzy rules must consider the effect of the PID parameters on the entire control characteristics influence. The tuning principles are:

- When the deviation $|e|$ is large, it is necessary to eliminate the error as soon as possible, speed up the system adjustment stage, and at the same time avoid the differential oversaturation caused by the instantaneous increase of the deviation $|e|$, resulting in the control output exceeding the control limit, so K_P should be selected. In addition, a small value of K_D can prevent the occurrence of differential saturation, and at the same time remove the integral action, namely $K_I = 0$, which can effectively avoid integral saturation, so that the system response will not have a large overshoot.
- If $|e|$ and $|ec|$ have the same sign, it means that the error tends to increase in absolute value. When the values of the deviation $|e|$ and the deviation rate of change $|ec|$ are moderate, the system is in the following process. To reduce the overshoot of the system response, the value of K_P, K_I, K_D should not be too large, the value of K_P should be smaller, and the value of K_I and K_D should be moderate. If the deviation $|e|$ is relatively large, a strong control should be applied, that is, a larger K_P torsion error change trend should be taken, and the absolute value of the error should be quickly reduced. At the same time, a small K_I and a medium K_D should be used to improve the dynamic performance and steady-state. If the deviation $|e|$ is relatively small, the change trend of the error can be changed by general control. Taking a moderate K_P, a large K_I and a small K_D can increase the stability of the system and prevent the occurrence of oscillation.

– If *e* and *ec* have different signs, it means that the error tends to decrease in absolute value. If the error $|e|$ is large, general control can be applied to reduce the absolute value of the error, taking a moderate K_P, while taking a small K_I and a moderate K_D to improve the dynamic and steady-state. If the deviation $|e|$ is relatively small, in order to make the system stable, K_P, K_I should be increased, and at the same time, in order to avoid oscillation near the stable value, the K_D value should be appropriately selected to enhance the robustness of the system.

Simulation experiment analysis

In order to verify the effectiveness of the porous media burner control system based on ARM embedded processor in practical application, a simulation experiment is carried out. In this paper, a single experimental platform of porous media burner is built for experimental research. The composition of the experimental platform is shown in fig. 7.

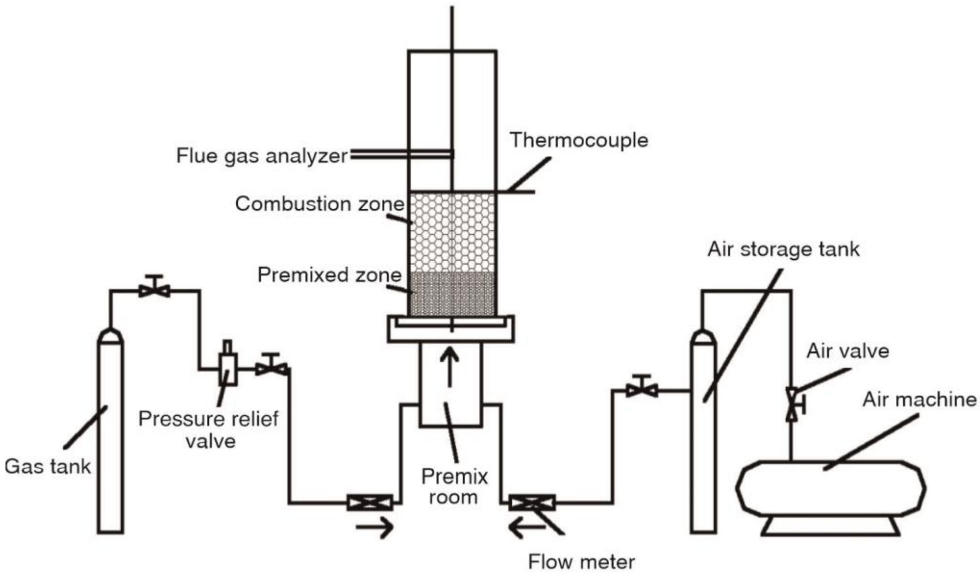

Figure 7. Composition of monomer experimental platform

The experimental gas is natural gas, and the combustion supporting air is provided by the air compressor. An air storage tank is set to stabilize the combustion supporting air pressure. The gas flow measurement adopts mass flow meter, and the control accuracy can reach 0.5% of 1 Lpm. The flue gas composition is measured by the flue gas analyser (TETO 350), and the temperature of the porous media panel is measured by the infrared thermal imager (fluke tix660). The surface of the porous media is equipped with a contact thermocouple (S-type) to measure the temperature of the porous media panel. The temperature measurement results of the infrared thermal imager and the thermocouple can be mutually confirmed, and the thermocouple is connected with a temperature collector. Sic Porous Media with 60 PPI in the small hole area and three kinds of porous media in the large hole area are Al_2O_3, SiC, and SiC-Al_2O_3 composite materials, respectively. The pore size of the large hole is 10 PPI. The test condition is that the excess air coefficient is equal to 1.08. Combustion heat load: 500 kW/m^2.

