ORIGINAL RESEARCH

DEVELOPMENT OF ARDUINO-BASED CENTRIFUGE WITH AUTOMATIC FEATURES

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Abstract

This paper is aimed to designing and manufacturing a laboratory tool called Centrifuge Aircraft based on Arduino Uno control system. This machine is basically used to separate substances that have different molecular weights. Blood particles in the blood will be split into plasma and serum. The speed and time settings for the module made by the author have been programmed according to the existing provisions. This research is an experimental, observational study. The observation method is to measure directly on the tool using observation guidelines. In this case, the rotational speed, measuring time, and excess temperature on the centrifuge will be measured with the existing measuring instruments in the laboratory. For example, completing an ABO blood sample requires a speed of 1000 RPM with a period of 1 minute. We use the DS18B20 sensor for temperature sensors. The accuracy of motor speed in this centrifuge design is 95.22%, and the accuracy level of the timer is 98.12%. This research is expected to simplify and reduce the budget for purchasing equipment.

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1. Introduction

1.1 Background

The community's needs and demands for health services are increasing in line with the increase in people's knowledge and abilities and the development of health science and technology. This demand must be supported by progress and the development of more efficient health equipment so that the quality of service can improve adequately. In the medical world, health equipment improves every year in quality in terms of accuracy, ease of operation, and safety in its use. The laboratory is a field that is also found in the health sector [1], [2]. As part of electromedical equipment, laboratory equipment, including a centrifuge aircraft, has also undergone modernization. This tool is widely used in clinical laboratories and hospitals. A centrifuge is a tool used to separate organelles based on their density through a deposition process [3], [4]. In the process, the centrifuge uses the principle of rotation or rotation of the tube containing the solution so that it can be separated based on density [5]–[8]. The solution will be divided into two phases: the supernatant in the form of liquid and pellets or precipitated organelles [9], [10].

Centrifuge equipment consists of a rotor or a place to place the solution to be separated [11]–[14]. This rotor will rotate quickly, which will cause the solution to split into two phases. The faster the rotation is carried out, the more cell organelles can be precipitated and vice versa [15], [16]. Apart from blood, other body fluids, such as urine, also, in some instances, need to be separated from their constituent components to facilitate the examination process [17].

Due to the large number of samples that must be separated and the demand to get results as soon as possible, many laboratory assistants find it challenging to change the speed and time settings for each different sample, such as blood, urine, sputum, and other samples that require additional speed and time to carry out the sample separation process. The large number of samples that must be separated also causes the motor to work even harder. The heavy workload raises whether the motor speed will always be stable [18].

1.2 State-of-the-Art

Table 1 shows several previous studies related to the research to be carried out, while Table 1 compares specifications between research results and commercial products.

Table 1 State-of-the-Art Past Research

No	Microcontroller	Rotor	Features	Ref
1	Arduino Uno	Fixed Angle Rotor	4*16 LCD, 500-3000 RPM, Buzzer	D.N Pradana. 2018 [19]
2	Arduino Uno	Fixed Angle Rotor	16*2 LCD, Automatic Setting Mode, Buzzer	K. A. Akbar. 2019 [20]
3	ATMEGA 8535	Fixed Angle Rotor	4*20 LCD, 1000-3000 RPM, Temperature Sensor LM 35	M. Ilham. 2017 [21]
4	SparkFun Electronics, Mega 2560	Fixed Angle Rotor	3D Printing Electrical and Electric Components, 3350 RPM	Luis F. Aquipa Moreno et al. 2022 [22]
5	Arduino Uno	Fixed Angle Rotor	16*2 LCD, 3000 RPM, Automatic Setting, Temperature Sensor DS18B20, Lid Lock	This work

Research related to this study is presented in Table 1. The first related study was conducted by M Ilham in 2017. This study developed a centrifuge capable of detecting excessive temperatures in the motor using an LM35 sensor, which can lead to damage to the motorbike. However, this study has a difference: the temperature sensor used, the DS18B20. The second related study was conducted by K.A. Akbar in 2019. This study incorporates an automatic setting mode for each predetermined measurement.

