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Design for Temperature Control System of Ignition Point Detection Instrument Base on Self-adaption

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For the purpose of better solving the problems about temperature control in ignition point detection, this paper studies the design for temperature control system of ignition point detection instrument based on self-adaption. This research is carried out through referring to related documents and least square algorithm to design hardware structure, temperature control system, technology and others of instrument. The result shows that the temperature response of controlled heating furnace can better track the given temperature rising curve and can reduce the effect produced by time delay and large inertia on temperature control system of ignition point detection instrument. The self-adaption Dahlin controller in this paper can better meet the requirements of heating rate control in ignition point test for coal sample and with fine practicality and accuracy, which is worthy of application.

1. Introduction

It is known to all that temperature is one of the most important parameters in petrochemical industry, electric power industry and others. Under the background of industrialized era of our country, the work difficulty of temperature measurement and control in chemical industries is increasing. Therefore, it is necessary for our country to spare more efforts for temperature measurement and control technology. Currently, the information technology and communication technology have been widely employed in various walks of life in China, especially in domestic industrial enterprises. Benefiting from the development of high and new technology, the systematization, intelligence and informatization are the future development direction of ignition point detection instrument of our country. All kinds of measurement and control equipment are digitized and can be centrally managed and controlled with the aid of network information technology platform. The ignition point of coal sample is one of the important technical parameters for coal enterprises. All the time, its measurement has always been regarded as the overriding work for enterprises and is closely related to the safety and economy of coal industry. Meanwhile, the explicit provisions for temperature control of ignition point detection instrument have been formulated in relevant laws of our country as well. However, in practice, some problems about ignition point detection instrument still exist in most of enterprises and need to be improved.
Aimed at above-mentioned background, the paper studies the design for temperature control of ignition point detection instrument based on self-adaption in order to better solve the problems regarding temperature control in ignition point detection. The author refers to related documents and design hardware structure, temperature control system and others of instrument to compose temperature control system of ignition point detection instrument through least square algorithm.

2. Literature review

According to the characteristics of temperature intelligent control, the automatic temperature control system is designed and analyzed based on PLC. Through the requirement of the control function, electric control circuit is researched, and hardware is selected. According to the programming language, the main program is designed to satisfy the intelligent control which can keep the temperature in specially appointed rang. The design process provides some guidance for the development of the intelligent control with PLC (Liu et al.,

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2014). Causticizing process is a large inertial, large time-delay, time-varying process with many random disturbances.
Aiming at these problems, this paper improved the single-loop PID temperature control system and presented the feed-forward feed-back temperature control system based on fuzzy logic. This paper analyzed the limit of applying the feed-forward feed-back system and discussed the application of Smith predictor. Combined with traditional fuzzy PID feed-back controller, the fuzzy feed-forward control system was applied to compensated the impact of vapor pressure on causticizing temperature. Simulation result showed that improved control system was much better than the traditional single-loop PID control system in dynamic performance and robustness. At last the paper also verified its excellent control effect by practical applications (You et al., 2013).
The thermocouple calibration temperature control system is constructed USB - 4716 200 ks/s, 16 multi-function USB module, JKH-C series thyristor phase shift trigger, PC machine as the main hardware, the U.S. National Instrument (NI) company Labview as the software development platform. According to the precious metal, base metal thermocouple wire thermoelectric EFM method to determine the temperature test point, the temperature control system using automatic control to test furnace temperature and realize the visual operation interface. Temperature control accuracy: temperature deviation calibration point is less than ± 5 °C when testing the thermocouple, constant temperature stability: constant temperature's change is less than 0.2 °C /min in the thermocouple testing process (Zhou and Zhao, 2013). Using fuzzy neural network to tune PID parameters, and DSP as processor, it was designed that a set of electric boiler temperature control system based on PID parameters self-tuning, including the design of each hardware module and each software subroutine of the system. Experimental results show that compared with the traditional PID temperature control system, this temperature control system has the advantages such as good control effect, easy parameter adjustment, strong anti-jamming capability, better adaptability and robustness, has the feasibility and practical value (Chen et al., 2013).
To overcome the shortcomings such as big volume,big noise and limited control precision of the tra ditional temperature control system of the semiconductor laser, a temperature control system of the semiconductor laser is developed based on the MSP430F449 single chip and DS18B20 digital temperature sensor. In the system, the drive current is controlled by using PWM pulse width modulation and combining with PID algorithm, so the constant temperature of the laser is controlled. The experiment results show the steady temperature condition can be offered for the semiconductor laser (Zhang et al., 2012). Humans can perceive thermal sensation at most in hundreds of milliseconds after the contact with external objects. This point indicates that the temperature of thermal display must be controlled with the tracking time that is shorter than the perception time, in order to ensure the sufficient performance for rendering of thermal sensation. This research utilizes Peltier device as a thermal actuator of the system and constructs the temperature control system by combining heat disturbance observer and local temperature feedback in order to enhance the response speed of the system. The experimental results show not only that the designed system can track the reference with sub-second settling time, but also that the system is well nominalized to simple second-order system even in the short settling time, which means that the transient response is easily adjusted (Morimitsu and Katsura, 2012).
In order to achieve stable control of temperature in the process control, a system based on LabVIEW platform has been designed which can switch between fuzzy controller and PID controller, with the advantages and disadvantages of PID and fuzzy algorithm taken into account. In this paper, the PID parameter self-setting principle which is based on ASTROM limit cycle of law is also employed. The experiment results show that, the proposed method which combines fuzzy algorithm and PID control method, implemented by flexible online programming based on LabVIEW, can achieve high precision and strong robustness in the industrial applications (Wang, 2012). In order to control the temperature of Antiseptic Machine, the temperature control method based on fuzzy theory is presented. A program of temperature control system based on fuzzy theory is designed. The program transmits the temperature signal which is got from DS18B20 to TA89S52 and then transmits the control signal to AD421. The purpose is to control the corresponding solenoid valve work so that the Pakistan antiseptic machine090005s temperature can be controlled. The test result indicates that the structure of the control system is simple and effective. The proposed method can overcome the object090005s pure time delay characteristic with fast response and small overshoot (Yao et al., 2014).
In many areas of scientific research and production practice, the temperature is an important physical quantity need to measure and control. It is closely related to almost all of the physical and chemical processes and has great influence on the industrial production process and quality. Put the test chamber temperature control as the breakthrough point to research the predictive control theory and set up the predictive control algorithm model, to design and construct the test chamber of temperature measurement and control system. The system adopts the platinum resistance temperature sensor to test the temperature in the test chamber for real-time measurement. When the data is processed by the single-chip computer, it heats the control circuit accord

