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Improvement of Electric Furnace Heating Function for Use in Aluminium Waste Management

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Abstract: A furnace is a widely used tool in metal recycling activities. The use of furnaces is mainly focused on the production of aluminium materials. The heating system for the furnace is an important aspect that will affect the material to be melted. It needs to be at an optimal level to ensure that the melting of each material undergoes a perfect process. The furnace heating system that has been developed before shows some limitations and shortcomings. The problem occurs when the furnace only uses one heating plate. This project was produced to improve the function of the electric furnace used to melt aluminium scrolls resulting from machining activities. This product is developed based on the Engineering Design Process model as a guide for the development of this product which has certain phases of the problem, carrying out research, specification of solutions, prototype design, prototype testing, and improvement. Evaluation is done to test the functionality of the product in solving the heating time problem. As a result of the observations made, the furnace can heat up to 650c between 5 minutes and 48 seconds to 7 minutes and 21 seconds. Based on the analysis, it can be explained that the objectives of the study have been achieved.

Keywords: Furnace, Heating System, Aluminium Waste Management

1. Introduction

In today's industrial sector, various types of materials are used to produce a product. According to data released by Trading Economics aluminum is widely used in aerospace, packaging, automobile and railway applications and as a building material. Aluminum material is widely used because of the advantages of the material. According to the statement of Lusquere (2018), one of the advantages of aluminum is that when it is recycled and reused, it may be able to reach the same quality level as the

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original. With the light nature of aluminum is also a focus for product manufacturers. Components for automotive use mostly use aluminum as the main material because it is lighter and easier to process to the desired shape. With its recyclable and reusable nature, it needs to be melted down before using the furnace tool to be reshaped.

A furnace is a widely used tool in metal recycling activities. The use of furnaces is mainly focused on the production of aluminum materials. According to Hussein (2022), the electric furnace is the most widely used in the industry. Electric furnaces use the concept of changing electrical energy to heat energy. It is more suitable to be used on a small scale, especially the machining workshop at the Faculty of Technical and Vocational Education at Universiti Tun Hussein Onn Malaysia. The use of electric furnaces is more effective compared to gas furnaces because the mechanism system is more environmentally friendly and can reduce air pollution because gas furnaces use an open combustion system while electric furnaces use heating iron as a source of heat. For optimal use, the system available on the furnace must be at the best level such as the heating system and heat-sealing system. Therefore, the presence of an electric furnace that works optimally can influence the management of aluminum material waste in the machining workshop.

1.1 Problem Statement

Based on the background of the problem that has been created, several things need to be paid attention to in the furnace problem that has been developed. System improvements need to be done on the furnace heating system and the heat-sealing system on the furnace body. Furnace heating systems that have been developed before show some limitations and shortcomings. The problem occurs when the furnace only uses one heating plate. The heating plate is placed at the bottom of the heating chamber. This causes an uneven temperature in the heating chamber because the heating that occurs is concentrated on the bottom where the heating plate is located. The upgrade that needs to be done on the furnace is to ensure that the heating focus occurs throughout the heating chamber by ensuring an even temperature in the heating chamber.

1.2 Project Objectives

The objectives of this product development are:

1. Identify the critical factors to optimize the heating function of the electric furnace.
2. Redevelop the electric furnace heating system that can reach the heating temperature with a shorter time rate.
3. Testing the functionality of the electric furnace from the aspect of heating time.

2. Methodology

This study uses a technical non-experimental research design in the form of a case study. The Engineering Design Process (EDP) model was chosen by the researcher to be used in the development of aluminum material processing tools. This model was chosen because the Engineering Design Process (EDP) Model has a comprehensive methodology to produce processing equipment for this aluminum material. This phase or procedure of the Model Engineering Design Process (EDP) consists of 6 phases, starting with the problem definition phase, carrying out research, determining the solution specification, prototype design, prototype testing, and finally the improvement and result.

2.1 EDP Model Procedure

After the researcher has done research related to research methods that have the potential to help in this study. From the study, the researcher chose the Model Engineering Design Process (EDP) as a guideline used throughout the project. To ensure the implementation and work processes carried out, the study was conducted based on the phases found in the model. This model approach is a chain of sequential and systematic activities (Masandug, 2022). The phases found in this model are the phase of analyzing needs, designing a project, project implementation, project testing, project use, and project maintenance (Masandug, 2022). The EDP model was chosen based on the advantages of this model where it has a phase that is compatible with the improvement of the project that has been done, which is the phase of examining the needs and problems that can help to ensure that the project's objectives are achieved. In addition, this model is also suitable for projects based on product development and improvement.

The stages in this model start from the planning stage to the management stage and are done gradually (Abdul Wahid, 2020). Based on the statement, this model is suitable to ensure that the product development process and the improvements made remain relevant and realistic. In the project that is done, a method is needed to form a framework that fits the needs or development plans that have been produced.

