The Development of CNC Hot Wire 3D Cutting Foam Tool

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***Abstract*— Wedding decorations are considered incomplete without decoration. The decoration business must prepare a skilled and creative workforce and improve the artistic creation skills of employees to provide several choices of decorating styles to clients. The material that was recently used in decorations is styrofoam. The purpose of this research is to design a CNC machine to get good results and neatly cut Styrofoam using a hot wire. This research also contributes to solving problems with Styrofoam cutting usually a problem with detailed and complicated work that can be solved automatically using a CNC machine. Tool hardware design requires Bluetooth connection, driver to the stepper motor, driver A4988 to CNC shield, and step down to the heating wire. Software design includes uploading GRBL firmware, creating G-code using Inkscape Software, and connecting Android applications to CNC machines. The result shows that for 2-dimensional styrofoam cutting with 1cm thickness, the best results are obtained in the range voltage of 7.4-8.5V. Styrofoam also testing is carried out using the same voltage 8.5V but with different feed rates and the result with 400 mm/min shows the best cut performance. The results of cutting 3-dimensional Styrofoam showed that for a voltage of 8.5V, a feed rate of 300mm/min, and a thickness of 10cm Styrofoam produced the best cutting texture from others. This shows that the heat generated by the wire is directly proportional to the feed rate.**

Keywords*— *Arduino Uno, CNC, Cutting Foam, Hotwire, G-code.

I. INTRODUCTION

Wedding decorations are considered incomplete without decoration. Apart from aesthetic reasons, such as decoration making the venue more pleasing to the eye, making the event livelier, and making photo documentation more beautiful. The decoration is also sometimes a matter of image and it causes people to be willing to spend very deeply on the cost of this decoration.

The wedding decoration business must prepare a skilled and creative workforce and continuously improve the artistic creation skills of employees and decorators to provide clients with several choices of decorating styles. For example, bringing up decorations from cork or styrofoam is indeed popular, even though many people are looking for it in various digital media. Now styrofoam can be formed easily so that decorations can be made as desired, including for the aisle.

For beginners, it may be difficult to cut Styrofoam. It looks simply, but it takes a careful technique in cutting Styrofoam. In addition to cutting styrofoam, there are several tools that you can use. To get good and neat results, you can cut Styrofoam using a hot wire. The working system of this tool is to melt Styrofoam with a heated wire to produce a smooth cutting edge. Detailed and complex work can be done automatically using CNC easily and in large quantities and with exactly t results efficiently and widely used in different categories [1]–[6]

A CNC Hot Wire Cutting Foam machine is used to cut and form a 3D foam with a predetermined shape without the need for hard tools and lasers[7]. The type of cutting used in the machine is called Hot Wire, or a special type of cutting wire (Nickel-Chromium Wire), The wire will be hot when an electric current is applied (I). Nickel-Chromium wire evaporates and melts the foam when an electric current passes through it, so users can easily get any shape they want and are more cost-effective.

The proposed system that we used to cut styrofoam is by using a CNC machine that is rarely used in decoration. The most common literature is using CNC machine to make a PCB layout, laser engraving, a 3D print, and many other applications. The problem that is usually found in decoration by manual hot wire is human error that causes the decoration isn't neatly perfect and hard to reach certain corners. To solve the problem, this research aims to design a CNC machine to get good results and neatly cut Styrofoam using a hot wire.

II. METHOD

The method used in tool testing is used to obtain data on the results of system work and find out how the tool can work. Tool testing is done by creating a G-code format file on a PC and then transferring it to Android, the existing G-code on Android, and then inputting it into the GRBL Controller application [8]. When it works, the CNC will work according to the image code.

