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PI Control For Rotation Speed Stability Of Induction Motor In Disc Mill Type Coffee Grinder

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ABSTRACT

In a coffee processing production process, roasted coffee beans can now be ground using a motor-driven grinder. For an industrial scale, a Disc Mill typecoffee bean grinder is generally needed because it is able to get coffee grounds faster and smoother than other types. However, a Disc Mill typecoffee bean grinder has a disadvantage if the grinding load increases, it will affect the rotational speed of the motor so that there is the potential for congestion in the Disc Mill blade. Therefore, a control method is needed to maintain the speed stability of the induction motor. The control method used is Proportional-Integral(PI). To obtain the exact value of the parameter used the Ziegler-Nichols method of oscillations. The PI controller using the Ziegler-Nichols method is considered capable of obtaining a relatively stable system response and get a shorter reference value. System testing with tuning values Kp = 0.108 and Ki = 0.13 was carried out at a speed of 1400rpm. A stable system response was obtained with a rise time of 4 seconds, a settling time of 5 seconds, a peak time of 9s, a maximum overshoot of 2.85% and a steady state error of 0.89%. With the application of the PI method, the Disc Mill type coffee bean grinding motor can maintain the stability of the rotational speed compared to without control.

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1. PENDAHULUAN

Coffee is determined as a strategic commodity that becomes a national priority so that it is prioritized to be facilitated and developed [1]. In the coffee powder processing industry, it is necessary to apply technology to the coffee bean grinder because of the lack of good handling carried out with conventional technology [2]. On an industrial scale, a Disc Mill type coffee bean grinder is generally needed because it is able to get coffee powder faster and smoother than other types[2]. Disc mill type grinding machine is a machine used to grind coarse raw materials or dry grains into flour grains with a certain level of fineness.

However, the Disc Mill type coffee bean grinder using an electric motor has a weakness, if the grinded load increases it will affect the rotational speed of the motor so that there is a potential for jams on the Disc Mill blade [2]. This is due to the fact that the speed of the induction motor is more difficult to control [3],[4],[5]. In controlling the

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speed of an induction motor, it is necessary to have a controller that can provide a good input response, so as to produce a good output with a very small oscillation value and a fast response.

Therefore, a control method is needed to maintain a stable motor speed [5],[6]. The control method commonly used in motors is the Proportional Integral (PI)[7]. The controller using the PI method is considered capable of getting a stable system response and achieving a shorter reference value. The use of PI control is very good because with the PI control, the error, overshot and undershot values can be minimized so that reference achievement can be done quickly and with a relatively smaller error rate[7],[8],[9],[10].

PI control can be done using the Ziegler-Nichols S curve method or oscillations. The method applied to the Disc Mill type coffee bean grinding system is the oscillation method. The use of PI control can help the output response to be better with a very short response time (<0.1s) to reach the reference value. So that the research was carried out by applying the PI Ziegler-Nichols oscillation method with the title "PI Control for Induction Motor Rotational Speed Stability in Disc Mill Type Coffee Grinders" to maintain the stability of the induction motor rotation on Disc Mill coffee bean grinders in order to work optimally.

2. RESEARCH METHOD

2.1 System Block Diagram

In Figure 1, the sections are input, process, and output. Inputs to the Disc Mill-type coffee grinder include a keypad, speed sensor, and current sensor. The process section includes a PI control system programmed through the Arduino Uno microcontroller, and an output consisting of an LCD display, an AC motor along with a motor driver.

The working principle of controlling the rotational speed of the Disc Mill-type coffee bean grinding motor is that, at the beginning, the system is turned on, then the set point value is entered in the form of the desired motor speed using the keypad, and it will be displayed on the LCD. Furthermore, the motor will rotate based on the set point value, and the rotational speed of the motor will be detected by the speed sensor, which is used as input for the actual value and will be compared with the set point value to obtain the error value. The error value will then be entered into the controller to stabilize the motor rotation speed based on the set point value using the PI method.

The current in the motor will be detected by the current sensor when a change in value occurs due to a load. When the current stabilizes again, the motor will stop, indicating that the process has finished operating.

