Development of the PID controller and real-time monitoring system for a low-temperature furnace.

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The PID controller and real-time monitoring system for a low-temperature furnace was developed .The system has two part, the PID controller, and the real-time monitoring part .An Arduino mega2560 microcontroller board was used for measuring and control the furnace temperature .A type-K thermocouple and a MAX31850 IC was applied for a furnace temperature measurement .The microcontroller board and a MAX31850 were connected via the One-wire bus for convert the temperature values and sent to a personal computer .The PID parameters can be varied by a user in the program, which developed by LabVIEW Software on a computer .The laboratory made furnace was established for testing the controller and monitoring system .The results have shown that the temperature with the range of 25-500 degree Celsius can be controlled .By the trial and error method with the PID parameters, kp was 250, Ti was 0.05 and Td was 0.20, the target temperature can be controlled with the maximum error of 1 degree Celsius .

1. Introduction

The temperature controller is a necessity in research on the thermal properties of substances. There are many types of research that have been conducted previously using temperature controller system. Such as the effect of heating rate on structural and functional properties of wheat and potato starch-water system in food science technology [1].The investigate the effect of each temperature-dependent material property on the transient temperature, residual stress and distortion of welding process [2] and examples of research that use high-temperature control. Such as The high-temperature ablation properties of NANO zirconia reinforced fused silica ceramic [3].In materials process technology. All of above was require the high resolution of the temperature controller and monitoring system.

The Proportional Integral Derivative (PID) Controller is the most common method for the temperature controls system designing. The heat treatment furnace in the industrial, which used Intelligent Fuzzy Logic and PID controllers to design of temperature controller [4]. Recently, the LabVIEW program applied to designs PID control system [5] and the PID temperature autotuning control designing can accomplish by using LabVIEW [6].

This research has development of the PID temperature control system and real-time temperature monitoring Using LabVIEW interface for Arduino. The temperature measured with sensor MAX31850 Communication with the master microcontroller over the 1-Wire bus. Read temperature data from a sensor with Arduino MEGA2560. Then we get temperature data from Arduino and real-time temperature monitoring with the LabVIEW software. In this research design of PID temperature control by Ziegler Nichols and trial error method.

2. Experimental

2.1 Hardware design.

The system composes of the temperature measurement and the Arduino microcontroller board. The furnace temperature was measured by the thermocouple amplifier with 1-wire breakout Board-MAX31850K. The Arduino board read the temperature data and send to display on a computer via USB port. The target temperature maintains by on/off a solid state relay (SSR) which controls the period with the Arduino. The diagram of the system shows in Figure 1.
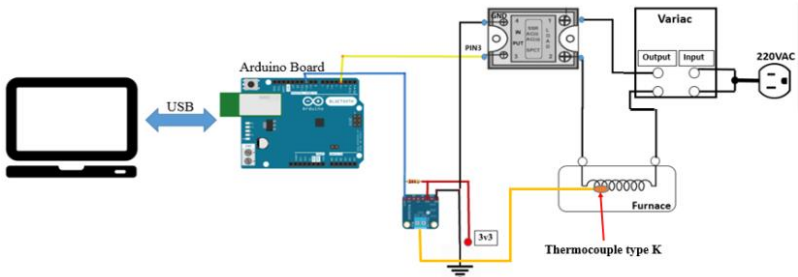
Figure1 . The diagram of the PID controller and real-time monitoring system.

2.2 Software design.

The PID parameters setting can be varies and real time temperature monitoring can be shows on the front panel of the developed program, respectively. The front panel of the temperature control system designed shows in Figure2 .
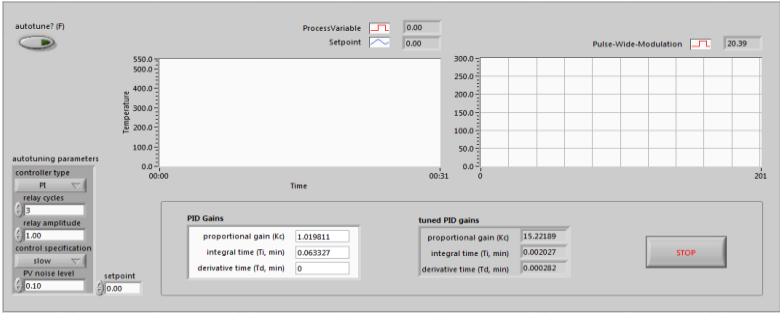
Figure 2.The front panel of the temperature controller

The block diagram of PID control program shows in Figure 3. The program read the furnace temperature from the Arduino and real time display in the front panel. The period for on/off the SSR accumulates from the PID parameters and send to the Arduino for on/off the SSR. The target temperature and the various PID parameters are the input parameter of the program. The Ziegler Nichols function from equation (1) used to calculate the output of signal and the trial and error used to find optimizes parameter of this system. WhereKp, Ti and Td is Parameter of proportional, integral and Derivative respectively   **.**

$$U = Kp(1 + \frac{1}{Ti} + Td) \tag{1}$$

Figure3. Block diagram of PID control from LabVIEW

3. Result and discussion

The Ziegler Nichols function used to generates the output signal for controller. The PID parameter was varied by the trial and error method.