In this paper, bcs4 porous media burner is selected as the experimental object, as shown in fig. 8, and its parameter settings are shown in tab. 1.

Figure 8. Porous Media Burner

Table 1. Parameter setting of Porous Media Burner

Supply voltage	AC 220 V, 50 Hz
Voltage fluctuation	AC 160~240 V
Power consumption	280 W
Insulation resistance	Between external terminals above 20 mΩ (dc500 megohmmeter) and power supply
Working temperature	0 ℃ ~+ 55 ℃
Work environment	It shall not contain corrosive gases

In order to verify the effectiveness of this system, the porous media burner control system based on ARM embedded processor, [5] system and [6] system designed in this paper are used to compare and analyse the control accuracy of porous media burner. The comparison results are shown in fig. 9.

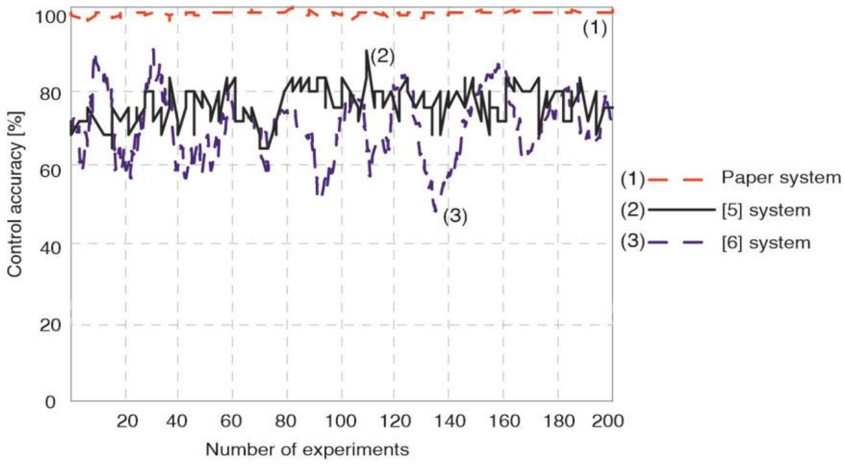

Figure 9. Comparison results of control accuracy of porous media burner of three systems

According to fig. 9, the porous media burner control system based on ARM embedded processor designed in this paper can control the porous media burner with a maximum accuracy of 99%, which is higher than that of the [5] system and the [6] system.

In order to further verify the effectiveness of this system, the porous media burner control system based on ARM embedded processor, [5] system and [6] system designed in this paper are used to compare and analyse the time spent in the control of porous media burner. The comparison results are shown in fig. 10.

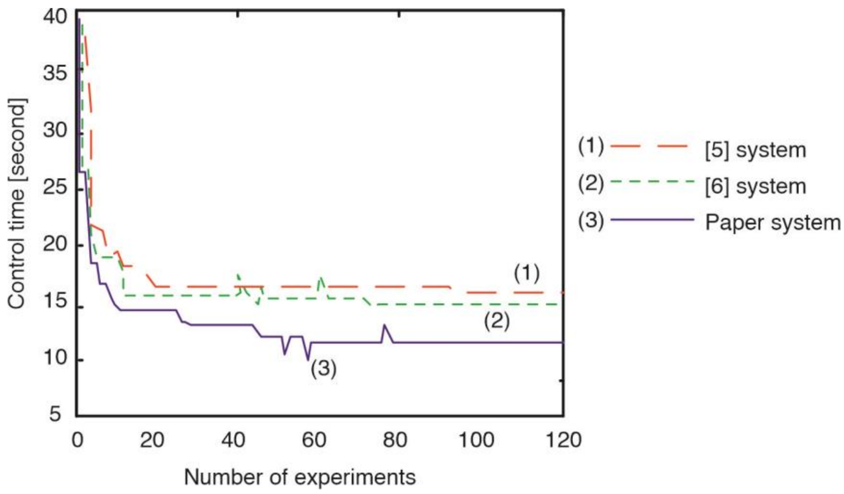

Figure 10. Comparison results of porous media burner control time of three systems

According to fig. 10, the porous media burner control system based on ARM embedded processor designed in this paper takes less than 14 seconds to control the porous media burner, and the time taken for the porous media burner control by [5] system and [6] system is less than 20 seconds. It shows that the porous media burner control system based on ARM embedded processor designed in this paper consumes the shortest time to control the porous media burner.

Conclusion

In view of the long time and poor control effect in the control process of porous media burner in the traditional system, this paper uses ARM embedded processor to design a new porous media burner control system, including system hardware and software. The system hardware is composed of ARM embedded processor, FPGA data acquisition card, power supply circuit, reset circuit and audible and visual alarm module. The system software completes the fuzzy control of porous media burner based on the fuzzy controller through the steps of fuzzy controller structure, fuzzy control rules, fuzzy variable assignment table, fuzzy control table, and defuzzification. The simulation results show that the porous media burner control system based on ARM embedded processor designed in this paper has the shortest time and the highest control accuracy, and improves the control effect and efficiency of porous media burner.

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