the predictive control model to realize the accurate control of temperature. The system can set the preset temperature through the keyboard on the instrument panel, and the displayer can display the temperature for real time in the test chamber.

3. Method

3.1 Basic principle of ignition point detection instrument for coal sample

The design of detection instrument refers to national standard of coal ignition point experiment in which the production method for coal sample (raw coal sample, oxidation sample and reduction sample), selection of sample glass test tube and use of copper heater are executed in strict accordance with national standard. The purpose is to make this new instrument be with reference and consistent with the test data of ignition point experiments conducted in the past. The basic steps of test are as follows:

1) 7 prepared coal sample tubes are first placed into 7 circular holes around copper heater in electric furnace (as shown in Figure 1). One standard Pt 100 thermal resistance is put into each coal sample tube and functioned as temperature measuring sensor. The platinum resistance placed in the middle of test tube is used to both measure ignition point and take temperature control sampling;

2) Then the power supply to electric furnace is connected to increase the temperature of coal sample. At the same time, temperature controller begins to control the temperature and the heating rate should be kept at 5±0.5°C per minute. Starting from 100°C, the current temperature values for a total of 7 coal samples are recorded every 1min and stored for view and to draw temperature rising curve for each coal sample;

3) When the temperature reaches 250°C, keep close watch on the coal sample tubes and wait for the occurrence of coal sample deflagration. When the deflagration happens in the coal sample tube, the thermal element for heating should be released immediately to accelerate heating up, so there must be a turning point on the temperature curve. This turning point, or called temperature of starting point, is taken as temperature of ignition point;

4) After all ignition points of coal samples are measured and the sign of automatic alarm shows the testing procedure is over, the data display subroutine is invoked to display the ignition point of each coal sample. The testing procedure is completed;

5) In the whole testing procedure, the heating curve and ignition point data recorded by SCM are taken as the final measuring result. If necessary, the result can be printed by printer. No one needs to be on duty, the data stored in nonvolatile memory can be queried when needed.

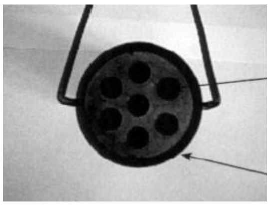

Figure 1: The cross section of the copper heater

3.2 Hardware structure of instrument

In consideration of the fact that the ignition point for most of coal samples is between 300℃ and 400℃, the measuring range of this instrument is set from 0°C to 450°C. The platinum (Pt100) thermistor sensor (range of measuring temperature≤1 000°C) selected to perform temperature measurement can meet the range of measuring temperature required by this instrument. The sensor adopts unbalanced bridge three-line connection. This connection mode can compensate for the effect produced by long-line resistance to improve the accuracy of temperature measurement. The small-signal voltage output from bridge circuit is sent to A/D for analog-to-digital conversion after being amplified by integrated single-supply instrumentation amplifier, AD623. This amplifier can provide output with full power supply at (+3V–+12V) single power supply and allows the use of single gain for setting resistance to conduct gain programming so that the users can use flexibly.

