Design and development wire cutter CNC for Styrofoam product

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Abstract. Cutting Styrofoam manually will result in inaccurate cutting and dissimilar shape. To upgrade the quality of the product, a Styrofoam cutting machine which can cut automatically is needed. Thus, the aim of this research is to create a Styrofoam cutting machine using CNC 2 Axis Wire Cutter which can cut the material according to the CAD drawing module, and accelerate the cutting process. The control system of the machine uses the Arduino UNO microcontroller. The cutting process is performed by sending G-Code file to the microcontroller through the Universal G-Code Sender software. Afterwards, the microcontroller sends a signal to activate the stepper motor, and it is generated actuator movement according to the drawing in G-code file. The optimal Styrofoam cutting resulted by using CNC Wire Cutter with 0.2 mm nickel wire, 220oC, and 2 cm thickness.

1. Introduction
The development of the industry is growing continuously. As an example, making decoration from Styrofoam Decoration can be used in various things, placards, art work, making safety goods on shipping, and others. The use of CNC Wire Cutter in making decoration will shorten the time needed [1]. Currently many Styrofoam craftsmen in Indonesia use manual Styrofoam cutting tools, namely cutters and hot wire [2]. A good and planned manual cutting of Styrofoam involves a number of other activities as supporting activities such as measurements, sketches and others. To overcome the large number of product ordered in different shapes, it will be a problem as it requires concentration in sketches, measurements and cuts [3].

To solve this problem, CNC Wire Cutter is used as a substitute for cutting tools made of cutter blades, multiplex saws or similar tools which are inappropriate in terms of cutting results compared to CNC Wire Cutter tools.

The working principle of the Cutter CNC 2 axis Styrofoam cutter is by converting electrical energy into heat energy. This CNC Wire Cutter already uses numerical control using CNC programming, and the cutting precision is much faster. Wire Cutter CNC machine can cut as designed by CAD drawing modules that work automatically with G-code input from the computer.

2. Literature review
CNC stands for (Computer Numerically Controlled,) beginning in 1952. In general, CNC machine tools work similarly to the conventional machine tools. The function of CNC replaces the human work in conventional machine tools such as the work of setting tools or adjusting the chisel movement to the...
position ready to cut, the cutting motion and movement back to the initial position, and others. CNC operating system parameters can be changed through the appropriate software program [4].

2.1. CNC machines
There are several CNC machine that has already existed in the world (Figure 1). The 5 axis CNC machine works with 5 limbs, which are X, Y, Z axis for linear motion then axis A for horizontal rotating motion, and C axis works for vertical rotating motion. CNC Lathe has two-way movement (2 axis) with numerical control (CNC). CNC Plasma Cutting Machine The construction works on a CNC plasma plate cutting machine, and very similar to a 2.5 axis CNC engraving machine or a 3-dimensional scanner. The only difference is that this plasma machine uses gas (plasma) throwers, not chisels.

![CNC milling machine](image1.png)

**Figure 1.** CNC milling machine

2.2. Hot-wire cutting (manual)
This model adopts a layered object manufacturing technique (LOM) used for fast manufacturing. It is to build a Styrofoam model that can be used (about 30-100 mm) in a Styrofoam layer cut with a hot wire and brought closer to form the intended object, an electrically heated wire (Figure 2).

![Hot-wire cutting (manual)](image2.png)

**Figure 2.** Hot-wire cutting (manual)
In order to cut it more accurately, it requires a lot of skills and manpower to achieve the desired results. This research is an effort to build a system that serves the needs we want which is to be faster and more accurate [5].

3. Research methods
The flow of the research process that will be carried out can be seen in the following flowchart Figure 3.

![Research flowchart](image)

**Figure 3.** Research flowchart

3.1. Stages of research implementation
The results of the research are as follows:

a. Design and manufacture of chassis in CNC Wire Cutter (Figure 4).
b. Set up on a Wire Cutter NC using the program MakerCam, Arduino, G-Code and GRBL (Figure 5).
c. Test on CNC Wire Cutter.
d. Analyse and discuss research data, and make conclusions

Figure 4. Block Design Process Diagram

Figure 5. Wire CNC Cutter design

3.2. CNC wire cutting machine
The equipment used in CNC Wire Cutter research is as follows
a. Nickel wire
Nickel wire is used to heat elements in styles using Styrofoam. There are two kinds of nickel wire and nickel flattened / flattened. Nickel wire is used to distribute heat and has a melting
point of 1400 °C. The normal to cut Styrofoam is 200° - 300° C. There are several sizes of nickel wire; 0.2 mm, 0.3 mm, 0.5 mm, 0.6 mm.

b. Stepper motor
Stepper motor is an electromechanical device that cannot move on their own and must be connected to the Arduino Uno and CNC Shield. Their movements are per step according to their specifications, and moving from one step to the next requires time and produces large torque at low speeds. The stepper motor used in this study has 200 steps per motor rotation.

