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Heating Rate Control in Electric Furnace with SSR and K-Type Thermocouple Using Arduino Uno Atmega 328P

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Abstract

An electric furnace is a tool that can melt, heat and change the physical shape of a substance. Electric furnaces sold in the market are still relatively expensive. Therefore it is necessary to make an electric furnace at a low cost. This research designed an electric furnace using a K-type thermocouple sensor as a temperature reader and an SSR relay as an ON/ OFF heater control. The keypad serves to enter the temperature value in the heating furnace. The heating element used is 1 mm in diameter and 1.86 Ω resistance with a load of 21 Amperes, capable of heating a C1-type refractory brick furnace tested to a temperature of 1000°C. The results of temperature reading sensitivity tests against the type-K thermocouple sensor get a coefficient value of 0.99893. This indicates that the thermocouple sensor is worth using. The electric furnace test thermocouple sensor has an average accuracy rate of 92.07% and errors worth 7.93%. A precision value of 98.786% shows that the system works optimally.

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***Kata kunci:** Arduino, Nikelin, Refraktori, SSR, Termokopel tipe-K*

Abstrak

Electric furnace adalah alat yang dapat digunakan untuk melelehkan, memanaskan serta mengubah bentuk fisis suatu zat. Electric furnace yang terjual di pasaran masih relatif mahal, maka dari itu diperlukan pembuatan electric furnace dengan biaya yang murah. Penelitian ini merancang electric furnace dengan menggunakan sensor termokopel tipe-K sebagai pembaca suhu dan relay SSR sebagai control ON/OFF heater. Keypad berfungsi untuk memasukkan nilai suhu pada tungku pemanas. Elemen pemanas yang digunakan berdiameter 1 mm dan resistensi 1,86 Ω dengan beban 21 Ampere, mampu memanaskan tungku berbahan bata refraktori tipe C1 yang telah diuji hingga suhu 1000°C. Hasil pengujian sensitivitas pembacaan suhu terhadap sensor termokopel tipe-K mendapatkan nilai koefisien sebesar 0,99893, hal ini menandakan bahwa sensor termokopel layak digunakan. Dari pengujian electric furnace sensor termokopel memiliki tingkat akurasi ratarata sebesar 92,07%, serta error senilai 7,93%. Sedangkan didapat nilai presisi sebesar 98,786% yang menunjukan sistem bekerja secara optimal.

1. Introduction

An electric furnace can melt, heat and change the physical form of a substance (Azes et al., 2020). Electric furnaces are widely used in the industrial and research sectors. The industrial sector utilizes electric furnaces for smelting metal, iron, and steel, while the research sector is used for testing samples and heating them to a specific temperature (Supriyatna et al., 2014).

Electric furnaces that are sold in the market are still expensive. Therefore it is necessary to make electric furnaces at a low cost. Making an electric furnace usually requires several components, including Arduino, Solid State Relay (SSR), Thermocouples, and Refractory Bricks, which function as heat retainers. In comparison, heat

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treatment functions as a component that performs the heating process on a material to the desired temperature. (Fitri et al., 2017).

Bashori (2013) has previously made an electric furnace by making electric furnace plates that are environmentally friendly and safe. Similar research was also carried out by Yudha (2021) by making an electric furnace using Arduino with the PID method and a keypad that is used to automatically control the temperature of the electric furnace in °C (degrees Celsius). This study uses the keypad to set temperature set point input value. Therefore, researchers are interested in making keypad input programs automatically.

This study designed the manufacture of an electric furnace with an automatic system using an Arduino connected to a 4x4 keypad as a component to set the desired temperature set point value (Hendra et al., 2017). In addition, this research uses a Solid State Relay (SSR) as a substitute for a magnetic contactor (MC) so that it does not cause noise and maintains a minimum voltage duration (Priyono, 2017) as well as the addition of an indicator light as a marker of whether the heater is working or not in the electric furnace. The heater is a type A1 Chantal wire coil capable of heating a furnace made of refractory bricks from 1°C to 1050°C. At the same time, the temperature readings in this study used a K-type thermocouple sensor whose output is connected to the LCD to display temperature values.

