Development of Batik Plotter and Dyeing Machine Based on Wireless Communication System

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Abstract— **The dyeing process in small-scale batik industries is generally performed by immersing fabric into a dye bath, which exposes operators' hands to chemical dyes and may cause skin irritation. In addition, manual handling often leads to quality degradation, as dyes can penetrate unintended areas when the wax layer peels or cracks, particularly due to fabric folding, resulting in distorted batik patterns. To address these issues, this study proposes a Computer Numerical Control (CNC)-based automatic batik stamping machine to improve process consistency, efficiency, and operator safety. The developed system employs three stepper motors to control movement along the X-axis, Y-axis, and Z-axis, where the Z-axis regulates the motion of an electric canting stamp. Machine operation is controlled using Mach3 software, which generates G-code commands transmitted wirelessly to an Arduino microcontroller via Universal G-Code Sender. Experimental results show that the optimal operating temperature of the electric canting tool is within the range of 55–70°C, ensuring stable wax flow. Accuracy testing indicates an average positional deviation of approximately 0.7 mm across all axes, demonstrating good mechanical precision. Furthermore, the 433 MHz telemetry-based wireless communication system provides reliable control up to a distance of 50 meters.**

Keywords— ***Arduino, Batik stamping machine, CNC, G-code, Stepper motor, Telemetry, Wireless communication***

I. INTRODUCTION

The history of Indonesian batik originates from the ancestral heritage of the Javanese people. Batik has been recognized by UNESCO as an Intangible Cultural Heritage of Humanity since September 2009 [1]. Over time, the traditional batik-making process has evolved in line with technological advancements. In the past, wax was applied using a variety of traditional tools known as *canting*. As the technique developed, brushes began to be used in addition to *canting*. Moreover, modern batik dyeing techniques have expanded beyond the traditional immersion method to include approaches such as airbrushing and the *colet* technique. These advancements have allowed for the creation of diverse effects and textures in contemporary batik designs [2]. In small-scale batik industries, the conventional dyeing process still involves immersing fabric into dye baths, often causing the operator's hands to be repeatedly exposed to chemical dye solutions, which can lead to skin irritation [3]. Furthermore, the quality of the batik may be compromised if the dye penetrates through cracks in the wax layer that has already peeled off. Wax damage caused by folding can also distort the intended pattern and color distribution [4]. Fauzan *et al.* in [5] focused on designing a CNC-based batik plotter machine with a robust structure, high precision, a functional batik pen, and integrated programming capabilities. The machine's frame was constructed from V-slot aluminium profiles, and it employed an Everman belt drive transmission system. The batik pen was engineered with a reservoir capacity of 34 cm³ and incorporated components such as an Arduino UNO microcontroller, MLX90614 infrared temperature sensor, cable-type heating element, temperature control unit, 16x2 LCD display module, and I2C module. The stepper motors were controlled using the Universal G-Code Sender (UGS) application. However, the system lacked wireless communication capability. While the authors in [6] developed a low-cost stamped batik production process with a focus on optimizing the stamp holder fabrication. Their study involved testing various spindle speeds and cutter diameters. The Vectric Aspire 4.0 software was used to convert hand-drawn batik images into CNC-compatible toolpaths, facilitating the automation of the stamping process. Rogelio *et. al* in [7] introduced an Automatic Tool Changer (ATC) system for a 3-axis CNC router. This research aimed to enhance productivity and competitiveness in the metalworking industry by automating tool changes previously performed manually. The ATC system was integrated into a CNC milling machine and was controlled through a numerically programmed interface on a computer, coordinating movements along the X, Y, and Z axes. One such advancement is the integration of CNC (Computer Numerical Control) technology. A CNC-based batik stamping machine typically includes three stepper motors that control movement along the X-axis (horizontal), Y-axis (vertical), and Z-axis (vertical tool movement) [8]. The system is operated via computer using Mach3 software, which processes G-Code commands and transmits them to a

CNC driver. The driver interprets these instructions and controls the movement of each stepper motor accordingly.

Based on the aforementioned above, the system has not considered dyeing functionality. In this paper, we propose a CNC-based system that integrates both pattern plotting and dyeing processes with wireless communication. The main contribution of this paper is formulated as

- A pattern plotter-dyeing machine is proposed to improve the quality of batik production with wireless communication. By integrating them, the batik production is more efficient.
- Experiment results show that the proposed machine can improve the batik production efficiency.

II. METHOD

A. *Research Methods*

This study employs a design and development research method as shown in Figure 1. Consequently, the answers to the research questions require stages of design, material and equipment preparation, parameter determination, and implementation. The research methodology consists of systematic steps to guide the development and implementation of the system, as outlined below.

