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Temperature Control System Using Pi Control In Electric Tube Furnace

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Abstract: Furnace is used for chemical analysis processes that can reach <600ºC. Temperature control is needed to produce a perfect heat process so that the analysis carried out on the content of substances accurate. Most of the furnaces already have automatic temperature control and interfaces but both are still on-off. In this study, the development of electric tube furnaces was carried out using Proportional Integral(PI) controllers. The PI controller is used to maintain temperature stability and regulate the temperature rise by ramp to the time. By using the STM32F103C8T6 microcontroller as the controller, the signal will be sent to the actuator to control the voltage that will be channeled to the heater after receiving feedback in the form of a k-type thermocouple sensor and setting temperature parameters. The results of bump test obtained PI control parameters(Kp=26.84, Ti=99.9). With a reference of 400ºC, the system response time rises(Tr) for 4385 seconds and the steady time(Ts) for 4658 seconds with an error of less than 2%. The system is able to stabilize and return the system response to the reference temperature(400ºC) after being given a disturbance with recovery time to steady state for 254 seconds.

Keywords: Furnace, Microcontroller STM32F103C8T6, PI, thermocouple

1. Introduction

In a chemical analysis, process of ash content testing becomes one of the ways to find out the substances contained in a substance. In some cases, process of ash content testing is used to determine the nutritional quality of the food, knowing toxic mineral contamination, and rate of material. Determination of ash content can be done by burn it directly at high temperature (500-600^{o}C) for several hours (2 – 8 hours), then review the combustion residue. The burning process is usually carried out in the furnace at high temperaturewith 1000^{o}C maximum temperature. Some furnaces in a labolatory have a simple temperature control and interface. Some of them using on-off controller with mechanic relay as the actuator. On-off controller can cause oscillation response around set-point[1]. This is very undesirable in a process that need constant output. Moreover, mechanic relay has weakness, one of them is spark between on and off condition. This spark is dangerous. Electric Tube Furnace is heater that used for synthesis and purification of organic compound by release the water and remaining solvent gradually. Electric Tube Furnace consist of a cylindrical tube which there is embedded heating coil inside with temperature control using thermocouple as feedback[2][3][4]. PI control is a type of PID control that can be used to control variable process. PI control commonly used in industrial process because the problem that occur can be repaired maximally only with PI control. The function of derivative control (D) is to stabilize system. But, D control is rarely used on FOPDT process because D control is always make steady state error[5]. PI control is combine of Proportional control (P) and Integral control (I).

2. Research Method

The design of the temperature control system using the PI control method in the Electric Tube Furnace using a closed loop control system is divided into 3 main parts, namely hardware design, software design, and PI control tuning. Hardware design includes hardware block diagrams, STM32F103C8T6 microcontroller circuit, AC voltage control circuit, thermocouple temperature sensor circuit, keypad circuit, and display circuit. Software design includes main programs, keypad programs, thermocouple temperature reading programs, LCD display programs, and AC voltage control programs. The tuning of PI control contains the determination of PI control parameters and PI control programs. The electric tube furnace plant is shown at Figure 1.

Figure 1. Electric Tube Furnace plant

2.1. Hardware

Temperature control system hardware block diagram in this paper can be seen at Figure 2. Hardware design is consist of STM32F103C8T6 microcontroller as controller thermocouple as temperature sensor, triac as voltage controller, keypad as input unit and LCD as display.

