Design of a Device for Utilizing Hazardous and Toxic Waste as Fuel For a Stove (Burner) with a PID Control System

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ABSTRACT

Used oil waste is treated by spraying oil into the combustion furnace using wind from a blower. Before pouring oil into the furnace, it is necessary to manually heat it up to 300°C to burn off the fat. The controls in this study control the valve and blower to reach the desired temperature up to 800°C by utilizing a k-type thermocouple temperature sensor to detect temperature. This burner stove research uses the PID control method because it has a response that is fast enough to reach the desired temperature. The PID method is a controller that can reduce the error rate in a system to provide an output signal with a fast response, small error rate, and small overshoot. One of the contributions to this research is the importance of reducing the negative impact of hazardous and toxic waste on the environment and being an alternative solution in dealing with hazardous and toxic waste. In other conditions, this research makes an important contribution to the development of technology for processing and utilizing hazardous and toxic waste materials. Hopefully, this research will help contribute ideas and thoughts on preserving the environment and utilizing existing resources more efficiently. From the results of this study, based on the number of test results from seven tests, it can be said that the conditions are optimal because the fire produced from used oil does not contain black smoke. Meanwhile, the maximum temperature generated was 809 °C at the 73rd second, and the temperature continued to fall at the 94th second, and so on until it reached stability. These conditions indicate that the fuel speed ratio (used oil) and applied air pressure have started to improve so that the temperature is stable at 806 °C. In conclusion, the optimum test results at a flame temperature of 806 °C, the resulting flame does not produce black smoke, so the combustion of the used evaporative lubricant produces much cleaner exhaust emissions.

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1. INTRODUCTION

Based on the latest data released by the Central Statistics Agency (BPS) regarding the development of the number of motor vehicles in Indonesia in 2022, the total number of all types of motor vehicles reached 148,212,865 units [1]. This condition shows the increase in the number of vehicles every year is almost close to 5%, the trend is the increase in motorized vehicles. The increasing number of vehicles has led to an increase in the number of workshops that provide maintenance and repair services for motor vehicles. The increasing number of workshops has both positive and negative impacts.

The positive impact is to provide employment opportunities and significant welfare for the community. On the other hand, if not managed properly, these workshops can cause environmental damage, one of which is the waste of hazardous and toxic materials such as used oil which causes deadly pollution to plants. This is very important because it can participate in conserving natural resources. Used oil waste is categorized as hazardous and toxic waste due to its toxic properties, which can directly or indirectly pollute and damage the environment, health, and human survival [2]–[6]. Therefore, it needs to be managed properly to benefit society, such as in this research, which aims to utilize used oil waste as a fuel for a stove.

The used oil waste is processed by spraying the oil into the burner combustion chamber using air from a blower. Before the oil spraying process, the combustion chamber needs to be manually preheated to a temperature of 300°C to burn the oil [3], [5], [6]. The control system in this research controls the valve and blower to achieve the desired temperature of up to 800°C, utilizing a Type-K thermocouple temperature sensor to detect the temperature.

The design of the burner stove is expected to have better economic value than conventional fuels such as gasoline, LPG, and others [4]. The combustion of used oil through evaporation produces exhaust emissions that are much cleaner, resulting in less smoke and less disturbance to the surrounding area. Moreover, the design of the burner stove must be easy to maintain.

In several previous studies, much has been discussed about the design of burner stoves using used oil. Still, in these studies, the temperature intensity on the stove was controlled so that it could not maintain the temperature based on the desired set point [3]–[6]. In other cases, PID is widely used in process control in various control applications, such as controlling temperature, speed, position, and level [7]–[53]. The use of PID is very important because this method can maintain stability in very varied controls, speed in responding has very high accuracy and is easy to use in various types of plans for control.

This research uses the PID control method because it responds quickly to the desired temperature. The PID (Proportional Integral Derivative) control method is a controller that can reduce the level of error in a system, providing an output signal with a fast response, small error, and small overshoot.

The role of the PID method in this research is to control the temperature to have a fast response. Utilizing the used oil waste as a fuel for the stove, controlled by the PID method, is expected to have better economic value than conventional fuels such as gasoline, LPG, and others.

