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Development of Portable 3-Axis Deployed Laser Cutting Machine

[1]Ravikumar S, [2]Chethan S, [3]Mohan Das A N, [4]Haseebuddin M R, [5]Hemaraju, [6] Mohammed Nadeem M

[1][2] ATME College of Engineering, Department of Mechanical Engineering, Mysuru, Karnataka, India
[3][4] Dayanand Sagar College of Engineering, Department of Mechanical Engineering, Bengaluru, Karnataka, India
[5]BGSIT-Adichunchanagiri University, Department of Mechanical Engineering, BG Nagara, Mandya Karnataka, India
[6] University of Bolton, Academic centre, Department of Mechanical Engineering, Ras Al khaimah-UAE

Abstract— In the present-day technology it is essential for laser machining equipment to be able to generate precise profiles on many materials at reasonable costs, with an easy-to-use interface. If such a device can be moved on-site and used right away, it will be most effective due to its portability. The present investigation focusses on design and development of a affordable, work bench, 3-Axis type, CNC regulated laser cutting machine, that is intended for precision machining of wood, acrylic, and other materials of a similar nature. The sheets of the raw materials are subjected to three-dimensional laser-cut profiles with the aid of the equipment. The machine has a working range of (410x320x60) mm.
The machine can accept programs directly in G- and M-codes, and a novel system has been created to regulate the "lasing" action of the laser diode using spindle controls. The performance analysis of the machine is done with a correlation between the information profiles and the contours created by the machine. This CNC laser cutting machine can be carried out in to create precise profiles for innovative work for applications and can also be used for rapid prototyping.

Index Terms— Arduino, CNC, Laser and low-cost machining.

1. INTRODUCTION

The present-day technology has given wide exposure related to machining and cutting operations with the aid of various sophisticated machines like Laser, Electron Beam, Plasma Arc etc. These machines have advantages of high accuracy, precise machining, higher speed of operations etc. However, there is limitation with respect to the size of the equipment. In order to overcome the voluminous effect of machines for small machining operations, the present investigation is focused to develop portable equipment with current sophisticated technology. Jamaleswara Kumar et.al has explored digital control technology which comprise of Engraving and cutting machines powered by Laser for different surface contingent by using various specifications of Laser diode. The author has identified has experimented with a fundamental goal is to design and fabricate Arduino CNC controlled laser cutting and engraving machine [1].

Alexander Stepanov et.al investigated the possibilities, benefits and challenges of use laser cutting in paper making machines for paper web edge trimming [2]. Practical aspects of laser cutting have been described in implementation and economic performance of such implementation. It has been identified that laser technology is more expensive at current state, mainly due to high initial cost of lasers. Rapid development of laser technology can bring the cost of laser cutting to similar level as water jet.

Miroslav Radovanovic et.al investigated that cutting plate is a difficult and time-consuming task, especially when the job calls for a tight tolerance or an unusual shape [3]. In those cases, advanced cutting processes such as laser cutting, abrasive water jet cutting and plasma cutting can be implemented. For advanced contour cutting processes of the greater importance is determining of cutting data, especially feed rate. One possibility to estimate of cutting data is using the cutting rate. In this paper is done an estimate of cutting data by laser cutting, abrasive water jet cutting and plasma cutting using the cutting rate.

Ow RC et.al published a Patent on Laser cutting system[4]. According to the experimentation the laser cutting device has a cavity designed to provide a controlled environment while the laser beam is used to cut metals to reduce or eliminate heat energy and changes brought about by oxygen is termed as mechanical characteristics of the metal. A separate configuration is set up to provide gas to the controlled environment with the cavity, as well as a means for consuming gas and cutting out debris from the cavity is also described. A moving tool is used to provide the flow of a shielding gas and also provide an alternative means for dispersing laser beam before it produces any damage to the work piece.

Cutting of sheet material by using Laser cutter improves when the sheet is bent into roll as per the experimentation from Horton N et.al [5]. A patent is published by the author on Computer- controlled laser cutter with optical sensor. The cutting device consists of a Laser, and then again, a collimator, mounted in a settled edge for conveying a static laser shaft that is focused onto the sheet material as it disregards a tubular roller. The cutting sample is controlled by an assistant head which mounts reflecting and focusing means and is flexible longitudinally parallel to the material support suggests for moving the inside motivation behind the column longitudinally of the material reinforce infers in synchronism with improvement of the material under the control of bi-directional material nourishment infers. In a favored alteration, an optical sensor is mounted on the helper head for seeing stamps on the sheet material, the yield of the optical sensor being sent to a control PC which has a yield mode and a cut mode. The yield technique for the PC is specialists to prompt the associate head and the bi- directional sustenance infers in synchronism while the laser is murdered, so that the optical sensor inspects the shape or sample on the sheet material. The delayed consequences of the yield are taken care of in the PC to construct, in the PC memory, a fancied cutting route composed to the shape or illustration on the sheet material; and the cut system for the PC is specialists to enact the helper head and the bi-directional nourishment suggests in synchronism while the laser is ordered, to cut the looked-for instance in the sheet material along the needed cutting way.

