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Design of Automatic Coffee Bean Roaster Based on Arduino Uno Microcontroller

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ABSTRACT

This study aims to design an automatic coffee bean roaster machine to meet the needs of supporting tools and machines for the downstream coffee industry. Design of a coffee bean roaster based on an Arduino uno microcontroller. The design is carried out by designing an automatic coffee bean roaster which includes making a tool framework, making programs or commands on the Arduino Uno, testing the automatic coffee bean design tool based on the Arduino Uno microcontroller. The results of the design of the automatic coffee bean roasting machine based on the Arduino uno microcontroller are functioning well. The automatic coffee bean roaster machine based on the Arduino Uno microcontroller consists of a 24V DC Power supply, Ds18b20 Sensor, 12V DC Fan, L298N Motor Driver, Servo, 12V DC Motor, 16x2 LCD, Arduino Atmega2560 Microcontroller, coffee bean roasting container and frame. Functional test results show that all components of the roasting machine are able to function according to their functions. By controlling the control system on the heating element based on a temperature of 100^0C which is read by the Ds18b20 temperature sensor using the Arduino Uno program, which is driven by a servo motor with an automatic coffee roaster capacity of 250 grams per one roast.

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1. INTRODUCTION

Indonesia is a country that produces products in the form of coffee beans. Coffee is one of the most popular drinks and is widely consumed because of its taste [1]. This product is one of the leading commodities for Indonesia's national income. Coffee is one of the most popular drinks and is widely consumed because of its taste. Roasting is an important stage in developing the taste and aroma of coffee beans. Different levels of roasting will produce different flavors. During roasting, coffee beans undergo physical and chemical changes such as moisture content, color, volume, hardness, and components of volatile compounds.Coffee roasting is the process of removing the water content in coffee beans and developing the beans, as well as reducing the weight of the coffee beans. Different levels of roasting will produce different flavors. During roasting, coffee beans undergo physical and chemical changes such as moisture content, color, volume, hardness, and components of volatile compounds [1] [2]. The key to the production of ground coffee is the

roasting stage. Roasting is the process of physical and chemical changes experienced by coffee beans such as changes in color and distinctive aroma by using a heater. The longer the roasting time, the color of the roasted coffee beans approaches dark brown-black [3]. Coffee roasting is the process of frying coffee without using oil. Coffee roasting is basically a process of changing the chemical and physical properties of coffee, in this case the aroma, sour taste and various flavors in coffee [4] [5] .

Automatic control technology is growing rapidly, increasing the need for automation in various equipment for industrial, household and other purposes [6]. The automatic control system is programmed to the required requirements [7] [8]. The production process that uses human power is very dependent on the limitations of human power [9] [10]. This makes the production process run very long, using equipment that works automatically to increase maximum production in the industrial sector [11] [12] [13]. People who tend to want everything done quickly and use little human assistance in its operation, therefore this research makes a home-scale automatic coffee bean roaster and cooler as the theme of this research, to make it easier for coffee lovers to make their own coffee at home starting from roasting [14]. So, it does not waste a long time in the automatic roasting and cooling of coffee beans. Based on these problems, the output of this research is to create a tool system by designing and realizing an automatic coffee bean roaster based on the Arduino Uno microcontroller [15] [16].

2. RESEARCH METHOD

Design methods are certain steps, procedures, techniques that carry out a certain number of activities used by the designer in the design process. There are several implementation methods used in this research, which can be presented in Figure 1 below:

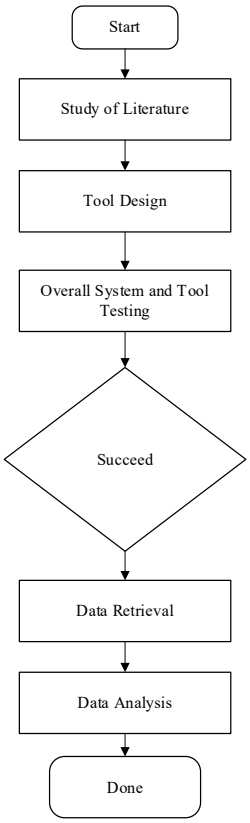


Figure 1. Research Flowchart

Design methods are certain steps, procedures, techniques that carry out a certain number of activities used by the designer in the design process. The implementation methods used in this research are as follows:

A. System Device Design

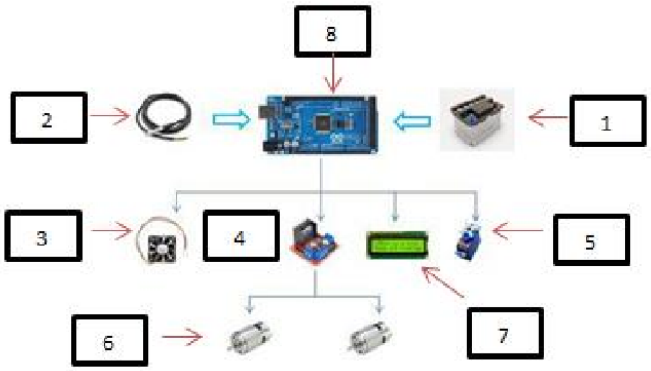


Figure 2. System Device Design

Explanation of Figure 2 :

1. Power supply 24V DC.
2. DS18b20 temperature [7].
3. Fan 12V DC.
4. Driver motor L298N.
5. Servo motor.
6. Motor 12V DC.
7. LCD 16 x 2.
8. Arduino Atmega2560 [17].

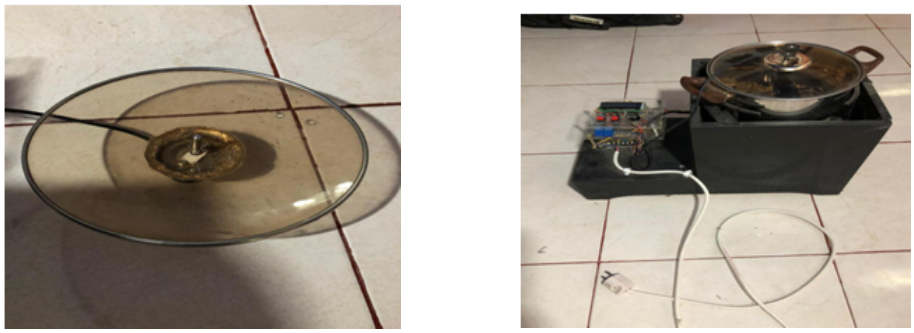
The heating element used in this design is a cast aluminum heater which is round like a plate, has a thickness of about 15mm and the maximum temperature for this heater is only 100^0C. The design of the working system is when the power supply is connected to the source, the microcontroller will change that value. into the form of ADC value (Analog to Digital Converter) then the analog value is processed by the microcontroller. And when the source has entered the microcontroller system, the green indication LED will turn on. On the control board there are 2 red buttons, namely the button to run commands on the Ds18b20 sensor, L298N Motor Driver and 12V DC Motor [18]. While the power window motor works as a driving actuator for the coffee bean roaster. In addition to using the LCD to display the temperature conditions in the roaster, there is also a temperature marker using colored LEDs, namely red (normal), yellow (warm) and green (hot) [19].

B. Coffee bean roaster dimension drawing

Here is a picture of an automatic coffee bean roaster based on the Arduino Uno microcontroller.

(a)

(c)



(b) (d)

Figure 3. Coffee bean roaster
(a) Control Box, (b) coffee bean mixer, (c) Cover and Temperature Sensor, (d) current connection cable to AC source

Testing and observation aimed at obtaining data relating to the security system and at the same time the control used in this study. Testing is done by making changes to the input of the circuit block and observing the output of the circuit block being tested. The test results data obtained will be analyzed to be used as a reference in drawing conclusions. So that it can be seen the characteristics of the reliability and speed of execution of the tool made and to find out its weaknesses. So it can be concluded whether the tool that has been made can run the system correctly and in accordance with the expected criteria. In the initial conditions there are known values, namely 220 Volt AC Heating Element Voltage, 12 Volt DC Motor Power Window, 5 Volt Sensor temperature, 5 Volt SPDT Relay, 5 Volt Motor Driver and 12 Volt Arduino Input.

