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Design and Fabrication of Laser Engraving Machine

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ABSTRACT

Laser engraving machine is used to mark various pictures and symbols on different materials. The laser engraving setup is advantageous due to its low operational cost, lightweight, portability and easy-to-learn features. The paper fabricates a low cost rapid prototype laser engraving machine. The proposed setup has been applied to Glass Fiber Reinforced Plastics (GFRP) composites, plastics, wood, cardboard, etc., to yield desired profile, contour, information and various drawings. Moreover, developed laser engraving setup has high precision and processing efficiency. Laser engraving technique involves color change of the surface due to thermal energy emerged by the laser beam. The simulation of this machine is done using Laser GRBL software. A 2.5 W diode laser is used to engrave the various materials. Various advanced software and hardware like Inkscape, MakerBase, GRBL controllers and microcontrollers are assembled together, further leading to the execution of the final engraving. Validity of the machine has been verified by performing dimensional, dependency and co-ordinate tests. Finally, pilot experimentation has been carried out on Cardboard composites.
Keywords : GRBL , Modeling, GFRP, MakerBase, Laser.

I. INTRODUCTION

Laser is the acronym of "Light Amplification by Stimulated Emission of Radiation". There are main three steps for light emission; they are absorption, Spontaneous Emission and Stimulated Emission. In past decades, laser has been widely and mostly used in welding and cutting operations, but in recent times due to inventions and progress, research and advancement in laser technology it has been adopted in other industrial processes like Engraving, marking and machining of different materials. Laser engraving is the process of using laser machine to engrave or mark an object or surface for product identification. Laser engraving is the process of removal of material from the top surface down to a specific depth. The laser engraving process can be very complex and often a computer system is used to drive the movements of the laser head. The laser engraving technique does not involve the use of any kind of inks, nor does it involve tool bits which contact the engraving surface and wear out. Various advantages associated with laser engraving compared with conventional engraving methods are no wear on tools, high degree of automation, free programming and choice of characters.

A laser engraving machine can be thought of as three main parts: a laser, a controller, and a surface. The main advantages of laser process are non-contact working, high repeatability, higher scanning speed, best surface.

1.2 Objective

The objectives of the work are:

a) To reduce the large scale industrial engraving machine to a small portable lab equipment.
b) To decrease the cost of engraving prototypes
c) To make it useable for engraving paper, polystyrene and thin sheets
d) Make the machine mobile.
e) Developing concept sketches and then reviewing it with the customers to find according to them what the shapes should be.

1.3 Problem Statement

The new design development in this thesis is based on small scale laser cutting and engraving machine. This approach consists of a easily portable body with a laser, in the arrangement the nozzle is equipped on top of body to provide the required manipulation capability (for proper laser cutting and engraving). The development of this machine is to make small scale work rather than using large industrial cutter system, which has design of movable bed and cooling system to dissipate heat produced during cutting. Here the laser movement is controlled by stepper motor in two dimensions, so no need of movable bed.

II. Literature Review

A. R. Khan studied on the influence of the Laser Power, No. of layers removed, laser Frequency and scanning speed on Surface roughness and marking time with the help of Taguchi Approach. A TruMark station 5000 UV Laser beam was used in laser marking process of Stainless Steel AISI 316L. A convex lens with focal length of 163 mm was used in the way of laser beam to focus the laser beam on work piece with an input voltage of 230 volts. A mix hatching mode scanning strategy was adopted because in multi-layer machining cycle surface roughness was reported to be reduced by simply changing the scanning direction. On experimentation it was investigated that main contributor for marking time was number of layers removed followed by scanning speed and For Surface Roughness, scanning speed is major parameter followed by laser power. Mathematical modelling was found to be very significant statistically at 95%confidence level with error contributing to only 1.08% for the model developed for marking time and 3.16% for the model developed for surface roughness. By confirmatory test good similarity between experimental and predicted results was investigated.

D. K. Patel has investigated on Laser engraving process for different Material using grey relational technique. They optimized parameters for laser engraving on Stainless Steel 304 with the use of Q-switched diode- pumped frequency-doubled over YAG green laser. In laser engraving processes the surface of material is heated up and subsequently vaporized. With the use of laser engraving machine the marking/engraving is possible by using different input parameter as spot diameter, laser power, laser frequency, different wavelength etc.

A laser engraving device has a cavity designed to provide a controlled environment while the laser beam is used to engrave soft 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 bars 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.

