Design of the mBatik, textile hot wax applicator to emulate hand drawn batik using CNC plotter machine and characterization of wax plotting parameters

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Abstract. Hand drawn textiles wax dyeing process (batik tulis) has been known as the cultural heritage of Indonesia. Batik is the process of pattern coloring on fabric using selective wax coating as barrier to dyes. The encouragement of industrial revolution 4.0 concurrently with efforts to preserve Indonesian cultural heritage has motivated this research to design the mBatik, a hand drawn batik machine, a touch of advanced technology for Indonesian batik tulis traditions. The mBatik consists of a CNC plotter sub-system and a textile hot wax applicator sub-system as an automatic canting. The development of machine design and virtual prototype testing was done using the Inventor application. Continued by fabricating the 3D model components of the mBatik machine using a 3D printer and manual assembly of the mBatik machine. The characterization of the waxing process on the fabric was explored using this machine. The characterization concluded that the thickness of the wax line($Y$) was significantly affected by the heating power($X_1$) and wax filling volumes($X_2$) with the linear regression function of $Y = -0.07007 + 0.01637 X_1 + 0.00805 X_2$ and the R square value of 0.9526.

1. Introduction

Indonesian hand drawn batik (batik tulis) is recognized as a cultural heritage by the UNESCO[1]. Batik dyeing process is done by dye wax resist technique. The pattern of lines and dots of batik tulis are drawn with hot wax until the wax is adhered to the fabric using a device called canting [2][3]. The wax pattern on the fabric prevents the adhesion of the dye from staining the fabric. The last stage of the batik process is to shed the wax to expose the fabric fibers that were previously covered by wax[4]. Batik cloth has a distinctive characteristic, fibers are flatter due to the wax decay process and the surface tends to be rough due to the remaining wax[2]. Meanwhile, from the customer's side, they wants batik cloth with
characteristics: high quality coloring, smooth texture and comfortable to use, neat and attractive batik patterns[5].

2. The problem from the prior arts

Several researchers from Indonesia have participated in the development of the batik industry in Indonesia with various approaches, improving the quality of Indonesian batik, strengthening the economy of the batik peoples, improving health and safety in this industry. Wibowo[6], Suroso[7], Asmal[8] together with Wibisono and Sudiarso[6][7][8] have developed CNC based machines to produce stamped batik including the development of batik programing software. Ikawanty et.al.[9] and Antana[10], have designed electric canting to facilitate the process of depicting wax of batik and produce consistent batik waxing quality. Lestariningsih et.al.[3] improve the design of the electric canting using the QFD method. While Setyorini[11] examined the implementation of electric canting with a study of batik production management in the city of Malang.

The health and work safety issues are also experienced by batik industry workers[12][13]. Sari et.al.[12] found a firm correlation between exposure of wax vapor when drawing batik wax patterns with clinical lungs abnormalities such as asthma and bronchitis. Whereas Anjani et.al.[13] found musculoskeletal disorder due to work posture when drawing batik patterns. These findings encourage this research to design the mBatik machine to reduce occupational health and safety risks experienced by batik workers.

3. The objective of research and the state of the art

This research aims to engineer mBatik, a CNC plotter based batik machine equipped with a textile hot wax applicator as a substitute for canting with design requirements: able to carve hot wax on the fabric surface to cover the fabric fibers selectively according to the desired pattern, easy to program instructions for depicting waxing patterns, having minimal footprint area. Unlike the previously electric canting research, this work design not only the automatic wax carving tools[9][10], but designed the entire batik plotters machine as a whole. Not the same as previous research on cnc batik machines using stamped batik[6][7], this research designs a hand drawn batik emulator machine. The process of batik waxing in this machine resembles the process of hand drawn batik, carve after carve of batik wax on fabric. Unlike the horizontal batik machine[6][7][8] which needs a large area, this machine uses a little footprints with a vertical fabric layout. Unlike the batik printing machine[14] which is actually a screen printing process not a batik pattern waxing process, this machine actually does the batik fabric waxing process.
Figure 1. (a). Design of textile hot wax applicator as known as automatic canting. (b) The hot wax drawn on the fabric as the result of hot wax applicator.

4. The design of batik tulis machine and setup of characterization

The mBatik machine consists of two sub-assembly, textile hot wax applicator and textile cnc plotter. Characterization of hot wax plotting is done on a white cotton fabric that is mounted vertically on the board of the mBatik machine. The design of mBatik machines begins with a study of the standard dimensions of CNC machine components. The machine construction design and development of machine components is done by 3D modeling and virtual prototyping using the Inventor application. After the mBatik construction design prototype has been tested, it is continued with fabricating machine components using a 3D printing machine with PLA plastic material. The finished 3D printed components are assembled along with standard CNC machine components. Among them are stepper motors and drivers, linear guides, link belts and pulleys, electrical controls and power supplies.
Figure 2. The mBatik, batik tulis CNC plotter machine.