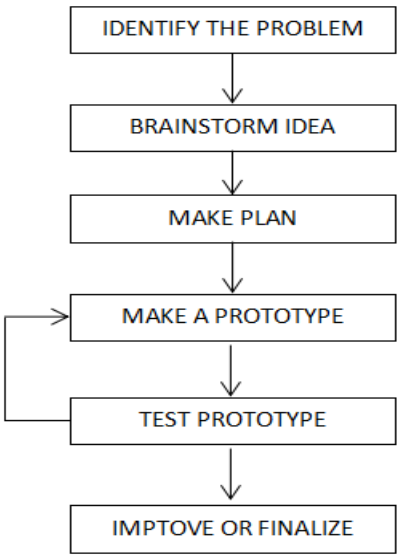

Figure 1: EDP Model

2.2 Research Instrument

Measuring tools are referred to as instruments when determining data and information obtained. The following techniques were used as a research tool for the improvement of electric furnace heating function for use in aluminum waste management.

i. Observational instrument
ii. Product development instrument
iii. Experiment instrument

2.3 Product Development

The steps taken are based on the methodology that has been described in the third chapter of the study. In addition, the entire matter related to the selection of materials is a guide by the researcher to realize the production of a more effective heating system. However, some things cannot be avoided such as the selection of existing material specifications from the manufacturing plant which is considered by the researcher in deciding for the selection of the type of material for product development.

2.3.1 Electric Furnace Heating System Design

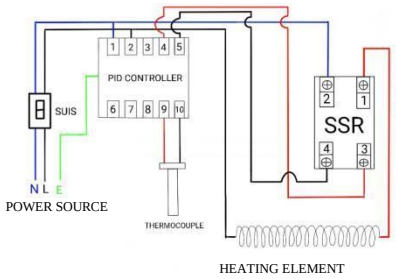

Figure 2: Wiring Heating system

The schematic circuit produced is based on the function of the system that has been set. According to Smith (2019), schematic wiring diagrams are used in many industries, including electrical engineering, electronics, and automobiles. The intended function of the system is that the heat produced by the heating element is uniform based on the settings made on the controller of the system. To maintain the current that heats the heating element to ensure that the temperature is even, the use of components such as solid-state relays is used in the system.

2.3.2 Material Selection

For the specification of this heating element, the resistance produced is around 18 Ohm. With the use of a power source of 240V, the current produced is around 13.33 Amp. From that value, it can be estimated that the total power used is 3200 watts. Therefore, the total power consumption during one hour of use is 3200 watts per hour. There are two formulas used in each calculation.

1. Voltage formula

$V = I \times R$

$I = V / R$

$= 240V / 18 \text{ ohms}$

$= 13.33333 \text{ Amps}$

2. Power formula

$P = V2/R$

$= 240 \times 240 / 18 \text{ ohms}$

$= 3200 \text{ watts}$

2.3.3 Determination of Specifications and Preparation of Heating System Components

To build an electrical system, the selection of components is an important matter that needs to be paid attention to and studied in advance. This is because the components available in the market have various specifications for specific purposes. The determination of these specifications is done to prevent damage in the system such as a situation where a component receives excessive power that can cause damage to the component.

Table 1: Component

	Component	Specification	Total	Sources
1	Heating Element	Khantal AF, Coil Diameter 10mm Panjang 1.3m	2	SH Heating Sdn Bhd
2	Solid State Relay	Input = 3 – 32v DC Beban V = 90 – 480v AC Beban Arus = 40 A	2	Robotronik
3	Ceramic Connector	Saiz 32mm ×27mm×18mm	2	MDK Swiftlet
4	Thermocouple	Type – K Bacaan Suhu 0°c – 1300°c	1	Taxnele.my
5	PID Controller	Voltan punca kuasa 240v Sensor K,J,T,R,S Suhu tetapan maksima 1300	1	SH Heating Sdn Bhd
6	Metal Net	Saiz 100 cm × 33 cm Size lubang 8mm × 4mm	1	Fastpackstore

2.3.4 Manufacturing Process of Heating Element Chamber

Figure 3: Making chamber

This process is carried out to create a space or slot in the heating area of the electric furnace to place the produced heating element. This process is very important to ensure that the heating element can be placed in the space safely and firmly. Cutting or producing this space is using a knife to cut the ceramic fiber blanket according to the size or size of the heating element.

2.3.5 Instrument Installation Process for Control Unit

Figure 4: Control unit installation

The installation process of electrical instruments is the main thing that needs to be done carefully. This is because, if there is a mistake when connecting the wiring between the instruments, the risk of a short circuit or damage to the instrument can occur. Among the instruments used in the production of this control unit are the Pid controller, Thermocouple, Solid State Relay, 15A Socket, and switch.