III. Mechanical Design

Two prototype iterations were constructed as designs for a positioning machine for the laser tool head. The goal was to design a low cost machine capable of positioning the laser module in three axes, achieving planar positioning and actuating the laser up and down vertically. Low cost was a design constraint that was constantly held in mind. The parts used in fabricating the prototypes were purposely chosen to be inexpensive and readily available to hobbyists. For convenience, most of the structure was constructed out of laser cut clear acrylic parts made using a commercial laser engraver, but all of the structural components could be readily made with a hack saw machine. Using a commercial laser engraver to fabricate a final design would also have the added benefit of creating a "selfreplicating" machine, a machine that is capable of creating the design on material according to the input.

The other design constraints involved in the mechanical design portion of this project included reducing the number of actuators to only one per axis, and paying attention to instances of over-constraint and methods to alleviate any jamming. Several possibilities were assessed in how to actuate the motion of the positioning machine. The most common approach to positioning machine actuation is the use of stepper motors. Another option was the use of standard motors or servo motors along with ten-turn potentiometers, which were also present in the laser driver circuit design, as a means of position feedback. Although the prices of servo motors and stepper motors are comparable, the extra cost of the controller used to operate the stepper motor made the stepper motor control less desirable.

Theme of the Paper

- Decrease the extensive scale mechanical slicing machine to a little convenient lab hardware.
- Diminish the cost of fabrication and usage.
- Usable for cutting paper, polystyrene and thin sheets, etc.
- Portable Machine.

Laser Safety

Any laser light that is shined directly into the eyes, no matter what the laser diode output power, should be considered dangerous and proper safety precautions should be taken. Any laser that is capable of burning constitutes an even greater danger and the safety measures are more important still. The lasers used in this thesis project are capable of burning through plastic, and have no problem burning skin and damaging eyesight. Proper laser safety goggles should be worn at all times when handling a laser that has the capacity to produce light. For the most part, besides where the laser is focused into a point, the laser light should not be strong enough to burn the skin, but skin contact should never occur and accidental exposure of laser to the skin should be prevented at all times. Never let reflected laser light reach unprotected eyes, although residual laser light has a low chance of harming skin.

Protect yourself from reflected laser light by making sure the laser light path ends in material that will absorb the laser light. These particular diodes are especially dangerous because they emit light on edge of the visible spectrum, and the laser beam itself is completely invisible. Because laser light damage to the eyes is rarely painful and takes time to show symptoms, unprotected eyes can be damaged without the user realizing the damage is occurring. Because they can burn skin and eye exposure can result in blindness, these laser diodes are considered Class IV lasers, the highest danger level assigned to laser mechanisms. They are powerful and should be treated as dangerous. Once again, never operate the laser diodes without the proper safety equipment, and be sure your laser goggles protect against the wavelength emitted by the diodes, in this case 440nm wavelength light

Future Scope of Work

Great strides were made toward developing the components necessary for a low cost laser engraving mechanism, but the ability of the machine would be limited beyond the initial intentions of the machine. Using the laser diodes explored in this thesis, the machine would be limited to engraving some of the material completely through. The low power outputs of the laser diode is the main limiting factor of the engraving potential of the laser. Although additional lasers focused to the same point improve performance, this method is not without its limits.

The mechanical structures tested in this thesis are a good start for designing a low cost machine capable of providing accurate positioning, but improvements are necessary before the machine will reach the design goals.

A better method of power transmission is the major issue preventing successful operation of the mechanical design. Perhaps testing a timing belt instead of round belts will improve the performance of the machine without increasing cost. The potential of using potentiometer feedback for positioning is a promising low cost method of position control. Were the mechanical design of the machine improved and the laser parameters optimized to provide adequate burning power from the laser, the machine would most likely serve prototyping purposes as a method of layout planning better than actual engraving.

Perhaps the machine would be better off used for marking material with layouts prior to traditional machining. Other uses for a well-positioned laser diode exist, and merely need a creative mind for implementing them. Using the components documented in this thesis, several useful mechanisms can be designed utilizing the laser diode and a low cost positioning system.

IV. Methodology

The structural design of the machine including to wiring connection and the software adopted to generate codes and C+ language. Finally, but not last is Development the base of the design that has been achieved.

The machine structure is the vital part of the machining tool. It merges all machine components into a single complete system. The machine structure is vital to the efficiency of the machine since it's directly affecting the total dynamic stiffness and also affecting the damping response. Perfectly designed structure can afford high stiffness, which leads to precise operation. Mini scaled machine tool required more precise stiffness than the regular large-scale machine tool. The initial design will be drafting or sketching then when the design satisfied. The next level will be deciding the criteria required which is firstly the length travel. The length travel is the length of the X, Y axis that travels from one point to another. The X axis move left & right, Y axis move front & back. Travel length that is to be designed is X axis 487mm and Y axis 446mm. This structure comes with less materials hence it's very less expensive to build which it's designed to engrave wood, plastic and aluminum.