![Figure 6. Bipolar stepper](image1)

Figure 6. Bipolar stepper

c. CNC shield
CNC Shield is an intuition between Arduino UNO and stepper motors with the ability to move 4 stepper motors to drive 2 Axis (Figure 7).

![Figure 7. CNC shield](image2)

Figure 7. CNC shield

d. Arduino UNO
Arduino UNO as shown in Figure 8 has 14 digital inputs / outputs (6 can be used as PWM outputs), 6 analogue inputs, a 16MHz Crystal oscillator, a USB connection, a power jack, a label, and a reset button.
e. Testing cutting process
Tests to be carried out with the following sizes (Table 1).

| No | Dimension | h (mm) | T (°C ) | V (mm/minute) | Error |
|----|-----------|--------|---------|---------------|-------|
| 1  | Square    | 20     | 310     | 250           | 5.2   |
| 2  | Square    | 20     | 300     | 250           | 4.4   |
| 3  | Square    | 20     | 290     | 250           | 4     |
| 4  | Square    | 20     | 280     | 250           | 3.6   |
| 5  | Square    | 20     | 270     | 250           | 3.1   |
| 6  | Square    | 20     | 260     | 250           | 2.6   |
| 7  | Square    | 20     | 250     | 250           | 2     |
| 8  | Square    | 20     | 240     | 250           | 1.4   |
| 9  | Square    | 20     | 230     | 250           | 1     |
| 10 | Square    | 20     | 220     | 250           | 0.5   |

T: Temperature (°C); h: thickness (cm); V: speed (cm/s); E: error (mm)

f. Mechanism of moving CNC wire cutter
This test was carried out in order to find the right temperature to cut 2 cm thick Styrofoam. Styrofoam was cut using a timing belt to move the Axis driven by 4 stepper motors with 2 movements, X, Y, the movement had been programmed using the software MakerCAM, Arduino UNO, Xloader and GRBL.

g. Testing of the same shape
The optimal result of cutting rectangular shape of 2 cm thick Styrofoam was with a temperature of 220°C, cutting speed of 250 mm/min and cutting edge of 0.2 mm. Cutting results of 2 cm thick Styrofoam produce the smallest error value of 0.5 mm and the biggest error of 5.2 mm with a temperature of 310°C, and cutting speed of 250 mm/min.

h. Testing with different forms
This test was carried out to determine the ability of CNC Wire Cutter with different shapes, rectangles, hexagons, triangles and circles.
i. Square testing
Cutting Styrofoam using G-code (Figure 9). The G-code file was programmed into GRBL and visual results as seen in Fig. 9. In the visual image, a red dot shows the zero point of the G-code image, the blue track will move according to the path and the red line in the G-image X and Y is axis line code. After the visualization results are in accordance with the design in the MakerCAM software, the G-code file is sent to the microcontroller and the cutting process runs automatically.

![G-code file](image1)

**Figure 9. G-code file**

In this test, the 2 cm thick Styrofoam was cut with a temperature of 250oC, cutting speed of 250 mm / min and cutting edge of 0.2 mm. Cutting results show an error value of 0.5 mm and can be seen in Figure 10.

![Square](image2)

**Figure 10. Square**
j. Hexagonal testing
In this test, the 2 cm thick Styrofoam was cut with a temperature of 250°C, cutting speed of 250 mm / min and cutting edge of 0.2 mm. Cutting results show an error value of 0.5 mm and can be seen in Figure 11.

![Hexagonal](image11)

**Figure 11. Hexagonal**

k. Triangular testing
In this test, the 2 cm thick Styrofoam was cut with a temperature of 250°C, cutting speed of 250 mm / min and cutting edge of 0.2 mm. Cutting results show an error value of 0.5 mm and can be seen in Figure 12.

![Triangular](image12)

**Figure 12. Triangular**
4. Conclusion
Based on the results of this research, the following conclusions can be drawn:
1. The author has succeeded in designing and constructing a 2 Axis CNC Wire Cutter,
   Styrofoam cutting converts electric current into heat using nickel wire.
2. Cutting CNC Wire Cutter using software MakerCAM, G-code, Arduino UNO, GRBL works
   well.
3. CAD systems can use line, circle, arc entities to produce product geometry.
4. The optimal result cutting the same shape Styrofoam of 2 cm thick is using the temperature of
   220oC, and a speed of 250 mm / min. The biggest error is 5.2 mm with temperature of 310°C.

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