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DESIGN OF A MULTI-TUBE VORTEX MIXER WITH ROTATION SPEED AND TIME SETTINGS

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ABSTRACT: A vortex mixer is a laboratory device used to mix solutions in small tubes homogeneously, but it can generally mix only one tube at a time. To improve laboratory work efficiency, a device was designed and constructed that mixes multiple tubes simultaneously. The purpose of this study was to design a practical and efficient multi-tube vortex mixer with motor speed and time settings via an LCD touchscreen, and to display the motor speed in real Time using an optocoupler sensor. Testing was conducted to assess the accuracy of the RPM reading from the optocoupler sensor, and the results showed that the device could produce motor rotation close to the tachometer reading. In the time accuracy test, an average error of 0.45% was obtained with an accuracy of 99.55%. Additionally, testing with a load showed that the tube load improved motor rotation stability. The optocoupler sensor also displayed real-time RPM values, with a difference of 28 RPM at 500 RPM. Overall, this device has been successfully developed and used for laboratory purposes.

INDEX TERMS: Multitube Vortex Mixer, DC Motor, LCD TFT, RPM Sensor.

I. INTRODUCTION

A vortex mixer is a laboratory device used to mix solutions in small containers, such as test tubes and centrifuge tubes [1]. Depending on the application requirements, various types of vortex mixers are used, including the multi-tube vortex mixer. The multi-tube vortex mixer is designed to mix multiple tubes simultaneously, enabling greater homogenization efficiency than standard vortex mixers, which can mix only one tube at a time [2]. In addition, the multi-tube vortex mixer is designed to be hands-free, making it easier for users to mix solutions without holding the tubes [3].

The multi-tube vortex mixer consists of an electric motor with a drive shaft that rotates like a whirlpool or a wind, thoroughly homogenizing or mixing liquids [4]. Vortex is defined as a whirlpool, while mixer is defined as a mixer [5].

This tool is commonly used in chemical and pharmaceutical laboratories for homogenizing paracetamol suspensions and for stirring liquid multivitamin formulations and antibiotic suspensions, such as erythromycin [6], [7]. In addition, this tool is also commonly used in bioscience and clinical laboratories. When using this tool, the speed and duration of mixing must be adjusted to the type of liquid being mixed. If not adjusted properly, the sample may be at risk of instability, including excessive foaming, oxidation, or damage to sensitive active substances that are susceptible to mechanical shear [8].

To obtain optimal mixing results, it is recommended that reaction tubes be filled to only 50-75% of their volume [9]. Reaction tubes should also be placed evenly to prevent excessive vibration; in a multi-tube vortex mixer with four tube holders, all four tubes should be filled at the same Time, while if only two tubes are used, they should be placed crosswise so that their positions balance each other.

The main component of this device is a DC motor that generates vortex motion in the sample tube. A DC electric motor or direct current motor is an electromagnetic device that converts electrical energy into kinetic energy [10]. A brushed DC motor works based on electromagnetic principles and consists of two main components, namely the stator, as the non-rotating part, and the rotor, as the rotating part [11]. This motor is controlled by a BTS7960 driver that uses a complete H-bridge configuration. This module can deliver high currents and supports motor speed and rotation direction control via Pulse Width Modulation (PWM) signals [12]. With this feature, the motor can be controlled with precision while also being protected against overcurrent and overheating [13].

In this era of increasingly advanced technological development, the design of this multi-tube vortex mixer uses a TFT LCD to provide a more interactive and functional interface. This screen offers a high-resolution, clear display and rapid color changes [14]. The use of TFT LCD is driven by the need for clear, responsive graphics to support precise speed and time settings. Thus, TFT LCD not only improves comfort when interacting with the system but also enhances the accuracy of the mixing process [15].

II. RESEARCH METHODS

This study presents the design of a multi-tube vortex mixer equipped with a touchscreen-based, hardware-and-software combined speed-and-time control system. This device uses a DC motor controlled by a BTS7960 driver with an Arduino Mega 2560 as the system control center.

An optocoupler sensor is used to monitor the motor speed in real Time to ensure the stability of the mixing process, while a TFT LCDs displays speed and time information. A buzzer is added as an indicator of the end of the mixing process.

The motor speed can be adjusted to 500-1500 RPM in increments of 100 RPM, while the operating Time can be set to 1-15 minutes in increments of 1 minute. In addition, the device is equipped with a manual pause feature that temporarily stops the process without resetting settings, facilitating visual observation and tube replacement [16]. The integration of these components and features enables the device to operate efficiently when mixing multiple tubes simultaneously in the laboratory.