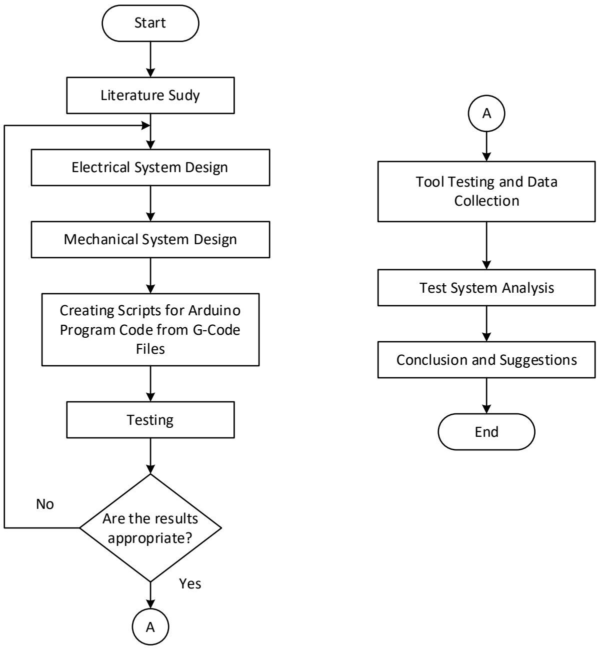


Figure 1. Research Design Flowchart

The first step begins with the design and construction of the plotter machine's mechanical framework, formed according to the X, Y, and Z axes for movement across specified points. Once the mechanical components are assembled, electronic components are integrated to perform their respective functions. The electronic system comprises an Arduino Uno microcontroller, a CNC shield with stepper drivers, stepper motors, and an RF 433 MHz module. This RF module enables wireless communication between the computer and the plotter machine [9][10] [11]. The Universal G-code Sender (UGC) software is used to transmit commands that operate the plotter.

Thereafter, focuses on designing the dyeing machine. The mechanical frame is shaped to follow the length and width of the fabric path and enables fabric movement. The mechanical assembly is equipped with a motor and pulley system, along with electronic components such as an Arduino Uno, stepper driver, and NEMA 23 stepper motor [12][13][14]. An RF 433 MHz telemetry module serves as the wireless communication bridge between the computer and the dyeing system, sending data from the plotter to the dyeing Arduino unit [15]-[18]. The Arduino IDE software is used to program and execute dyeing commands.

B. *System Designs*

The system design for this final project report involves several phases of system development, including the mechanical design, electrical system configuration, wiring, and machine software implementation, as illustrated in Figure 2.

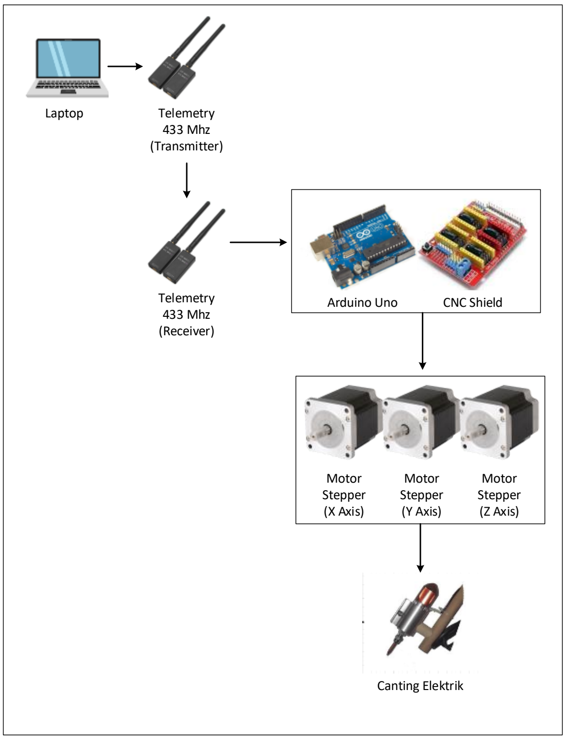


Figure 2. Plotter Machine Block Diagram

The system architecture utilizes a wireless communication method based on a 433 MHz telemetry module to transmit data between the control unit and the machine. The process starts from a laptop where the G-code is generated and transmitted via the 433 MHz telemetry transmitter module. The data is then received by the telemetry receiver module connected to an Arduino Uno microcontroller equipped with a CNC shield. This shield interfaces with three stepper motors that control movement along the X, Y, and Z axes. The Z-axis specifically manages the operation of the electric canting tool, which functions as the drawing instrument for plotting batik patterns onto fabric. This configuration allows for remote, wireless operation of the plotting system, enabling precise and automated control of the batik production process.