3. RESULTS AND DISCUSSION

Based on the design results of the Arduino Uno-based Automatic Coffee Roaster, this tool has been designed to be completed, namely by using the DS18b20 sensor to roast coffee beans automatically. The sensor used is in accordance with the provisions that have been set so that it is connected to a DC motor so that it can roast coffee beans automatically. The following is a picture of the overall one line diagram of the automatic coffee bean roaster [20].

The object of coffee research was carried out in Lentik village, Kebayakan sub-district, Central Aceh district. The coffee research process is: First pick the red coffee beans then grind and take the outer skin of the coffee then wash the ground coffee beans, then after the coffee beans are dried in the sun until the water content in the coffee beans reaches 11%-12%, the next stage is The next step is to grind the coffee beans again to remove the husks on the coffee beans and after that do the selection of damaged or rotten coffee beans and after that the coffee beans are directly roasted or roasted according to the wishes of coffee lovers. The types of coffee beans in the study were Arabica, Rebusta and Wine coffee beans.

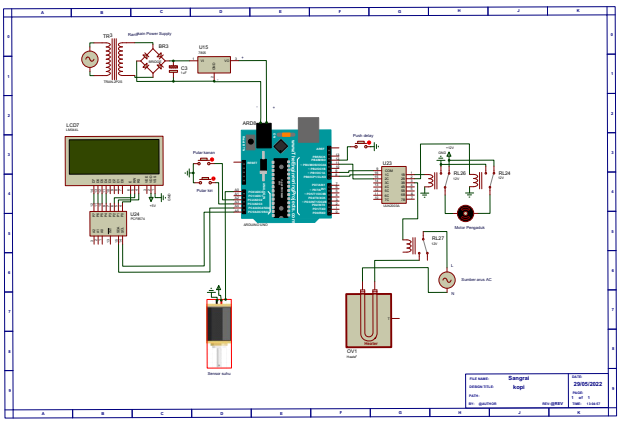


Figure 4. Schematic circuit of control system design

From the circuit above, we can see that the source that enters the power supply is 220V AC voltage and then the power supply converts the 220V AC voltage into 12V DC voltage. Where we know Arduino can be used using DC voltage instead of AC voltage. The output power supply is 12V where the potentiometer can adjust the voltage that goes into the power supply from the output power supply to Arduino with a voltage of 5V where on Arduino there is a step down module or voltage reducer, from the output pins A4 and A5 we can turn on the LCD. already used IC ITC (Serial Communication) which is for output savings. The temperature sensor is used as a tool to determine the temperature in the roasting pan, the temperature sensor uses pin A0 (Analog 0). From the temperature sensor, we see that there is a triangular arrow that indicates the voltage used is 5V, while the broken triangular line is a symbol of grounding. For the stirrer motor and hitter using 3 relays where the stirrer motor uses 2 relays and the hitter uses 1 relay, so the input used for the stirrer motor and hitter is 3 pins, namely pin 11, pin 9 and pin 8. Pin 12 is used for the push delay button which functions as toggles the direction of rotation of the stirrer motor, the analog pins used to reverse the rotation of the motor are Analog pin 2 (A2) for rotation to the right and Analog pin 3 (A3) for rotation to the left. Push delay often experiences errors due to frequency shock and causes Arduino to research again.

3.1. Hot Element Test

The process of testing the automatic coffee bean roaster based on the Arduino Uno microcontroller is carried out in stages by testing the heating element. The test can be seen in the table below.

