Design of temperature control system in rotary type cloth dryer to optimize drying time

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Abstract—Erratic climate change and limited drying space in apartments lead to an inefficient clothes drying process. Commercial clothes dryers are often sub-optimal in terms of drying duration and energy efficiency. Clothes dryer technology without dependence on solar energy has been widely circulated, but has disadvantages, such as long drying time and high price. This research develops a temperature control system on a prototype rotary-type clothes dryer to optimize drying time. The dimensions of the prototype are 0.65 cm x 0.70 cm x 90 cm, the power consumption of the cloth dryer is 598.4 watts, using a DHT22 sensor to control the temperature. The motor speed rotates at 730-790 rpm, with the fan rotating constantly, and the heater has temperature set points of 43°C (upper) and 45°C (lower). The system applies an on-off control method to achieve the desired temperature set point. The test results show that the temperature control system in the clothes dryer with the on-off method is successful with an error rate of 0.74% for a mass of 1 kg of clothes. This error rate meets the set standard of no more than 5%, indicating that the on-off control system works as expected.

Keywords—Rotary Dryer, Optimization of Drying Time, Temperature Control.

1. Introduction

Climate change causes erratic weather, such as sudden changes from heat to rain, which makes sun-drying clothes difficult [1, 2]. Clothes drying traditionally uses sunlight at 33-39°C, but unstable weather and limited space, especially in apartments, make this method less than optimal [3, 4, 5, 6]. Commercial dryers are available, but they are often slow, expensive and less efficient, influenced by rotation speed and factors such as humidity and fabric type [7, 8]. Rotary-type dryers are superior because they distribute heat evenly and save space compared to top load dryers [9]. Previous research uses a 200W monocrystalline solar panel to generate power that drives a DC motor and fan. The fan regulates airflow from the bottom to the top and throughout the cabinet. The solar-powered clothes dryer is designed to achieve 66.43% efficiency in 1 hour and 30 minutes [10]. The study titled "Design of Temperature Control System in Rotary Type Cloth Dryer to Optimize Drying Time" designed a temperature control system with a DHT22 sensor to maintain a temperature of 43-45°C, a motor rotating 1000 rpm, and a constant fan. The system works by detecting the temperature, delaying 10 seconds, then activating the drum, heater, and fan until the clothes are dry, then automatically shutting down. The system aims to produce an efficient and fast automatic dryer for apartments.

2. Previous Researches

The increasing demand for efficient and sustainable clothes drying systems has driven research and innovation in the field. Several researchers have made sophisticated and environmentally friendly automatic clothes dryers. Mulawa and Fitriyanah (2023) designed a portable automatic clothes dryer that integrates advanced control systems and Internet of Things (IoT) capabilities. The system utilizes an ESP32 microcontroller, fuzzy logic algorithms, heating lamps, and fans to optimize drying time and efficiency. A DHT22 sensor is employed to measure humidity and temperature, while the Thingspeak platform enables users to monitor drying progress in real-time via their smartphones. Experimental results demonstrate the system's capability to dry five types of clothes (polyester, cotton, jersey, and thick cotton) in approximately 290 minutes, three types of clothes (polyester, cotton, and thick cotton) in 100 minutes, and a single microfiber garment in 60 minutes. These findings highlight the potential of portable automatic dryers to provide convenience and efficient drying for modern households.

Conyette and Ajayi (2023) proposed a conceptual model for a Hybrid Heated Clothes Drying Cabinet (HHCDC) that utilizes composite energy sources. The system is designed as an enclosed cabinet where clothes are hung, and hot air is circulated for drying. Photovoltaic (PV) panels serve as the primary energy source, while sunlight acts as a secondary energy source, ensuring sustainability. The system incorporates low-energy components such as fans and servo motors, which significantly reduce energy consumption compared to conventional gas or electric dryers. This approach demonstrates the feasibility of integrating renewable energy into clothes drying systems, offering a sustainable and energy-efficient alternative.

3. Method

3.1. Literature study

A literature study will be conducted to support research on a temperature control system for a rotary-type clothes dryer to optimize drying time. The literature includes journals, scientific articles, internet sites, and final project research with similar topics. This study analyzes existing systems, including sensors, actuators, controllers, and control methods. Data from the literature is processed to strengthen the idea to be realized.