C. System Flowchart

Figure 3 illustrates the workflow of the plotter to be implemented in the system development.

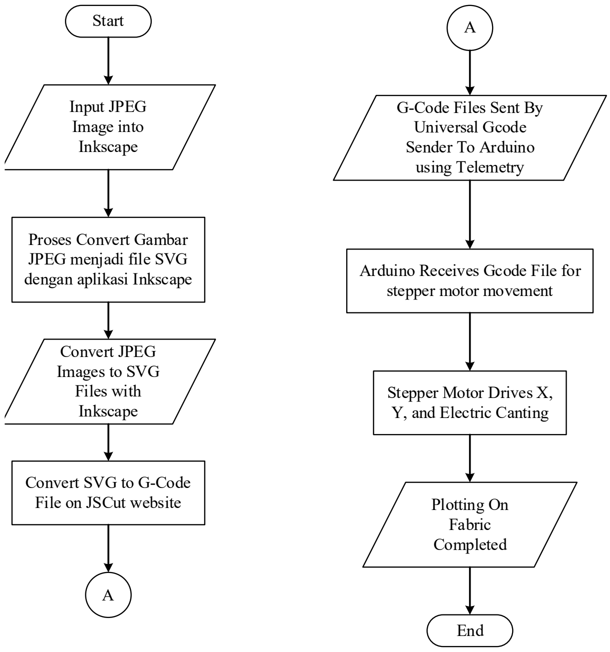


Figure 3. Plotter Machine System Flowchart

The plotting process begins with importing a JPEG image into the Inkscape application. Within Inkscape, the image is converted into an SVG (Scalable Vector Graphics) file format, which is necessary for further processing. Once the JPEG is successfully converted to SVG, the file is then exported to the JS Cut website to be translated into a G-Code file. This G-Code contains the instructions needed to control the movement of the stepper motors and the electric canting tool. After conversion, the G-Code is transmitted wirelessly via a telemetry system to the Arduino microcontroller using Universal G-Code Sender software. The Arduino receives and processes the G-Code, which is used to drive the stepper motors along the X and Y axes and to control the electric canting tool on the Z-axis. As a result, the plotting process is performed directly onto the fabric, completing the batik pattern transfer with improved precision and automation.

D. Dyeing System Flowchart

Figure 4 illustrates the workflow of the dyeing system to be implemented in the system development.

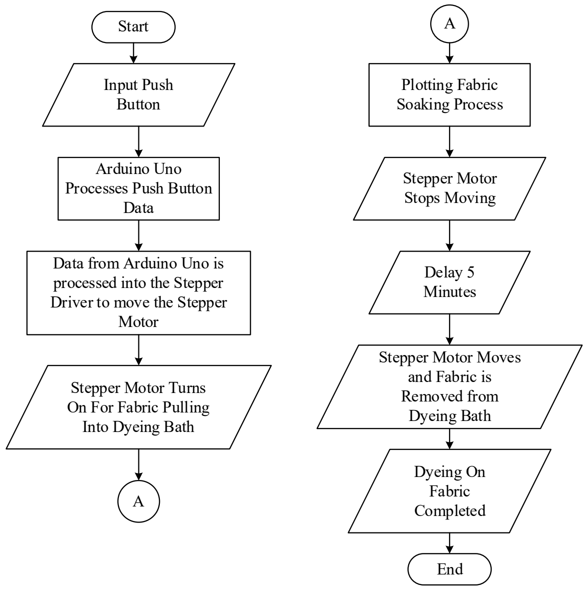


Figure 4. Dyeing Machine System Flowchart

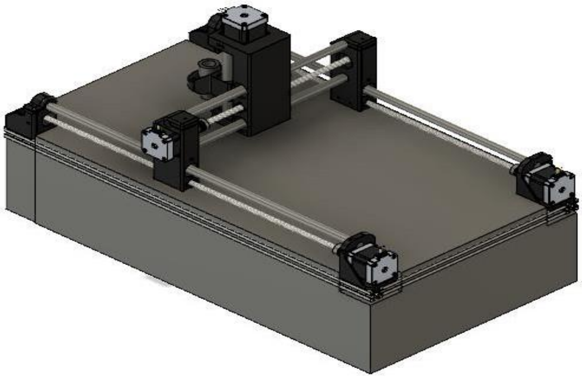
The working process of the automated batik dyeing system begins with the user pressing a push button, which serves as the initial input to activate the system. This input is detected and processed by the Arduino Uno microcontroller, which then sends the corresponding signal to the stepper motor driver. The driver activates the stepper motor, causing it to rotate and pull the fabric into the dyeing bath. Once the fabric is fully submerged, the motor stops, allowing the fabric to soak in the dye solution. The system then enters a delay phase, maintaining the fabric in the dye bath for approximately five minutes to ensure proper absorption of the dye. After this soaking period, the stepper motor is reactivated to lift the fabric from the dyeing bath, completing the coloration process. This automated sequence significantly enhances the efficiency and consistency of the batik dyeing process by reducing manual labor and improving dye application precision.