.A. DIAGRAM BLOCK

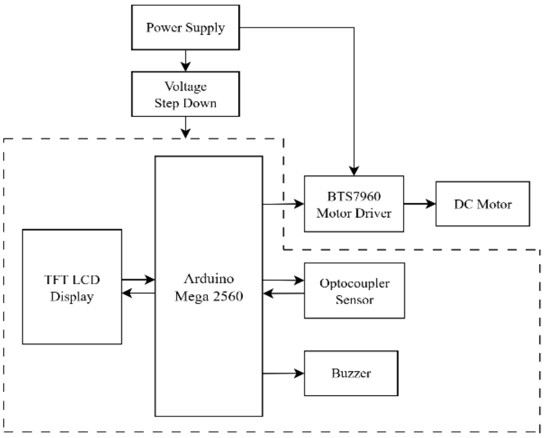

FIGURE 1. **Block Diagram of the developed Multi Tube Vortex Mixer device module.**

As shown in Fig. 2, the power supply receives input from a 220V AC power source, converts it to 12V DC, and then distributes the voltage to the step-down module, the BTS7960 motor driver, and the DC motor. The stepdown module then reduces the 12V supply to 5V to power components that require a lower voltage, such as the microcontroller, optocoupler sensor, TFT LCD, and buzzer.

When the device is turned on, the microcontroller will control the entire circuit. The speed and Time are set via the TFT LCD, then sent to the microcontroller. Next, the microcontroller activates the motor driver to run the motor as commanded. The optocoupler sensor measures the motor rotation speed, and the result is sent to the Arduino Mega 2560 for display on the TFT LCD screen. When the elapsed Time matches the setting, the microcontroller will issue a stop instruction to the motor driver, causing the motor to stop rotating and the buzzer to sound.

B. HARDWARE DESIGN

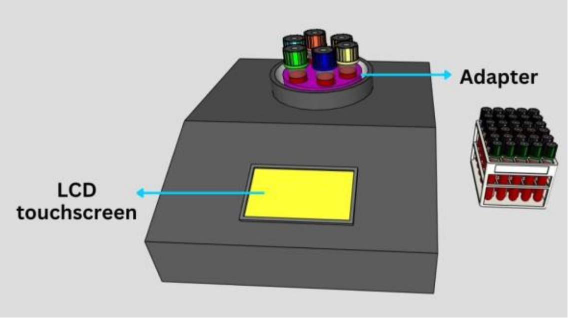

FIGURE 3. **Front view design of a multi-tube vortex mixer with an adapter and LCD touchscreen.**

From Fig. 3, it can be seen that an LCD touchscreen serves as a display and controls the speed and Time.

C. DATA COLLECTION TECHNIQUES

1. Data Collection Techniques

In this study, the author collected data by testing the accuracy level of a multi-tube vortex mixer. The objectives were to determine the accuracy of the optocoupler sensor RPM reading using a tachometer, measure the accuracy of the Time when the motor started and stopped using a stopwatch, test the motor speed under load conditions, and test the stability of the speed sensor (optocoupler).

2. Research instrument

This study also required several tools to support data collection. The tools used included a tachometer to measure the rotational speed of the multi-tube vortex mixer, a stopwatch to measure mixing Time, and test tubes to simulate laboratory conditions.

III. RESULTS AND DISCUSSION

This chapter presents the results of the multi-tube vortex mixer design process, including the physical form of the device after assembly, preparation of the tools and materials used in the manufacturing process, standard operating procedures, and the data collection process, which was analyzed using accuracy-level calculations.

Fig. 4 shows the physical appearance of the multi-tube vortex mixer. There is an adapter made of EVA foam that serves as a holder for four reaction tubes, with a switch on the back of the device.

FIGURE 4. Physical form of the multi-tube vortex mixer from the front and back views.

A. OPTOCOUPLER SENSOR RPM READING ACCURACY TESTING

Motor speed was measured at each speed setting (500–1500 RPM) using a tachometer, and the results were compared with the RPM values displayed on the device's TFT LCD screen.

TABLE I
OPTOCOUPLER SENSOR RPM READING ACCURACY TESTING

$\bar{X}$ Device (RPM)	$\bar{X}$ Tachometer (RPM)	|Error|	% Error	Accuracy
521.8	519.8	2	0.40%	99.60%
597.4	608	10.6	1.76%	98.24%
716.4	721.4	5	0.71%	99.29%
839	829.8	9.2	1.15%	98.85%
889	899.6	10.6	1.17%	98.83%
1012.6	1000.4	12.2	1.22%	98.78%
1089	1112.4	23.4	2.12%	97.88%
1204	1204.6	0.6	0.05%	99.95%
1296	1322.2	26.2	2.01%	97.99%
1426	1427.6	1.6	0.11%	99.89%
1468	1500.8	32.8	2.18%	97.82%
	Mean		**1.17%**	**98.83%**

Based on Table I, the complete results of the motor speed measurements, taken five times at each speed level (500–1500 RPM, with an increment of 100 RPM), are shown. From these results, an average error percentage of 1.17% and an accuracy level of 98.83%. These results indicate that the motor speed regulated by the device is sufficiently accurate, and the difference remains within the tolerance limit.

