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Design of a Thermal Conductivity Measurement Technique for Clay Furnace Materials Using an Arduino-Based Thermocouple Sensor

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ABSTRACT

This study aims to design a thermal conductivity measurement system for solid clay furnace materials, measure the thermal conductivity value of a clay furnace using an Arduino-based Thermocouple sensor, and determine the relationship of the thermal conductivity value to variations in clay furnace samples using an Arduino-based thermocouple sensor. The method used in research, design, manufacture, and testing of tools. Data collection in this study was to measure the thermal conductivity of 4 samples of clay furnaces based on differences in husks using an Arduino-based Thermocouple sensor. Analysis of research data was carried out using descriptive statistics and inferential statistics, assisted by Microsoft Excel and SPSS programs. In data analysis, univariate and bivariate analysis was performed. The relationship between the value of thermal conductivity to the husk material in each sample has a positive relationship between time and temperature variables; in other words, the more time the temperature increases, the faster the temperature increases. From the results of the study, it can be concluded that the best thermal conductivity is in sample one, with a value of 1.5375 J/ (K.m), and the poorest is in sample four, with the lowest conductivity value of 0.3125 J/ (K.m).

I. INTRODUCTION

Technology is a tool used by humans to facilitate a job, technology has also developed over time. One of the sciences that has experienced technological advances in physics. In Physics, Electronics, and Instrumentation, it is enough to help humans in meeting their needs, one of which is used as a measuring tool for the value of thermal conductivity by designing a thermal conductivity measurement system for solid materials in clay furnaces to find out the relationship between thermal conductivity values and variations in clay furnace samples with using an Arduino-based thermocouple sensor.

In the previous study (Astuti, 2015) entitled Thermal Conductivity of Copper, Brass and Iron Metals with the Coupling Method, the results of the study showed that: "This tool is suitable for use in practice and can distinguish the values of the thermal conductivity of various metals, and the value of the thermal conductivity of two metals. similarly using the coupling method obtained k = (3.5 ± 0.1) x 102 Wm-1K-1 for copper; k = (1.0 ± 0.1) x 102 Wm -1K-1 for brass; and k = (0.8 ± 0.0) x 102 Wm-1K-1 for iron".

One of the heat-producing tools is the furnace, used as cooking utensils made of clay and shaped in such a way that it can be used for cooking. The stove is fueled by dry wood twigs and has been used by the community since ancient times (Afandi dkk., 2018). Soil is the main material for making furnaces. The type of soil used is clay mixed with husks. Based on research conducted by (Kurniawati dkk., 2013) using several materials, cement concrete, brick, and fire brick, with variations in the thickness of each material are 2, 3, 4, and 5 cm. By looking at the heat loss value, the lower the heat loss value, the higher the efficiency of the furnace

The difference between this study and previous research is by varying the value of the husk in each sample as a mixture used in the manufacture of the furnace to determine the difference in thermal performance of each material by measuring the value of thermal conductivity using an Arduino-based thermocouple sensor.

II. METHOD

2.1 Tools and Materials

The tools used in this design include thermocouple sensors, Arduino, clay stoves, connecting cables, LCDs, and laptops.

2.2 Block Diagram Design

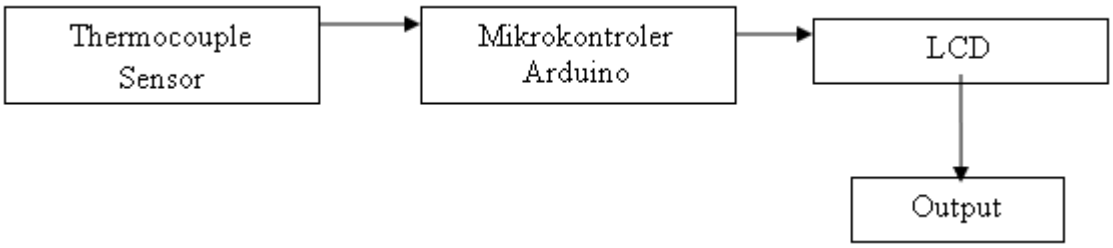


Figure 1 Block Diagram

Based on the block diagram above, it can be seen that the temperature detection device circuit consists of a Thermocouple sensor circuit. The first step is to supply power through the laptop to the entire circuit system. Then the Arduino Uno microcontroller functions as a controller and receiver of power from the laptop. After that, the microcontroller will process the input data on the sensor. After that, it is forwarded to the LCD to display the detection results on the detected object.