The method used in system design begins with the design stage which is continued with the manufacture of the system until it is completed according to the plans made. System design begins with the stage of collecting equipment such as mini-PCs and monitors, and then installing the Arduino board

and the CNC Shield port, for communication through the CNC we need to install the HC-05 port and set up Bluetooth. [9]–[11]. Search for sources of information in the form of books or journals in which related to Arduino and CNC Shield microcontrollers and their applications, then references from the internet in the form of explanatory videos related to materials such as CNC cutting styrofoam, Bluetooth settings related to the system to be worked on.

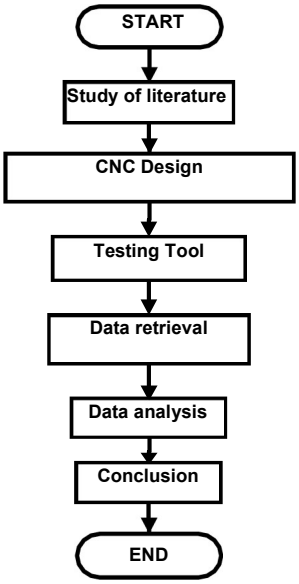

Figure 1. Research flow study

Figure 1 shows the research flow chart starting from the literature study, design, tool testing, data analysis, and the conclusion of the research. Literature sources can be in the form of a final project, thesis, and journal. Data obtained could be in the form of results reading tool measuring nor data from source literacy next processed to analyze and get a conclusion.

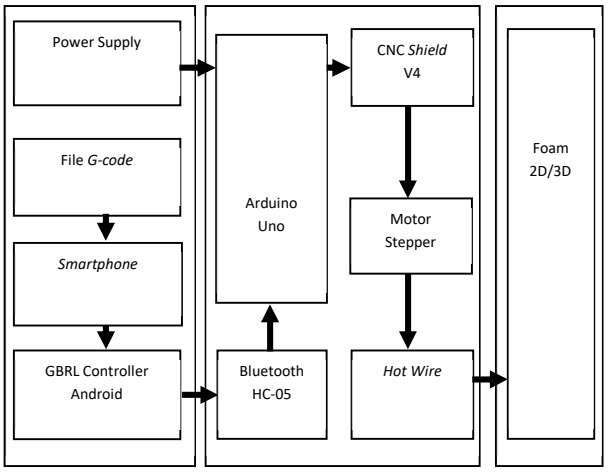

Figure 2. Block diagram

The design stages of CNC Hot Wire Cutting Foam start from the design of the block diagram as shown in Figure 2. The system used by Arduino Uno as the process is to control the stepper motor and Bluetooth connection [12], [13]. In designing a 3-axis CNC machine control system, several processes are shown in Figure 3. Arduino Uno and CNC Shield are turned on with a power supply, then to the input section the G-code file is transferred to Android, then with the help of the Android Controller GRBL application it can transfer it to Arduino via Bluetooth, after that Arduino processes commands and then transmits commands to CNC Shield, The CNC Shield shares these commands with the installed motor drivers.

The G-code file is transferred to Android, and with the help of the Android Controller GRBL application, it can transfer to Arduino via Bluetooth [14], [15]. After that Arduino processes the command and then transmits the command to the CNC Shield, the CNC Shield divides the command to the installed motor driver, Then the driver runs and controls the stepper motor with a limit switch as a movement limiter [16], [17]