The product is aimed for students, engineers and as well as common people. The product is designed as low cost easy maintenance lab equipment. The mechanism is kept simple so that even the common man can use the machine with full comfort, effectiveness and safety. The machine being small and portable it can be moved and setup at any place where the user wants.

The laser beam is condensed by machining lens and while the laser beam thus condensed is being applied to a work piece the laser beam are moved to engrave the work piece. The work piece is fixed on the platform with help of fasteners or magnets. The movement is achieved in laser beam from stepper motor attached to it which in turn is controlled by pulsed input from MakerBase and easy motor drive. The input to MakerBase is given from a software switch which is used by the user to get the desired movement of the beam. The laser beam can move in x and Y axis only. The laser diode is mounted in a laser housing to prevent it from overheating and fro focusing the beam.

Laser diode along with the laser housing is mounted onto the vertical stand which provides movement in "X" axis with help of stepper motor. Here also the movement is controlled by the same as explained above.

The code burnt in MakerBase is basic which involves producing high output when software switch is pressed and the rpm is set once along with the rotation angle.
The 12V power supply is used to provide supply to laser diode which utilizes maximum of 3v in forward bias condition. The 12v power is consumed by 2 stepper motor which is used in movement of laser.

V. Parts and Description

5.1 Laser Module

It is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. It has many uses in the industries and it is used for cutting, engraving and welding etc.

Figure 1(a)- Laser source

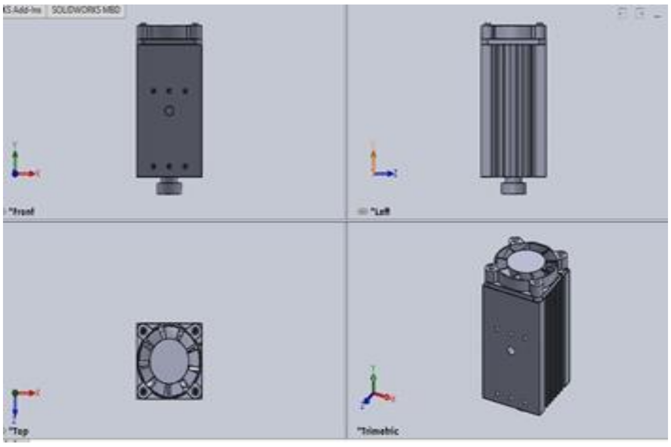


Figure 1(b)- 3D model of Laser source

Technical specifications

- Laser Wavelength: 445nm (Blue).
- Light Power: 2.5 watts (2500mW).
- Cooling Method: Forced Air Cooling.
- Input Voltage: 12V DC.
- Can engrave plastic, wood, PVC, PCB, on behalf of the wood and other materials.

5.2 Control Board- MKS DLC V2.0 (MakerBase)

MKS DLC (MakerBase) is a controller main board, which works with the ATmega 328p microprocessor.

It is developed for laser engraving, CNC, writing plotter and other small machines. It has complete interfaces and can be controlled externally.

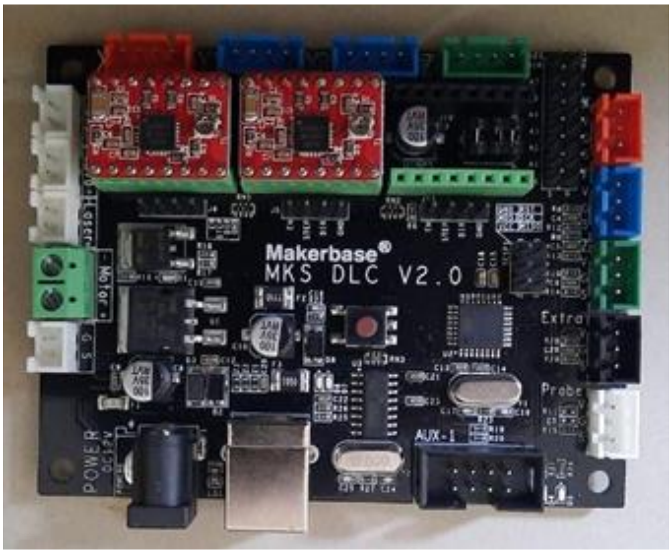


Figure 2 - MakerBase Control Board

Features of the MKS DLC v2. 0

- ATmega 328p Processor
- 4 x motors Drivers (3 axes): X Y1, Y2, Z
- Can be connected via USB
- Laser control ports: TTL / PWM, 12V, 5V1
- Power: 12V DC
- Software – LaserGRBL

5.3 Aluminum Profile- V-Slot

It is a linear guide extruded aluminum section. The purpose of the V-Slot guide is to mount a linear guiding system with wheels specifically designed for this profile, which slide smoothly and robust on the profile form.