Conclusively based on the experimentations carried out by various investigators, the present experimentation focusses on design and development of Portable 3-Axis Cutting Machine powered by Laser for cutting paper and plastic materials.

2. MATERIALS AND COMPONENTS

A. Components deployed in Cutting Machine powered by Laser

The specification and type of components deployed plays a significant role in the working of portable 3-axis cutting machine powered by Laser. Portable 3-axis cutting machine powered by Laser comprises of components namely Laser diode, stepper motor, Arduino, Motor driver LC, DPDT relay switch, work platform and power supply for stepper motors. The functions of each of the components for effective working of Laser machine is provided as follows.

B. Laser Diode

The Laser Diode as shown in Fig. 1 plays vital role in the cutting machine. As the cutting machine powered by Laser is used to cut or engrave thin sections of cardboard or plastic material, A 10W Laser Diode is used to cut materials with thickness ranging from 0.03mm to 1mm and can engrave on materials with thickness ranging from 3mm to 5mm with depth of engrave maximum upto 1mm.

C. Stepper Motor

When it comes to a CNC machine, the heart and soul of the machine relies in the motor. The CNC routers speed, accuracy, and precision all rely on the size and type of the motor. Fig. 2 represents the Nema 17 stepper motor deployed in order to provide smooth and steady movement to the shaft with a maximum torque of 0.8Nm.

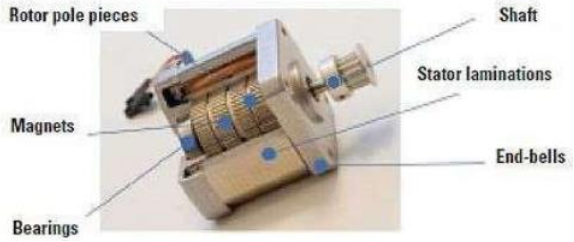

Fig 1: Laser Diode
Fig 2: Stepper Motor

D. Arduino

Fig. 3 depicts Arduino Uno Atmega 328f used for ease of programming using Arduino IDE due to its versatility. Atmega 328f Arduino Uno comprise of CPU of 8-bit 20MHz AVR with a flash memory of 32kB. 2kB SRAM with 1kB EEPROM is used for data storage purpose. Atmega 328f consists of about 28 pins with 16 capacitive touch channels. Atmega 328f Arduino Uno is used to supervise the motion of the laser and the "lasing" action, which includes the depth of cut of the material, operation time and idle time of the laser diode.

E. Motor driver LC

L293D dual H-bridge motor represented in Fig. 4 is used as the Motor driver IC. The motor driver IC is used to regulate the speed of the motor and also to enable the movement of the motor in either direction. The stepper motor and the DPDT switch is controlled by L293D dual H-bridge Motor driver IC.

Fig 3: Arduino

Fig 4: Motor driver LC

F. DPDT Relay Switch

DPDT is a 4-way switch used to regulate the movement of Lasing material during cutting operation. Fig. 5 depicts the DPDT Relay switch deployed in the cutting machine powered by Laser. The relay switch helps to move the Laser according to the program developed by applying M-codes and G-codes. There are two sections in DPDT switch which are input and output. The input section consists of a coil with two pins which are connected to the ground and input signals. The output section consists of contractors which connect or disconnect mechanically.

G. Work Platform

The work platform used for the cutting machine consists of wooden platform having the dimensions of 220 mm in length and 440 mm in width. Wooden platform is used as the in the application because of its beneficial properties of High durability and workability.

Fig 5: DPDT Relay Switch

Fig 6: Work Platform

H. Coding of the Arduino

The design details so far dealt with the mechanical aspects of the project consisting of the basic framework whereas there are certain interdisciplinary concepts required to supervise the motion of the laser and the "lasing" action, which includes the depth of cut of the material, operation time and idle time of the laser diode.

