FUZZY IMPLEMENTATION FOR TEMPERATURE CONTROL ON COFFEE ROASTER MACHINE

Fauzi Imaduddin Adhim[1*], Ilham Syahrial Akbar[1], Fivitria Istiqomah[1], Ciptian Weried Priananda[1], Lucky Putri Rahayu[1], Arif Musthofa[1]
[1] Departement of Electrical Automation Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111

Email of corresponding: fauzi@eea.its.ac.id

Present Address:
Jl. Teknik Kimia, Keputih, Kec. Sukolilo, Kota Surabaya, Jawa Timur, 60111, Indonesia

Abstract— A roaster machine is a machine that is used for the process of determining the quality of the coffee it gets. The roaster machine at Puslitkoka still uses a manual process so that the Post Harvest operator always maintains the roasting process when doing research to get quality coffee beans. The roaster machine at Puslitkoka is still maintained by the operator to stabilize the temperature of 140oC - 200oC with a time of 10 to 15 minutes to get the desired coffee beans. As a result of some of the problems above, it is necessary to develop a roaster machine. By adding a thermocouple sensor to measure the temperature that can move the servo valve to stabilize the gas output during the roasting process using the fuzzy logic method. When it reaches a temperature of 140oC the servo motor opens as an input for coffee beans. All data obtained will be managed by Arduino Mega 2560. With the creation of this tool, it was found that the temperature control on the coffee roaster using the fuzzy method has a smaller average steady state error of 5.85%. The conventional method has a larger error than fuzzy logic because the temperature increase is linear with time. For the required roasting time, the fuzzy method has a shorter time with an average of 549.67 seconds than the conventional method with an average time of 811.34 seconds.

Keywords—*Temperature Control, Fuzzy Logic, Roaster Machine for Coffe*.

1. INTRODUCTION

The Indonesian Coffee and Cocoa Research Center (Pusat Penelitian Kopi dan Kakao Indonesia - Puslitkoka) is a national coffee and cocoa research and development institution based on the Decree of the Minister of Agriculture no. 786/Kpts/Org/9/1981 which was established on January 1, 1911 during the Dutch colonial period, at that time named Besoekisch Proefstation. Currently the Puslitkoka is managed under PT. RPN (Research Perkebunan Nusantara) has a vision to become a leading international standard research institution by 2020. Puslitkoka has a strategic mission in producing science and technology (IPTEK) to support the development of national coffee and cocoa. The mission is not only limited to efforts to achieve science and technology and superior products but also disseminates coffee and cocoa development centers throughout Indonesia. For this reason, it is necessary to have a supporting machine for coffee production and research needs, namely a roaster machine.

The roaster machine at Puslitkoka is the same as the roaster machine in general, which still uses a manual process. So when doing research, operators in the Post-Harvest Department have to wait for the roasting process to become coffee beans that are ready to be marketed. The roasting process which is considered to take a long time makes the process considered less effective by using a manual roaster machine, because the operator maintains the roasting process to keep the roaster temperature stable. The temperature given to Puslitkoka for roasting coffee is around 140ºC - 200ºC with 10 to 15 minutes in one roasting using 1 kg of coffee beans.

As a result of the above problems, in this Final Project a tool design will be made to develop a roaster machine by adding several sensors and actuators. The development that will be carried out is the modification of the roaster machine with fuzzy implementation for temperature control by making the servo valve work stably according to the temperature that is the Puslitkoka standard. For light roast coffee beans, the temperature is in the 140ºC - 160oC range with a 140ºC set point, for medium roasts in the 160ºC - 180ºC range with a 160ºC set point, and for dark roasts in the 180ºC - 200ºC range with a 180ºC set point. When it reaches a temperature of 140ºC the servo motor opens as an input for coffee beans for the roasting process with a time of 7 to 12 minutes in one roasting, which is 200 grams. So that it can facilitate the roasting process during research and increase sales of roaster machines at Puslitkoka

2. PREVIOUS RESEARCHES

The roasting of coffee beans is an important process in the coffee industry which greatly determines the quality of the coffee drink it produces. This process converts unsavory, raw coffee beans into a drink with a delicious aroma and taste. Roasting is usually carried out at atmospheric pressure, as a heating medium, heating air or combustion gases are usually used. The processing of these coffee beans needs to be adjusted to the demands and preferences of consumers. Roasting levels consist of: light roast, medium roast, and dark roast. According to the National Coffee Association (1911) in the roasting process there are several levels of maturity, namely as follows:

1. Light level, at this level the coffee beans are light brown, the character is light from the bean side, there is no oil layer on the surface, and the acidity level is higher.
2. Medium level, at this level the natural sugar content has started to caramelize a little, and the acidity also begins to decrease.
3. Dark level, at this level dark colors like brown and sometimes almost black. A thick layer of oil on the surface, and can be seen on the surface of the cup when the coffee has been brewed. Bitter taste becomes more prominent, smoky aroma, taste character is reduced.