Table 2 State of the Art for Commercial Centrifuge

No	Features	Rotor	RPM	Ref
1	Low Noise Level <60dbm, Choice of accessory rotors, 2*16 LCD	Fixed Angle	100-3000	LMC-300
2	Temperature control, Door closing protection, Control for rotating speed control	Various Rotor	0-16000	AMTAST TGL-16MC
3	CPU controls speed and time, automatically opens the lid when processing is complete, Low noise level <60dbm	Fixed Angle	300-4500	Mini Centrifuge D0412
4	LCD 16*2, Automatic Setting, Temperature Sensor DS18B20, Lid Lock	Fixed Angle	0-3000	This Work

Table 2 compares the specifications of the centrifuge designed in this research with commercial centrifuges. Specifications are obtained from the product length of each manufacturer selling centrifuges in Indonesia. The advantages of each centrifuge product circulating in Indonesia can be known by comparing these specifications. This can be used as a reference in developing a centrifuge for this research.

This study describes the testing methods and technical parameters of a centrifuge module designed with adjustable speed and time control, integrated with an Arduino-based over-temperature protection system. We aim to design and develop a centrifuge module with predetermined time and speed modes based on Arduino, equipped with an overheating temperature detector on the motor in accordance with safety standards, so that it can support students practical learning. The system utilizes a DC/BLDC motor controlled through PWM, with operating time managed by an internal timer and temperature monitored using a sensor connected to the microcontroller. Key technical parameters include rotational speed range (RPM), timer setting range, temperature safety threshold, power supply specification, and load capacity. This research contributes to producing a prototype that uses low-cost components and can be effectively reproduced as an educational learning medium.

Functional testing was conducted to evaluate the performance of the speed and time control systems. Speed accuracy was measured using a tachometer and compared with the programmed RPM values, while time accuracy was verified using a digital stopwatch. Each test was repeated to assess system stability and consistency. Accuracy analysis was performed by calculating the percentage error between the set values and measured results for both speed and time. The performance of the over-temperature protection system was also evaluated by observing the automatic shutdown response when the temperature exceeded the predefined limit, ensuring the module meets acceptable technical tolerance and operational stability standards.

2. Methods

Metode harus disusun sebagai berikut:

2.1 Research Method

This research is experimental, observational research. Observative research only analyzes up to the description level, namely analyzing and presenting data systematically to be more easily understood and concluded. In contrast, exploratory research is research that aims to find something new in the form of grouping a particular symptom, fact, and disease. Experimental, descriptive research seeks to describe the state of a phenomenon; in this study, the research focuses on explaining performance of variables such as speed, time, and temperature control within the developed centrifuge module.

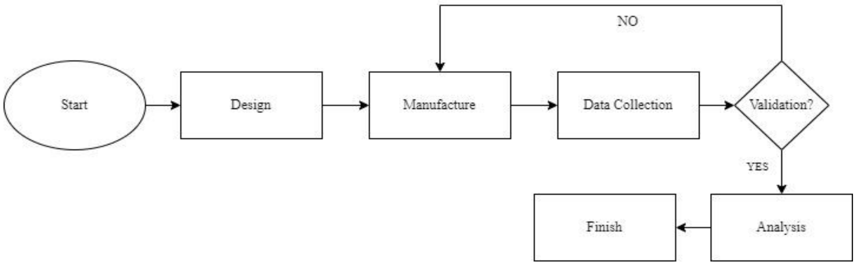

Figure 1 Research methodology diagram

The initial phase of developing this module involves creating a design plan based on the specified requirements, focusing on mechanical and physical aspects. Following this, the manufacturing stage commences by gathering all necessary mechanical and electronic components. These components are then assembled to construct a centrifuge design equipped with an automatic speed and timer functionality and an over-temperature regulator for the motor. The system utilizes an AC motor as the main driving component and an DS18B20 temperature sensor to monitor motor temperature. Subsequently, data collection ensues by activating the tool and assessing its overall functionality, covering mechanical and electronic operations. Should any disparities arise during data collection compared to the predetermined specifications, troubleshooting steps are implemented, and the manufacturing process is revisited to identify and rectify the issue. Upon successful validation and confirmation of a problem-free operation, the subsequent step involves data analysis based on the collected data, utilizing tools such as a Tachometer and Thermometer. Each measurement is repeated five times to ensure reliability and consistency of the results. The acceptable tolerance standard applied in this study is ±5% of the set value. If discrepancies beyond the tolerance limit are identified, troubleshooting and system adjustments are carried out before retesting. Data is collected across the tool's system, and the acquired data is grouped, processed, and analyzed using relevant theories. The data processing and analysis stage delves into evaluating the stability of speed and time in each operational mode and assessing the DS18B20 temperature sensor's accuracy in controlling the motor. Conclusions are then drawn from the processed and analyzed data to address the initial problem formulation for the tool, along with recommendations for further tool development.