Initially, the controlling of the stepper motor was executed using the in-built open-source libraries provided with a standard Arduino installation. However, this proved to be rather cumbersome as with increasing complexity of the profile being machined, the complexity of the code increased exponentially. This difficulty was overcome using a GRBL-based approach.

there are sure challenges in controlling the arrangement straightforwardly utilizing the Arduino IDE. Since machining processes are basically programmed using general codes and miscellaneous codes (M-codes and G-codes respectively), Thus it is essential to develop a system that accepts M-codes and G-codes such that the codes can be directly fed by the user to regulate the cutting machine powered by Laser.

It was feasible to accomplish this by transferring a GRBL-based firmware onto the Arduino and utilizing the "UniversalGCodeSender" software, A Java applet is used to conveniently input the G-codes or M-codes.

I. Interface the code

The codes developed is interfaced with a microcontroller which compiles the input codes and generates equivalent electrical impulses, which act as an input to stepper motor and laser diode, imparting precision motion and action control. Codes are interfaced in Serial format, so that any other program/ programming language that has serial capabilities can easily be communicated with Arduino. Hence, the code is developed in ctt and interfaced using Arduino IDE.

3. RESULTS AND DISCUSSION

A. 3D Design using Solid works

The CAD model of final assembly is represented in Fig. 7. Fig. 8 depicts the CAD models drafted for the development and assembly of Portable 3-Axis cutting machine powered by Laser. The components are drafted based on the design calculations keeping sufficient factor of safety consideration. The different components used for the development of cutting machine comprise of Mild Steel Extrusion, 3D printed Y axis Block, V wheels, 3D printed Leg support, L-clamp, Laser Head and Z- Axis block.

Fig 7: CAD Model of Final Assembly

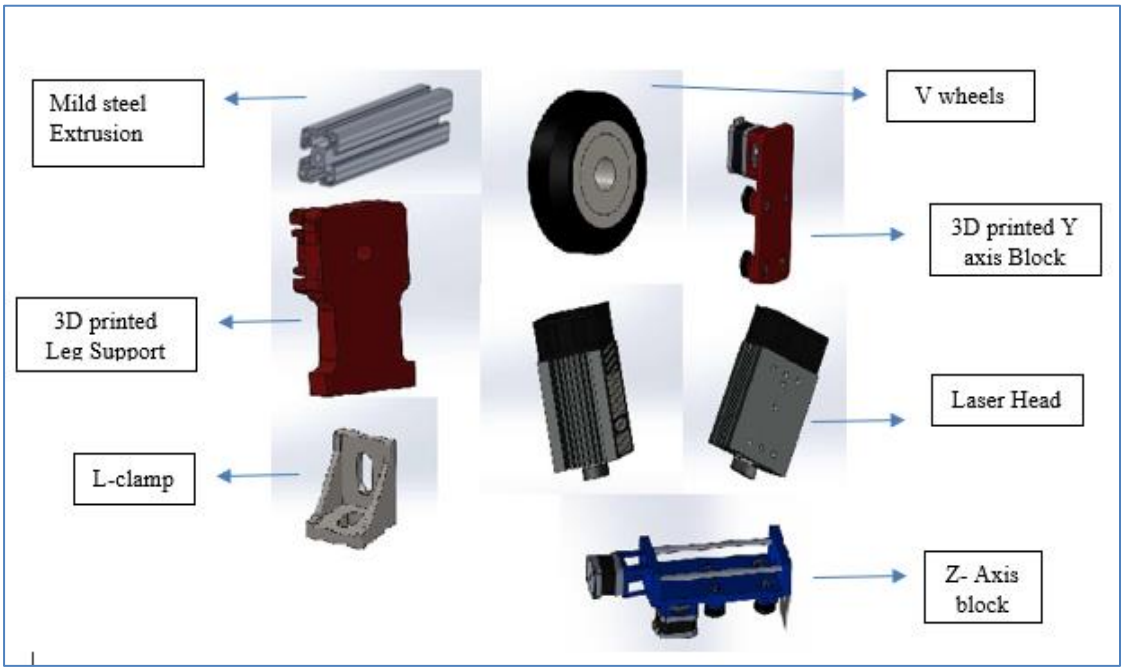

Fig 8: CAD Model of Components of Portable 3-Axis Laser Cutting

B. Design Calculations

The material used for the platform is made up of hot rolled mild steel and the weight of the entire cutting machine is ascertained as 4.85kg such that the equipment is suitable for portability. The friction μc generated during starting and running of the stepper motor is determined as 0.101 and 0.084 respectively. The frictional force generated by split nut and screw threads is evaluated as 0.228, which is sufficient to overcome the frictional forces generated by stepper motor, ensuring non slippage during operation.