These different roasting methods in addition to affecting the taste, also determine the color of the coffee produced. The purpose of roasting coffee beans is to synthesize compounds that form the distinctive taste and aroma of coffee in the coffee beans. Roasting time varies from 7 to 30 minutes depending on the type of equipment and the quality of the ground coffee [1].

Fuzzy logic is one of the right ways to map an input space into an output space. Fuzzy logic imitates human thinking by using the concept of the vagueness of a value. The stages of building a fuzzy system can be concluded that there are fuzzification, fuzzy logic interface, defuzzification [2].

The whole system is programmed with Arduino IDE. Arduino IDE is software used for programming, monitoring and debugging microcontrollers. Arduino IDE stands for Integrated Development Environment, or in simple language it is an integrated environment used for development.

3. METHOD

In the modification of the roaster machine at Puslitkoka using Arduino Mega 2560 as the control of the whole system. The sensors used are type K thermocouple sensors, servo valves and servo motors. The design and manufacture of the system used in this final project will be explained by using a system functional block that describes the functional relationship between components in Figure 1. The design of this tool system consists of several components that are interconnected, where there are inputs, namely the power supply, thermocouple sensor and the MAX6675 module. The outputs are servo motor, tube turning motor, and servo valve. The controller used is Arduino Mega 2560.

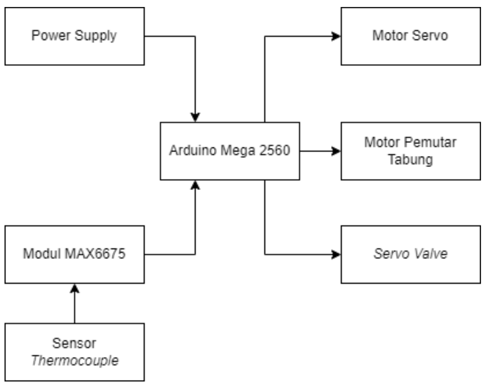

Figure 1 Diagram System

For the program flow of this system can be seen in Figure 1 where the flow shows the process from the beginning to the end of the program. The flowchart of the system shows that the first thing to do is to turn on the system so that the active servo valve opens the gas valve fully. After that start the fire by turning on the lighter manually. Then select push button (PB) 1, 2, or 3 to select the desired coffee bean yield. For light roast coffee beans, you can choose PB1 with a set point of 140oC, medium roast coffee beans can choose PB2 with a set point of 160oC, and dark roast coffee beans can choose PB3 with a set point of 180oC. After pressing the push button, the tube rotating motor moves at 35 rpm and fuzzy logic runs, causing the servo valve to rotate. Furthermore, the thermocouple sensor reads the temperature. When the temperature reaches 140oC, the servo motor opens 90o which causes the coffee beans to enter the tube turning motor. Next, the coffee bean roasting process begins and produces light roasted coffee beans with a roasting temperature of 140oC-160oC, a medium roast with a roasting temperature of 160oC-180oC, and a dark roast with a roasting temperature of 180oC-200oC, causing the coffee beans to come out and the process is complete.

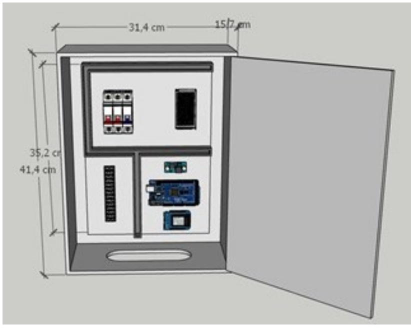

Figure 2 Design Control Panel

In the design of the panel box made as shown in Figure 2, it is a component for the needs of the roaster machine. Inside the panel box there is a power supply, step down MCB, terminal block, Arduino Mega 2560, and the wiring of each sensor.

In designing this controller circuit, Arduino Mega 2560 is used to receive data input from the MAX6675 module which is connected to the thermocouple sensor, adjusts the angle position to the servo motor, and adjusts the condition of the servo valve. The following in Table 1 is a table for the use of pins on the Arduino to be made.