One of the contributions to this research is the importance of reducing the negative impact of hazardous and toxic waste on the environment and being an alternative solution in dealing with hazardous and toxic waste. In other conditions, this research makes an important contribution to the development of technology for processing and utilizing hazardous and toxic waste materials. Hopefully, this research will help contribute ideas and thoughts on preserving the environment and utilizing existing resources more efficiently.

2. METHODS

2.1. Designing the Tool/Device

Generally, the design of this device is created to determine the specifications and placement of supporting components such as blowers, sensors, and solenoid valves in the used oil burner stove. Fig. 1 shows the result of the used oil burner stove device design.

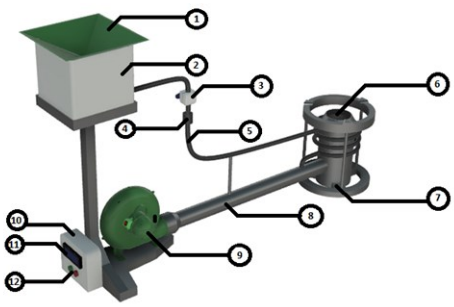

Fig. 1. The Design of the Burner Stove Device

The numbering and function description of the burner stove components in Fig. 1 are as follows:
1. Funnel functions as a channel for delivering oil to the oil storage container.
2. Oil container serves as an oil storage container.
3. Solenoid valve serves as an oil regulator.
4. Hose functions as a channel for delivering oil to the stove burner.
5. Stove burner serves as a place for burning oil.
6. Thermocouple type K sensor functions as a temperature reader on the oil combustion stove.
7. Oil pipe serves as a channel for delivering oil to the stove burner.
8. Blower functions to regulate oil spraying on the stove burner.

9. Component box serves as a container for components such as Arduino Uno microcontroller, step down, power supply, and others.
10. LCD functions to display sensor readings.
11. Push button serves as a button to turn the system on or off on the burner stove tool.

2.2. Control System Block Diagram

The control system block diagram is used to understand the control system or the process of how the system works. The control system block diagram on the burner stove equipment is shown in Fig. 2.

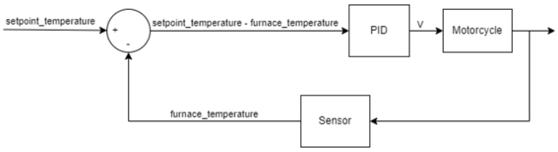

Fig. 2. Control System Block Diagram

The control system block diagram in this study is to map the processes in the system from input to the expected output with the closed loop control system used. The block diagram of the stove burner control system can be explained as follows:

1. The input to the system is in the form of the furnace temperature set point denoted by the variable temperature_set point with the temperature set point value of the intended furnace being 800°C.
2. The sensor used in this control system is the result of reading the type k thermocouple sensor, which reads the temperature of the furnace (temperature_oil). This sensor will compare it with the set point data.
3. The Proportional Integrative Derivative (PID) controller functions as a controller that reduces the error signal so that the output data is the same as the input data. The value of temperature_setpoint – temperature_oil is the input in the PID. While the output from the PID is in the form of a v (RPM) value to set the blower speed that must be given.
4. The actuator in the system is a motor that will regulate the given blower speed according to the PID output.
5. The output of this system is the actual viscosity (temperature_actual).

In this study using the PID method with the following mathematical formulation.

$$Et_{\_1} = (\text{Setpoint\_temperature} - \text{temperature}) \tag{1}$$

$$Eint\_Update = \frac{((Et + Et_{\_1}) * Ts)}{2} \tag{2}$$

$$Eint = Et_{\_1} + Eint\_update \tag{3}$$

$$Edif = \frac{Et - Et_{\_1}}{Ts} \tag{4}$$

$$PID = (Kp * Et) + (Ki * Eint) + (Kd * Edif) \tag{5}$$

2.3. Flow Diagram The Burner Stove Toll System

The following is a flowchart of the burner stove tool system as shown in Fig. 3. The stove burner starts with pouring the used oil into the oil reservoir, after that inserting some wood chips or coconut shells into the furnace, then mixing the used oil and gasoline with a ratio of 1:1 as an initial lighter to burn the wood chips or coconut shells and turning on the stove. using a lighter (lighter). After the furnace is lit, the next process is reading the temperature of the furnace until the temperature reaches 250°C. After the used oil container selenoid valve opens, the oil will spread in the hose. Then the blower valve opens, and simultaneously, the blower turns on. The air supplied by the blower will be read how much air discharge passes through the flow sensor and the temperature in the furnace in real-time, whether the temperature has reached 800°C. If the temperature is less than 800°C, a control valve blower will be carried out using the PID method so that the output obtained is in the form of a temperature in the furnace reaching 800°C.