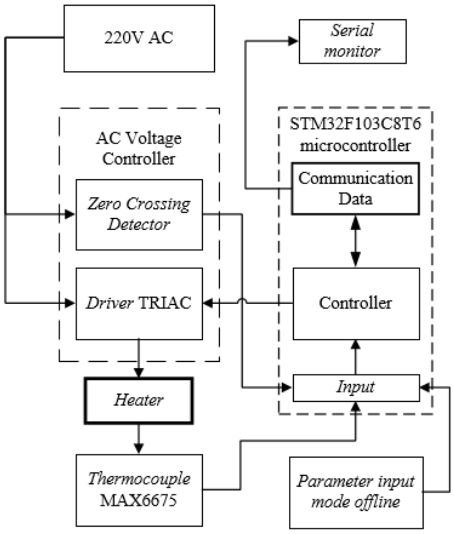


Figure 2.Hardware Block Diagram

The voltage controller is usually used by bidirectional triode thyristor (triac). Triac is two-ways conductive, triac can be considered as two thyristor with gate connection. Pin MT1 and MT2 are switches that control load current. In normal condition, pin MT1 and MT2 do not connect, so there is no load current flow. When pin G gives signal, then MT1 and MT2 connect and the load current flow. STM32F103C8T6 a 32-bit microcontroller Reduce Instruction Set Computing (RISC) is made by STMicroelectronics that has construction and based on prosessor ARM® Cortex-M3. This microcontroller can be compiled by various type of compiler such as Keil® uVision, EmBitz, Arduino IDE, maupun compiler lain dengan bahasa pemrograman C [6].

2.2. K-type Thermocouple

Thermocouple is one of most commonly used sensors to measure temperature because its relatively inexpensive but accurate which can operate in hot or cold temperatures[7]. If two materials are connected in a circuit and the two junctions are maintained at different temperatures it will generate an electromotive force (emf) and an electric current will flow in the circuit. This is known as seebeck effect. The amount of electric current depends on the type of metal and the temperature difference between two connection points.K-type Thermocouple is shown by Figure 3

Figure 3.K-type Thermocouple

The output signal of thermocouple is very small to be read by microprocessor, therefore it is necessary a signal conditioner that called MAX6675. The MAX6675 is a signal conditioner from the Thermocouple and digitizes the output from the K-type Thermocouple. 12-bit resolution output data. Its accuracy is 0.25ºC and can reach a temperature of 1024ºC.

2.3. Tuning PI Control

PI control is used to control temperature of electric tube furnace according to reference given. Determination PI control parameter (Kp and Ti) is done through bump test experiment by sending through u signal (step) manually[8]. Figure 4. shows block diagram of PI control design

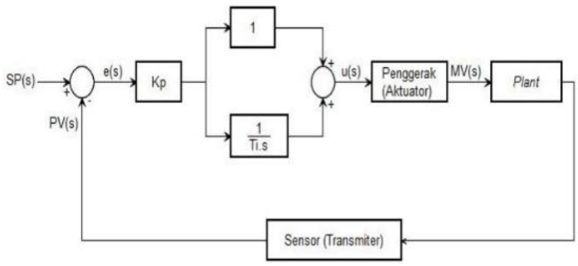
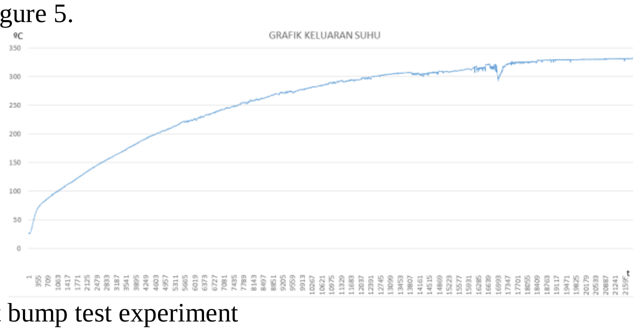
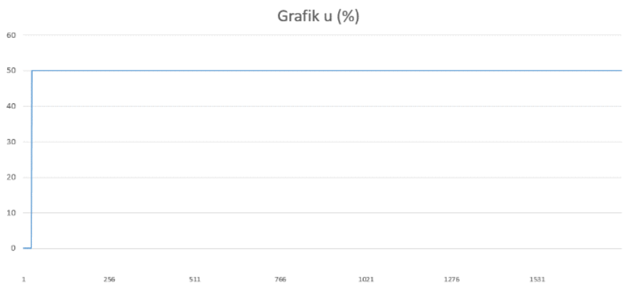


Figure 4.PI control design block diagram

Bump test experiment in PI control design is done by sending signal from 0% to 50%. This experiment starts at 26ºC shown by Figure 5.



a. Output temperature at bump test experiment



b. Signal changing from 0% to 50%

Figure 5. Result of bump test experiment

Figure 5. shows output process of system until the temperature steady, so the process model used is model self regulating (FOPDT) with