Tabel 1 Port Configuration

NO	Modul	PIN *Analog/Digital*
1.	Modul MAX6675	VCC : 5 V GND : GND SO : *Digital* 10 CS : *Digital* 9 SCLK : *Digital* 8
2.	Sensor *Thermocouple*	+ Pada Modul MAX6675 - Pada Modul MAX6675
3.	Motor Servo SG5010	Brown cable : OUT (-) *stepdown* Red Cable : OUT (+) *stepdown* Yellow Cable: *Digital* 2
4	*Servo Valve*	Brown Cable : OUT (-) *stepdown* Red Cable : OUT (+) *stepdown* Yellow Cable : *Digital* 3

This gas control system uses the Sugeno fuzzy logic method to determine the condition of the servo valve. By utilizing the change in the value of the thermocouple sensor as input, the error and error values will be given and the servo valve condition as output. In controlling the temperature of the thermocouple, a membership function is made, where each value of a membership set will determine the output of the valve condition value. Starting from determining the membership of the fuzzy set of each variable.

The error membership function for temperature is divided into 3 fuzzy sets, namely N (Negative), EN (Negative Error), and EP (Positive Error). The error membership function is divided into 5 fuzzy sets, namely NB (Big Negative), NK (Small Negative), NO (Zero), PK (Small Positive) and PB (Big Positive). The variable of the valve condition consists of 4 fuzzy sets, namely (TSK) Open Very Small, (TK) Open Small, (TB) Open Large and (TSB) Open Very Large. After the formation of the membership function on each variable, the input in the form of crisp values will be converted into fuzzy input, namely determining the degree of membership of the input value in a fuzzy set, this process is called defuzzification.

After the formation of the fuzzy set, then the formation of fuzzy rules (rule set) is carried out as in Table 2. Rules are formed to express the relationship between input and output. Each rule is an implication. The operator used to connect between inputs is the AND operator, and the one that maps between input-output is IF-THEN.

Tabel 2 Rule Evaluation Fuzzy

		Error		
		N	**EN**	**EP**
Δ***Error***	**NB**	**TSK**	**TSK**	**TK**
	NK	**TSK**	**TSK**	**TB**
	NO	**TSK**	**TSK**	**TSB**
	PK	**TSK**	**TK**	**TB**
	PB	**TSB**	**TK**	**TSB**

From the rules that have been obtained, then determine the predicate of each rule by using the implication method, namely making decisions or consequences based on the minimum value (MIN) between antecedent propositions. Composition rules using the MAX function. The composition of the rules is the overall conclusion by taking the maximum membership level of each consequent application of the implication function and combining all the conclusions of each rule. The last step in this process is defuzzification or also called the affirmation stage, which is to convert the fuzzy set into real numbers. The defuzzification used in determining the condition of the servo valve is the centroid method.

4. RESULT AND DISCUSSION

Coffee roasting machine testing is carried out using manual control and fuzzy logic control embedded in Arduino which functions to determine the comparison of the stability of the roasting machine system. All conventional tests and fuzzy logic tests were carried out with coffee beans weighing 200 grams using a low heat of 198oC/minute. The first test of the roasting machine is operated with manual control to get light roast coffee beans with a certain time. From the graph in Figure 4.1, it can be seen that the temperature increase every second seems to increase so that the temperature increase is linear with time. In Figure 4.1 a graph shows that the time range takes 690 seconds with a temperature setpoint of 140oC. At the beginning of the time, the temperature reads 31oC. Running for about 480 seconds, the system undergoes a rise time with the temperature reaching the setpoint of 140oC which then the roaster machine overshot up to 189.5oC.

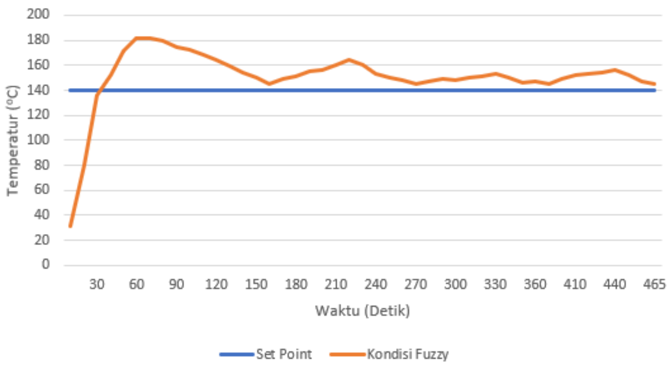

Figure 3 Graph of Fuzzy Light Roast Logic Temperature Testing

In Figure 4.4 is a graph of temperature testing using fuzzy logic control. The graph in Figure 3 shows that the time range takes 465 seconds with a temperature setpoint of 140°C. To reach the set point, the system undergoes a rise time of about 30 seconds and overshoots up to a temperature of 182oC.