Blower speed flowchart using the PID method as shown in Fig. 4. The inputs given are the values of Kp, Ki, Kd, setpoint_temperature, and furnace_temperature. If the oil temperature value is low, then the blower

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speed (RPM) value must be given or equal to the small blower speed. Meanwhile, if the furnace temperature is high, the value of the blower speed (RPM) that must be given is equal to the speed of the large blower. After that, the process of reading the temperature of the furnace. If the temperature in the furnace reaches 800°C, the process is finished, and if it does not reach 800°C, the process will be repeated.

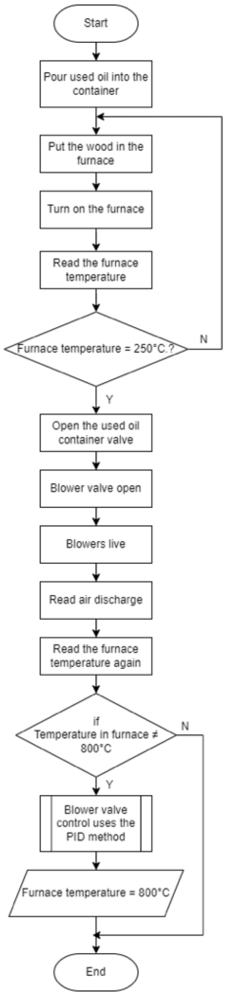

Fig. 3. Burner Stove Tool Flowchart

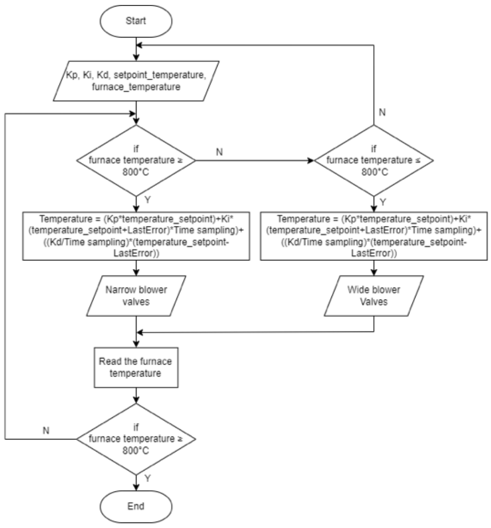

Fig. 4. Blower Speed Control Flowchart Using the PID Method

3. RESULTS AND DISCUSSION

This section will explain program implementation, and system analysis from research on stove burners. Researchers will also carry out the mechanical assembly of the stove burner, test the performance of the tool or sensor used, and test the combustion results in the form of flame length obtained based on the given air pressure value. So, the test results will be in accordance with the expected setpoint, namely, the temperature in the furnace can reach 800°C. This burner stove utilizes waste or cooking oil as the fuel used.

3.1. Thermocouple Sensor Design Results

This study uses a k-type thermocouple sensor where this sensor is used to read the temperature in the stove, where the sensor readings will be processed by the microcontroller, which will then produce an output, namely the blower speed. The following will present the results of the Arduino electronics design with a thermocouple sensor as shown in Fig. 5.

Fig. 5. Results of Electronic Design of Thermocouple Sensors

3.2. Flowmeter Sensor Design Results

This study also uses a flowmeter sensor where this sensor is used to read the wind pressure that passes through the pipe to the stove. The following will present the results of the Arduino electronics design with a flowmeter sensor as shown in Fig. 6.

Fig. 6. Flowmeter Sensor Electronic Design Results

3.3. Burner Stove Assembly

The assembly of the burner stove is carried out at the Mechatronics Engineering Laboratory and the Industrial Automation Laboratory at Trunojoyo Madura University, the welding and joining processes of materials are as shown in Fig. 7.

Fig. 7. Material Assembling Process

The stove is made of stainless steel, blower pipe, faucet stop and used as a conduit for used cooking oil using a copper pipe with a diameter of 5 mm. The blower display is shown in Fig. 8.