2.2 Standardized Criteria Calculation

In this study, data processing uses standardized statistical formulas to determine the accuracy and stability of measurements so that the developed centrifuge module complies with predefined feasibility limits. This formula is used to analyze speed, time, and temperature. The acceptable tolerance standard applied in this research is ±5% of the set value.

Formula:

1. Average on inspection mode

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

Description:
$\bar{x}$ = average measurement value
xi = random values of measurement data $x1$, $x2$, i
n = amount of data taken error value
Based on formula (1) above, we can calculate the average of ungrouped data. For example, if $x1$, $x2$, and so on are data collected from a sample, they can be symbolized by $\bar{x}$. From the data that has been obtained, it will be entered into a formula so that we get the calculated average.

2. Error value

$$\text{Error} = \bar{x} - \text{uut} \quad (2)$$

Description:
$\bar{x}$= average measurement value
Uut = standard value/setting value
Based on formula (2), we can calculate the error value, where we have to find $\bar{x}$ or the average value, which will later be subtracted from the setting value or value set.

3. Error Percentage Value

$$\%\text{Error} = \frac{\bar{x} - Xset}{Xset} \text{ x } 100\% \quad (3)$$

Description:
$\bar{x}$ = average measurement value
Xset = The value that is set
Based on formula (3), we can calculate what percentage error value will be found in the tool being made. The centrifuge module is considered feasible if the percentage error dose not exceed ±5%.

4. Accuracy Percentage Value

$$\%\text{Accuracy} = 100\% - \%\text{Error} \quad (4)$$

Based on formula (4), we can determine the percentage error value obtained in the accuracy.

5. Long-Term Stability Evaluation

To assess system reliability, stability testing is conducted by observing RPM performance over a specific operating duration. The RPM fluctuation over time can be presented in graphical form to evaluate speed stability under continuous operation. The module is considered stable if RPM fluctuations remain within the ±5% tolerance limit throughout operation.
Through these calculations, the feasibility of the centrifuge module is determined based on accuracy, precision, and operational stability, ensuring compliance with acceptable engineering performance standards.

