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Design of Heater Control System on 3D Printer Filament Extruder Machine with Fuzzy Logic Controller

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Abstract— *3D Printing is a new breakthrough in the field of technology, which is being able to print the exact same thing in the desired software in 3D (not just printing images on paper). Because the printout is not in the form of images or writing on paper, the 3D printer does not have ink but uses filament. Filament is the material used to make the product. To create three-dimensional objects with various structures, the ink in the printer is replaced with filament material made of plastic seeds. Because the basic materials in the manufacture of 3D Printing are still expensive, and the size of the 1.75mm filament is therefore designed a tool that can simplify the process of making 3D Printing by recycling filament material from plastic waste using Arduino Mega. The process of recycling plastic waste into products with high economic value uses a 3D Printer filament extruder machine based on a Fuzzy Logic Controller with solar cell as a power source. In its work, this extruder machine has several advantages including being able to work automatically with the principle of clean energy because its resources are supplied by solar cells so that its use will be environmentally friendly and minimal pollution. This tool uses an induction heater and is supported by a control system that applies Artificial Intelligence with the Fuzzy Logic Controller method. The Fuzzy Logic Controller method works in regulating the set point temperature heater and controlling the speed of the DC motor used.*

Keywords— *Filament, plastic waste, extruder machine, fuzzy logic controller, induction heater.*

I. INTRODUCTION

Technological advances cannot take their eyes off the global problem that is still difficult to overcome, namely the presence of waste in the environment. A lifestyle that makes people constantly need goods. Without realizing it, billions of tons of waste are left in the Final Disposal Site (TPA). It is estimated that by 2025, waste production in Indonesia will reach 130,000 tons per day[1]. Sri Merdekasari, General Chairperson of the Indonesia Solid Waste Association (INSWA) some time ago said that based on statistical data on Indonesia's domestic waste, the amount of plastic waste which reached 5.4 million tons per year was only 14 percent of the total waste production in Indonesia. Of the total waste, 57% was found on the beach in the form of plastic waste. As many as 46 thousand plastic waste floats in every square mile of the ocean, even the depth of plastic waste in the Pacific Ocean has reached almost 100 meters [2].

Based on the problems above, it is necessary to have an alternative process of recycling plastic waste into more valuable products. The alternative solution requires a machine that is able to work automatically to process plastic waste into 3D printing filaments. 3D Printing is a new technology in the field of technology. 3D Printing is known as additive layer manufacturing with a layered printing process to print objects in 3D. The existence of this 3D printer is considered to be able to help human life in various fields. The advantage of 3D printing is that it can create many complex shapes. This is due to the freedom of movement of printing in 3D. Because the printout is not in the form of images or writing on paper, the 3D printer does not use ink but uses filament. Filament is the basic material used in the manufacture of products. Because the basic materials in the manufacture of 3D Printing are still expensive, and the size of the 1.75mm filament is therefore designed a tool that can simplify the process of making 3D Printing by recycling the filament material from plastic waste [3]. This can be used as a solution for processing plastic waste considering that currently the need for filament as a raw material for 3D printing is quite high.

The control system applied in the production process uses Artificial Intelligence with the Fuzzy Logic Controller method. The application of Fuzzy Logic Controller is expected to produce filament products with quality that meets standards. Fuzzy logic controller is an artificial intelligence-based controller that is often used in the industrial world that requires accurate control, one of which is temperature control in heat exchangers. The neuro-fuzzy method or the fuzzy artificial neural method used is able to stabilize the heat exchanger temperature well [4]. The heating system with Fuzzy Logic Controller provides accurate control in any industrial application, the response of the fuzzy controller in all experimental conditions is as expected and does not go out of the maximum and minimum temperature limits [5].

II. METHODOLOGY

A. System Diagram

The diagram system of the Printer's Filament Extruder Machine is shown in Figure 1.

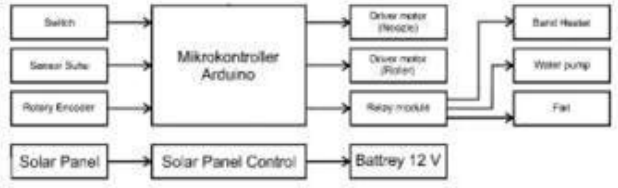

Fig. 1. Diagram of filament printer system of plastic waste

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1. A microcontroller is a device that will process data from inputs consisting of switches, temperature sensors (thermocouple type-K), and rotary encoders that will be processed into output to control motor drivers and relay modules. The microcontroller used is the Arduino Mega.
2. The sensor detects the temperature of the nozzle. The temperature sensor used is a type-K thermocouple.
3. Rotary encoder is used to calculate the length of the filament produced by the extrusion process based on the number of spins on the roller.
4. Motor driver is a device used to set the speed of motor rotation.
5. DC motor is a motor used for roller drive and thrusters on the nozzle.
6. Relay is a device used as an electrical switch to power heaters, fans and water pumps.
7. Heater nozzle extruder is a device used to heat plastic seeds to melt and then removed on the nozzle hole.
8. A fan is a device used to reduce heat around the nozzle to keep the temperature stable.
9. A water pump is used to cool the filament coming out of the noozle.