Output control module adopts zero-crossing trigger solid state relay. The internal of this solid state relay comes with photo coupling and can be directly driven by single chip port cable. Owing to zero-crossing trigger, the harmonic pollution will not be produced in electric network. The minimum power regulation unit is the power occurred within 10ms, which is the power occurring in half cycle of power frequency voltage. The keyboard comprises of four keys, function key, execution key, up addition key and down subtraction key. Function key and execution key are used to select and execute the selection and switching for clock adjustment, sampling, control, data display and others. The up addition key and down subtraction key perform switching of sampling channel number, as well as addition and subtraction function for clock adjustment. The display component comprises of 5 7-Seg LED Nixietubes. The display clock includes hour, minute and second readings. When sampling and controlling, the first reading is to show current sampling channel number and the last four shows the temperature reading with a decimal point. The control panel is shown in Figure 2.

Figure 2: The control panel of the coal sample burning point detection instrument

3.3 Temperature control function of ignition point detection instrument for coal sample

The temperature control regulator formed by software provides users with self-adaption Dahlin control algorithm. After the temperature rise for maximum temperature that is allowed to reach has been set and the heating rate is given, the SCM starts to execute the temperature rising control process that the set temperature value is the final value and given temperature rising slope is the reference input. AT89C55 constantly receives the digital sampling values from A/D. The temperature value of current coal sample will be formed after conversion and compared with reference temperature value that should be reached at present. The generated deviation signal e(t) is input into controller to produce the appropriate control signal. The control quantity driving device, solid state relay, achieves power regulation through adjusting conduction time in the cycle of 2.56s. The resolution of power regulation output is given in Formula (1):

(Unit time of minimum power regulation/power regulation cycle)=$\Delta t/\Delta T=10ms/2.56s=0.00390625$ (1)

In the software, the range of pulse width modulation register can be set as any integer in PWM-Register=[0, 256].
The periodic interference and random interference of instrument system are difficult to be anticipated and eliminated by circuit, which can usually be suppressed by the method of multiple samplings and calculating mean value. Such kind of filtering method can be considered as an equivalent low-pass filtering process. This instrument adopts the mean filtering method based on distribution diagram method. This method eliminates the blunder error and interference, with high accuracy, and is convenient to use computer for programming.
The system time constant, T0, produces great impact on the quality of control. If the time constant is large, the regulating effect of regulator on the change of controlled parameters will not be in time. The transition time of system will be prolonged, which will reduce the quality of control. The reason for pure time delay, τ, of system may be caused by signal transmission process and heat conduction process of heating device. No matter what causes the time delay, it always produces the negative effect on control quality of system. The time delay of measurement will make the controller fail to detect the change of controlled parameters in time. And the time delay of control will make the control effect fail to produce the deserved effect in time. All of these will increase the dynamic deviation of system and overshoot, resulting in decline of control quality.
Owing to very large inertia of system and very obvious time delay, its dynamic performance is worse. The range of temperature that the control effect is satisfactory is from 250℃to 450℃ (the temperature range that ignition point is most likely to occur). It means that the controlled heating process must reach the satisfactory temperature control effect before 200℃ so that, after adjusting the control quantity, the time that is basically stable should be less than the time constant, T0. Obviously, the poor dynamic performance of control system itself greatly increases the control difficulty.

4. Result and discussion

The above-mentioned self-adaption Dahlin, self-adaption control algorithm, is used to conduct control simulation for electric heating furnace model of coal sample ignition instrument. The result shows that this algorithm cannot only compensate for the effects produced by time delay and large inertia, but also can swiftly track the parameter change of controlled object.
In order to test the tracking ability of RLSEF algorithm for parameters, it is supposed that the inertia time constant of heating furnace is provided with time-varying characteristic and changes alternately and slowly

between T0=1000s and T0=5000s, as shown in Figure 3, so that the parameters of discrete model will follow to change as well. The expected closed-loop time constant, Te, is set as 400s. In RLSEF algorithm, the constant parameters are set as follows: ρ = 0.9; P(0)= 10I. The reference input temperature, r(k), is set as triangle wave with cycle of 18720s and amplitude of [20, 800]°C. In this way, the rate of reference temperature rise (or temperature drop) is 5 (°C/min). When the parameter, T0, constantly changes, after self-adaption Dahlin control algorithm introduced, the situation that the temperature y (k) of controlled heating furnace follows reference input r(k) and the temperature changing rate (y(k)-y(k-1))/Ts follows given heating rate (r(k)-r(k-1))/ Ts= 0.0833(°C/s) is shown in Figure 4.