1. Dead Time (L) = 30 seconds
2. Process Time (T) = 5476 seconds
3. *Gain* statis process (K) = 6,12.

Based on three parameters FOPDT, we can determined PI control parameter use to Ziegler Nichols 1 method

1. $Kp = \frac{0,9\,T}{K.L}$

   $= \frac{0,9\,.\,5476}{6,12\,.\,30}$

   $= 26,843$

2. Ti = 3,33 L
   = 3,33 . 30
   = 99,9

2.4. Software Design

Algorithm of software of PI control on electric tube furnace as follows

1. Start.
2. Calculation*error* = *setpoint* – themperature.
3. Calculation P control output.
4. Calculation I control output.
5. Conditioning I control output.
6. Calculating PI control output.
7. Conditioning PI control output to control heater.

Flowchart of PI control is shown at Figure 6.

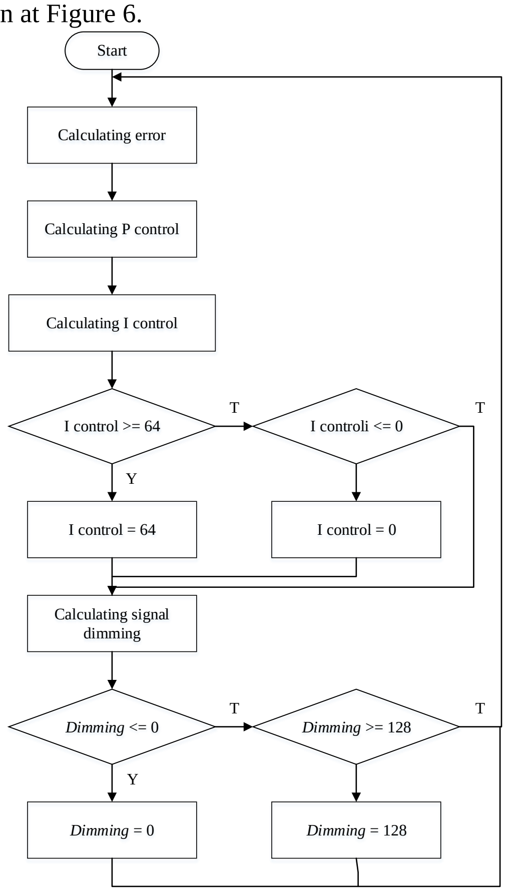


Figure 6.Flowchart PI control

3. Result and Analysis

3.1. Sensor testing

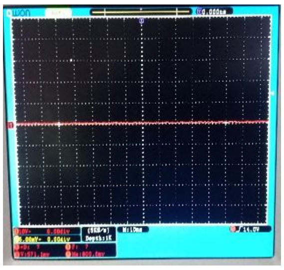
Sensor testing of thermocouple is done through compare the temperature by thermometer and thermocouple. This test is done at 30ºC - 100ºC with average error 1,5ºC that shown at Table 1.

Table 1.Compare result of thermocouple and thermometer

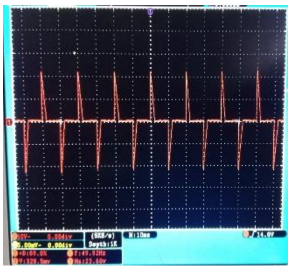
Thermocouple tipe K	Thermometer	Error
27	30	3
35	34	1
42	39	3
53	51	2
64,5	64	0,5
70	72	2
73	74	1
79	80	1
102	102	0
	Average	1,5

3.2. Voltage Controller Testing

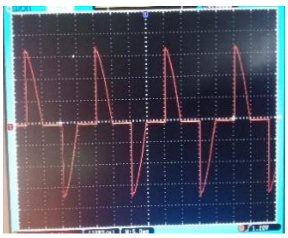
Voltage controller testing is done through with zero crossing detector circuit and microcontroller STM32F103C8T6 system. Output of the system is seen by oscilloscope and shown by Figure 7 and Table 2.