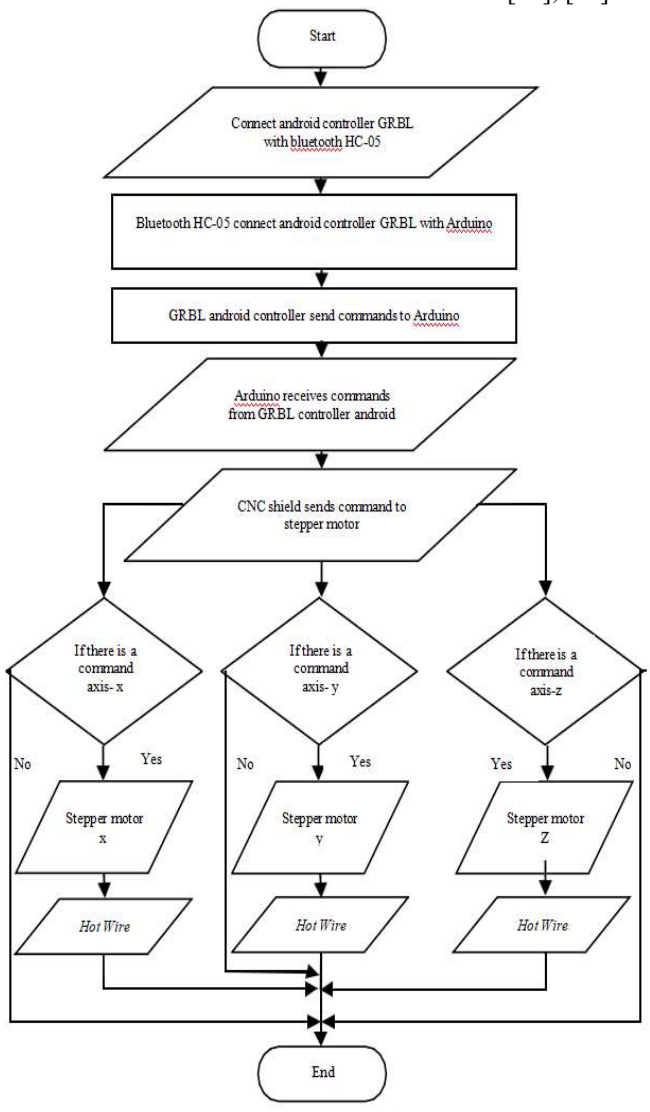

Figure 3. Flowchart

Process study inside it has several components and materials used. The material used is styrofoam and the main components used in this study include step-down XL4016, Hotwire, Driver A4988, Stepper motor, Arduino, and Power supply 12V 10A. An isometric view of the mechanical design of a hot wire CNC machine is shown in Figure 4.

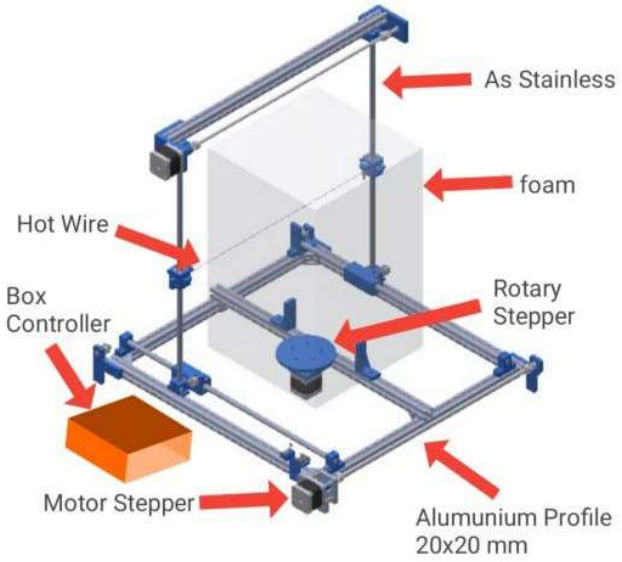

Figure 4. Isometric view mechanical design

III. RESULTS AND DISCUSSION

3.1 Hot Wire Cutting Testing with Different Thickness

Based on the CNC design above, we need to calculate and test the CNC Hot Wire Cutting Foam to determine the performance of the tool and analyze which factor that determines CNC operation.

TABLE I
THICKNESS STYROFOAM CUTTING TEST

No	Voltage (V)	Thickness Object (cm)	Results
1	7.4V	1cm	
2	7.4V	2cm	
3	7.4V	3cm	
4	7.4V	4cm	

Table I shows the styrofoam cutting result from several styrofoam thicknesses. The cutting test uses the same tension for 4 Styrofoam sheets with a thickness of 1cm, 2cm, 3cm, and 4cm. The cutting is smooth and the tolerance width of the hot wire is not too wide < 5mm. From the results obtained, the voltage of 7.4V is best used for cutting styrofoam with a thickness of 1-2cm only, while cutting styrofoam size >3cm requires a voltage above 7.5V, this aims to make the heating wire move balanced with the stepper motor so that the cutting results obtained precision.