2.3 Design of Centrifuge

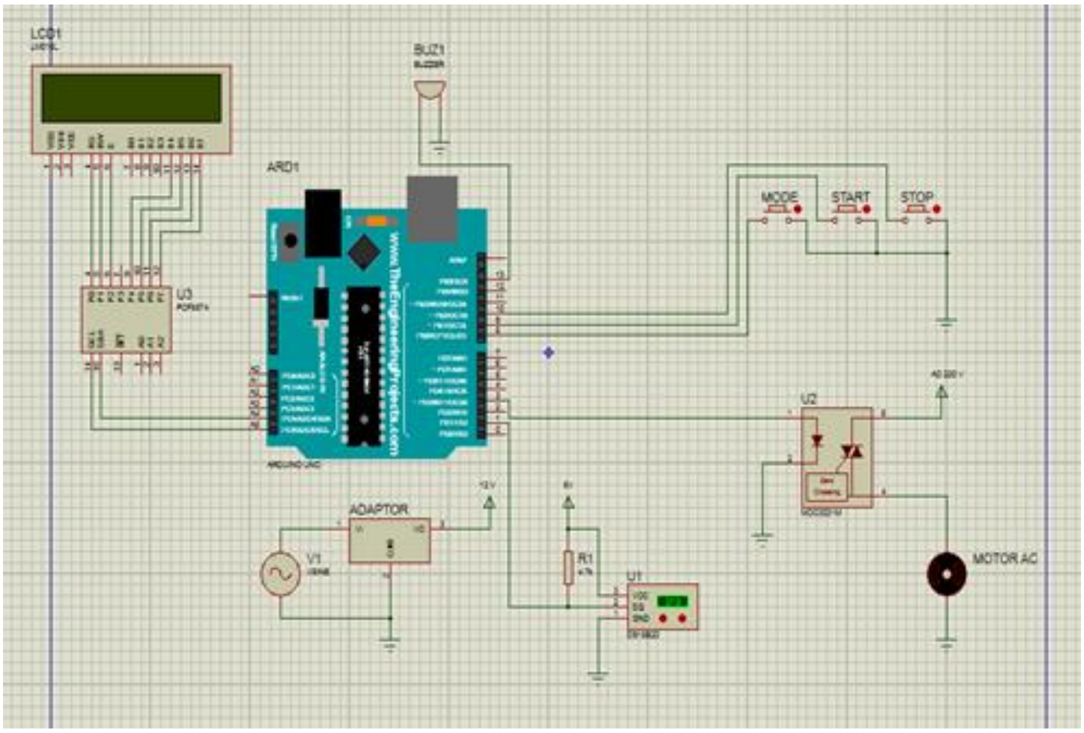

Figure 2 Diagram Circuit

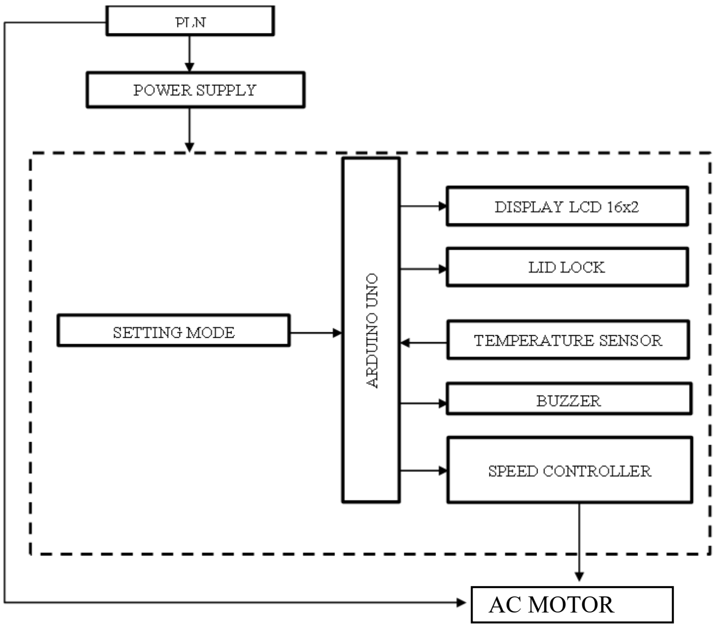

Figure 3 Block Diagram

The workings of the block diagram are: first, when the tool is connected to a PLN 220 V AC voltage source and the ON/OFF button has been pressed to the ON position, the PLN voltage will flow to the power supply, which will convert the 220 V AC voltage to a 5V DC voltage, and 12V. The 5V DC voltage will supply voltage to the Arduino, the 12V voltage will supply the Lid Lock, and the 5V voltage will also provide voltage to other circuits. The initial display will appear on the LCD when the circuit receives a voltage supply. After the process is complete, select the mode setting, which will then be processed by Arduino and forwarded to the motor speed controller, which will then activate the motor to centrifuge. After the engine runs, the temperature sensor DS18B20 reads the motor's temperature and sends a signal to Arduino. Arduino will process the incoming data and send it to the LCD. In addition to temperature monitoring, the system is equipped with overcurrent protection to enhance operational safety. A current sensor module monitors the motor's current consumption during operation. If the detected current exceeds the predefined safe limit, indicating overload or abnormal operating conditions, the Arduino automatically cuts off the motor drive signal and stops the centrifugation process to prevent damage to the motor and electronic components. A warning message is displayed on the LCD, and the buzzer is activated as an alert to the user. After the centrifugation process is completed according to the set time, the motor automatically stops, and the buzzer sounds to notify the user that the process has finished. This integrated system ensures safe, controlled, and reliable centrifuge operation through coordinated speed control, temperature monitoring, lid locking, and overcurrent protection mechanisms.

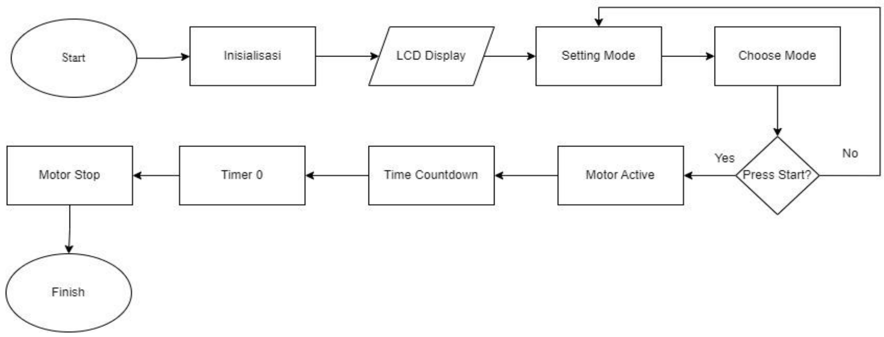

Figure 4 Workflow Centrifuge

The workflow begins with the initial step of connecting the power cable to the mains PLN. The power line is connected to the mains PLN as soon as the workflow commences. Following this, the gadget is powered on after attaching the power cable. An initialization process will then occur on the display. Subsequently, the fluid for analysis was introduced, and the appropriate mode was selected. To commence device operation, press the start button. The motor will activate automatically and operate at the selected speed. Displayed on the screen are the temperature, RPM, and processing time. As the timer reaches zero, the motor will gradually halt, allowing the lid to be opened.