3.2. Software Design

Then there is a system work scheme in software design which is intended as a form of integration used in running a system as visualized in Figure 2. The work scheme shown is a system work scheme for a cloth dryer that uses several components, where the power supply functions as a voltage and current provider needed by all components in the system. The DHT22 sensor is used as a temperature detector in the cloth dryer. This sensor will be connected and controlled by the Arduino Nano ATMega328 microcontroller. Arduino Nano ATMega328 will give a signal to the relay as a command to turn on or turn off the fan at a constant speed and heater with a set point upper is 45°C and lower is 43°C. This relay is also connected to receive a signal in order to turn the motor on or off. After receiving the signal, the DC motor will move the drum with a speed of 730-790 rpm. Information about the mass of clothes and temperature will be displayed on the LCD, allowing the user to monitor the status of the dryer in real-time.

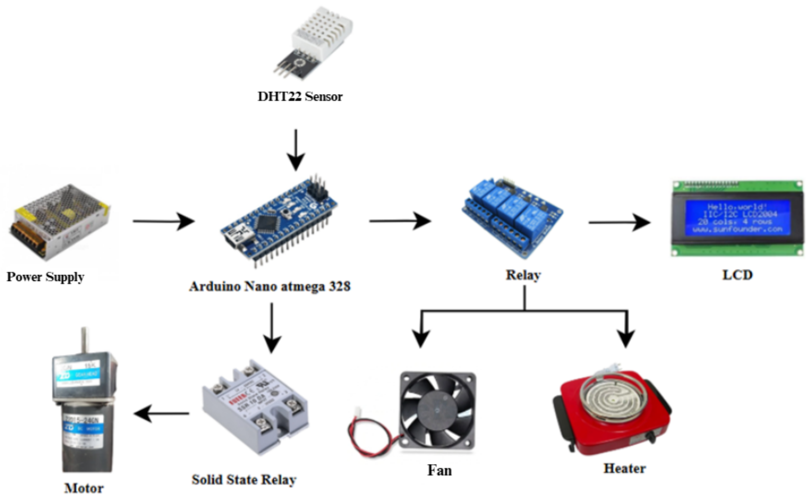


Figure. 2. System Working Scheme

The temperature measurement system is carried out by reading the DHT22 sensor. The results of the DHT22 sensor reading will be programmed through the Arduino Nano ATMega328 so that the reading can display the temperature value which will be displayed on the 16x2 LCD.

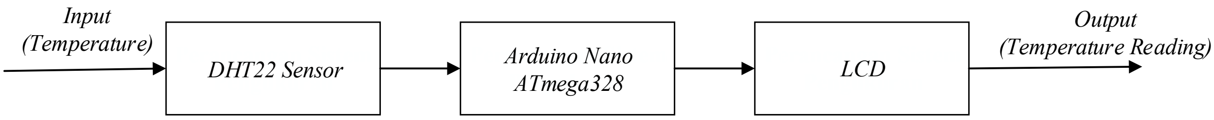


Figure. 3. Block Diagram of Temperature Measurement System

However, it is different from the temperature control system on the cloth dryer in this tool which is a close loop control system. The block diagram of the control system can be seen in **Figure 4.** In the block diagram of the temperature control system in **Figure 4**, the set point of this system is temperature. The set point will be compared from the DHT22 sensor reading in ºC and will be forwarded to the Arduino Nano ATMega328 microcontroller. The Arduino Nano ATMega328 will provide a control signal to command the actuator, namely the relay to work. The relay will activate and deactivate the fan with a constant speed, the motor with a speed of 730-790 rpm, and the heater with a set point of lower is 43ºC and upper is 45ºC.