2. Research Methods

The tools and materials used in this research are Arduino, Nikelin Coil, SSR, K-type thermocouple and MAX6675 Module, 5 VDC Power Supply, Heating Element, Type C1 Refractory Brick, AC Fan, MCB, Indicator Light.

2.1 Research Design

The tool design in this electric furnace control study is arranged in a block diagram tool design that can be seen in **Figure 1**.

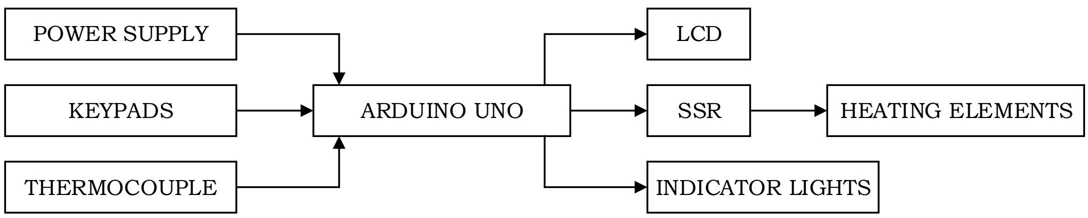


Figure 1. Block Diagram of How the Tool Works.

The overall system design can be seen in Figure 1. There are three input process components MCB, Power Supply, and Arduino Uno. The MCB source is from PLN, which has a voltage of 220 V AC, which will be channeled to turn on the Power Supply. The Power Supply has an AC voltage of 240 V, whose output is a DC voltage of 12 V which is used to power the Arduino Uno.

Turning on an Arduino can use a laptop or power supply source. The Arduino itself sets the thermocouple that reads the temperature in the electric furnace by entering a program into the Arduino after the program is uploaded. The sensor will read and display the sensor reading results on the LCD. While the keypad functions to input a set point value into the program. A schematic of the monitoring and sensor system circuit is shown in **Figure 2**.

