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Cascade PID-FUZZY Controller for Temperature System with Long Dead-Time

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In industrial practice, there are many production processes involving the temperature system. The product quality depends on how good the temperature system is controlled. The temperature system is one of challenging topics in control system because of its long dead time. The dead-time makes the control of temperature system more difficult since it produces additional lag in the phase of system which decreasing gain margin and phase of the transfer function. Dead-time is caused by the time needed to transfer heat from heart source to the sensor because sensor position is far from heat source. To control the temperature system with long dead-time, a cascade PID-Fuzzy control is proposed. The proposed control system combines the Zieglers Nichols PID with 3x3x3 fuzzy control system. The proposed control system gives fast rise time and little dead time around 6 seconds without overshoot.

Keywords: *temperature system, PID, Ziegler Nichols, fuzzy controller*

1. Introduction

Temperature control system is very important for production process in industry because it affects the product quality (1) . The stability of temperature on combustion process must be maintained to produce good quality product (2). Temperature in combustion process is very high up to thousand degree Celcius. Temperature sensor (3) cannot be placed on the heat source in combustion process because it will melt. The solution of this problem is placing temperature sensor far from the heat source. But, this solution causes a transport delay (4) or dead-time (5). Because the temperature sensor cannot be used directly at heat source, it waits until the heat is transported from the source to the sensor. The transport delay causes several effects as mentioned in (6). The value of transport delay depends on distance of sensor and heat source. It also depends on the air velocity (7) to transport heat from source to sensor.

The transport delay needs to be minimized by using control system. The common control system which is used on temperature system are PID and Fuzzy Logic Controller (8). PID Controller usually uses basic experimental Ziegler-Nichols tuning rules (9). This conventional PID controller is the most used in industries to control non-linear processes like temperature. (10). Tuning method (11, 12) is developed to overcome weakness of previous conventional PID controller. Fuzzy control system is also developed to overcome transport delay problem (13, 14). Both fuzzy control system and PID controller have their own weaknesses and advantage. To get best temperature control system, a hybrid controller is developed recently such as Smith-fuzzy control system (15), Feedforward DMC-PID (16), Switch PID-Fuzzy (1, 17). This paper propose a control system that can minimize transport delay. A proposed control system is cascade PID-Fuzzy controller.

2. Experimental Details

The experiment is conducted by using temperature system plant inspired from (18). The plant is made from pipe with Diameter 5 cm, Length 100 cm, Heater 100W, Fan, temperature sensor LM35. There are two sensors used in this plant. The first sensor, which is placed near the heat source, is called monitor sensor. The second sensor, which is placed far from heat source, is called feedback sensor. The distance between the feedback sensor and the heat source is 95cm. Monitor sensor measures temperature around the heater. Feedback sensor is used to measure temperature of area that is far from heater, which is sent to controller. This plant uses DAQ 6008 to collect temperature data and Labview to control the temperature system. The heat from heater is controlled by using PWM signal from DAQ 6008. The fan is used to transport heat from source to feedback sensor. The plant is showed by **Error! Reference source not found.**.

This experiment combines Ziegler Nichols PID with 3x3x3 fuzzy controller. This controller is made by using block programing from Labview. There are two main blocks in the program, PID block and fuzzy block. The block diagram of this controller is showed by figure 2 .The Ziegler Nichols method 2 is used to tuning PID block. Tuning PID Ziegler Nicols Performed by searching for Kp constants in critical states called KCr. KCr is the value of the Kp constant which results in the system response being critical. A critical state is a state in which the system responds constantly to oscillation. The value of KCr is obtained by increasing the value of Kp bit by bit until it gets critical condition. In this critical state also obtained a critical period called PCR that is used to calculate the constant Ki and Kd Constant. PCr is the critical period obtained by calculating the distance between the oscillation waves of the system in a critical state.The result of this tuning is showed by table 1.

Table 1 Zigler Nicols Second Method Tuning

	Kp	Ti(min)	td(min)
P	0,5Kcr	-	-
PI	0,45Kcr	$\frac{1}{1.2}Pcr$	-
PID	0,6Kcr	0,5Pcr	0,125Pcr

The fuzzy block has two inputs and one output. The inputs are error and rate error. The output is PWM signal. Fuzzy controller used in this experiment is 3x3x3. The membership of the fuzzy controller is showed by figure 2. The rule of the fuzzy controller is showed by table 2.