3.2 Effect of Feedrate on Styrofoam Cutting Results

Stepper motor speed testing aims to determine the best feed rate for cutting styrofoam. The hot wire moves following the

stepper motor, so the speed is directly proportional to the hot wire motion. The feed rate setting is on the speed button in the controller application, the speed feature can be seen in Figure 6.

Figure 6. The Feedrate Feature on the Controller Application

The feed rate that can be achieved using the controller application is 400mm/min or 200% of the default feed rate. The results of the trial cuts using feed rates of 100%, 150%, and 200% can be seen in Table II. It shows that the feed rate for an object with a thickness of 10 cm is suitable by using 400 mm/min because the wire is hot and it needs a fast cutting to get a neatly perfect cut.

TABLE II
EFFECT OF FEEDRATE ON 3D STYROFOAM

No	Voltage (V)	Feed Rate	Thickness Object (cm)	Results
1.	8,5V	200 mm/ min (100 %)	10cm	
2.	8,5V	300 mm/ min (150 %)	10cm	
3.	8,5V	400 mm/ min (200 %)	10cm	

3.3 Current and Voltage Analysis on Hot Wire

Based on the wire material used is Nickel in wire with a resistance of 4 /m, a wire length of 33 cm, and a wire diameter of 0.5 mm, so the cross-sectional area with the formula (1) for the area of a circle:

$$A = \pi r^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$
$$A = 3{,}14 \times (0{,}25)^2$$
$$A = 0{,}1965\ mm^2$$

Based on the wire material used is Nickel in wire with a resistance of 4 /m, a wire length of 33 cm, and a wire diameter of 0.5 mm, so the cross-sectional area with the formula for the area of a circle by using the formula (2) below:

$$R = \rho \frac{L}{A} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$
$$R = 4 \frac{0{,}33}{0{,}19625}$$
$$R = 6{,}72\ \boldsymbol{\Omega}$$

TABLE III
MEASUREMENT OF CURRENT, RESISTANCE, AND POWER ON 3D CNC

No	Voltage (V)	ρ (Ω/m)	R (Ω)	I (A)	P (watt)
1	6.5	4	0.91	5,915	5,38
2	7.4	4	1.04	7,696	8
3	8.5	4	1.21	10,285	12,44
4	9	4	1.3	11.7	15,21
5	9.5	4	1.44	13.68	19,69
6	10	4	1.57	15.7	24,64
7	11.4	4	1.83	20,862	38,17

Based on Table III, there is some electrical test of a CNC machine hot wire 3D cutting foam tool by increasing the voltage but the hot wire is the same using nickel wire. It shows that CNC hot wire power is proportional to the increase in voltage and current.

IV. CONCLUSION

Styrofoam cutting tools make it easy to work on detailed cutting designs for wedding decorations. The use of 0.5mm nickel wire with a resistance of 4Ω is enough to cut Styrofoam. Based on the result, it can be seen that resistance is inversely proportional to the current flowing. The longer the conductor, the greater the resistance. For 2-dimensional styrofoam cutting with 1cm thickness, the best results are obtained in the range voltage of 7.4-8.5V. Styrofoam also testing is carried out using the same voltage 8.5V but with different feed rates and the result with 400 mm/min shows the best cut performance. The results of cutting 3-dimensional Styrofoam showed that for a voltage of 8.5V, a feed rate of 300mm/min, and a thickness of 10cm Styrofoam produced the best cutting texture from others. This shows that the heat generated by the wire is directly proportional to the feed rate.

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