2.3 Flowchart

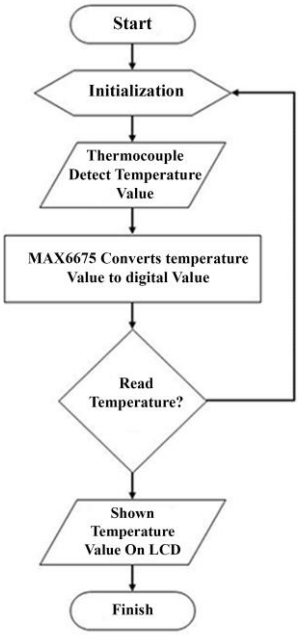


Figure 2 Type-K Thermocouple Sensor Work Flowchart

2.4 System Circuit

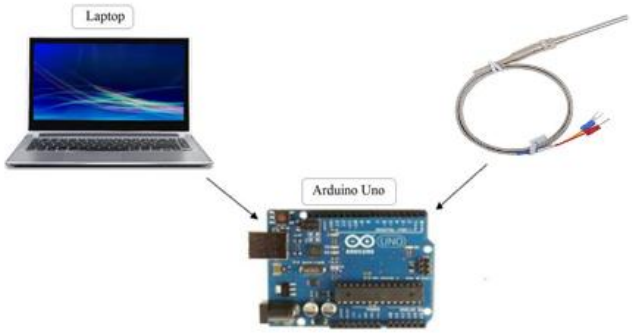


Figure 3 Circuit Schematic

After designing the system, the next stage is connecting the circuit to be tested. The design of this system is also an important part of the design. The components in this system use an Arduino Uno microcontroller, Thermocouple sensor, and Laptop. Based on the schematic drawing of the research circuit, it can be described that Arduino is connected to a laptop using an Arduino Uno USB cable. In contrast, the Thermocouple temperature sensor is connected to Arduino using a connecting cable. Furthermore, display the output of this circuit using the LCD.

2.5 Data analysis technique

The data collection technique in this study was to measure the thermal conductivity of 4 samples of clay furnaces based on differences in the husks as a mixture of soil materials consisting of: (1) furnace sample 1, (2) furnace sample 2, (3) furnace sample 3, (4) Sample Furnace 4 using Arduino Based Thermocouple E sensor.

Table 1 Furnace sample and material composition

No	Furnace Sample	Furnace Material Composition	
		Clay(*Kg*)	Husk(*Kg*)
1	Sample 1	34	24
2	Sample 2	34	36
3	Sample 3	34	48
4	Sample 4	34	60

III. RESULT AND DISCUSSION

3.1 Result

3.1.1 Univariate Analysis Result Of Measurement Data

To find out whether the ability of the furnace grill system is in line with expectations. Necessary to test the tool. Univariate analysis was conducted to determine the distribution of research subjects by calculating the frequency and percentage of each research variable. The variables in this study were between time and temperature. By testing for 30 minutes on each material with a time range of 5 minutes, this univariate data consisting of time, temperature, and test images obtained the following results:

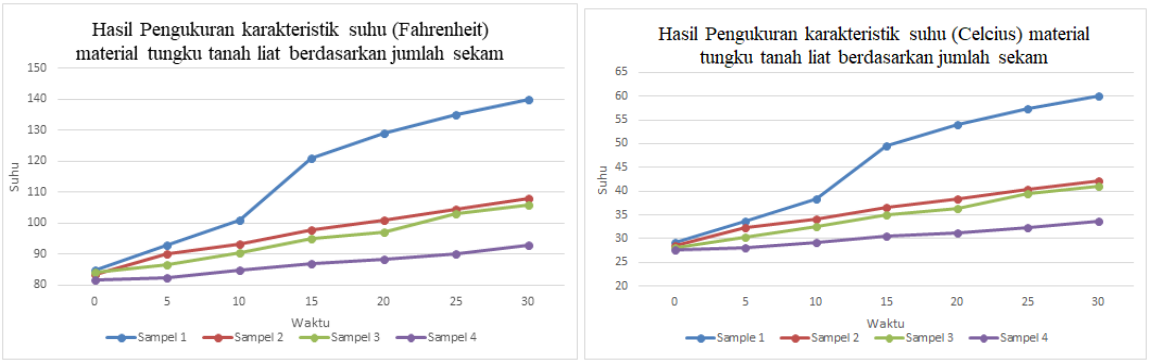
Table 2 Results of measuring the temperature characteristics of clay materials based on the amount of husks

Furnace Sample	Temperature	Time (Minute)						
		0	5	10	15	20	25	30
1	℃	29,25	33,75	38,25	49,5	54	57,25	60
	℉	84,65	92,75	100,8	121,1	129,2	135	140
2	℃	28,5	32,25	34	36,5	38,25	40,25	42,25
	℉	83,3	90,05	93,2	97,7	100,8	104,4	108
3	℃	28	30,25	32,5	35	36,25	39,5	41
	℉	84	86,45	90,5	95	97,25	100	106
4	℃	27,5	28	29,25	30,5	31,25	32,25	33,75
	℉	81,5	82,4	84,65	86,9	88,25	90,05	92,75