2.3.6 Installation of the Heating System on the Furnace

Figure 5: Installation of heating element

This process is the last in the development of this heating system. In the process, two steps will be done which is the installation of the heating element in the space or slot that has been produced at the beginning of the process. After completing the installation of the heating element, the next step is to make the connection between the control unit that has been produced during the second process and the heating element. The connection between the wires from the control unit and the heating element will be done using a ceramic connector.

3. Result and Discussion

Data analysis is the phase of analyzing the rate of time taken by the heating system to reach the set temperature. Several temperature settings have been set by the researcher during the product testing process in studying the rate of heating time. The analysis phase is made through data collected during the product testing process carried out to achieve the objectives of the study.

3.1 Rate of heating time

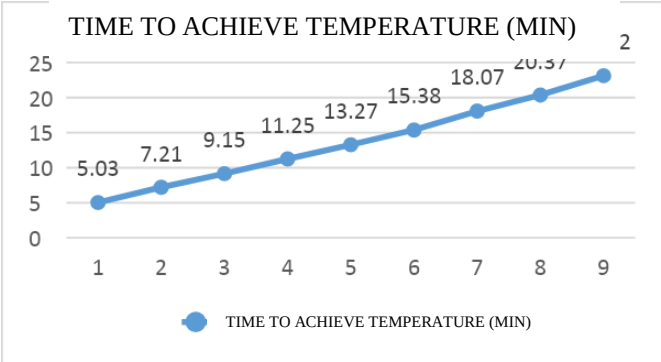

Figure 6: First test of the rate heating time rate

The figure above shows the time required for the heating system to reach a certain temperature. For the first test of the minimum temperature of 650℃, it took 5 minutes 3 seconds and for the maximum temperature of 1000℃, the time taken was 23 minutes 12 seconds.

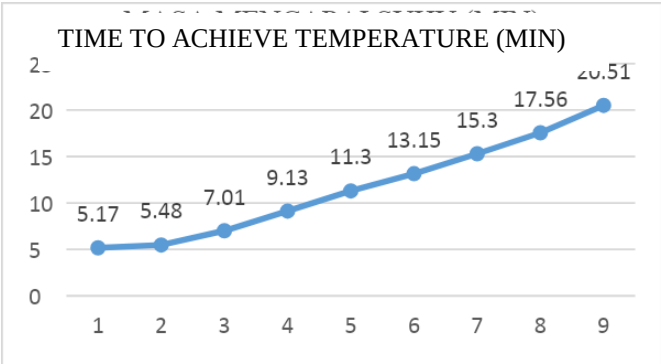

Figure 7: Second test of the rate heating time rate

The figure above shows the time required for the heating system to reach a certain temperature. For the second test of the minimum temperature of 650℃, it took 5 minutes 17 seconds and for the maximum temperature of 1000℃, the time taken was 20 minutes 51 seconds.

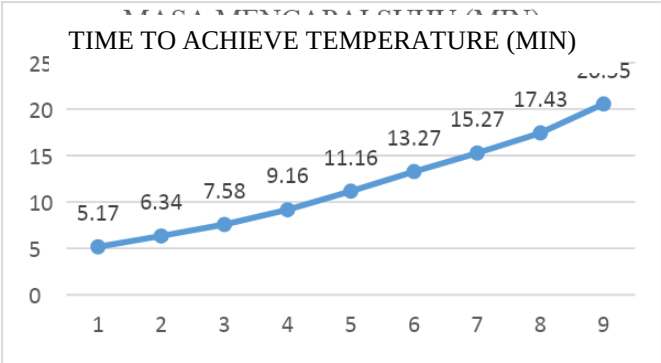

Figure 8: Third test of the rate heating time rate

The figure above shows the time required for the heating system to reach a certain temperature. For the first test of the minimum temperature of 650℃, it took 5 minutes 17 seconds and for the maximum temperature of 1000℃, the time taken was 20 minutes 55 seconds.

Comparisons are made by comparing the heating time data before improvement with the heating time after improvement. On the heating system before being improved, the set temperature is a temperature pad of 670°c. For the heating system, the time taken for the heating system to reach the specified temperature is 43 minutes and 24 seconds. If a comparison is made with the heating system that has been improved, for the setting of 700°c and the temperature it is higher compared to testing the previous heating system. The time required was only 9 minutes and 15 seconds on the first test, 7 minutes and 1 second on the second test and the time required during the third test was 7 minutes and 58 seconds. All three total times recorded are lower than the heating time of the previous system. This shows that the new heating system is 4 times faster and more efficient than the previous heating system.