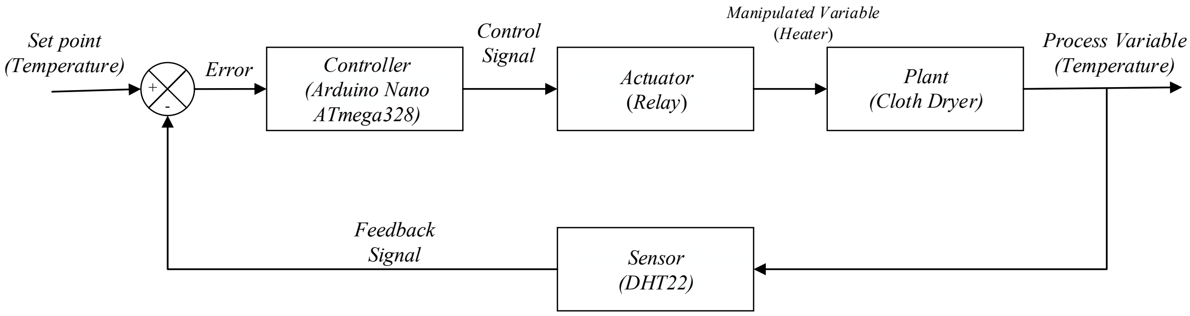
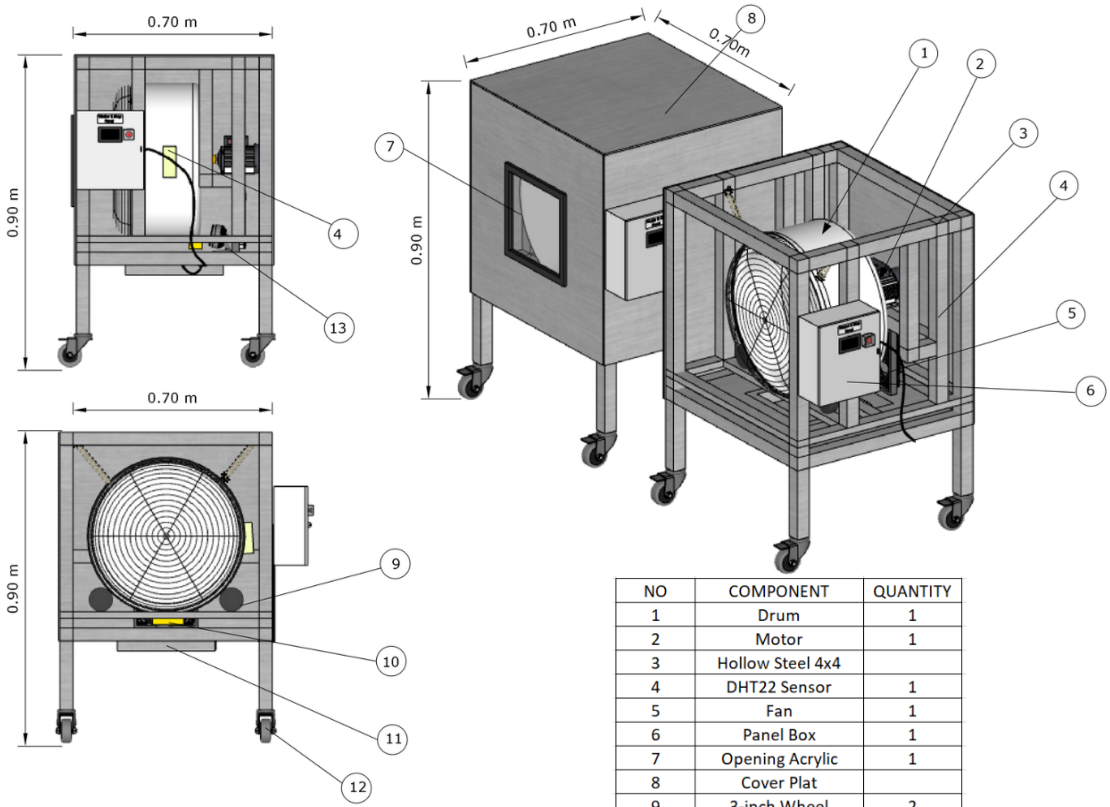


Figure. 4. Block Diagram of Temperature On-Off Control System

3.3. Hardware Design

In this hardware design, a 3D tool design is made using the SketchUp platform shown in **Figure 5** below. In this tool design, the panel box is located on the side of the cloth dryer. DHT22 sensor will be placed outside the drum to measure the temperature in the cloth dryer room. The fan and heater are on the back side of the drum, so that hot air can spread throughout the cloth dryer room. The motor is right behind the drum to move the drum easily. There is an acrylic opening to make it easier to see whether the system is running or not.