Table 2 Rules of Fuzzy Controller

e/Δe	N	Z	P
N	M	S	S
Z	M	M	L
P	L	L	M

PID and fuzzy controller are combined by summing the gain of each controller. The experiment was conducted by setting the set point and then tuning on the plant. The GUI will show the result of controller. The controller will keep the temperature on the setting point.

3. Results and Discussion

This Experiment start with conventional PID controller with Zigler Nicols Tuning Second Method. In this control system gain constant we used are Kp=90, Ti=5,5 and Td=1,375. The result of this control system is showed in figure 4. From this result we can see transport delay of the system is 3 second. There is no overshoot in this system but there is oscillation. This oscillation shows that the system is unstable. The ITAE of this control System is 6.346,1.

Experiment of proposed controller was conducted with two tuning. The first one used Ziegler Nichols, the second one used trial error based on Ziegler Nichols result. The result of proposed controller is showed by figure 5a. Figure 5a shows the result of Ziegler Nichols PID and Fuzzy Controller experiment with set point 50˚C. In this experiment the transport delay or Dead-Time is 6 seconds. This controller gives fast rise time without overshoot but it has oscillation around the set point. The rise time of this controller is 12 seconds. The ITAE of this controller is 6.978,5.

The figure 5b shows the result of Trial Error PID and fuzzy Controller experiment with set point 50˚C. In this experiment the dead-time is 5 seconds. This controller has slower rise time but minimum oscillation.

The rise time of this system is 18 seconds. There is no overshoot either in this controller. The ITAE of this controller is 6.171,9.

If we compare the result of Conventional PID controller with proposed controller, we can see the transport delay of conventional PID controller is better than proposed controller. But if we compare the oscillation that is occurred in the system, proposed controller is better than conventional PID controller. The ITAE of proposed controller also smaller than conventional PID controller so it is mean the proposed controller better than conventional PID controller in handling error. So overall the proposed controller gives better result in controlling temperature system with transport delay.

4. Conclusion

The proposed controller works well on temperature system plant with long dead-time. It can remove the overshoot which is usually produced by PID controller. Also, this proposed system can minimize the rise time of temperature control system which is the weakness of fuzzy controller. So, this control system can improve performance of previous control system for on temperature system plant with long dead-time. This control system is gives better result than conventional PID control System.

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Figure captions

Figure 1. Temperature System Plant
Figure 2. Block diagram of control system
Figure 3. Fuzzy membership (a) input error, (b) input rate error, (c) output control signal
Figure 4. Experiment result Conventional PID Controller
Figure 5. Experiment result (a) Ziegler Nichols PID+Fuzzy Logic Control, (b) Trial error PID+Fuzzy Logic Control

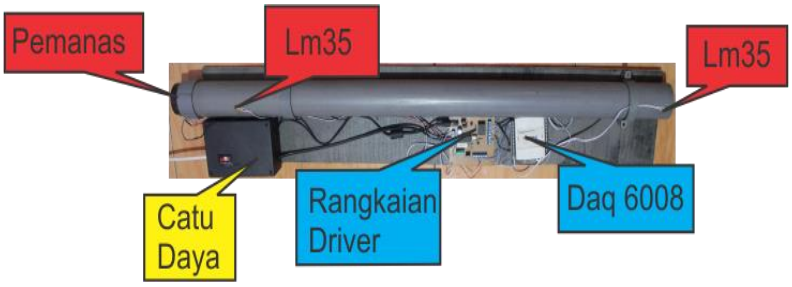

Figure 1 Firmansyah et al (in Bahasa Indonesia)

