Development of Laser Beam Machining using Power Diode Laser for leather cutting application

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Abstract. Leather is a robust, durable and stretchy material created by tanning animal rawhide and skins. It is used to make variety of articles including footwear, bags, fashion accessories, furniture etc. The conventional method of cutting leather is a tiresome process. Laser diode technology offers advantages in cutting intricate geometries, stable cutting quality and potential to make the most use of leather product effectively. In this study, the machinability of leather using diode based laser beam machining and surface quality of the leather product have also been examined. The goal is to acquire the thermal effect caused by the laser at the cut contour edges. Buffalo leather has been taken as specimens in the present study. While cutting leather, it has been proposed that diode based Laser Beam Machining minimize carbonization layer more than traditional machining.

Keywords: Buffalo Leather, Diode laser, LBM, Carbonization

1 Introduction
Laser Beam Machining in leather cutting applications significantly involved in several sectors prior to the latest advanced technologies to increase the overall standard end product together with enhanced efficiency improvement. The greatest benefit of laser cutting is standardized quality. Laser cutting often holds production in top standard in a limited timeframe [1,6]. Commonly leather cut had been performed using knives and scissors. It’s not the most noticeable method used for the leather cutting [2]. The primary goal is to develop a diode laser beam machining prototype for leather cutting that would be controlled by pulse mode [3,8]. The limitation to laser cutting technique is the presence of carbonization in the laser cut edges. The diode laser is preferred over other types of laser for its tunability, adaptable and moveable nature. The benefit of using laser diode is due to its capability to eradicate disadvantages such as carbonization, power consumption and overcutting over other conventional laser cutting techniques [4,7]. In the present scenario CO₂ and Optical lasers revolutionize the various industrial environments. The focus of this study is to explore the possibilities for diode laser specially in the field of leather cutting [5].
2 Design and components of diode LBM

The CAD model of LBM setup using diode laser is shown in Figure 1. The setup is said to be gantry type because there are two support frames are placed opposite to each other and also connected by a perpendicular frame rod which enables the movement of the laser. This setup is capable of moving in the X and Y direction. The two degrees of movement is made possible by the presence of three stepper motors. In these two steppers motors are used for the Y-axis movement and one stepper motor is used for the X-axis movement.

![Figure 1. CAD Model](image)

The frames are connected to each other by means of brackets which are used to maintain the structural integrity of the entire setup.

2.1 Frame

The frame is the structure on which all the physical components such as the laser, motors, control board are attached in such a way that it forms a gantry type setup. The frame rods are made up of aluminium because of its lightweight, high tensile strength, flexibility, anti-rust properties and also available in abundance in nature which makes it economically viable. The laser is connected on the perpendicular frame rod and it is mounted with the help an aluminium base and tightened to ensure its adherence to the base. Two stepper motors are placed opposite to each other and each attached to its own acrylic plates in order to facilitate the belt drive mechanism which helps in the motion of the motors. At the end of each frame rod, the belts are tightened by means of the small acrylic plate, which is used to maintain the tension in the belt. All the nuts and bolts are also made of aluminum.

2.2 Electronic Components

The electronic components used for this LBM setup is listed in Table 1. Arduino microcontroller is used to control the stepper motor speed and direction. The Arduino is connected with the PC. This work consists of Arduino UNO with 14 digital pins and 6 analog pins. Arduino has 6 output pins, through which the input is given to PWM for controlling laser. The stepper motor driver is attached to the CNC shield along with the heat sink on it. The heat sink acts as a resistant to heat emitted during operations.
Table 1. List of electronic components

| Sl.No | Components          | Quantity |
|-------|---------------------|----------|
| 1     | Arduino             | 1        |
| 2     | CNC Shield          | 1        |
| 3     | Diode Laser         | 1        |
| 4     | TTL Driver          | 1        |
| 5     | Stepper Motor       | 3        |
| 6     | Waveform Generator  | 1        |
| 7     | Power Supply        | 2        |