The maximum torque generated during cutting of card board is computed to be 0.2744Nm as per the design calculations and torque of 0.3563Nm is generated during cutting of thin plastic material. Nema – 17 has capacity of 0.8Nm and it is evident form the design calculations that maximum factor of safety is maintained during cutting operation.

C. Final Assembly Portable 3-Axis cutting machine

A view of the final assembly of Portable 3-Axis cutting machine powered by Laser is shown in Fig. 9. The machine is subjected to operation when all the various parts and components have been assembled. Upon testing the same, by attaching marking instruments to the diode's position, it is identified that machine traces the various loci input by M-codes and G-codes accurately.

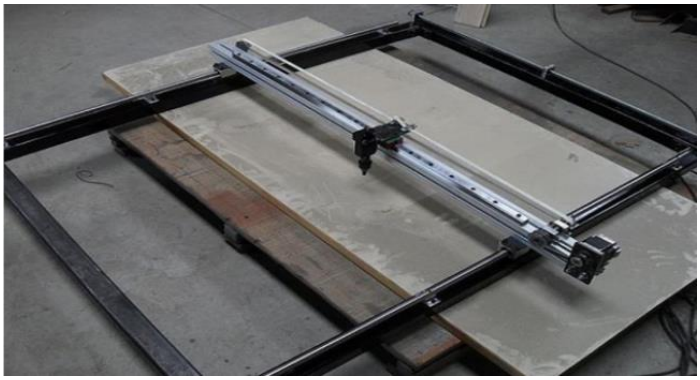

Fig 9: Final Assembly of Portable 3-Axis Cutting Machine Powered by Laser

Further, upon integrating the laser diode with the CNC shield it was found that the laser diode's switching action as well as beam intensity could be controlled as well.

D. Performance Analysis

The equipment developed for cutting operation powered by Laser is subjected to performance analysis by generating a NACA 0012 airfoil profile on balsa wood sheet. NACA 0012 airfoil profile shown in Fig. 10 is fed to the machine and based on the profile, the M-codes and G-codes are developed. The Laser diode started engraving the profile on balsa wood sheet of 3mm thickness based on the M-codes and G-codes and the final output on the balsa wood evaluated to be conforming with NACA 0012 airfoil profile. Few deviations are observed while comparing the output profile with that of input profile which is identified as limitations of the GRBL software. Fig. 11 depicts the final output profile of airfoil created on the balsa wood sheet of 3mm thick.

Fig 10:. NACA 0012 Airfoil Input Profile

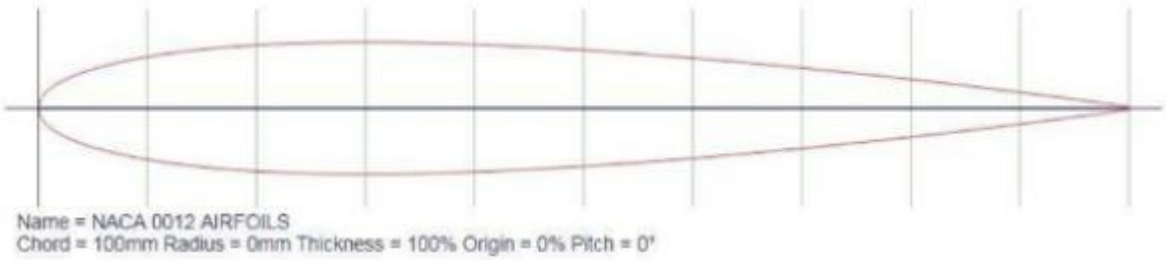

Fig 11: Profile Machined on Balsa Wood

4. CONCLUSIONS

Based on the utilization of materials for the assembly of the equipment design experimentations, and results & discussion, the following conclusion can be formulated.

1. CAD model of the various components used for development and assembly of Portable 3-Axis Cutting Machine powered by Laser has been designed using solid works software.
2. Laser diode with a capacity of 10W is deployed for cutting and engraving the materials such as paper, cardboard and plastic materials upto cutting thickness of 1mm.
3. Design calculations are carried out to ensure that the equipment has significant factor of safety during operations.
4. The cutting machine is interfaced with Arduino board to control the movement of the Laser diode. M-codes and G-codes are developed for Airfoil profile of NACA 0012. The codes are then imported to the cutting machine for cutting operation.
5. The airfoil is created on a Balsa wood sheet of 3mm thickness and the output is compared with input profile. The profile is found to be conforming with the input profile

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