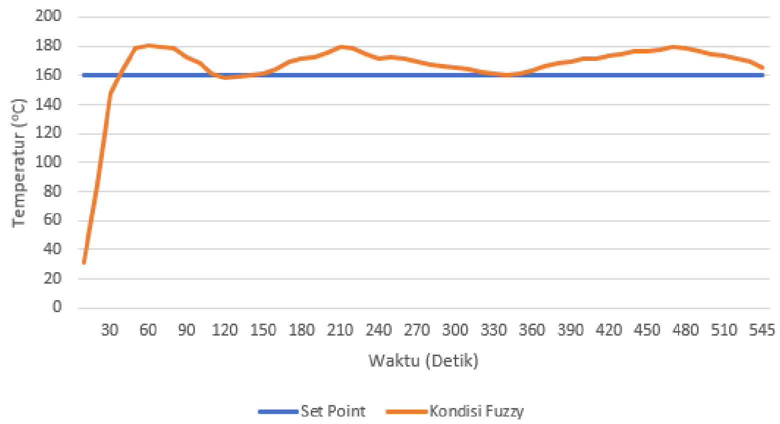

Figure 4 Graph of Fuzzy Medium Roast Logic Temperature Testing

In Figure 4 are the results of temperature testing using fuzzy logic control. The graph of Figure 4 shows that the time range takes 545 seconds with a temperature setpoint of 160°C. To reach the set point, the system has a rise time of about 40 seconds and an overshoot to a temperature of 180.5oC.

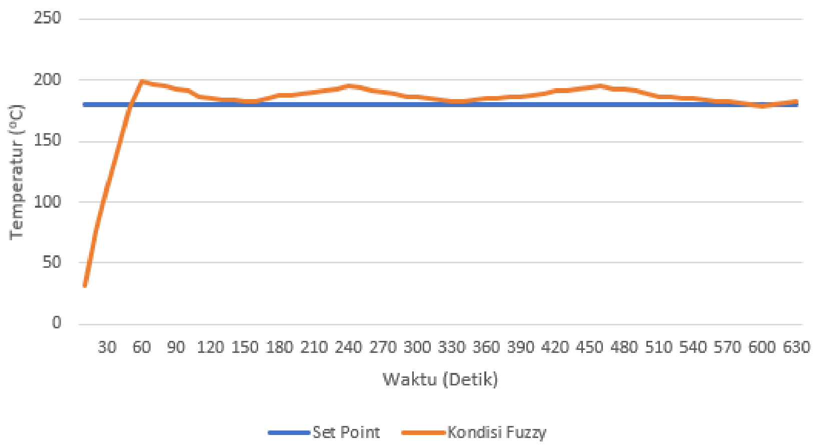

Figure 5 Graph of Fuzzy Dark Roast Logic Temperature Testing

In Figure 5 are the results of temperature testing using fuzzy logic control. The graph of Figure 5 shows that the time range takes 630 seconds with a temperature setpoint of 180°C. To reach the set point, the system has a rise time of about 40 seconds and an overshoot to a temperature of 199oC. From the comparison in Figures 3, 4 and 5 shows that testing using the fuzzy logic method obtained better results than the conventional method. Tests using the fuzzy method obtained a difference with a setpoint ranging from an average of 10°C where the result of the test is 150°C with an average steady state error of 7.14%. While the temperature test using the conventional method, the difference in error from the setpoint ranges from an average of 30°C which reaches up to 170.06°C with an average steady state error of 21.4%.

5. Conclusion

Based on the results of the analysis and discussion that has been carried out, it can be concluded that the design and manufacture of the Final Project entitled "Implementation of Fuzzy for Temperature Control in Coffee Roaster Machines":

1. In testing light roast coffee beans using the fuzzy method, the difference with the setpoint ranges from an average of 10°C, where the result of the test is 150°C with an average steady state error of 7.14%. While the temperature test using the conventional method, the difference in error from the setpoint ranges from an average of 30°C which reaches up to 170.06°C with an average steady state error of 21.4%.
2. In testing medium roast coffee beans using the fuzzy method, the difference with the setpoint ranges from an average of 9.88°C, where the result of the test is 169.88°C with an average steady state error of 6.17%. While the temperature test using the conventional method, the difference in error from the setpoint ranges from an average of 24.5°C which reaches up to 184.56°C with an average steady state error of 15.3%.

3. In testing using the fuzzy method, the difference with the setpoint ranges from an average of 7.6°C, where the result of the test is 187.6°C with an average steady state error of 4.23%. While the temperature test using the conventional method, the difference in error from the setpoint ranges from an average of 14.38°C which reaches up to 194.38°C with an average steady state error of 7.98%.

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