3.1 Critical factors to optimize the heating function of the electric furnace

To identify the factors to optimize the heating function of the electric furnace, a questionnaire was given to the students. Throughout the development of the questionnaire, several items were included as question criteria. The questions developed are related to questions related to the functionality of existing electric furnaces. The functionality prioritized in the development of the question is focused on the existing electric furnace heating system in the general machining workshop. While getting to the furnace, it could not work. Therefore, to give the students an insight into the operation of the furnace, a video that had been developed by previous students was taken and placed in the questionnaire. For the previous warm-up time, it cannot be displayed in the video. The researcher had to make a search related to previous furnace data.

After completing the development of the questionnaire, the next process is the distribution of the form to the students. The constraint that occurs is that the filling of this form needs to be prioritized for students who have used the furnace. The researcher needs to ask some students whether they have ever used the furnace or not. Findings from the search there are several students whose junior sergeant projects use the furnace for the testing process they do. The furnace is less used because of its low functionality. Students who have never used the furnace will refer to the video and test data provided on the questionnaire.

As a result of the students filling in the questionnaire, most of them agreed that the heating system used in the furnace was less efficient. Therefore, the respondent agreed to increase the operating rate of the heating time of the furnace. The heating time is an important factor that affects how quickly the furnace can reach and stabilize at the desired operating temperature Elsevier, (1982).

3.2 Electric furnace heating system that can reach the heating temperature in a shorter time

The heating tool that can be used for the development of this heating system is the resistance heating alloy. Resistance heating alloys used for high temperatures can be divided into two main groups, iron-chromium-aluminum (FeCrAl, Kanthal) and nickel-chromium (NiCr, Nikrothal®) basic alloys based on Kanthal (2019). Based on Kanthal's statement, Kanthal A-1 can reach a maximum temperature of up to 1400°C (2550°F); Nikrothal 80 has a maximum temperature of 1200°C (2190°F). Nikrothal heater. Nikrothal's malleable nature is also an advantage because, after long-term use, it remains malleable Kanthal (2019). For the development of this heating system, the material chosen is kanthal. From the results of the comparison of data and requirements, the researcher chose the use of kanthal-type resistance wire as a heating device that will be used in the development of the heating system.

The temperature that can be produced is low. The researcher had to find the cause of the incident. Researchers continue to research and research using Google and YouTube platforms. The researcher found that the resistance wire needs to use certain ohms or resistance to ensure that the temperature and time of the heater can be determined. The researcher refers back to the supplier regarding the matter.

The supplier informs that the appropriate resistance to reach a temperature of 1000℃ to 1300℃ is 18 ohms with the use of a voltage of 230 volts. The researcher continues the process by turning off the resistance on the wire whose resistance is 18ohm using a multimeter.

Increasing the temperature continuously until it exceeds the setting set on the control unit. The researcher needs to identify the cause of the damage. After operating to identify the problem, the researcher found that the problem occurred due to damage to the Solid-State Relay which did not work because it did not cut the power flow to the resistance wire. The researcher refers to the resistance wire supplier company because they know more about the heating system. There was a discussion related to the problem and the result of the discussion found that the Solid-State Relay that the researcher used was fake. To overcome the problem, the researcher explained that their company has a suitable and high-quality Solid-State Relay. The researcher made the purchase directly after the discussion took place with the purchase of Solid-state relay 25 A.

3.3 Functionality of the electric furnace from the aspect of heating time

Throughout the testing process, several problems arose. During the first test, there was a problem where the power socket used became hot and melted. The researcher examines the problem in depth to solve the problem. For power consumption, the power used is 13.33 Ampere. After the researcher conducted a study, the researcher found in the Domestic Installation Electrical Wiring Guidelines book published by the Malaysian Energy Commission (2022), every heating system must use a power socket that uses a minimum 4mm wire. Home power sockets use 2.5 mm diameter wires. It is not suitable for the use of heating devices. The researcher acted by wiring a new socket that uses 6 mm wire for the safety of the wiring during the testing process. The action successfully overcomes the problem that occurs.

The power switch on the electric furnace control unit overheated and melted. It causes the switch to not work. The researcher identified that the switch used before was not suitable because the specification for the switch was for low ampere consumption. The researcher had to find a new switch that had the appropriate ampere specification. After getting the appropriate switch, the furnace can work well.

4. Conclusion

Overall, this electric furnace heating system has been successfully developed and works well. The developed heating system can also achieve the goals and objectives of the development of this system. This electric furnace heating system is built through several processes, namely the process of identifying problems that can be used as the main cause of the study. Determine the solution to be used and the development and testing of the electric furnace heating system. Those processes to some extent help the researcher to build a heating system well. Researchers hope that the electric furnace heating system will develop and improve the functionality of the electric furnace to reprocess aluminum scroll waste for reuse. The specifications of the product that can be developed are a heating temperature of 1000℃, a power consumption of 3200 watts per hour, and a current used is 13.33A. The suggestions mentioned can also be used by other researchers to ensure that electric furnaces can be improved and follow future technology circulation.

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