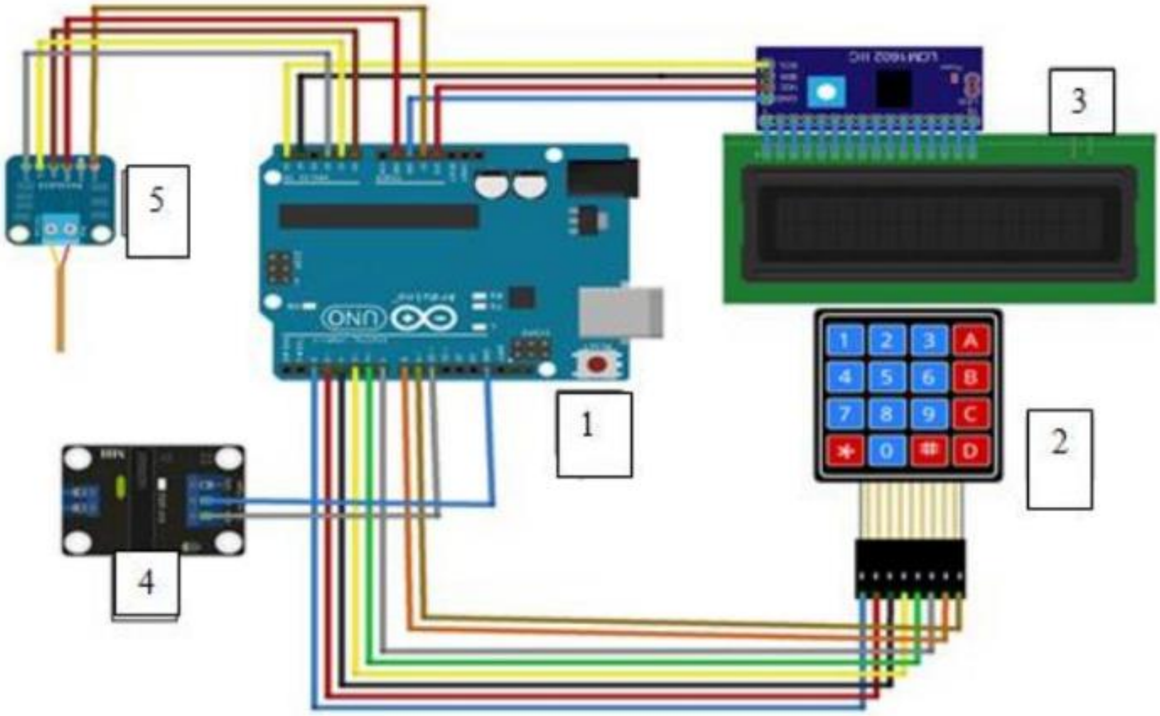


Figure 2. Tool Schematic Series. 1. Arduino Uno Atmega; 2. Keypad; 3. LCD I2C; 4. Relay Solid State Relay (SSR); 5. MAX6675 Thermocouple Sensor.

Based on **Figure 2**, the Max6675 thermocouple sensor circuit schematic, LCD, 4x4 keypad, and solid state relay (SSR) are controlled by the Arduino Uno Atmega microcontroller. This design uses 13 Arduino pins and VCC and GND pins. These 13 pins are used, including pins A4 (SDA) and A5 (SCL), which function for 12C communication between Arduino Uno and LCD. Meanwhile, pins 2 to 9 Arduino are connected to a 4x4 keypad which functions to input setpoint values. Then pin ten is connected to the SSR relay input pin. In comparison, pins A0 (SCK), A1 (CS), and A2 (SO) are connected to the Max6675 thermocouple sensor, which functions to read the temperature displayed on the LCD. The design of the heating furnace to be made can be seen in **Figure 3**, **Figure 4**, and **Figure 5**.

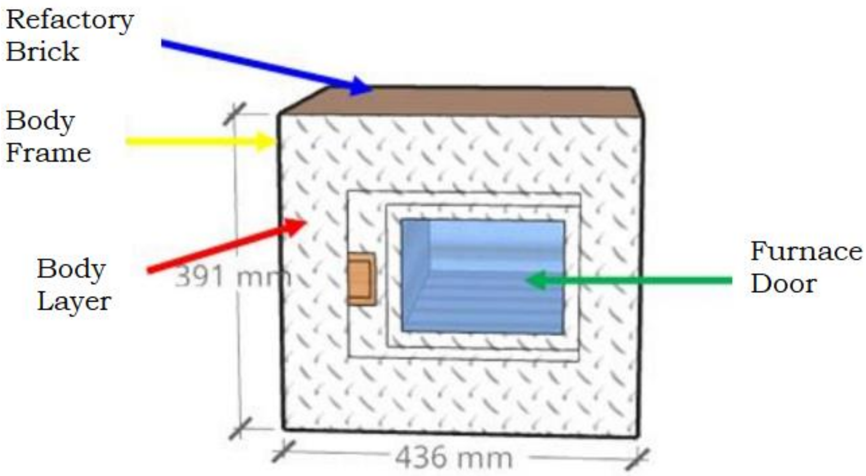


Figure 3. Design of a Heating Furnace.

Based on **Figure 3**, the heating furnace design scheme. The manufacture of a heating furnace uses type C1 refractory brick because it can withstand heat up to 1540°C. Then the body framework functions to arrange refractory bricks for making heating furnaces. Meanwhile, the lining of the heating furnace uses fire cement so that the temperature inside the furnace does not escape and the heat is maximized. Then on the door of the heating furnace, use a plate made of ceramic fiber blanket, which can withstand temperatures up to 1540°C.