E. Mechanical Design

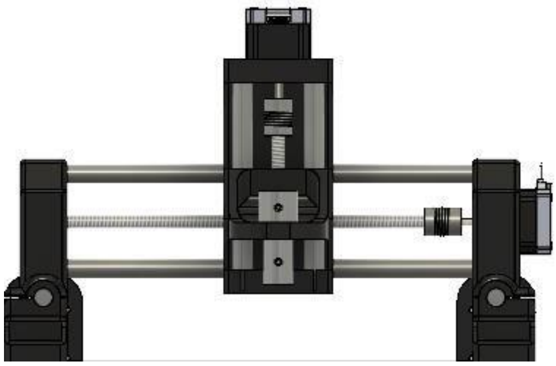
The batik plotter device is constructed using a lightweight yet sturdy aluminum frame, designed in a rectangular form as shown in Figure 5. The overall dimensions of the machine measure 240 × 100 cm, determined in the initial design phase to accommodate sufficient workspace for fabric plotting and dyeing processes. Each corner of the aluminum frame is reinforced with L-brackets, which are fabricated using 3D printing. The custom brackets provide structural stability and serve mounting points for the stepper motors.

The X and Z axes of the batik plotter utilize two steel rods and a single lead screw to facilitate the horizontal and vertical movement of the canting tool. These steel rods serve as guide rails, with linear bearings installed to ensure smooth, stable, and low-friction motion. The lead screw is responsible for driving the linear movement, with nuts functioning as the interface to convert rotational force into linear displacement.

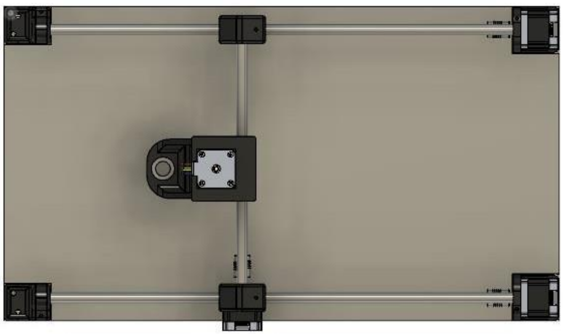
A shaft coupler connects the stepper motor to the lead screw, effectively transmitting torque while compensating for minor misalignments between components. On the Y-axis, the system employs two stepper motors positioned on either side of the frame. Each motor controls a lead screw and is supported by a steel rod, enabling precise and synchronized lateral motion across the work area.



(a)



(b)



(c)

Figure 5. Plotter Device Design: (a) Initial Design (b) View from X and Z Axis (c) View from Z Axis

The dyeing machine frame is constructed from iron plates shaped as an isosceles trapezoid with dimensions of 100 × 90 × 50 cm and an inclination of 80 cm as shown in Figure 6. The frame legs are made from angled iron bars. On the lower right side, there is a metal holder for mounting the stepper motor and pulley system complete with a timing belt. The stepper motor operates in bipolar mode, providing high torque output to the pulley, allowing the roller shaft to rotate under heavy load without overburdening the motor.

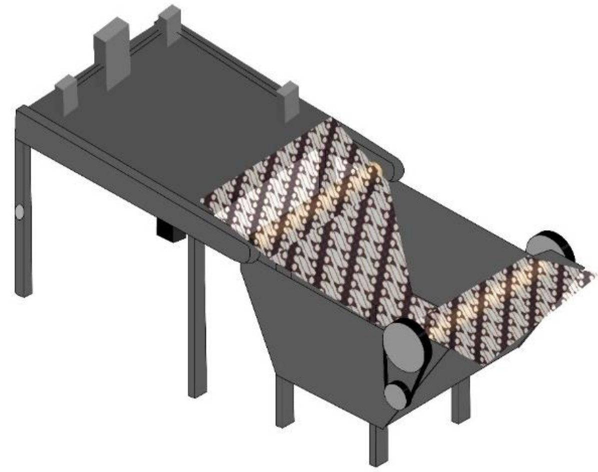


Figure 6. Plotter & Coloring Machine Design

III. RESULTS AND DISCUSSION

In this section, we evaluate the performance of the proposed pattern plotter-dyeing machine.

A. Implementation Results

Figure 7 shows the positioning between the machine and the user.