Table 3 Calculation Results of Thermal Conductivity Values in Furnaces

Furnace Sample	Time (Minute)						
	0	5	10	15	20	25	30
1	0	1,35	1,35	3	1,35	0,975	0.825
2	0	1,125	0,525	0,8203	0,525	0,6	0,6
3	0	0,675	0,675	0,75	0,375	0,975	0,45
4	0	0,15	0,375	0,375	0,225	0,3	0,45

3.1.2 Bivariate analysis the results of the relationship between the value of thermal conductivity and the variation of husk mass



(a) (b)

Figure 4 (a) Results of Measurement of Temperature characteristics in degrees Celsius (b) Results of Measurement of characteristics of Temperature in Faranheit

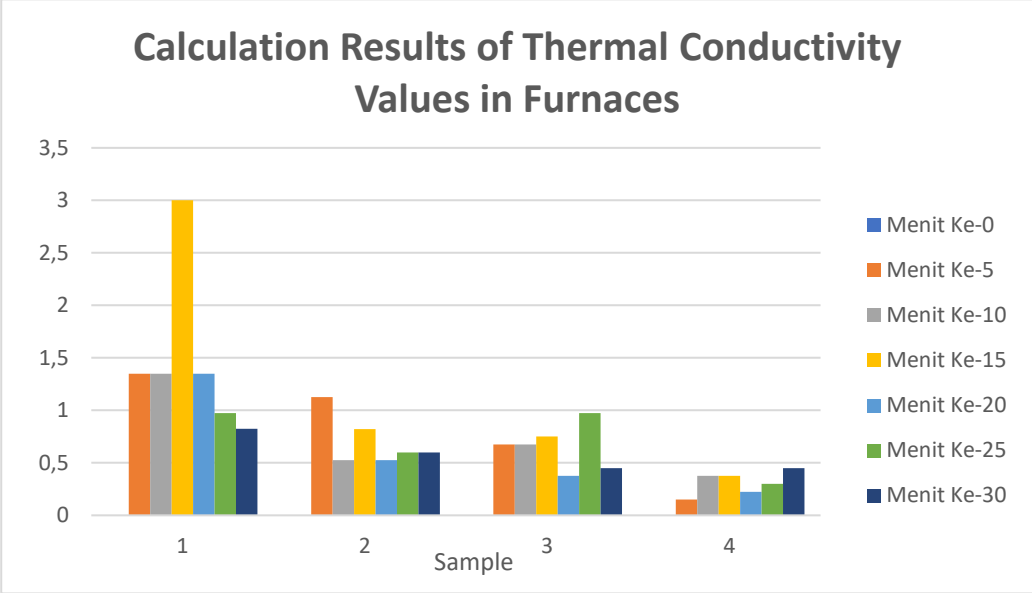


Figure 5 Calculation of the thermal conductivity of the furnace sample

Based on the graphical presentation of the measurement results shows that as time goes on, the temperature continues to increase. The range of thermal conductivity values for each material includes samples 1 to 4. It is concluded that there is a positive relationship between time and temperature variables.

The study's results stated that the more clay and husk mixture composition in sample 4 variation experienced a slower increase in thermal conductivity value compared to the furnace, which had the lowest variation of husk in sample 1 variation with a significantly faster temperature increase representation of all furnace samples. Based on the results of these measurements, it is concluded that furnaces with mixed husk material are the best to use and are more durable but take longer to conduct heat, while furnaces with chaff mixture materials that have less range have structural damage but are fast in delivering cooking.

IV. CONCLUSION

This research produces a tool that can measure the thermal conductivity of a clay furnace. The measurement results are as follows: Sample [1] soil composition of 34 kg and husk 24 kg produced a thermal conductivity of 1.5375 J/(K.m), sample [2] soil composition of 34 kg and husk 36 kg produced

a thermal conductivity of 0.6992 J/(K.m), sample [3] composition of soil 34 kg and husk 48 kg resulted in a thermal conductivity of 0.65 J/ (K.m). Sample [4], the composition of soil 34 kg and husk 60 kg resulted in a thermal conductivity of 0.3125 J/(K.m).

So the best thermal conductivity is in sample one, which has a value of 1.5375 J/(K.m), and the poorest is in sample four, with the lowest conductivity value of 0.3125 J/(K.m).

The results of the correlation test resulted in a relationship that states that each material has a significant positive relationship. In other words, the longer the time, the temperature increases.

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