3. Results

3.1. Arduino Uno-Based Centfiguge Prototype

The tool that has been made in this study is an Arduino Uno-based centrifuge equipped with an automatic timer and speed settings, a lid lock, and an over-temperature detector. Arduino Uno is the central controller that can receive, process, and execute commands given via push buttons to select measurements to be carried out to carry out the centrifugation process. LCD is communication between the device and the user, displaying information from the time, rpm, and temperature. This tool has equipment specifications, namely voltage: 220VAC with a frequency of 50/60 Hz, the output voltage of the power supply is 5VDC with an output current of 10A, the motor voltage is 220 VAC with a power of 200W, which has a maximum speed of up to 3000 rpm, has a maximum temperature of 37°C size tool dimension length: 46.5 cm, tool dimension width: 27cm, and tool dimension height: 27cm. The Arduino Uno-based centrifuge tool can be seen in Figures 5 and 6.


Figure 5 Front View

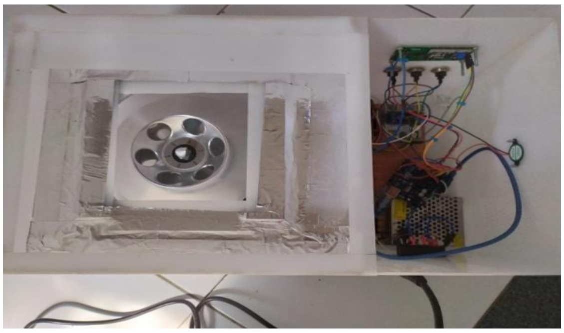
Figure 6 Inside of the Tool

Table 3 Specification Centrifuge

No	Specification	
1	Device Name	Centrifuge
2	Dimensions	46,5*27*27 cm
3	Maximum Capacity	6*20 ml
4	Setting Mode	ABO Blood, Urine Sediments, Crost Test, Coombs Experiment, Sputum Check
5	Supply Voltage	DC +5V, 9V, and +12V, 220V AC
6	Display	LCD 16*2
7	Maximum Speed	3000 RPM
8	Maximum Temperature	37°C
9	Temperature Sensor	DS18B20
10	Frequency	50-60 Hz
11	Operation Button	Start, Setting, and Stop
12	Microcontroller	Arduino Uno

3.2. Speed Testing

Speed testing was carried out three times with a tachometer in each mode, namely ABO blood mode, urine sediment mode, ABO cross test, coombs experiment, and sputum check. The speed test results on the motor can be seen in Table 4, and the results of the speed calculation analysis can be seen in Table 5.

Table 4 Speed Testing with Tachometer

No	Mode	Measurement (Tachometer Digital) RPM			Average
		1	2	3	
1	ABO BLOOD (1000RPM)	1017	1030	1085	1044
2	URINE SEDIMENTS (2000RPM)	1979	2050	2038	2022
3	CROSS TEST ABO (1000RPM)	1160	1045	1085	1096
4	COOMBS EXPERIMENT (1000RPM)	1072	1050	1048	1057
5	SPUTUM CHECK (3000RPM)	2977	3034	3078	3030

Table 5 Analysis of Speed Accuracy Calculation

No	Mode	Error Value	Error Value (%)	Accuracy (%)
1	ABO BLOOD	44	4.4	95.6
2	URINE SEDIMENTS	22	2.2	97.8
3	CROSS TEST ABO	96	9.6	91.4
4	COOMBS EXPERIMENT	57	5.7	94.3
6	SPUTUM CHECK	30	3	97

3.3. Timer Testing

Timer testing was carried out three times using a stopwatch in each mode, namely ABO blood mode, urine sediment mode, ABO cross test, coombs experiment, and sputum check. The results of the timer test can be seen in Table 6, and the results of the timer calculation analysis can be seen in Table 7.