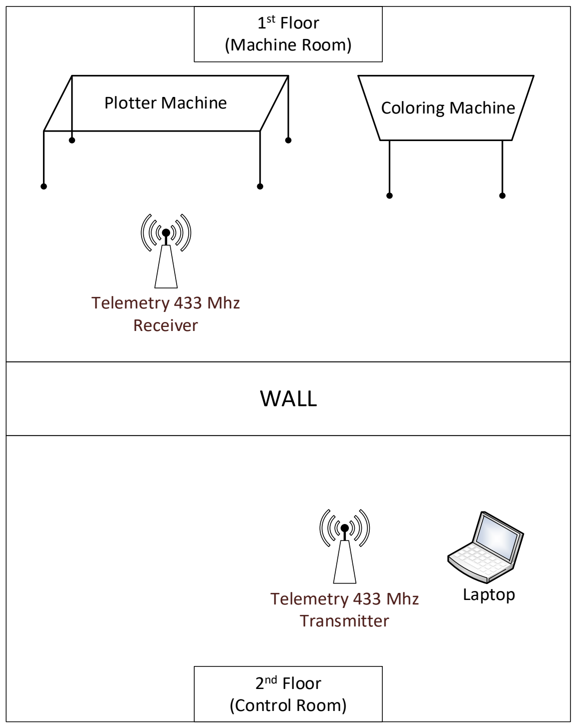


Figure 7. Plotter and Coloring Machine Placement

The setup consists of two floors: the first floor serves as the machine area, while the second floor functions as the control room. Illustrates the batik cloth plotting and dyeing system based on the 433 MHz RF telemetry module, which connects devices on the first and second floors. On the first floor, there is a 433 MHz RF telemetry receiver (Rx) module controlled by an Arduino microcontroller. Arduino receives signals from the transmitter and manages two main units: a CNC-based batik plotter machine and an automatic dyeing machine. These machines operate based on wireless commands sent from the second floor. On the second floor, a laptop serves as the control center, connected to the 433 MHz RF telemetry transmitter (Tx) module. This laptop sends G-Code data wirelessly to the first floor to control the batik plotting and dyeing processes.

B. Machine Implementation Results

The batik pattern plotting device constructed features three axes: X, Y, and Z, where the Y-axis comprises two stepper motors. The plotter's working area spans 900 x 650 mm. The electric canting temperature is regulated by an NTC sensor, with its values displayed on an LCD, as shown in Figure 8. The batik plotter device in Figure 4.2 integrates several components forming a machine control system. This system ensures the machine operates according to user requirements. Key components of the control system include a computer/laptop, Arduino Uno, CNC Shield, Stepper Driver, and Stepper Motor.

The software used to control the batik plotter device is Universal G-Code Sender, which acts as the interface between the device and the computer. G-Code files are uploaded via this software. Before uploading, the user must configure the machine settings to ensure dimensional accuracy between the file and the machine's execution. Speed and acceleration settings can also be adjusted through the software.

C. Stepper Motor Steps Result

This test was conducted by comparing calculated displacement values with actual movement based on the number of steps executed by the stepper motor. The discrepancy between the calculated and measured displacement.

TABLE I
PLOTTING RESULTS OF THE NUMBER OF STEPS GIVEN TO THE MOTOR

Steps	Initial Results (mm)	Measured Results (mm)	Errors (mm)
1600	4	4	0
2000	5	5	0
3200	8	7.5	0.5
4000	10	8.5	1.5
6400	16	15	1
8000	20	18.5	1.5
9600	24	22.5	1.5
12800	32	32	0
16000	40	39	1
22400	56	55	1
32000	80	78.5	1.5

(a)

(b)

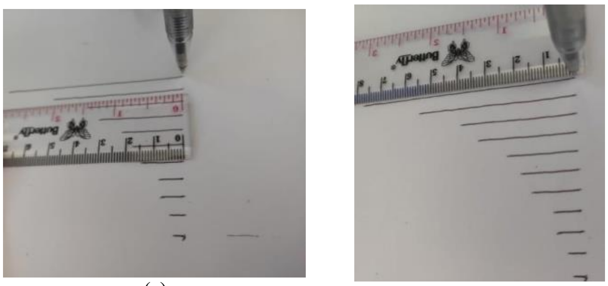
(c)

Figure 8. Machine Design Results: (a) Front View (b) Side View (c) Top View

The test used a ballpoint pen as a marker attached to the Z-axis. Each motor was incrementally driven from 1600 steps to 32,000 steps. The resulting movement was measured using a ruler. Table I presents the plotting results based on the number of steps input into the motor.

Based on Table I, the difference between the calculated and actual displacement was found to be minimal, approximately 0.8 mm. This indicates high step precision, with measurement discrepancies likely caused by human error due to the use of a standard millimeter-scale ruler.