The CNC shield circuit is entirely fixed on the Arduino therefore they are controlled by Arduino itself. The LBM setup used in the present work is Blue Laser of 5.5 Watt and 450nm Wavelength. Laser diode can cut a maximum depth of 2 mm. Laser diode is used because of its advantage of high quality cut at varying cutting speed. TTL driver is used to control the diode laser. The supply is given to waveform generator and the probes are connected to the TTL driver. The current and the voltage can be increased or decreased using the knobs in the TTL driver to control diode laser. Stepper motor is actuated by Arduino codes by predefining the pins of stepper motor connected to Arduino. Stepper motor is used because it is easily controlled and exactly rotates as defined. Stepper motor used in this work is NEMA 17. NEMA has 17 steppers 1.7 x 1.7-inch faceplate. The step angle is 1.8 degree. Therefore 200 steps are required to get one complete rotation. Stepper motor driver is used to control the stepper motor. The stepper motor driver gets initiated by the signals obtained from Arduino. The stepper motor driver sits on top of CNC shield. The CNC shield is mounted on top of Arduino. Therefore the signals from Arduino are sent to the stepper motor pins for the angle of turn and direction. The arbitrary Waveform Generator is used for the generation of square wave signals. This signal is given as a input to the TTL circuit. The Waveform Generator is used to set the input parameter values before each experiment is carried out. The Switch Mode Power Supply (SMPS) is connected to laser via TTL driver. The supply is of 12 volts from the source to TTL driver through which the laser is actuated by electrical means. The power supply is also connected to the Arduino which is a microcontroller requires power source.

3 Methodology

The block diagram of the laser diode based LBM setup is shown in Figure 2. The Power Supply Unit (PSU) is connected to controller and CNC shield. The PSU is also connected to PWM generator to generate square wave signal. PWM is used to provide input to the TTL driver to control power intensity. The X and Y axis is controlled by the actuation of the stepper motor. The CAD models are given as an input in dxf format, and then it is imported into the Arduino for the machining process.
The stepper motor pins are connected to the CNC shield which is mounted on top of the Arduino. The source is connected to the waveform generator and the probes of generator are given to TTL driver circuit. The PWM with various duty cycles generates different output values. The CAD software helps in creating complex geometries for machining.

3.1 Flowchart

The procedure of machining is the geometry that is to be machined in leather is drawn using CAD software. Then the CAD model is converted to G-Codes. The G-Code generator button generates G-Codes. The code is further converted into stepper motor signals and sent to Arduino for the axis movements. The Algorithm behind each process is explained as follows.

Flowchart Description

The CAD software is used to draw the required geometry for machining. The diagram is further converted into the G-Codes using the CAD software. Then the G-Codes are saved in NC script format. Now the general flowchart of G-codes to stepper motor signals is explained in the flowchart as shown in Figure 3.
Figure 3. Flowchart for G-Codes to Stepper Motor Signal

The description for the given flowchart is first the NC script first line is read and checks whether G code is detected or not. If yes then the suitable library is used. For example, say G03 is detected then it is known that clockwise circular interpolation has to be performed. Similarly the X coordinates is checked in the same line if yes then the corresponding values are noted for the movement of X axis. If X axis coordinates is not detected then the program proceeds for Y axis. The calculated values for each axes is listed below in Table 2.

Table 2. Step angle for each axis

| Axis | Distance | Step angle |
|------|----------|------------|
| X    | 1mm      | 10.08      |
| Y    | 1mm      | 18.18      |
Once the first line is finished and the signal is sent then the loop is moved again to initial step for reading the next line. The program is continued until the NC script lines are finished. For each step of lines the signals were sent to the stepper motor for the movement. The step angles for 1 mm are calculated for each stepper motor. According to the values of the NC script lines the stepper motor step angle is rotated for the each axis to reach the coordinates.

3.2 Control Parameters

The controlling parameters are the parameters used to compensate the error in the system and give the optimal results by adjusting each parameter. The control parameters is of two types mechanical control parameters and electrical control parameters. The mechanical parameters are the cutting speed and standoff distance[9]. The electrical parameters are duty cycle, amplitude and frequency.

4 Results and Discussion

The experiments were performed in a laser diode and CO₂ laser. The effect of carbonization layer with laser diode and CO₂ laser were observed as shown in Figure 4. The laser cut edges are to be analyzed with the help of USB digital microscope with 2 Megapixels quality. It comprises of 8 built-in LED lights whose brightness can be varied by means of the dial attached to the microscope. The microscope interfaces with the computer by means of a USB cable attached to it and also the lens offers magnification within the range from 50x to 500x.

Figure 4. Carbonization layer for CO₂ and diode laser

Leather cut quality investigation was carried out on sharp edges. Owing to the less power density the carbonization layer was reduced significantly in diode laser. The power density distribution is spontaneous and uncontrollable in case of CO₂ laser due to which heat affected zone is higher than diode laser.

Conclusion

In this study, the machinability of buffalo leather using diode based laser beam machining and CO₂ based LBM have been examined. From the investigation the following conclusions were made.

(a) Diode laser can produce less carbonization layer over CO₂ laser.
(b) Compared to CO₂ lasers, diode laser will reduce dross formation.
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