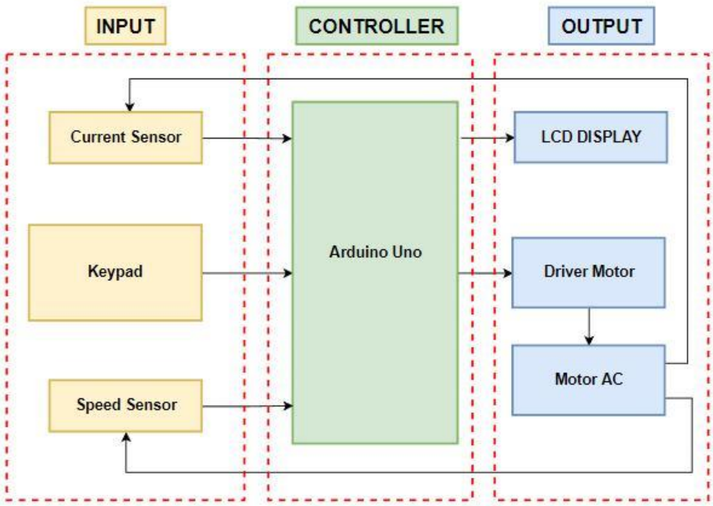

Figure 1. System Block Diagram

2.2 Control Block Diagram

Figure 2 shows the control system block section is used to regulate the rotational speed of the AC motor for the Disc Mill-type coffee bean grinder. The controller employed is the PI controller. The plant on the Disc Mill-type coffee bean grinder is used to rotate the grinder, which is connected to an AC motor and driven by a motor driver

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according to the commands of the controller. The sensor, in this case, the digital rotary encoder speed sensor, is used to read the rotational speed of the AC motor during the milling process.

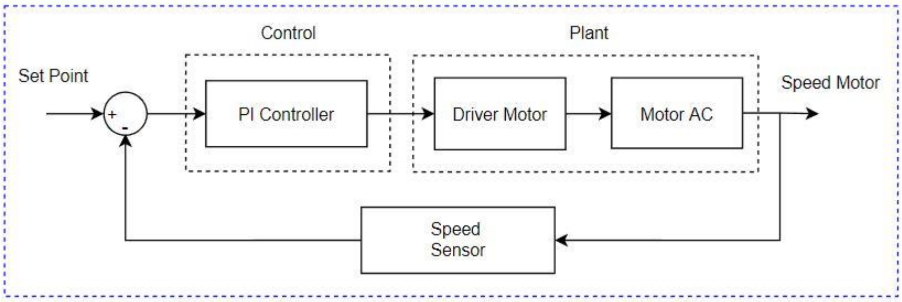

Figure 2. Control Block Diagram

2.3 Tool Specifications

The mechanical specifications in the induction motor speed stability control system are shown in Table 1 below.

TABLE I : MECHANICAL SPECIFICATION

	Dimensions	
1	Long	96 cm
	Weight	43 cm
	Tall	15.3 cm
	Capacity	5 kg
	Material	
2	Disc Mill	Iron
	Tool Frame	Iron

2.4 Electronic Design

The electronic components in the induction motor speed stability control system are shown in Table 2 below.

TABLE 2 : ELECTRICAL COMPONENTS

Sensor	Optocoupler, ACS712
Actuator	AC motor
Display	LCD 16x2
Processor	Arduino uno

2.5 Design of PI control for induction motor speed stability

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In the PI control design, the constant values of Kp and Ki are determined. Various methods can be employed to determine the values of Kp and Ki. However, in this design, the method used is the second Ziegler-Nichols method, commonly known as the Ziegler-Nichols oscillation method. The Ziegler-Nichols oscillation method was chosen because this method is suitable for systems that allow a continuous oscillating response. This method is carried out in a closed-loop plant condition.

Initially, the integrator parameter is set to infinity, and the differential parameter is set to zero (Ki = and Kd = 0). The proportional parameter is then gradually increased, starting from zero until it reaches a value that causes the system reaction to oscillate. The reaction system must oscillate steadily (sustain oscillation).

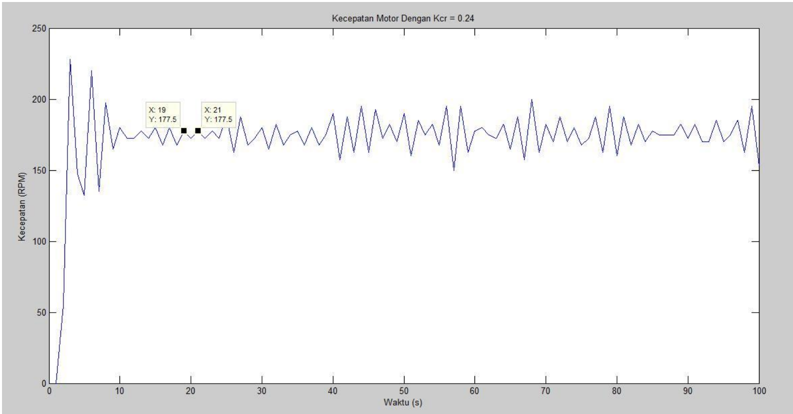

Figure 3. The initial graph of the system oscillation using the Ziegler-Nichols 2

In the Ziegler-Nichols 2 oscillation method, the first, most stable part of the oscillation is the part that will be used as a benchmark for tuning the PI. From Figure 3, with Kp = 0.24, the system exhibits oscillations that tend to be more stable than other oscillations. There were several spikes after sampling due to the characteristics of the motor used. In accordance with the PI tuning, the Kp value obtained is used to find the Kcr and Pcr values, taken from the difference between the same wave or the same oscillation. Figure 3 shows the value of Kcr = 0.24, so that based on the calculation of 1 the Pcr value is obtained from the time difference between the stable oscillating wave and the Pcr value is 2s.