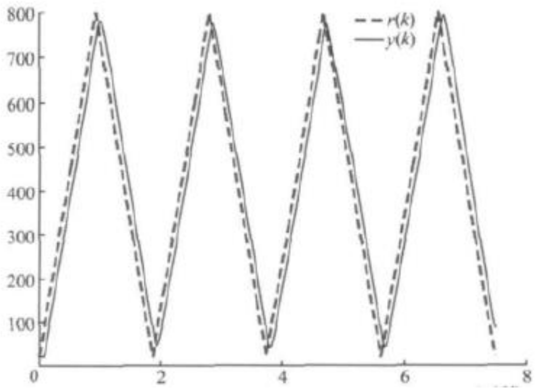

Figure 3: heating furnace temperature heating curve

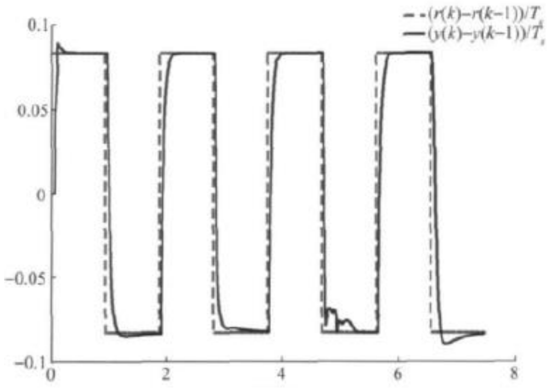

Figure 4: Heating furnace heating rate follows a given curve

It can be seen that the temperature response of controlled heating furnace can better track the given temperature rising curve and can enter the range of determined heating rate after t≈2000s. At this time, the corresponding temperature is 122°C. It can guaranteed that the detection process of coal sample ignition point enters the range required by temperature control rate before 200°C. The identification result of online RLSEF algorithm for discrete parameter of system is shown in Figure 5. It shows that this algorithm can better track the change of parameters. It converges to the true value of time-varying parameters as time increases.

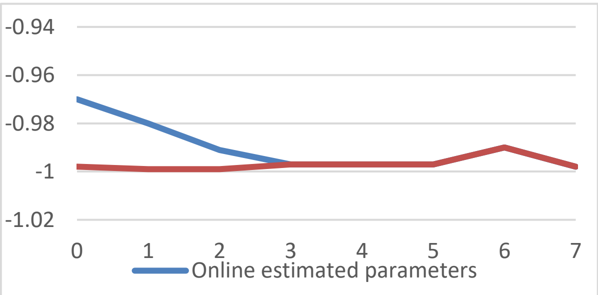

Figure 5: The identification of discrete time parameters of the furnace with RLSEF algorithm

Figure 6 is temperature rising velocity tracking curve in practical heating experiment. The temperature rising velocity enters the required range of ±0.5 (°C/min) and is maintained in it. The designed temperature control system can meet the requirements of temperature control.

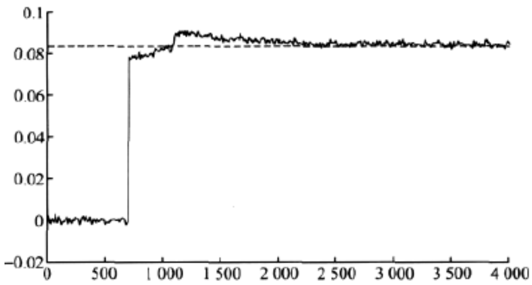

Figure 6: The temperature rising velocity tracking curve(only the first 15 000 s are shown)in the heating experiment of the furnace with Te= 400 s

5. Conclusion

This paper studies the design for temperature control system of ignition point detection instrument based on self-adaption so as to better solve the problems about the temperature control in ignition point detection. The author refers to related documents and designs hardware structure, temperature control system, technology and others of instrument through the least square algorithm to compose control system of ignition point detection instrument. In this paper, the research result shows that the temperature response of controlled heating furnace can better track the given temperature rising curve and can reduce the effect produced by time delay and large inertia on the temperature control system of ignition point detection instrument. It can be seen that the self-adaption Dahlin controlled in this paper can better meet the requirements of temperature rising velocity control in ignition point detection experiment for coal sample and with fine practicality and accuracy, which is worthy of application. It should be noted that the experiment in this paper is performed under the ideal condition. In practical application, the various complex interference signals will be involved. Therefore, the anti-interference ability about temperature control system of ignition point detection instrument needs to be further studies and the possible problems occurred need to be further solved.

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