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Fig. 8. Two Inch Diameter Blowers

3.4. Burner Stove Testing Tool

Tool testing was carried out at the UTM Mechatronics Engineering Laboratory. The results of the used oil stove experiment are shown in Fig. 9.

Fig. 9. Used Oil Stove Ignition Test

The temperature sensor readings on the LCD are displayed as shown in Fig. 10.

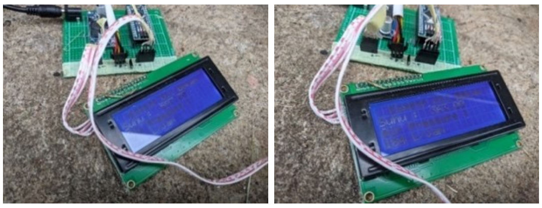

Fig. 10. Temperature Sensor and Flowmeter Reading Results

3.5. Burner Stove Testing Chart

The temperature velocity graph on the used oil stove, at each given level of air pressure (Pa), is:

a) Air discharge value (q) = 100 L/hour, used oil flow rate (v=0.058 m/s), then air pressure (P) = 0.7 Pa (Fig. 11).

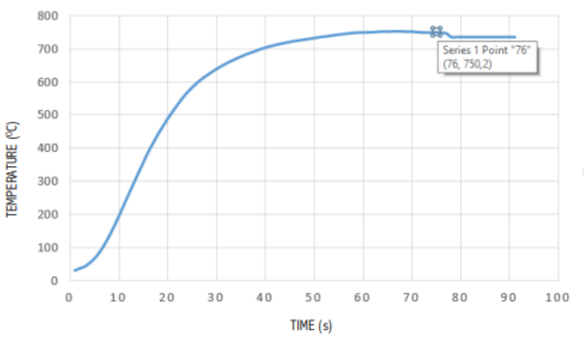

Fig. 11. The relationship between temperature (°C) vs time (s) at air pressure (P) = 0.7 Pa

Based on Fig. 12, when the air pressure is 0.7 Pa, the resulting flame is red and there is a lot of black smoke which indicates too much fuel that is not completely burned. The temperature produced by the stove is 753°C at 64 seconds, in the next second, the temperature drops at 71 seconds, and so on, the temperature is stable at 736.5°C.

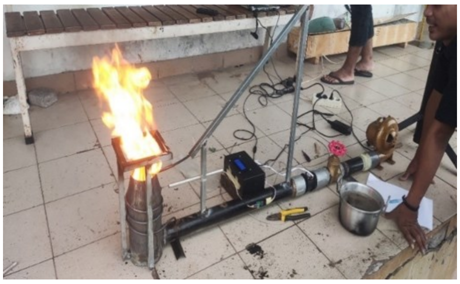

Fig. 12. Flame at 0.7 Pa air pressure

b) Value of air discharge (q) = 208 L/hour, speed (v) of oil (v=0.058 m/s), and air pressure (P) = 3.004 Pa (Fig. 13).

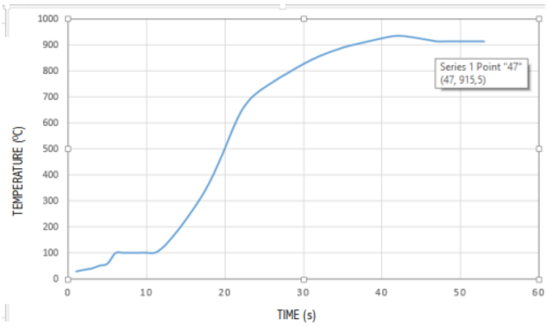

Fig. 13. Relationship of Temperature (ºC) vs Time (s) at Pressure(P)= 3.004 Pa

In Fig. 14, the air pressure on the stove is 3.004Pa, the flame is still hot, and there is still a lot of black smoke, which indicates that there is too much-unburned fuel. The resulting temperature is 935ºC, at the 43rd second, and it begins to decrease in temperature at the 44th second and the temperature stabilizes at 915.5ºC at the 47th second, and so on.

Fig. 14 The flame is at an air pressure of 3.004 Pa

c) Value of air discharge (q) = 320 L/hour, oil speed (v=0.058 m/s) and air pressure (P) = 7.11 Pa (Fig. 15).