B. Desain Software

In this section it is explained about software design as a monitoring media for extruder machine systems on smartphones shown in the following flowchart.

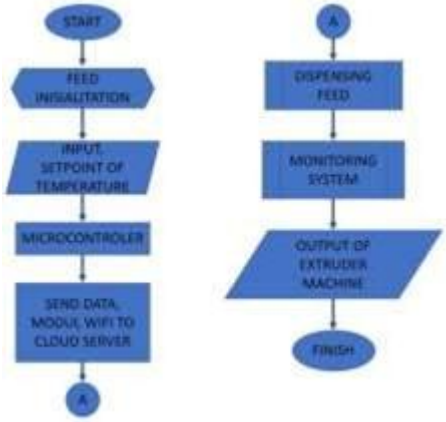

Fig. 2. Software system flowchart

Figure 2 is a flowchart that shows the software system on an extruder machine. Input in the form of temperature setpoint will be processed through arduino uno microcontroller. Then the data obtained will be sent on the cloud server and will be displayed on the smartphone monitoring system.

C. Prototype Design of Waste Recycling Machine 3D Printing Filament Printing

Eco Extruder Machine of 3D Printer Filament from Economical Plastic Waste is a tool consisting of a counting machine, heater, printer, coolant, roller that processes processing plastic waste into 3D printing filaments. This machine works by using a fuzzy logic system as a controller and the system can be monitored through applications that have been integrated through a smartphone. The power supply is obtained from solar panels.

The production capacity of this tool can reach 0.625kg/hour with an operating time of 8 hours/day. Motor speed of 70 rpm with a plastic melting point of about 180°C. So that the total produced is 5 kg/day.

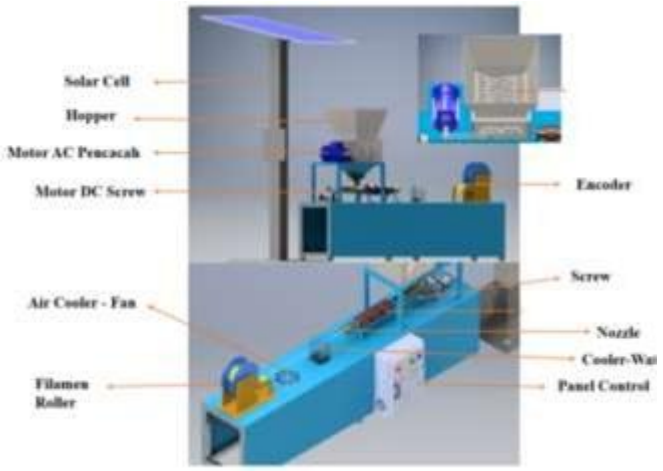

Fig. 3. Prototype of filament printing machine for plastic waste

D. Fuzzy Logic Controller

The input variables used in this method are errors and delta errors, while the output variables in the form of controller values adjust the PWM work cycle. The following is a fixed frequency PWM block diagram.

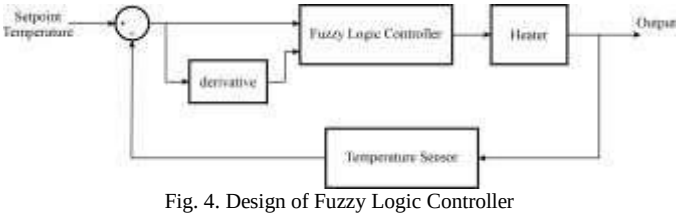

Fig. 4. Design of Fuzzy Logic Controller

Membership function input error can be seen in Figure 5. Each is divided into five: Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS) and Positive Big (PB).