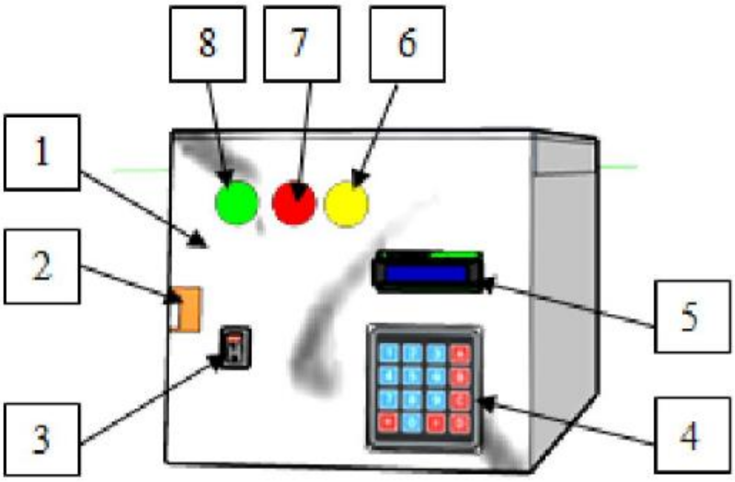


Figure 4. Control Panel Design. Description: 1. Box Panel 2. Door Box Panel 3. Switch ON – OFF 4. Keypad 4x4 5. LCD 6. Power supply indicator 7. Furnace working indicator 8. Furnace current indicator.

The design of the control panel is shown in **Figure 4**—all control components, such as the MCB, power, and 4x4 keypad. The panel's supply, Arduino Uno, SSR (solid state relay), Max6675 thermocouple, and control LCD are also equipped with an indicator light to determine the On/Off on the heating furnace.

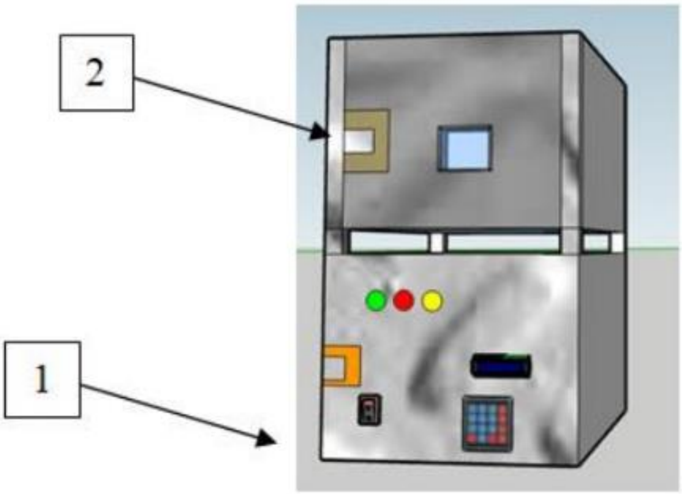


Figure 5. Design of Control Panel and Heating Furnace. 1. Control System; 2. Heating Furnace

The design of the control system and the heating furnace is shown in **Figure 5**. Before the heating furnace works, the control system must first be turned on. After the control system works, input the setpoint value via the keypad so that the heating furnace works.

3. Results and Discussions

3.1. Tool Realization

Control of the heating rate in an electric furnace with SSR and Type-K thermocouple using Arduino Uno Atmega328P has been realized with the results shown in **Figure 6**.