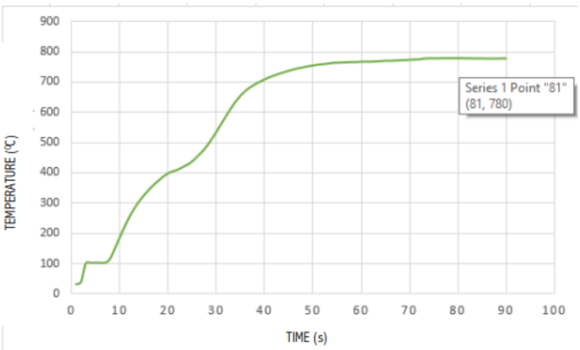

Fig. 15. The relationship between temperature (ºC) vs time (s) at pressure (P) = 7.11Pa

Based on Fig. 16 and the provision of 7.11Pa air pressure, it can be seen that the flame is not normal, and there is still black smoke, which indicates that there is still too much fuel that is not completely burned. The temperature achieved under these conditions is 779 °C in the 74th second.

Fig. 16. The flame is at an air pressure of 7.11 Pa

d) Value of air discharge (q) = 424 L/h, oil speed (v=0.058 m/s), and air pressure (P) = 12.48 Pa (Fig. 17).

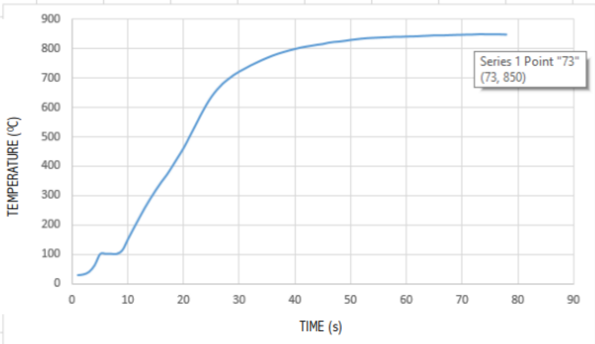

Fig. 17. The relationship between temperature (°C) vs time (s) at pressure (P) = 12.48 Pa

Based on Fig. 18, the flame produced at an air pressure of 12.48 Pa, the flame is not too red, not too much black smoke. These conditions indicate that the ratio of fuel speed (used oil) and air pressure has started to improve; the stove temperature reached 849 °C in the 71st second and is stable at that temperature.

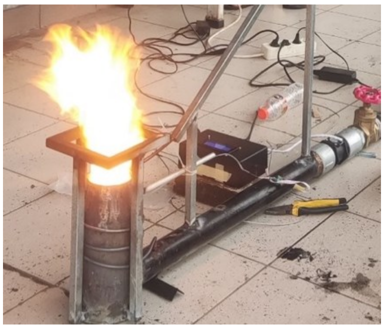

Fig. 18. The flame is at a pressure of 12.48 Pa

e) Value of air discharge (q) = 520 L/hour, oil speed (v=0.058 m/s), and air pressure (P) = 18.78 Pa.

Based on Fig. 19, the resulting flame reaches a temperature of 758°C at the 63rd second, decreases at the 74th second, and is stable at a temperature of 750°C. The flames are not so red, and the black smoke is absent. The flame at air pressure 18.78 Pa shown in Fig. 20.

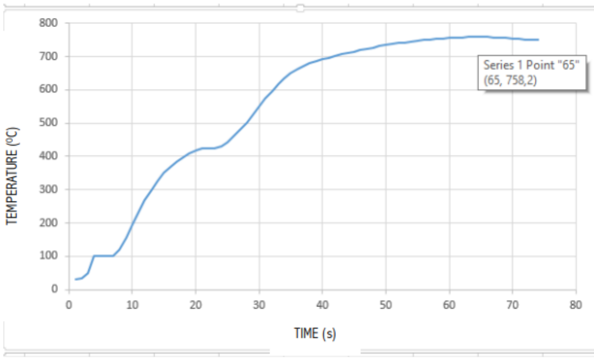

Fig. 19. Temperature (ºC) vs Time (s) at Pressure (P) = 18.78 Pa

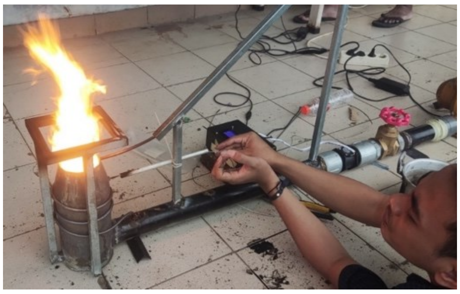

Fig. 20. The flame at air pressure 18.78 Pa

f) Value of air discharge (q) = 624 L/hour, oil speed (v=0.058 m/s), and air pressure (P) = 27.04 Pa (Fig. 21).