Figure 9 shows the actual plotting results based on the number of steps provided to the motor.



(a) (b)

Figure 9. Actual Plotting Results of Step Count: (a) Step count 6400 is 15 mm long (b) Step count 32000 is 78.5 mm long

D. Steps Number from Stepper Motor Results

The movement results of the X-axis shown in Table II, therefore Table III of the Y-axis, and Table IV of the Z-axis.

TABLE II
X-AXIS MOVEMENT RESULTS

No.	Input	Initial Distance (mm)	Measured Distance (mm)	Errors (mm)
1.	G00 X300	300	300	0
2.	G00 X200	200	200	0
3.	G00 X150	150	15	0
4.	G00 X130	129	129	1
5.	G00 X100	99	99	1

TABLE III
Y-AXIS MOVEMENT RESULTS

No.	Input	Initial Distance (mm)	Measured Distance (mm)	Errors (mm)
1.	G00 Y300	300	300	0
2.	G00 Y200	199	199	1
3.	G00 Y150	149	149	1
4.	G00 Y130	129	129	1
5.	G00 Y100	99	99	1

TABLE IV
Z-AXIS MOVEMENT RESULTS

No.	Input Kode	Initial Distance (mm)	Measured Distance (mm)	Errors (mm)
1.	G00 Z25	24	24	1
2.	G00 Z20	20	20	0
3.	G00 Z15	15	15	0
4.	G00 Z10	10	10	0
5.	G00 Z5	5	5	0

Accuracy testing was carried out by inputting commands from a computer and comparing the movement dimensions between the input code and the actual motion. The input used was G-Code with the G00 command, which moves the axis linearly. This test aimed to determine the device's precision. A travel resolution of 400 steps/mm was applied.

Based on Tables II, III, and IV, the average difference between the input and actual movement on the X, Y, and Z axes was 0.7 mm. This discrepancy may be attributed to measurement accuracy, as the measurements were taken with a standard ruler with 1 mm precision. This small difference indicates high device precision. This is supported by the motor's step angle of 1.8° and a microstep driver resolution of 16, resulting in an effective step angle of 0.1125°.

E. Quality of Melted Wax from Electric Canting

The wax melting quality test aimed to determine the optimal temperature for use during the plotting process. The test was conducted using an electric canting tool whose temperature could be adjusted via a built-in probe.

TABLE V
MELTED WAX QUALITY

Temperature	Results	Images
40 - 50°C	Not Melted	-
55 - 60°C	Melted	
70°C	Melted	
>80°C	Melted	

Test results showed that wax began to melt effectively at temperatures between 55°C and 60°C. At temperatures below 50°C—particularly in the 40–50°C range—the wax did not show significant signs of melting. This indicates that these temperatures are still below the minimum melting point of the wax used in this study.

When the temperature increased to the 55–60°C range, the wax began to melt steadily, indicating that this range is the threshold melting point of the wax material. Melting continued at 70°C and even above 80°C, but temperatures above 80°C posed a risk of overheating, potentially causing the wax to become too fluid, disrupting the flow during canting.

It can be concluded that the optimal temperature for wax melting in this process is within the 55–70°C range. At this range, the wax melts properly and maintains suitable viscosity for use with an electric canting tool. Proper temperature regulation is crucial to ensure consistent wax flow while creating batik patterns using the CNC machine with the electric canting tool.

Figure 10. Batik Pattern Plotting Results with Temperatures Between 55-70°C

Figure 10 shows the canting test results, which demonstrate that the 55–70°C temperature range yields the best performance in terms of batik pattern quality. At this range, the wax melts stably and flows smoothly through the canting tip without clogging or excessive flow. The consistent flow forms neat, smooth lines that match the design. The batik patterns produced at this temperature range exhibited sharp and contrasting colors, as the wax was able to penetrate the fabric surface effectively. Thus, the 55–70°C range is optimal for the canting process using an electric canting tool.