Table 6 Timer Testing Using a Stopwatch

No	Mode	Measurement (Stopwatch) Minutes 1	2	3	Average
1	ABO BLOOD (1 MINUTE)	1.04	1.06	1.08	1.06
2	URINE SEDIMENTS (5 MINUTE)	5.17	5.15	5.16	5.16
3	CROSS TEST ABO (1 MINUTE)	1.05	1.05	1.07	1.06
4	COOMBS EXPERIMENT (1 MINUTE)	1.06	1.08	1.05	1.06
5	SPUTUM CHECK (15 MINUTE)	15.58	15.59	15.57	15.58

Table 7 Timer Calculation Analysis

No	Mode	Error Value	Error Value (%)	Accuracy (%)
1	ABO BLOOD	0.6	0.6	99.4
2	URINE SEDIMENTS	0.16	3.2	96.8
3	CROSS TEST ABO	0.6	0.6	99.4
4	COOMBS EXPERIMENT	0.6	0.6	99.4
6	SPUTUM CHECK	0.58	3.8	96.2

3.4.Temperature Testing

We give a maximum temperature limit for the 37°C motor because the author tested it by turning it on for 30 minutes. The temperature reached ±37°C. Therefore, the author gives a maximum temperature limit for the 37°C motor. If the temperature exceeds 37°C, the motor will turn off, and the buzzer will sound. Temperature test data can be seen in Table 8.

Table 8 Motor Temperature Test

No	Mode	Measurement (Max Temperature 37ºC) Thermometer Digital 1	2	3	Average
1	ABO BLOOD 31.9°C (Display)	1.04	1.06	1.08	1.06
2	URINE SEDIMENTS 32.1°C (Display)	5.17	5.15	5.16	5.16
3	CROSS TEST ABO 32.1°C (Display)	1.05	1.05	1.07	1.06
4	COOMBS EXPERIMENT 31.8°C (Display)	1.06	1.08	1.05	1.06
5	SPUTUM CHECK 32.3°C (Display)	15.58	15.59	15.57	15.58

4. Discussion

The performance evaluation of the Arduino Uno–based centrifuge shows that the developed system meets the intended operational requirements for laboratory practice applications. This discussion aligns directly with the measured results of speed, timer, and temperature testing presented in Tables 4–8.

Speed Performance Analysis

Based on the speed testing results (Tables 4 and 5), the centrifuge demonstrated speed accuracy ranging from 91.4% to 97.8% across all operational modes. The highest speed deviation occurred in the cross test ABO mode, which recorded an error of 9.6%. This deviation is likely influenced by mechanical load variations and rotor imbalance during operation at lower preset speeds. Nevertheless, all measured speed errors remained below the 10% tolerance limit, indicating acceptable rotational stability for laboratory use. Modes with higher target speeds, such as urine sediments (2000 RPM) and sputum check (3000 RPM), showed better stability, with accuracy values above 97%. This suggests that the motor control and PWM regulation perform more consistently at higher rotational speeds, which is in line with characteristics of AC motor-based centrifuge systems reported in previous studies.

Timer Accuracy Analysis

Timer testing results (Tables 6 and 7) indicate high consistency between the programmed time and actual operation duration, with accuracy values between 96.2% and 99.4%. Short-duration modes (1 minute), including ABO blood, cross test ABO, and Coombs experiment, exhibited the highest accuracy (99.4%), reflecting the reliability of the Arduino internal timing mechanism for brief operational cycles. Slightly higher errors were observed in longer-duration modes such as urine sediments (5 minutes) and sputum check (15 minutes). These deviations may be attributed to internal clock drift and the manual nature of stopwatch-based measurements. However, the observed timing errors remain within acceptable limits and do not significantly affect the centrifugation process or sample separation outcomes.

Temperature Monitoring and Safety Mechanism

Temperature testing results (Table 8) confirm that the motor operating temperature remained within a safe range of 31.8–32.5 °C during normal operation, which is well below the predefined safety threshold of 37 °C. This indicates that the motor operates efficiently under the tested workload conditions. The over-temperature protection mechanism functioned as intended during extended testing, where the system successfully shut down the motor and activated the buzzer once the temperature exceeded the threshold. This demonstrates that the DS18B20 sensor provides reliable real-time temperature monitoring and effectively enhances operational safety by preventing motor overheating and potential equipment damage.

5. Conclusion

A centrifuge has been successfully designed and produced, featuring automatic settings, a lid lock mechanism, and over-temperature detection using an Arduino Uno-based system. According to the results and discussions, the tool demonstrates efficient functionality, with temperature, speed, and timer measurements showing a correction value of less than 10%. The over-temperature detection mechanism for the motor operates effectively, with the motor ceasing operation if the temperature exceeds 37°C as predetermined by the author. Additionally, the lid lock system functions smoothly, automatically halting the motor if the door is opened while the tool is operational.

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