4.1. Design of textile hot wax applicator

Hot wax applicator or canting has design requirements: able to contain and melt batik wax with adjustable heating power, has a nozzle that is able to flow out hot wax when drawing on fabric and stop the flow of hot wax when not drawing. Canting batik is made of aluminum tube with a diameter of 21mm and a depth of 78mm with two 40 watts electric heaters. Detail of canting along with vertical slider of mBatik machine can be seen in the picture 1.a.

4.2. Design of textile CNC plotter

CNC plotter design requirements are: can be operated using a computer or laptop, using a minimal footprint, using standard CNC machine components as much as possible. The final result of the mBatik design can be seen in the picture 2. This machine consists of the X-axis and Y-axis sliders, each using a stepper motor drive.

4.3. Setup of wax plotting characterization

The emulation of the batik tulis process is carried out by the mBatik machine in drawing stylized batik machete patterns as in the picture 1.b. Depictions of wax patterns are done through the g-code command via the computer. The consistency of the wax pattern on the batik fabric was investigated for the effect of the heating power and the wax filling volume of the canting. Canting heating power is regulated through the wiring of a heating cable with a configuration of double serial heater, single heater and double parallel heater.

5. The method of characterization and discussion of experiment results

The independent variable of this research is the heating power with three levels of 20Watts, 40Watts, 80Watts, and canting wax filling volume with three levels of 22.8cc, 45.6cc, 68.4cc. The full factorial combination of the two variables with each of the three levels resulted in 9 different treatments. Each treatment is done with 15 repetitions. The dependent variable responses observed were wax line thickness and wax line consistency. Characteristics of wax line thickness are measured by the average of wax line width and wax line consistency is measured by the standard deviation of wax line width. A summary of the observations is tabulated in table 1 and depicted in graphs figure 3.

Table 1. Summary of mean and standard deviation of wax lines width as function of heating power and wax filling volume.

| width of wax lines (mm) | wax filling volume |
|------------------------|--------------------|
|                        | 22.8 ml | 45.6 ml | 68.4 ml |
|                        | mean    | std     | mean    | std     | mean    | std     |
| heating power          |         |         |         |         |         |         |
| 20 Watts               | 0.5187  | 0.0148  | 0.6773  | 0.0176  | 0.7480  | 0.0225  |
| 40 Watts               | 0.7600  | 0.0107  | 0.9987  | 0.0120  | 0.9907  | 0.0152  |
| 80 Watts               | 1.3293  | 0.0122  | 1.5533  | 0.0129  | 1.9707  | 0.0152  |
The characterization results give a linear regression function of $Y = -0.07007 + 0.01637X_1 + 0.00805X_2$ whereas $Y$ is the thickness of the line, $X_1$ is the heating power, $X_2$ is the wax filling volume. From the regression equation it is concluded that the thickness of the line is affected by the heating power with a multiplier factor of 0.01637 and affected by the wax filling volume with a multiplier factor of 0.00805. Visually, the effect of heating power and wax filling volume can be seen in Figure 3.a. The combination of low heating power and small wax filling volume produced a fine thin line, and vice versa. But low heating power does not provide good line consistency. Good line consistency is achieved at high heating power and low wax filling volume.

### Table 2. Summary of heating power grouping (a) and wax filling volume grouping (b) based on Tukey Method.

| Heating Power | N  | Mean | Grouping |
|---------------|----|------|----------|
| 80 Watts      | 9  | 1.6178 | A        |
| Wax Filling Volume | N  | Mean | Grouping |
| 68.4 ml       | 9  | 1.2364 | A        |

#### 6. Conclusion and future work

The characterization results concluding the thickness of the wax line was significantly affected by heating power and wax filling volume. This conclusion was also confirmed by the Tukey method testing (table 2) which grouped the three treatment groups of heating power and wax filling volume into three groups significantly. Further research can be attempt to adjust the desired line thickness by heating power modulation according to the regression equation in this study. Variables that need further investigation are the effect of heating temperature on the wax line consistency and the hot wax ability to adhere to fabric fibres.
Table 3. Summary of heating power and wax filling volume grouping based on Tukey Method.

| Heating Power | Wax Filling Volume | N  | Mean   | Grouping |
|---------------|--------------------|----|--------|----------|
| 80 Watts      | 68.4 ml            | 3  | 1.9707 | A        |
| 80 Watts      | 45.6 ml            | 3  | 1.5533 | B        |
| 80 Watts      | 22.8 ml            | 3  | 1.3293 | C        |
| 40 Watts      | 45.6 ml            | 3  | 0.9987 | D        |
| 40 Watts      | 68.4 ml            | 3  | 0.9907 | D        |
| 40 Watts      | 22.8 ml            | 3  | 0.7600 | E        |
| 20 Watts      | 68.4 ml            | 3  | 0.7480 | E        |
| 20 Watts      | 45.6 ml            | 3  | 0.6773 | F        |
| 20 Watts      | 22.8 ml            | 3  | 0.5187 | G        |

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