NO	COMPONENT	QUANTITY
1	Drum	1
2	Motor	1
3	Hollow Steel 4x4	
4	DHT22 Sensor	1
5	Fan	1
6	Panel Box	1
7	Opening Acrylic	1
8	Cover Plat	
9	3-inch Wheel	2
10	water storage tank	1
11	1.5-inch Wheel	4
12	Heater	1

Figure. 5. 3D Tool Design

In the hardware design, there is a wiring that is intended to facilitate cabling when making the system. Power supply is used for the supply of this system. The DHT22 sensor is connected to each pin on the Arduino Nano ATMega328. The fan, DC motor, and heater will be connected to a relay in order to activate and deactivate the fan, DC motor and heater. The LCD will display how long the duration of time the cloth dryer has been on and what temperature is inside the cloth dryer.

4. RESULT AND DISCUSSION

4.1. Hardware Design

Temperature Control System on Rotary type Cloth Dryer in this final project uses a prototype framework and rotary type drum equipped with a motor that functions to move the drum. In addition, on the inside of the framework there is a DHT22 sensor that functions to measure the temperature in the cloth dryer and there is a heater and dc fan that functions to help dry the clothes in the cloth dryer. There is a panel box that contains Arduino nano microcontroller, relay, MCB, power supply, and LCD. Here are the results of making a temperature control system tool on a rotary type cloth dryer.

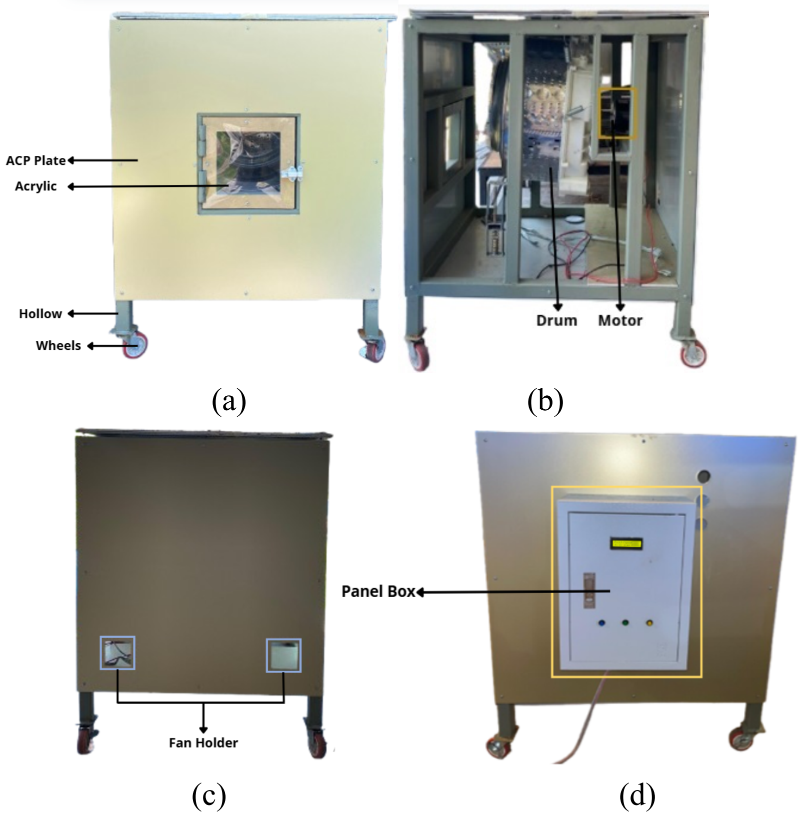


Figure 6. (a) Front view, (b) Side view, (c) Back view, (d) Side view

4.2. Panel Box Result

Electrical components in the cloth dryer will be stored in a panel box with a size of 35 x 40 x 15 cm. **Figure 7** is a picture of the inside of the panel box of the temperature control system on a rotary type cloth dryer which contains components namely the Arduino nano microcontroller, *relay*, *Solid State Relay,* MCB, *power supply*, dan LCD.