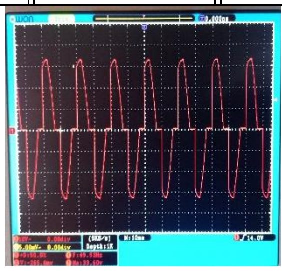
a. CO = 0%



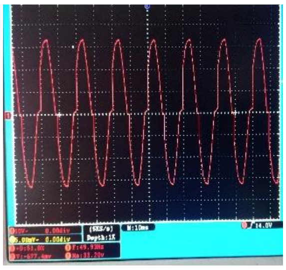
b. CO = 25%



c. CO = 50%



d. CO = 75%



e. CO = 100%

Figure 7. Output load signal wave

Table 2. Testing data of voltage controller

Signal control (%)	*Timer*	Output Voltage (V)
0	128	0
25	96	54
50	64	152
75	32	215
100	0	231

3.3. Testing of System Response with fixed Reference

Testing of system response with fixed referense is done through themperature reference 400ºC from 26ºC. This result is shown by Figure 8.

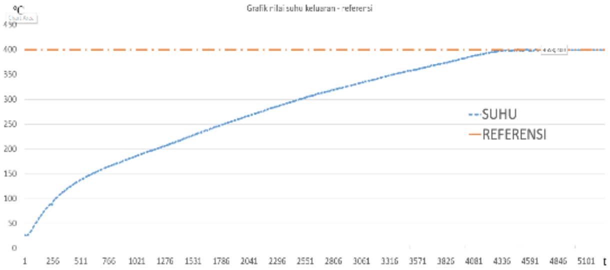


Figure 8. Result of system response with fixed referense

Based on Figure 8. we can conclude that PI control can follow the referense and stable at 400ºC with time rise 4385 seconds, and time steady 4658 seconds.

3.4. Testing of System Response with Periodic Reference Changes

Testing of system response with periodic reference changes starts from 26ºC to 400ºC for 3 hours with 15 minutes interval. The result is shown by Figure 9.

Figure 9. Result of system response with periodic reference changes

Based on Figure 9. we can conclude that PI control can follow and steady at reference that given periodically

3.5. Testing of System Response with Disturbance

Testing of system response with disturbance is done when the system in steady condition at 400ºC. Then the system is given disturbance for a few minutes that shown by Figure 10.

Figure 10. Result of system response with disturbance

Based on Figure 10. we can conclude that disturbance effect makes the system unstable and themperature drops to 374,5ºC. After a minute, the disturbance is eliminated and themperature rise until given referense. The system comes back to referense for 254 seconds from the disturbance gone.

4. Conclusion

Has successfully designed the temperature control system on the electric tube furnace with Ziegler-Nichols method on the control action with PI parameters (Kp = 26.84, Ti = 99.9).The time response of 400°C reference are Time Rises (Tr) 4385 seconds, and Time Steady (Ts) 4658 seconds. The system can follow reference than given by periodically and stabilize the temperature after being disturubed.

References

[1]. Ogata. K, "Teknik Kontrol Automatik Diterjemahkan oleh E. Laksono,"Erlangga. Jakarta, 1994.
[2]. Guofang G., Zhengzhong L. (2012) Design of Heating Furnace Temperature Control System Based on Fuzzy-PID Controller. In: Zhu R., Ma Y. (eds) Information Engineering and Applications. Lecture Notes in Electrical Engineering, vol 154. Springer, London
[3]. Devendra Rawat, Kritika Bansal, Pandey A.K. (2017) LQR and PID Design Technique for an Electric Furnace Temperature Control System. In: Singh R., Choudhury S. (eds) Proceeding of International Conference on Intelligent Communication, Control and Devices. Advances in Intelligent Systems and Computing, vol 479. Springer, Singapore
[4]. J. D. Corbett, "Synthesis of Solid-State Materials" in Solid State Chemistry: Techniques, A. K. Cheethan and P. Day, Eds. Clarendon, Oxford, 1987.
[5]. I. Setiawan, Kontrol PID Untuk Proses Industri. Elex Media Komputindo, 2008.
[6]. K. Ogata, Modern Control Engineering, Fifth. Prentice Hall, 2010.
[7]. Maxim. “MAX6675 Datasheet.” © 2014 Maxim Integrated Products, Inc.
[8]. G. Brown, “Discovering the STM32 Microcontroller,” vol. 85, pp. 1–244, 2012.

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