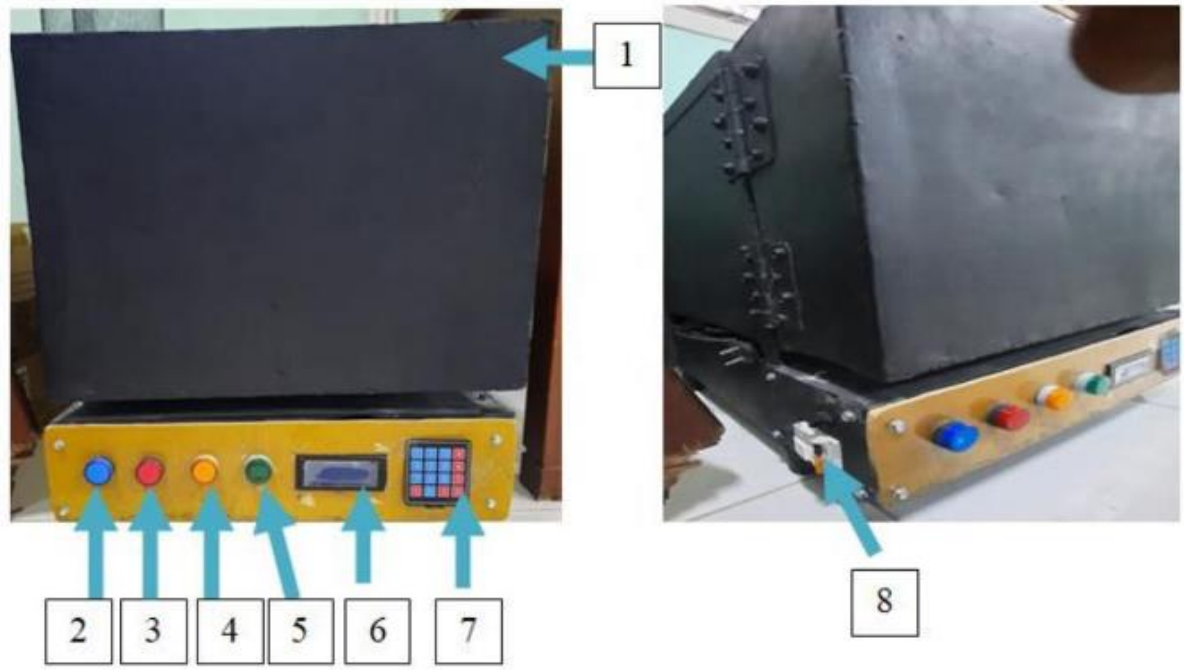


Figure 6. Electric Furnace Design. 1. Heating Furnace; 2. Standby Indicator; 3. Indicator Off; 4. Indicator On; 5. Current Indicator; 6.LCD; 7. Keypad; 8. On/Off Switch.

The design of the control panel and heating furnace is shown in **Figure 6**. All control components include the heating furnace, LCD, 4x4 keypad, and On/Off Switch. Then the control panel is also equipped with standby indicator lights, Off indicators, On indicators, and current indicators.