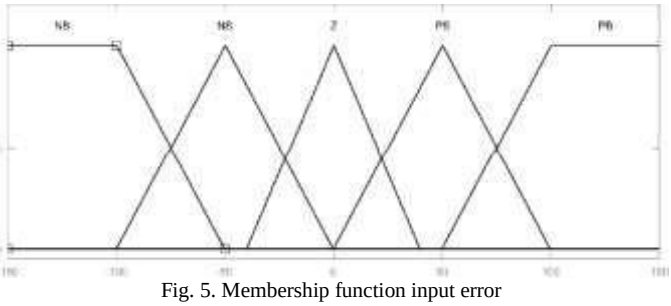

Fig. 5. Membership function input error

The delta error input is divided into seven, namely Negative Big1 (NB1), Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Big (PB), Positive Big1 (PB1) as shown in Figure 6.

Membership output control is divided into five, namely Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Big (PB) as shown in Figure 7. Output

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control is the duty cycle of the PWM signal to control the heater.

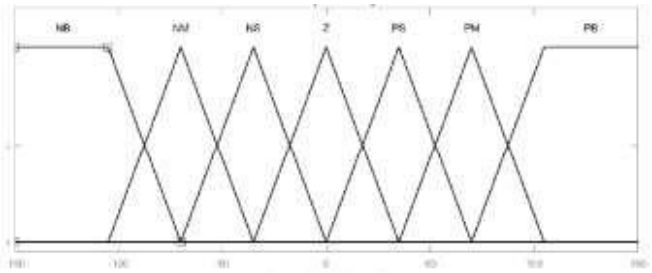

Fig. 6. Membership function input *delta error*

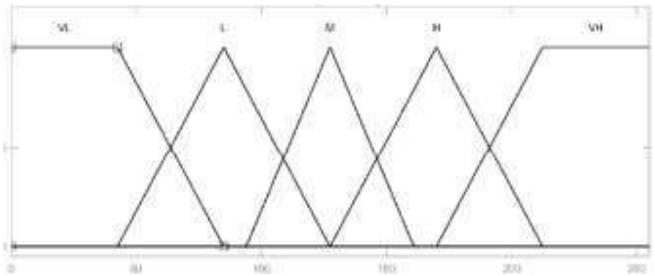

Fig. 7. Membership function output *control*

Fuzzy base rules are structured by considering input errors and delta errors until the best response is obtained. There are 35 rule bases for proportional control output as shown in Table 1.

TABLE 1. Rule base Fuzzy output control

RULE					
Error / d_Error	NB	NS	Z	PS	PB
NB	VL	VL	L	L	M
NM	VL	L	L	M	M
NS	VL	L	L	M	H
Z	VL	L	M	L	M
PS	M	M	M	L	M
PM	VL	VL	M	H	H
PB	VL	VL	M	H	VH
NONE'	VL	VL	M	L	VL

III. RESULT

The test is done by providing a set point that is worth 120 degrees. Observations were made on robots with Fuzzy Logic Controller, PI controller, PID controller, and no controller. The PWM Heater's output response can be seen in Figure 8.

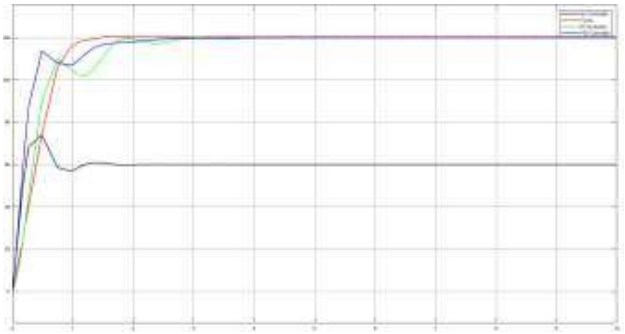

Fig. 8. Heater response

TABLE 2. Controller test results

No	Type	Overshoot (%)	Rise Time (ms)	Settling Time (ms)
1	Fuzzy Logic Controller	0.505	191.411	1555
2	No Controller	-	-	-
3	PI Controller	0.515	594.98	2604
4	PID Controller	0.076	392.269	2607

IV. CONCLUSION

Based on the results of the design, testing and analysis carried out on the "3D Printer Filament Extruder Machine with Fuzzy Logic Controller", it can be concluded:

1. Design of a 3D Printer Filament Extruder Machine as a tool that is able to work automatically to process plastic waste into 3D printing filaments and can help human life in various fields with satisfactory results
2. Based on the simulation results, it can be concluded that the heater control with Fuzzy Controller has better performance when compared to the others. Using a Fuzzy Controller can achieve a faster and more stable setpoint with an overshoot of 0.505% with the smallest rise time of 191,411 ms, and settling time of 1555 ms.

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