F. Fabric Dyeing Results

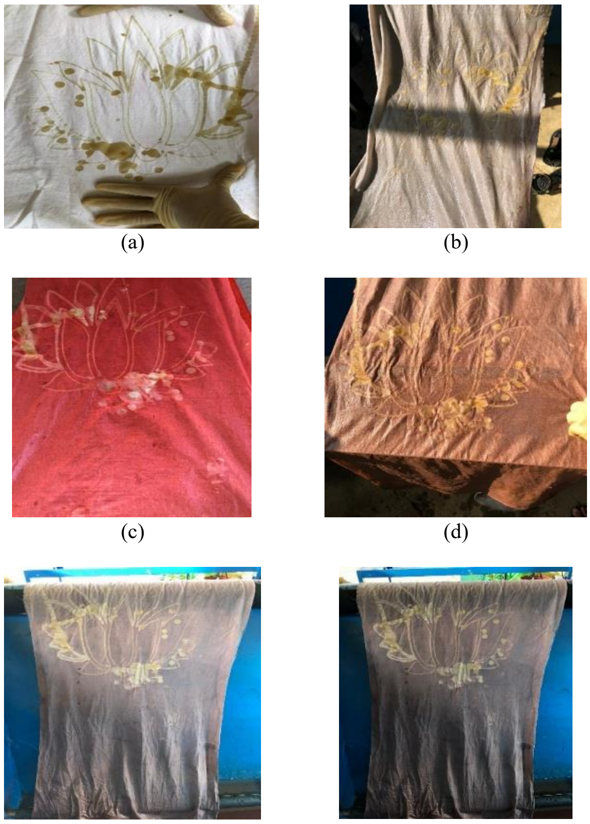
The color quality test aimed to determine the actual color achieved during the dyeing process. The test used four different materials for optimal results. The dip-dyeing process in this study employed a dye solution based on diazonium salts combined with detergent as a penetration agent. Dyeing was performed in stages using repeated immersion to achieve the desired color intensity.

Observations showed significant color gradation changes over time. In the first 10-minute dip, the fabric showed no significant color change, displaying only a whitish hue with a slight yellow tint. This suggests that the dye solution had not fully penetrated the fabric fibers or that the chemical reaction between the diazonium compound and the fibers required more time.

After 20 minutes, a silver tone began to appear, developing into red at the 30-minute mark. By 40 minutes, the color deepened into brown. This indicated progressive absorption and reaction between the dye and the fibers. At the 50-minute mark, the fabric turned light blue, and by the sixth dip at 60 minutes, a deep blue color was achieved. This demonstrates that the dip-dyeing process using these materials requires approximately one hour and six cycles to attain maximum color depth. The results also indicate that coloration does not occur instantly but requires time and layering for stable and even coloration.

G. Bit Error Rate (BER) PC 1 to PC 2

This test was conducted to measure the Bit Error Rate (BER) in a wireless connection network. It involved three distance-based tests: 10 meters, 50 meters, and 100 meters as shown at Table VI. At a distance of 10 meters, the BER value was 0, indicating no bit transmission errors and demonstrating that the 433 MHz RF module maintained excellent and stable communication over short distances.



(a) (b) (c) (d) (e) (f)

Figure 11. Batik Fabric Color Quality: (a) 10 Minutes (b) 20 Minutes (c) 30 Minutes (d) 40 Minutes (e) 50 Minutes (f) 60 minutes

At 50 meters, the BER increased to 1.449×10^{-3}, meaning about 1.4 bits were incorrectly transmitted per 1000 bits. This value is still within the acceptable range for plotter control applications. At 100 meters, the BER increased to 6.666×10^{-3}, indicating signal quality degradation over longer distances. This increase in bit errors may result from signal attenuation, environmental interference, or the RF module's limited transmission power.

TABLE VI
BIT ERROR RATE (BER) PC 1 TO PC 2

No.	Distance (m)	Bit Error Rate
1	10	0
2	50	$1449x10^{-5}$
3	100	$6666x10^{-5}$

The 433 MHz RF communication is still feasible for machine control within a 50-meter range with tolerable error rates. However, for distances beyond 50 meters, signal boosters, external antennas, or more reliable communication

systems are recommended to ensure stable and accurate communication.

IV. CONCLUSIONS

The design of the plotting system using a microcontroller was successfully implemented using an Arduino Uno and G-Code files to generate X, Y, and Z steps for stepper motor control, enabling the plotting process. The integrated batik dyeing system works by pulling the plotted fabric using rollers. Data communication between the PC and the plotter machine via the 433 MHz telemetry module can be carried out at distances of up to 100 meters.

REFERENCES

[1] L. Maulana Hakim, "Batik Sebagai Warisan Budaya Bangsa dan Nation Brand Indonesia," *Nation State J. Int. Stud.*, vol. 1, no. 1, pp. 60–89, 2018.

[2] M. Waty, "Airbrush Karawo Batik Design," *J. Soc. Sci. Stud.*, vol. 6, no. 1, p. 128, 2019.

[3] M. Ahda and D. A. Perwitasari, "Evaluasi Kesehatan Pembatik Dan Pengetahuan Tentang Efek Berbahaya Pewarna Batik Di Kampung Batik Giriloyo," *Semin. Nas. Has. Pengabdi. Kpd. Masy. Univ. Ahmad Dahlan*, pp. 219–223, 2018.

[4] A. Haerudin and V. Atika, "Komposisi Lilin Batik (Malam) Biron untuk Batik Warna Alam pada Kain Katun dan Sutera," pp. 1–23, 2016.