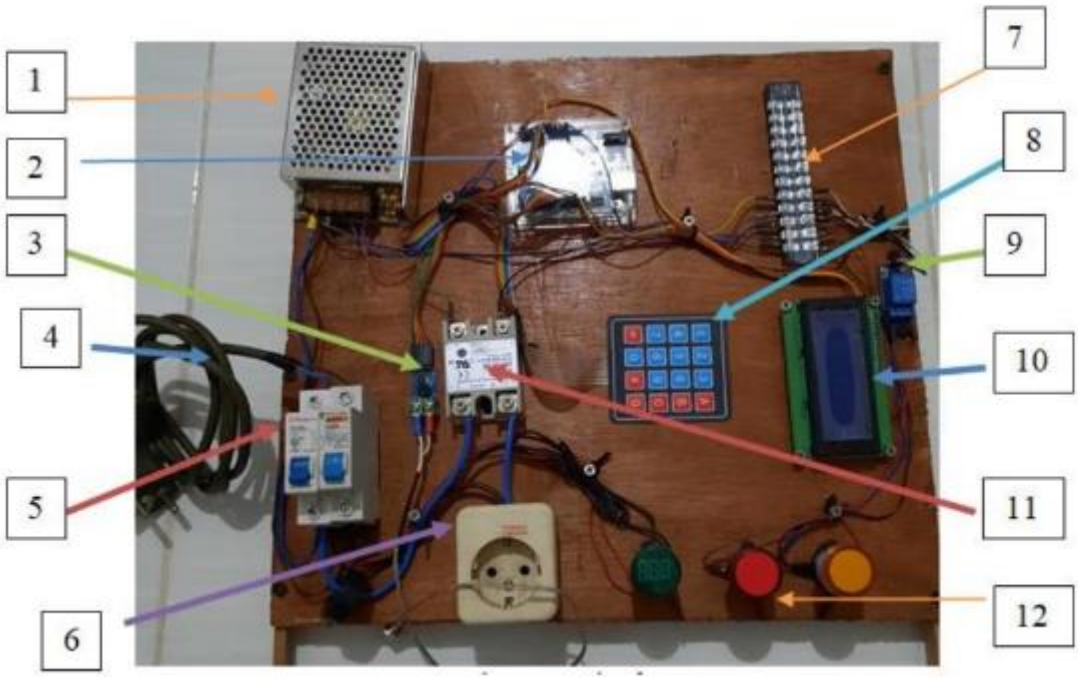


Figure 7. Electric Furnace Control Panel Description: 1. Power Supply; 2. Arduino Uno Atmega328p; 3. Thermocouple Sensor and Max6675 Module; 4. Outlet; 5. MCB; 6. Furnace; 7. Terminal; 8. Keypad; 9. Relays; 10. LCD; 11. SSR; 12. Indicator Lights On, Off, Current, and Stand By.

The design of the control panel is shown in Figure 7. All control components such as power supply, Arduino Uno, thermocouple sensor and Max6675 module, outlet, MCB, furnace, terminal, keypad, relay, LCD, and SSR (solid state relay). Then the control panel is also equipped with indicator lights to know On, Off, Current, and Stand By on the heating furnace.

3.2 Testing of Thermocouple Sensors

The design of the electric furnace begins with testing the K-type thermocouple sensor. This test determines the sensor's accuracy, precision, and error level. This test was carried out by comparing the temperature value read on the K-type thermocouple sensor with the temperature value calibrated on the HTC-2(°C) measuring instrument. The graph is shown in **Figure 8** (Widiatmoko et al., 2007).

$$error = \left| \frac{Y - X_n}{Y} \right| \text{X } 100\% \quad (1)$$

$$Akurasi = \left[1 - \left| \frac{Y - X_n}{Y} \right| \right] \text{X } 100\% \quad (2)$$

$$\text{Presisi} = \left[1 - \left| \frac{X_n - \overline{X}_n}{\overline{X}_n} \right| \right] \text{X } 100\% \quad (3)$$

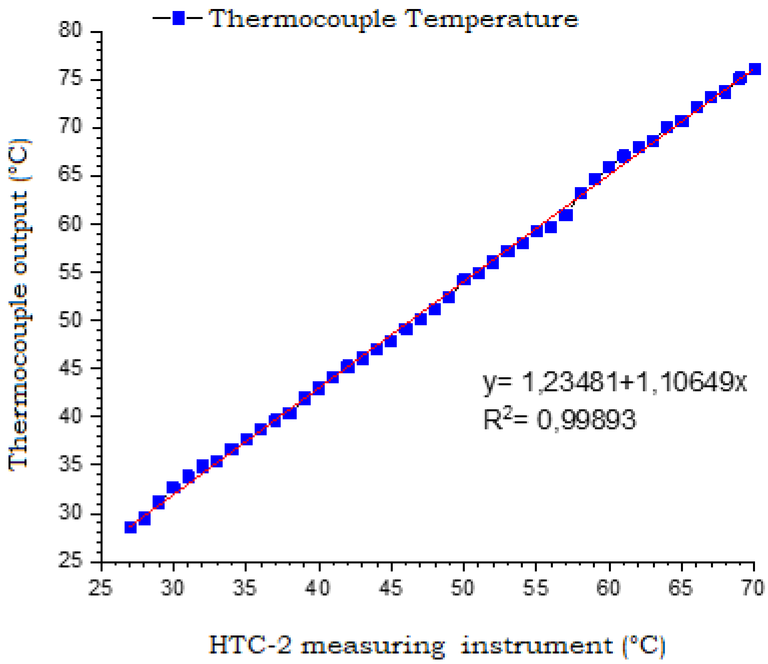


Figure 8. Graph of Thermocouple Sensor Testing.

Based on Figure 8, the results of this thermocouple sensor test repeated data collection three times with a temperature range from 27°C to 70°C. It can be concluded that the thermocouple sensor has an average accuracy value of 92.07% and an error of 7.93%. While the obtained precision value of 98.786%.