B.COMPARISON OF SETUP TIME AND MEASURED TIME

Time measurement on the device was performed by comparing the Time set on the device with the Time measured with a stopwatch to determine the device's accuracy. We repeated 5 times for each duration: 3 minutes, 6 minutes, and 15 minutes.

TABLE II
COMPARISON OF SETUP TIME AND MEASURED TIME

Trial	**Time Setting (seconds)**	**Measured Time (seconds)**
1	180	180.71
2	180	180.98
3	180	182.72
4	180	175.78
5	180	175.87
Mean		**179.23**
Error		**0.75**
Percentage Error		**0.41%**
Accuracy		**99.59%**

Based on Table 2, at a setting of 3 minutes (180 seconds), tested 5 times, the results showed an error percentage of 0.41% and an accuracy rate of 99.59%.

TABLE III
COMPARISON OF SETUP TIME AND MEASURED TIME

Trial	**Time Setting (seconds)**	**Measured Time (seconds)**
1	360	360.25
2	360	360.78
3	360	355.97
4	360	359.18
5	360	356.12
Mean		**358.46**
Error		**1.54**
Percentage Error		**0.42%**
Accuracy		**99.58%**

TABLE IV
COMPARISON OF SETUP TIME AND MEASURED TIME

Trial	**Time Setting (seconds)**	**Measured Time (seconds)**
1	900	900.58
2	900	901.28
3	900	894.39
4	900	892.14
5	900	888.3
Mean		**895.34**
Error		**4.66**
Percentage Error		**0.51%**
Accuracy		**99.49%**

Based on Table 3, at a setting of 6 minutes (360 seconds), tested 5 times, the results showed an error percentage of 0.42% and an accuracy rate of 99.58%.

Based on Table 4, at a setting of 15 minutes (900 seconds), tested five times, the percentage error was 0.51% and the accuracy rate was 99.49%.

The results of the analysis of the measurement data on the accuracy of the setting time with the measured Time are summarized in Table 5.

TABLE V
COMPARISON OF SETUP TIME AND MEASURED TIME

Time (seconds)	Error	Accuracy
180	0.41%	99.59%
360	0.42%	99.58%
900	0.51%	99.49%
Mean	**0.45%**	**99.55%**

E. MOTOR SPEED TESTING UNDER NO LOAD AND UNDER LOAD CONDITIONS

This test was conducted under three different conditions: without load, with an empty tube, and with a tube filled with 7 mL of distilled water. In all three conditions, the device speed was set to 1000 RPM, and the speed was measured with a tachometer. The speed measurement was performed five times, and the results were compared to determine the difference in RPMs across the three conditions.

. Under no load conditions, the speed accuracy obtained was 95.86%. When the device has an empty tube, the accuracy increases to 96.8%. Meanwhile, under conditions with a tube containing 7 mL of distilled water, the speed accuracy reached its highest value, namely 98.36%.

From this data, adding load actually improved the stability of motor rotation. This is likely due to the additional mass in the tube, which helped stabilize the rotation when the motor was operating. Thus, we concluded that the motor speed was better when a specific load was used during testing.

F. SPEED SENSOR (OPTOCOUPLER) STABILITY TEST

The stability test of the RPM reading on the speed sensor displayed on the LCD screen was conducted by setting the motor speed at a fixed value of 500 RPM. The RPM is measured every 4 seconds during the 1-minute test duration.

Based on Table 6, the device's RPM readings are not always the same. The lowest reading is 494 RPM, while the highest reading is 566 RPM. The average sensor reading is 528 RPM, indicating a difference of 28 RPM from the set speed.

According to this study, the optocoupler sensor cannot provide completely stable readings. The RPM value tends to be slightly higher or lower than the set speed. This can occur due to strong vibrations during motor operation. These vibrations prevent the sensor from reading consistently, resulting in unstable RPM readings.

TABLE VI
COMPARISON OF SETUP TIME AND MEASURED TIME

Time (Second)	Speed Setting (RPM)	Display (RPM)
4	500	494
8	500	499
12	500	513
16	500	542
20	500	513
24	500	528
32	500	513
36	500	523
44	500	523
48	500	528
52	500	547
56	500	556
60	500	566

IV. CONCLUSION.

The multi-tube vortex mixer was successfully created with motor speed and time settings via a touchscreen LCD, and real-time RPM readings were obtained using an optocoupler sensor. This device can mix up to 4 sample tubes simultaneously, increasing laboratory efficiency. The motor speed test results show that the device can produce rotations that closely match the optocoupler sensor readings. The optocoupler sensor used can read and display RPM values in real Time.

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