[5] A. Fauzan, H. Soegiharto, A. T. Prasetyawan, and A. I. Zain, "Perancangan Mesin Plotter Batik Berbasis Computer Numerical Control (Cnc)," *Semin. Nas. Teknol. dan Rekayasa*, pp. 139–151, 2019.

[6] I. Hermawan and A. Suwondo, "Making of Stamped Batik by Machined Batik Stamp Pattern Made from Hand Made Design Batik Image," *Int. J. Innov. Res. Adv. Eng.*, vol. 3, no. 03, pp. 2014–2017, 2016.

[7] J. P. Rogelio, "Development of an Automatic Tool Changer (ATC) System for the 3-Axis Computer Numerically- Controlled (CNC) Router Machine," *7th IEEE Int. Conf. Humanoid, Nanotechnology, Inf. Technol. Commun. Control. Environ. Manag.*, no. November, 2014.

[8] Kadriadi, A. B. Pratama, H. L. Wijayanto, K. W. Wirakusuma, and Amiruddin, "Modifikasi Struktur Rangka Dan Bahan Computer Numerically Controlled (Cnc) Router Mini 3 Axis," *SINERGI POLMED J. Ilm. Tek. Mesin*, vol. 4, no. 2, pp. 79–86, 2023.

[9] Arduino, "Arduino UNO Datasheet," 2023.

[10] Y. M. Hasan, L. F. Shakir, and H. H. Naji, "Implementation and Manufacturing of a 3-Axes Plotter Machine by Arduino and CNC Shield," in *2018 International Conference on Engineering Technology and their Applications (IICETA)*, 2018, pp. 25–29. doi: 10.1109/IICETA.2018.8458071.

[11] I. Ibrahim, W. Wahyudi, and E. Handoyo, "Perancangan Telecontrolling Dan Telemetering Pada Ground Control Station Untuk Purwarupa Autonomous Surface Vehicle," *Transient J. Ilm. Tek. Elektro*, vol. 9, no. 4, pp. 581–588, 2020, doi: 10.14710/transient.v9i4.581-588.

[12] J. Ctibor and I. Pazdera, "The New Stepper Driver for Low-Cost Arduino Based 3D Printer with Dynamic Stepper Control," in *Mechatronics 2017*, T. B\vrezina and R. Jabłoński, Eds., Cham: Springer International Publishing, 2018, pp. 458–466.

[13] A. Mujadin and D. Astharini, "Uji Kinerja Modul Pelatihan Motor Penunjang Mata Kuliah Mekatronika," *J. Al-AZHAR Indones. SERI SAINS DAN Teknol.*, vol. 3, no. 3, p. 127, 2017, doi: 10.36722/sst.v3i3.217.

[14] Y. Saputro and D. Y. Saksono, "Pengembangan Desain Alat Pemotongan Kripik Singkong Dalam Peningkatan Produksi (Studi Kasus Pada UMKM di Pemalang)," *Accurate J. Mech. Eng. Sci.*, vol. 2, no. 2, pp. 1–4, 2022, doi: 10.35970/accurate.v2i2.854.

[15] M. Z. Arifin, E. Utami, and E. Pramono, "Perancangan Sistem Deteksi Dini Bencana Banjir Menggunakan Teknik Pengiriman DTMF Berbasis Modul RF 433 Mhz Dan Arduino," *J. Teknol. Inf. dan Komun.*, vol. 8, no. 2, pp. 1–5, 2020.

[16] Mustafa, L. D., Susilo, H., & Perdana, R. H. Y. (2020). Detection of Salak Chips readiness on vacuum frying machines based on vacuum pipe temperature and frying time. *IOP Conference Series: Materials Science and Engineering*, *732*(1).

[17] Hariyadi, A., Taufik, M., Hudiono, H., Hidayati, N., Rakhmania, A. E., & Perdana, R. H. Y. (2021). Efisiensi Daya Perangkat Wireless Sensor Network Pada Penerangan Jalan Umum (PJU) Berbasis Algoritma Leach. *Techné: Jurnal Ilmiah Elektroteknika*, *20*(2), 101–112.

[18] Hudiono, Taufik, M., Perdana, R. H. Y., & Rakhmania, A. E. (2021). Digital centralized water meter using 433 mhz lora. *Bulletin of Electrical Engineering and Informatics*, *10*(4), 2062–2071.

[19] Hudiono, H., Taufik, M., Perdana, R. H. Y., & Rakhmania, A. E. (2021). Telemetering of Rainfall Measurement Results Using 433 MHz Wireless Transmission. *Jurnal Infotel*, *13*(3), 143–150.