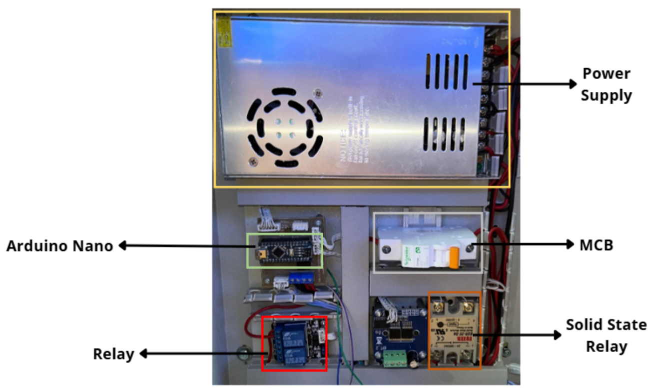


Figure 7. Panel Box Result

4.3. Validation Testing Result

The results of testing the temperature sensor with the DHT22 type as a temperature measurement in a cloth dryer. Testing is done by comparing the DHT22 sensor with standardized measuring instruments. Testing is done by comparing the reading value of the DHT22 sensor and thermometer validator. The testing scheme involves variations in the number of candles, starting from 2 candles to 14 candles with a gradual increase of every two candles. This variation aims to produce a gradual difference in air temperature, so as to test the ability of the DHT22 sensor. From the results of 5 times repeated measurements on each candle variation, a value range of 26°C -50.6°C was obtained with an error rate of 1.59%, with an accuracy of 98.95%. With an error <5% and accuracy <95%, this shows that the DHT22 sensor is feasible to use in the final project.

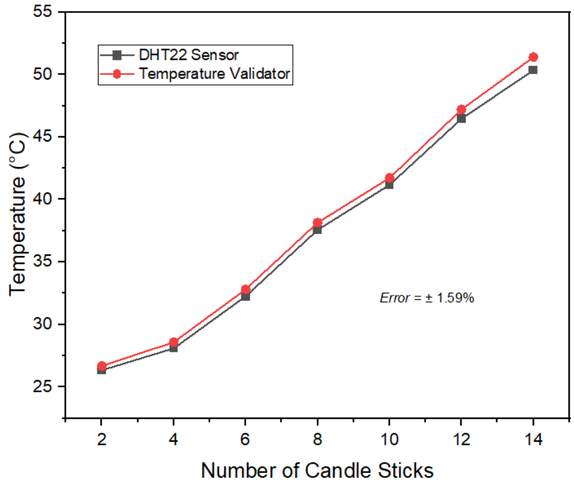


Figure 8. DHT22 Temperature Sensor Validation Test Results

Then in addition to sensor validation testing, it is also necessary to test the actuators. sensor validation, it is also necessary to test the actuator. Actuators that are tested are relays. Relay actuator testing is used to ensure whether the relay 1 actuator connected to the heater can maintain the temperature value in accordance with the set point, which is at 45°C to 43°C, relay 2 to ensure that the control system is on when the drying system is active and off when the drying system is not active can run according to conditions, and Solid State Relay to ensure whether the motor works at a speed of 730-790 rpm. The relay 1 test results are shown in **Figure 9** and the relay 2 test scheme is shown in **Figure 10.**