Table 3. PI parameter tuning for Ziegler-Nichols

Controller type	**Kp**	**Ti**	**Td**
P	0.5 Kcr	∞	0
PI	0.45 Kcr	1/1.2 Pcr	0

After determining the Kcr and Pcr values, the next step is to calculate Kp and Ti using the PI control table. Based on Equation 2 and Equation 3, the Kp value is 0.108, and Ti is 0.83. In Equation 2, the value of Kp represents the proportional constant, and the value of Kcr represents the critical constant. In Equation 3, the value of Ti represents the integral time, and the value of Pcr represents the proportional critical.

$$P_{cr} = t_u - t_i \quad (1)$$

$$K_p = 0,45 \; x \; K_{cr} \quad (2)$$

$$T_i = \frac{1}{1.2} \; x \; P_{cr} \quad (3)$$

$$K_i = \frac{K_p}{T_i} \quad (4)$$

In Equation 4 where the value of Kp = proportional constant and Ti = Integral time using the Ziegler-Nichols. oscillation method can be obtained, the value of Ki = Integral constant can be obtained. So that the Proportional and Integral tuning values implemented on the system are Kp = 0.108 and Ki = 0.13.

3. Results and Discussion

3.1 Speed Sensor Test

Optocoupler speed sensor testing is carried out to find out that the readings from the speed sensor with the tachometer measuring instrument are appropriate. The speed sensor in its readings changes as the AC motor oscillation changes. The results are shown in Table 4.

Table 4. Speed Sensor Reading Comparison Table with Tachometer

No	Speed Sensor (rpm)	Tachometer (rpm)	Error(%)
1	340	344	1.16
2	427	432	1.15
3	523	523	0
4	612	612	0
5	700	701	0.14
Average Error			0.28

From the speed sensor test results as shown in Table 4, it is proven that the speed sensor readings with the tachometer have detected the motor rotation per minute properly. The results of the comparison of the AC motor speed readings produce an average error value as shown in table 4. The results of the error calculation are carried out every setpoint given to the microcontroller on the speed sensor test, from the results of these calculations the maximum error is 1.16% and the minimum error is 0. The results speed sensor testing has an average error of 0.28%.

3.2 Current Sensor Test

Current sensor testing is carried out to analyze whether the current sensor used has detected the current in the AC motor according to the calibrated measuring instrument. The current sensor changes as the AC motor oscillation changes, so the values taken are average values. The results are shown in Table 5.

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Table 5. Comparison Table of Current Sensor Readings with Clampmeter

No	Current Sensor (A)	Clampmeter (A)	Error(%)
1	0.50	0.50	0
2	0.53	0.55	3.6
3	0.56	0.58	3.4
4	0.61	0.61	0
5	0.61	0.62	1.6
6	0.63	0.64	1.5
Average Error			1.68

From the data from the tests carried out to compare the ACS712 sensor readings with the Clampmeter measuring instrument, Table 5 shows the maximum error value of 3.6% and the minimum error value of 0%. The error value on the ACS712 sensor reading can still be tolerated because the error tolerance value of the current sensor is 5%, so the resulting error value does not interfere with the performance of the ACS712 current sensor reading. The currentsensor test results have an average error of 1.68%.

3.3 PI Speed Control System Control Test

In the control test, the test was carried out with the input set point of 1400 rpm so as to produce the graphic data shown in Figure 4. The design of a control system for the Disc Mill type coffee bean grinder using the Ziegler-Nichols 2 oscillation method with the parameter values obtained, namely Kp = 0.108, Ki = 0.13 resulting in a response graph as shown in Figure 4. The PI system used with Kp and Ki values which has been calculated previously is used for tuning the value of the motor rotation speed with a value of 1400 rpm. The 1400 rpm set point has a measurement parameter of rise time of 4 seconds, settling time of 5 seconds, peak time of 9s, maximum overshoot of 2.85% and steady state error of 0.89%.

Figure 4. System graphics using Ziegler-Nichols 2 oscillation method at 1400rpm

4. CONCLUSION

From the results of design, testing, and analysis on the Disc Mill type coffee bean grinding system, it can be concluded that the speed sensor readings and current sensor readings have an average error value of less than 5% which can be used to support the control system in the grinding process. Disc Mill type coffee beans. By applying the *Ziegler-Nichols* rule 2 oscillation method with parameter values that have been obtained, namely Kp = 0.108, Ki = 0.13. The 1400 rpm set point has a measurement parameter of rise time of 4 seconds, settling time of 5 seconds, peak time of 9s, maximum overshoot of 2.85% and steady state error of 0.89%. This can prove that the Disc Mill type coffee bean grinding motor can maintain a stable rotation speed compared to without control.

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