3.1 The Kp parameter optimization

Table 1. Shows the temperature settling value, the steady state error, and the overshoot where Ti was 0, Td was 0 and the parameter Kp was varied the Kp has the effect on the settling and steady state error. The optimize Kp was 250.

Table1. List of comparisons of response parameter of all design Kp at $Ti = 0$, $Td = 0$

Parameter	Settling value	Steady state error (°C)	Overshoot
$Kp = 50$	This temperature is below the setpoint at 3°C	± 6	No overshoots.
$Kp = 100$	This temperature is below the setpoint at 3°C	± 6	No overshoots.
$Kp = 150$	This temperature is below the setpoint at 2°C	± 5	No overshoots.
$Kp = 200$	This temperature little below the setpoint at 1°C	± 3	No overshoots.
$Kp = 250$	This temperature is oscillates around the setpoint at ± 2 °C	± 2	Overshoot is absorb

3.2 The Ti parameter optimization

Table 2. Show the rising time, the steady state error, and the overshoot temperature where the Kp was 250, the Td was 0, and the Ti was varied. The results shown that the Ti has the effect of rising time and the oscillates of temperature. The optimize Ti value was 0.05.

Table2. List of comparisons of response parameter of all design Ti at $Kp = 250$, $Td = 0$.

Parameter	Rising time (s)	Steady state error(°C)	Overshoot (°C)
$Ti = 0.05$	120	± 1	5
$Ti = 0.10$	155	± 2	5
$Ti = 0.15$	165	± 3	5
$Ti = 0.20$	185	± 4	5
$Ti = 0.30$	210	± 6	7

3.3 The Td parameter optimization.

Table 3. Show the rising time, the steady state error, and the overshoot temperature where the Kp was 250, the Ti was 0.05, and the Td was varied. The results shown that the least Td has minimum rising time and the minimum oscillates was 1 °C with the Td value was 0.20

Table3. List of comparisons of response parameter of all design Td at $Kp = 250$, $Ti = 0.05$

Parameter	Rising time (s)	Steady state error (°C)	Overshoot (°C)
$Td = 0.05$	120	± 3	4
$Td = 0.10$	180	± 2	3
$Td = 0.15$	195	± 2	3
$Td = 0.20$	180	± 1	2
$Td = 0.25$	180	± 2	4

The experiment shown that the optimize of the Kp parameter was 250, the Ti parameter was 0.05, and the Td parameter was 20.

3.4 Test the temperature control.
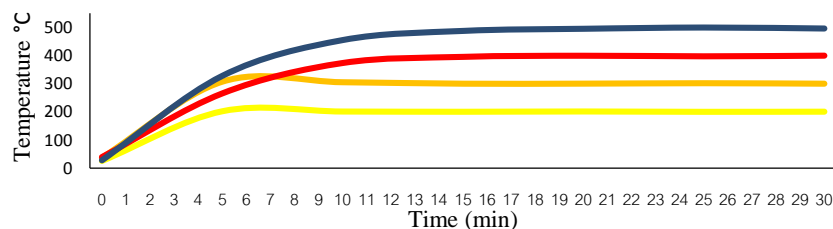
Figure 4 . The various target temperature control with the optimized PID parameter.

The results shown that all of target temperature can be controlled with the maximum error of 1°C . The rising time of control was 270, 290, 720, and 1200 second with the target temperature 200°C, 300°C, 400°C, 500°C respectively.

Conclusion

In research, to developed and designed the PID temperature control which can be monitoring the temperature on the computer display. From experiments to find parameters of PID show that the best of Kp cause to the system response better and the output is a small steady-state error. The best Ti value cause to decrease the response of the system and the best Td cause to decrease overshoot of the system and increase the response of the system. By trial and error method with the PID parameters, Kp was 250, Ti was 0.05 and Td was 0.20. The experimental results of control temperature can be controlled to a stable temperature. The maximum error is 1 °C and rising time of temperature 200°C, 300 °C, 400°C, and 500°C was 270,290,720, and 1200 second respectively.

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