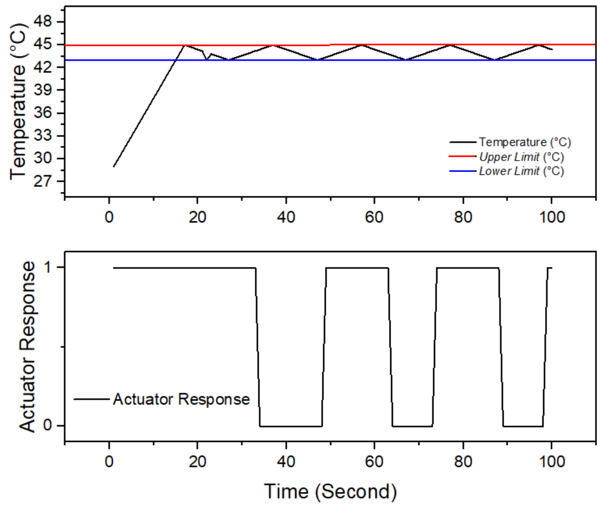


Figure 9. Graph of Temperature Actuator Testing Reay 1

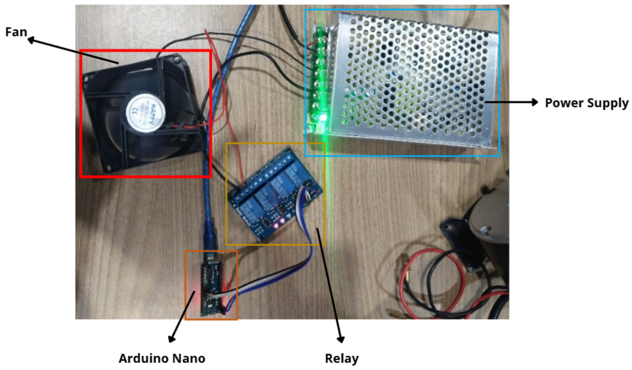


Figure 10. DC Fan Actuator Testing Relay 2

4.4. Temperature Control System Performance

In the temperature control system of the rotary type cloth dryer to optimize drying time, there are graphical results of 3 experiments with a mass of 1kg on the control system.

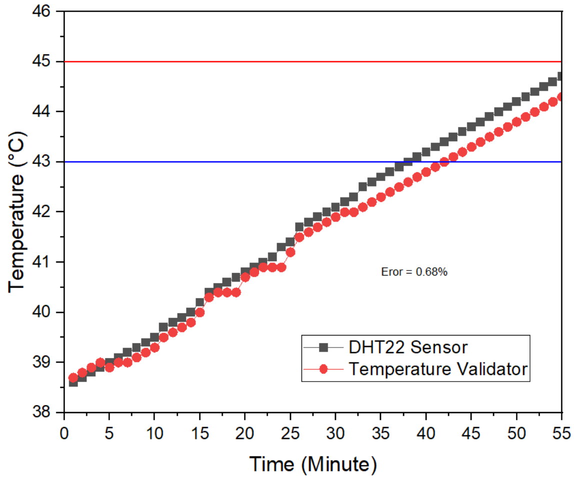


Figure 11. Graph of the correlation between temperature and validator

The graph in **Figure 11** shows how the on-off control system successfully achieves the desired temperature set point. With an error rate of 0.68% for a mass of 1 kg, the system shows optimal performance in maintaining the temperature within the set range, *set point lower* 43°C dand *set point upper* 45°C.. While in **Figure 12** the average error of the first measurement is 1.04% and **Figure 13** with the average error of the first measurement is 0.74%.

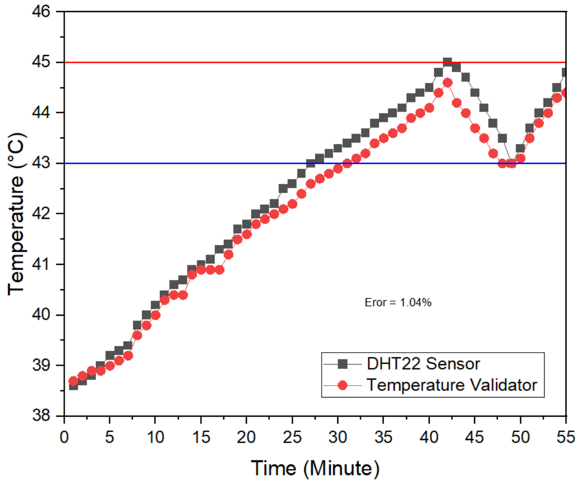


Figure 12. Graph of the correlation between temperature and validator

Table 4.5. Comparison of System Testing Based on Time

Dry Clothing Weight (kg)	Clothing Mass After Spinning (kg)	Cloth Dryer		Dryer Front Load	
		Drying Time (Minute)	Precentage Decline (%)	Drying Time (Minute)	Precentage Decline (%)
0.75	1	55	16%	60	20%
0.75	1	55	19%	60	22%
0.75	1	55	23%	60	19%