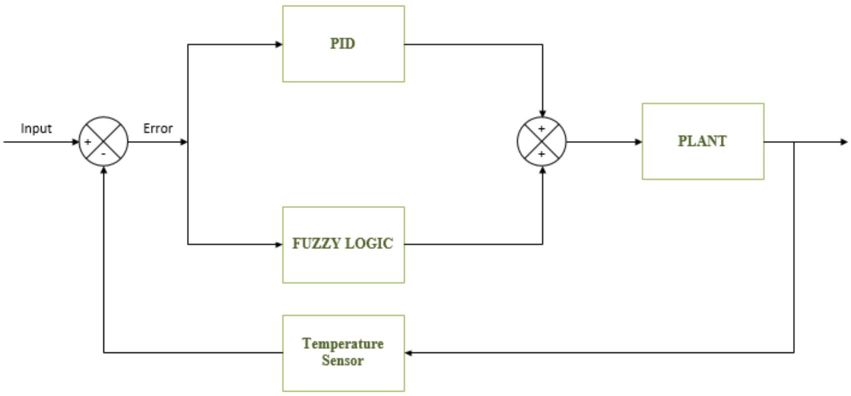

Figure 2 Firmansyah et al

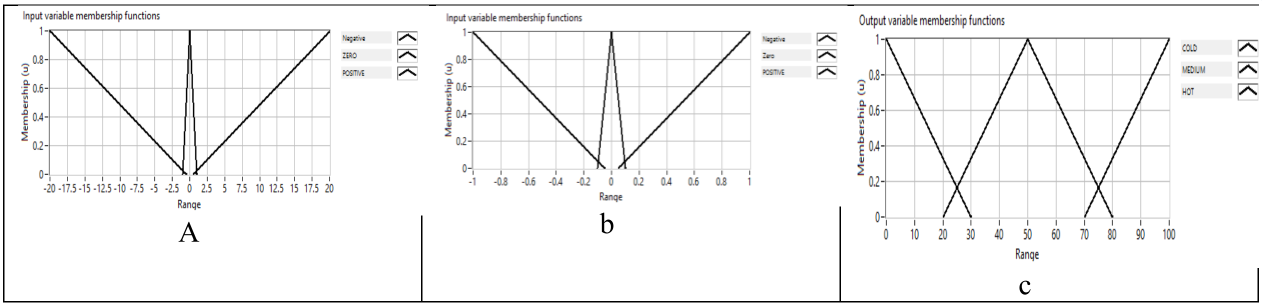

Figure 3 Firmansyah et al

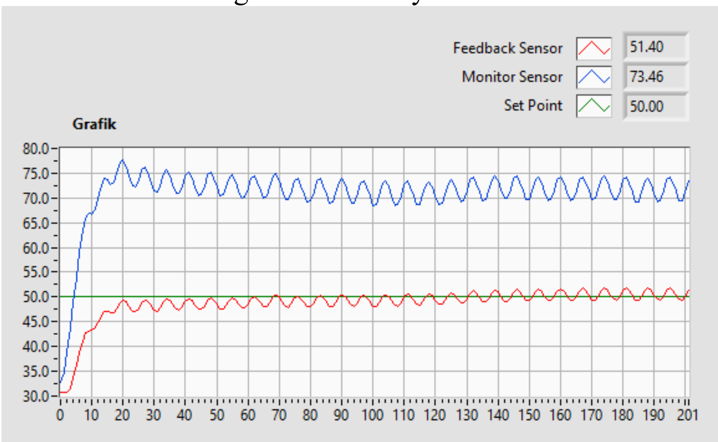

Figure 4 Firmansyah et al

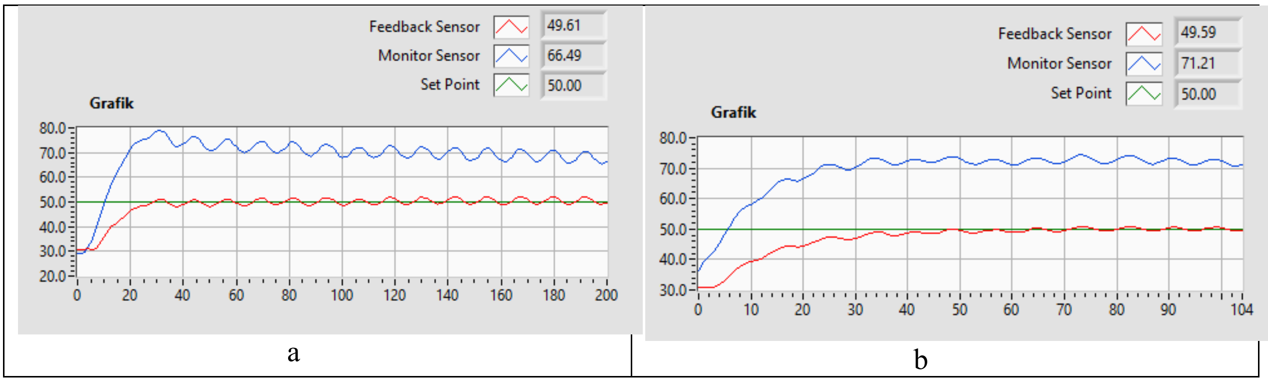

Figure 5 Firmansyah et al