Table 1. Heating Element Data

No	Roasting time (Minutes)	Temperature (℃)	Coffee condition	Heating Condition
1	0	0	Dark green	ON
2	1	10	Dark green	ON
3	3	30	Dark green	ON
4	5	60	Dark yellow	ON
5	7	80	Light brown	ON
6	9	95	Light brown	ON
7	10	100	Black	ON/OFF
8	11	85	Black	ON/OFF
9	12	85	Black	ON/OFF
10	33 MAX	100	Solid Black	ON/OFF

It can be seen in the table above that when the time is 0 minutes and the temperature is 0℃ with the heating element ON, the coffee beans are dark green. When running time for 1 minute the temperature increases by 10°C and the heating element remains in the ON position, the coffee beans are still in a dark green condition. When the running time is 3 times the temperature rises by 30°C and the heating element remains in the ON position, the coffee beans are still in a dark green condition. By the time 5 runs the temperature has increased by 60°C and the heating element remains in the ON position, the coffee beans have started to turn dark yellow. By the time it ran for 7 the temperature had risen by 80°C and the heating element remained in the ON position, the coffee beans had changed color to light brown. By the time it ran for 9 the temperature had risen by 95°C and the heating element remained in the ON position, the coffee beans had turned dark brown. And when the running time for 10 minutes the temperature increases by 100°C and the heating element position is in the ON/OFF position, the coffee beans have turned black. When running for 11 minutes the temperature will remain at 100^0C, the coffee beans are black. And at 12 minutes running the temperature remains at 100^0C and the coffee beans are black. The element heater is in the ON / OFF position because the maximum limit for the element heater is only at a temperature of 100°C, if it reaches the 100°C position then the heater will be ON / OFF until the heater temperature drops below 100°C. The heating element will drop to 80°C to 95°C in order to operate normally and takes about 5 minutes. We can see in the table above that the max time is 33 minutes, the roasting time has been completed because the coffee beans have been cooked or can be grinded / ground into a coarse powder form. When conducting research the temperature dropped

to 80°C to 95°C due to the heating element which is only able to flow a max temperature of 100^0C only.

The effect of the heating element on the motor is that when the heating element reaches a max temperature of 100^0C, the motor will stop rotating because the heating element can only reach a max temperature of 100^0C. The motor will spin again when the temperature is around 80°C to 95°C. The effect of the heating element on other tools is that when the temperature reaches max 100°C then all other devices will turn off or bypass and will reset for about 5 minutes, after 5 minutes of bypass the temperature on the heating element will drop at 80°C to 95°C and after that the tool will operate return

Table 2. Acidity level and type of coffee

No	Type of coffee	Coffee oil	Acidity degree	Coffee bean taste	Temperature
1	Arabica	Greasy	6,5% / seed	Bitter	100^0C
2	Robusta	Greasy	10.0% / seed	Bitter	100^0C
3	Liberica	Greasy	4,7% / seed	Bitter	100^0C

From the table above, we know that the 3 types of coffee Arabica, Robusta and Liberica all contain oil. Where the coffee bean roasting process is very influential on the temperature level used during the roasting process and the acidity level of the coffee beans. The longer the roasting process, the less water content in the coffee beans and the higher the acidity level. When roasting for too long and the temperature is too high, the coffee beans will release oil, the taste of the coffee beans will be very bitter and the color of the coffee beans will be very black.

3.2. DC Motor Rotation Test (Potenciometer)

The process of testing the roasting of coffee beans is still ongoing, namely by testing the rotation of the DC motor (Potenciometer). We can see the test in the table below.