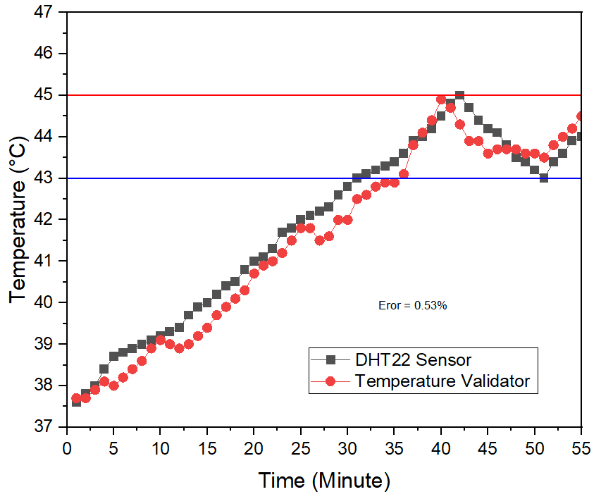


Figure 13. Graph of the correlation between temperature and validator

This shows that the implementation of the on-off control method in this system has run optimally. However, the temperature increase is a little slow because there are several factors that are thought to be the main cause, one of which is the environmental conditions during data collection which are very diverse, such as rainy or hot weather, differences in data collection time between day and night, and other environmental temperature fluctuations.

4.5. Comparison Of System Testing Agains Time

Comparison of system testing based on time in **Table 4.5** shows the results of the drying performance comparison between the rotary type cloth dryer designed in this final project and a commercial front load dryer based on drying time. In testing the system against time, the average mass of clothes after drying using a cloth dryer is 0.8 kg, with a drying time of 55 minutes. This shows that the designed rotary type cloth dryer drying system is able to reduce the water mass of the clothes significantly in a relatively short time.

4.6. Convection Transfer Analysis

In the test with a mass of 1 kg conducted in the afternoon, the ambient temperature (T∞) was 35°C, while the surface temperature (Ts) of the cloth dryer reached 45°C. With a plate surface area of A=0.49 m2, the heat transfer rate is calculated as follows:

$$h = \frac{Nu.L}{k}$$

$$Re = \frac{\rho.v.L}{\mu} = \frac{1.165 \text{ x } 1.5 \text{ } x \text{ } 0.08}{0.019 \times 10^{-3}} = 7357.89$$

$$Nu = 0.664 \text{ x } Re^{0.5} x \text{ } Pr^{\frac{1}{3}}$$

$$Nu = 0.664 \text{ x } (7375.89)^{0.5} x \text{ } (0.72)^{\frac{1}{3}}$$

$$Nu = 51.05$$

$$h = \frac{Nu.L}{k} = \frac{51.05x0.08}{0.685} = 5.96\frac{W}{m^2}.k$$

Then it is distributed into

$$\dot{Q} = h\ x\ A\ x\ \Delta\mathrm{T}$$
$$\dot{Q} = 5.96\ x\ 0.49\ x\ (45 - 35)$$
$$\dot{Q} = 29.204W$$

Description:

Nu	: Nusselt number
Pr	: Prandtl number (Pr = 0.72 for air).
k	: Thermal conductivity of aluminium composite panel (k = 0.685 W/m)
L	: Fan diameter (L = 0.08 m)
ρ	: Air density (1.145 kg/m3)
μ	: Dynamic viscosity of air (0.019×10^{-3}kg/m)
v	: Fan speed (1.5 m/s)

5. Conclusion

The The conclusion of this research is that the development of a temperature control system on a rotary type cloth dryer can increase the efficiency of clothes drying time, especially for residents who have limited space. By using DHT22 sensor to measure the temperature, this system is able to adjust the motor speed and temperature on the heater automatically. The results of the design show that the application of this system not only speeds up the drying process but also optimizes energy usage, this becoming a practical solution to the problem of drying clothes in uncertain weather conditions and limited space.

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