3.3 Setpoint Testing

The setpoint test determines whether the keypad can function as an input component in a control system circuit that controls the heat temperature in the furnace. This test is carried out by entering a value using the keypad, which the controller will then read, and setting the furnace to heat the coil according to the set point input value. The graph of the setpoint test is shown in **Figure 9**.

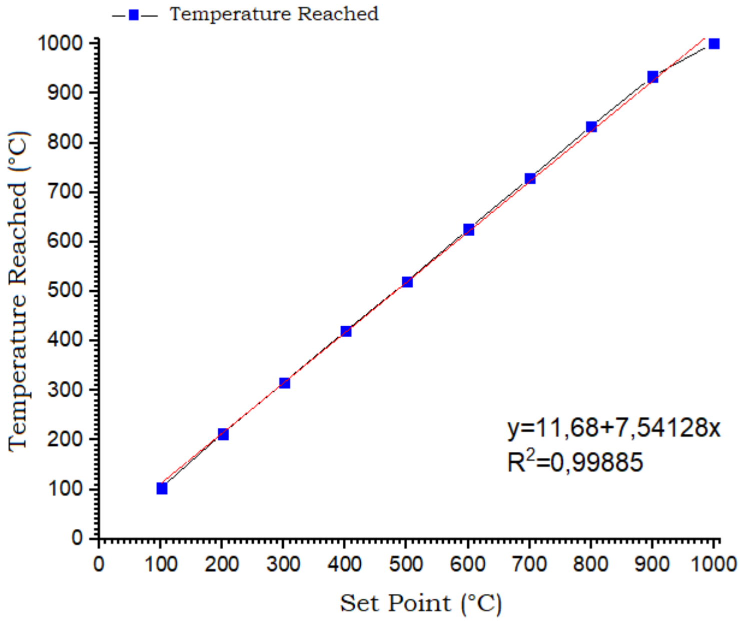
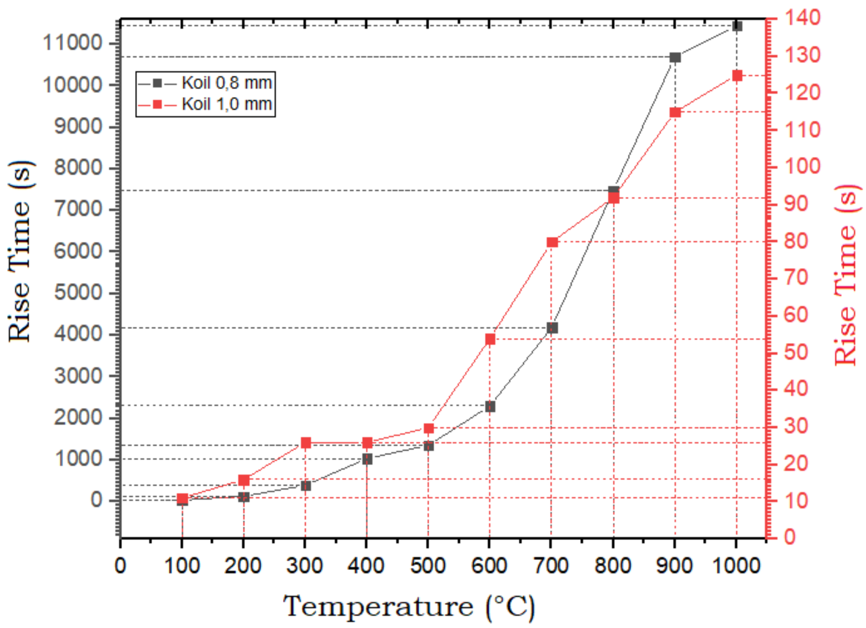


Figure 9. Setpoint Test Graph.