Table 3. DC Motor Rotation Data (Potenciometer)

No	Voltage Potentiometer Volts (VDC)	Motor Relay Driver (Digital)	Potentiometer sensor value (Analog)	Potentiometer loop $0/360^0$
1	12	255	1024	360^0
2	9	175	737	270^0
3	6	125	512	180^0
4	3	112	261	90^0
5	0	0	0	0^0

From the table above, we can see that the rotation of the DC motor is fully controlled using a potentiometer. If the potentiometer is in the 0^0 position, the value of the potentiometer motor sensor is 0, as well as the motor driver and the voltage is 0. If the potentiometer is rotated by 90^0 then the maximum potentiometer sensor value is 261, the motor driver is 112 and the voltage is 3V. if the potentiometer is rotated to 180^0 then the sensor value of the potentiometer is 512, the motor driver is 125 and the voltage is 6V. if the potentiometer is rotated by 270^0 then the maximum potentiometer sensor value is 737, the motor driver is worth 175 and the voltage is 9V. if the potenciometer is rotated 360^0 then the maximum potenciometer value is 1024, the motor driver is worth 255 and the voltage is 12V.

Roasting is done using a DC engine which is controlled by a potentiometer rotation. The motor driver or relay functions as an alternator in the direction of rotation of the motor in the pan where the coffee beans are roasted so that the roasted coffee beans are stirred evenly in the roasting pan.

3.3. Formula to find water content

The formula to find the water content is as follows

$$Water\ content(W) = \frac{W1-W2}{W}\ 100\% \quad (1)$$

Explanation:
W = initial air content
W1 = Moisture content before drying
W2 = Air content before drying

At this stage an experiment is carried out to calculate the water content, the results of this experiment can be seen in the table below

Table 4. Experiment for calculating water content

Calculation	W1	W2	W	Water content (%)
Experiment 1	24	13,5	24	0,43%
Experiment 2	24	12	24	0,5%
Experiment 3	24	12,2	24	0,49%

3.4. Calculating the power consumed when roasting

To calculate the power used when roasting coffee beans, it can be searched in the following way.

$$P = P1 - P2 \quad (2)$$

Explanation:
P = Power
P1 = Total initial Kw on KWH Meter
P2 = Total Kw final in KWH Meter

From the above formula we can find out how much power is used when roasting is:
Solution:

Is known :
P1 = 10.18
P2 = 9.01

Asked : P = ?
P = P1 - P2
P = 10.18 KW – 9.01 KW
P = 1.17 KW

From the Kilo Watt (KW) unit, we can convert it into Watt units in the following way:

= 1.17 KW x 10^3
= 1.17 KW x 1000
= 1,170 Watts

So in doing roasting for 33 minutes, the power used is 1,170 Watts.

In calculating the power used when roasting, three experiments were carried out, the results of the test calculations can be seen in the table below.

Table 5. Calculation of used power

Calculation	D1	D2	D	Power used (Watt)
Experiment 1	10,18	9,01	1,17	1,170
Experiment 2	9,01	7,95	1,06	1,060
Experiment 3	7,95	6,91	1,04	1,044

3.5. The effect of water content on coffee quality and the importance of measuring the water content in coffee beans

Over-drying can cause permanent damage to the coffee beans, such as decreased aroma, acidity and taste. In addition, coffee beans can become too brittle and break easily when ground. Excessive drying can also reduce the freshness and color of the coffee beans which will affect the quality of the roasted beans and also the selling price. This is why a gentle and slow drying process is required, while continuously monitoring the condition of the coffee beans. On the other hand, if it is not dry enough, then the fungus will probably breed on the coffee beans due to the high humidity. The growth of toxic mold on coffee beans can carry health risks if ingested.

Moisture Meters can help you measure various things which you can use to make decisions in the roasting process. Before starting roasting, a coffee roaster can take note of the moisture content, density and temperature of the planned roaster. During roasting, all necessary data is recorded. This will help you to analyze the data, understand the final result and narrow down the parameters to achieve the desired roasting propyl in each type of coffee.

4. CONCLUSION

Based on the results and analysis of the system that has been made, several conclusions can be drawn, namely:

1. The relationship between water content and roasting time is that the longer the roasting time, the less water content in the coffee beans.
2. The relationship between the roasting time and the condition of the coffee beans is that the roasting greatly affects the condition of the coffee beans, because the longer the roasting is done, the condition of the coffee beans will change, such as: the color of the coffee beans, the taste of the coffee beans, the shape of the coffee beans and the acidity of the beans coffee.

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