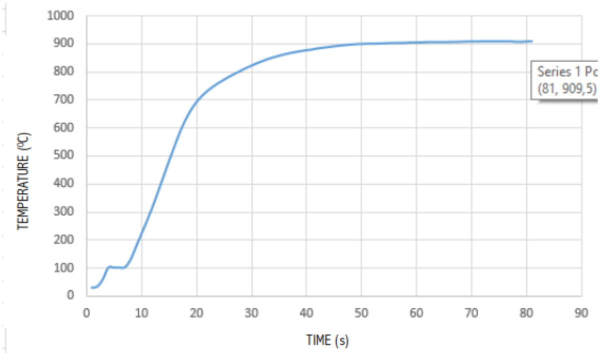

Fig. 21. The relationship between temperature (ºC) vs time (s) at pressure (P) = 27.04 Pa

Based on Fig. 22, the flame is not that big, black smoke is not formed and the temperature is 909 ºC at the 71st second and so on, there is no black smoke.

Fig. 22. The flame at air pressure 27.04 Pa

g) Value of air discharge (q) = 750 L/hour, oil speed (v=0.058 m/s) and air pressure (P) = 39.06 Pa (Fig. 23).

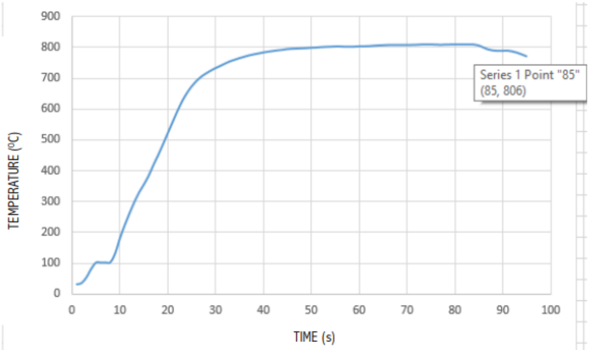

Fig. 23. The relationship between temperature (°C) vs time (s) at pressure (P) = 39.06 Pa

Based on Fig. 24, the resulting flame does not contain black smoke. While the resulting maximum temperature is 809 °C at the 73rd second, and the temperature continues to fall at the 94th second, the temperature is stable at 806 °C.

Fig. 24. The flame at air pressure 39.06 Pa

The results of this study have significant advantages compared to several previous studies. One of the advantages of this research is that the fire produced by used oil is stable and does not emit black smoke, so it is optimal for high temperatures. Another advantage of this research is that the PID control method can stabilize the results of burning used oil at the expected temperature of 800 °C., with the actual result being 806 oC. This result has never been found in previous studies, so it can be said that this study has good strength because it can prove optimal temperature findings at 800 °C. If you review the results of previous studies. His research focuses not on optimizing temperature stability but on the effect of used oil on the resulting fire and its function in general.

4. CONCLUSION

Based on the test results in this study, it can be concluded as follows. The seventh test can be said to be optimal because the resulting fire does not contain black smoke. Meanwhile, the maximum temperature generated was 809 °C at the 73rd second, and the temperature continued to fall at the 94th second. These conditions indicate that the fuel speed ratio (used oil) and applied air pressure have started to improve so that the temperature is stable at 806 °C. Optimal test results at a flame temperature of 806 °C, the resulting flame does not produce black smoke, so burning used lubricant by evaporation produces much cleaner exhaust emissions. This research can make an important contribution to reducing the negative impact of hazardous and toxic waste on the environment and to become an alternative solution in dealing with hazardous and toxic waste. This research can make an important contribution to the development of technology for processing and utilizing hazardous and toxic waste materials to preserve the environment and utilize existing resources more efficiently.

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