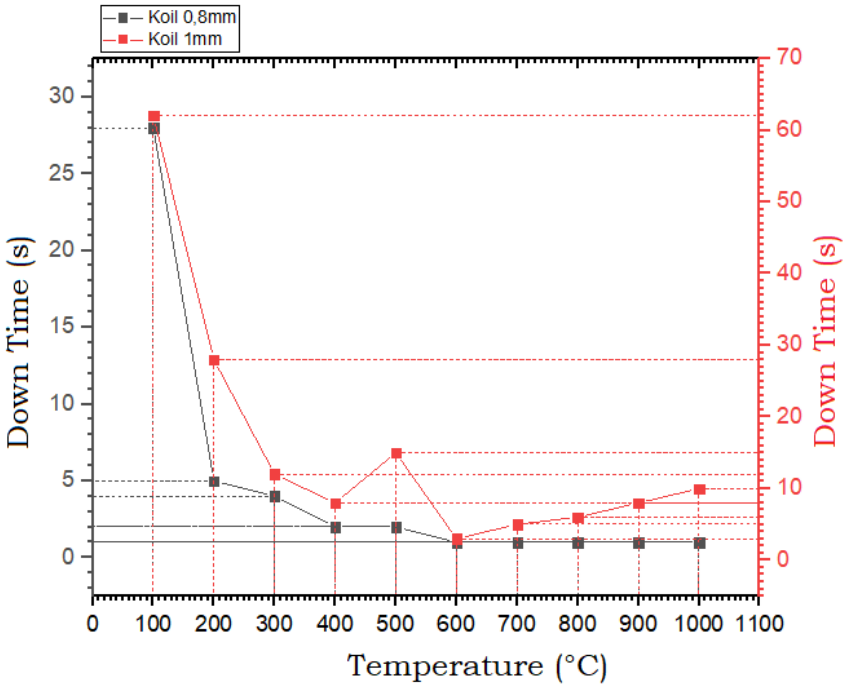
Figure 9 shows the repeated setpoint data collection test 5 times with a temperature range from 100°C to 1000°C. Obtained an average accuracy value of 95.82%, and the error has a value of 4.18%. While the obtained precision value of 92.439%.

3.4 Heating Rate Testing

The heating rate test determines the time the temperature increases and decreases. This test is carried out by entering the setpoint value using the keypad, which will then translate the value by the controller and adjust the furnace to heat the coil according to the given setpoint input value. This test was carried out with variations using two different coils, including 0.8 mm and 1 mm. The heating rate test graph is shown in **Figure 10**.



(a)



(b)

Figure 10. (a) Time for 0.8 mm and 1 mm Wire Temperature Increase, (b) 0.8 mm Wire Temperature Decrease Time and 1mm.

Figure 10 shows the test for retrieving heating rate data when the temperature increases and decreases. Using a variation of the coil, including 0.8 mm when rising from 100°C to 200°C, the rise time is 2 minutes 8 seconds and the decrease is 5 seconds. Meanwhile, in a 1mm coil with a temperature of 100°C to 200°C, the rise time is 16 seconds, and the decrease is 1 minute 2 seconds. This experiment was conducted over a temperature range from 100°C to 1000°C (Newalse et al., 2019). Based on tests using two variations of the coil, it can be concluded that when using a 1mm coil, the heat gain is faster, and the heat dissipation takes a long time. Meanwhile, in the 0.8 coils, the heat gain is longer, and the heat dissipation is faster. This research uses a 1mm coil with a stable heat level and decreases.

Based on the test results on nickel coil variations with a diameter of 0.8 mm and 1 mm. Variations in wire diameter affect the temperature rise in the furnace. The longer the heating time, the higher the temperature (Hakiki, 2018). This is due to an electric current flowing in an introductory wire caused by electron charges (Slamet, 2015). This is because a diameter with a large size has a little resistance value so that the current that flows is large.

The greater the current flowing in the coil, the faster the coil will heat up, and vice versa for coils with a small diameter (Kusharjanto, 2015).

4. Conclusion

Heating Rate Control has been realized in Electric Furnace with SSR and Type-K Thermocouple Using Arduino Uno Atmega 328p with a temperature range of up to 1000°C. The test results found that the accuracy of the thermocouple sensor with measuring instruments was 92.07%, the precision was 98.78%, and the error was 7.93%. Making a heating furnace is better to use a coil with a diameter of 1 mm because the heating process is very stable.

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