Figure 3(a)- Aluminum Profile

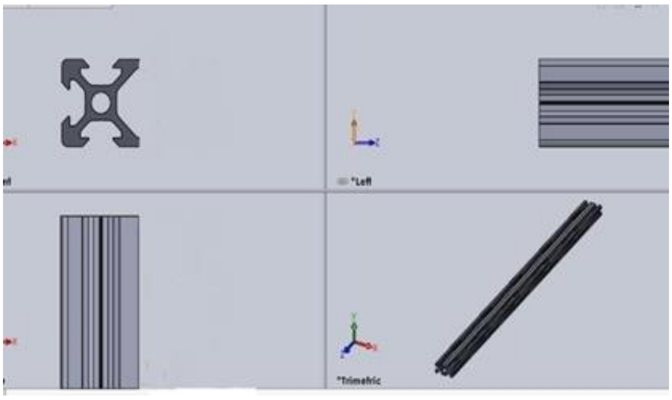


Figure 3(b)- 3D Model of profile

Features of Aluminum Profile-

- The V-Slot, system is accurate, robust and easy to assemble.
- The guidance system with V-Slot is economical and reliable
- The V-Slot is manufactured from extruded aluminum 6063 T-5.
- The profiles has a perfectly smooth anodized finish.

Dimensions

- Aluminum Profile- 20 x 20 mm
- Width – 6mm
- Distance between steps – 2mm
- For X- Axis – 450mm
- For Y- Axis- 492mm

5.4 Stepper Motor- NEMA-17

The NEMA 17 Stepper Motor is a hybrid bipolar stepper motor. It is made of neodymium magnets that give higher performance and torque. The stepper motors can provide direct and precise movements in a small space. This type of stepper motors are the most used, in the construction of 3D printers and small CNC machines.

They are robust and have precise movements. High power at low speeds, maximum torque is achieved. As with all stepper motors can divide the steps in microstepping (a major division of torque microstepping is lost).

This pole motor has a torque (power) of 5.5kg-cm and a shaft diameter of 5mm. They are connected to drivers or bipolar plates (on the maker base control board) for specific control for 3D printers and CNC.

Figure 4(a)- Stepper Motor

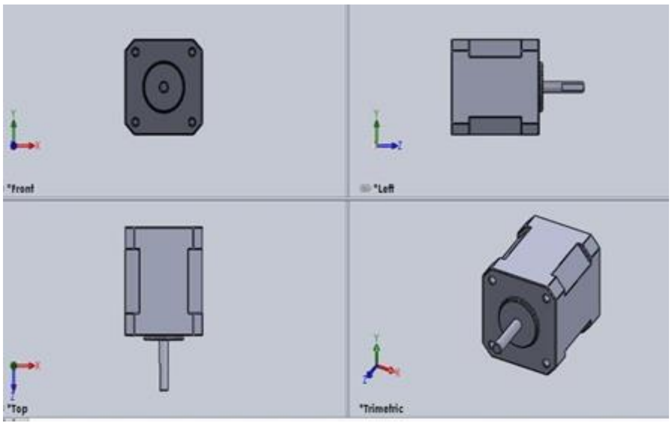


Figure 4(b)- 3D model of Stepper Motor

Technical Specifications -

- Step Angle 1.8 degrees
- Steps per revolution: 200
- Voltage: 3V DC
- Current: 1.68A / phase
- Holding torque: +/- 2NM (or) 12Kg-cm
- Number of phases: 2
- Shaft diameter: 5mm
- Max. temp. working: 80 degrees
- Weight: 0.35 kg

5.5 Pulley - GT2 pulley

The GT2 pulley is a high quality aluminum timing pulley, ideal for 3D printers, automation or CNC. The 5mm shaft is the shaft normally used in Nema 17 stepper motors.

Figure 5(a) - GT2 pulley

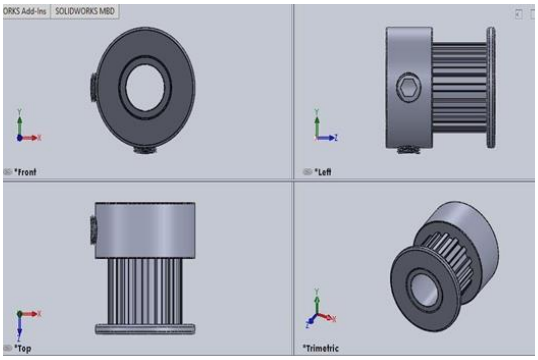


Figure 5(b)- 3D model of GT2 Pulley

Technical Specifications

- Distance between steps- 2 mm
- Number of teeth- 20 Teeth.
- Tape width- 6 mm (up to 7 mm).
- The size of the shaft -5mm

5.6 Timing Belt

Timing belts transfer rotational motion (from a stepper motor) into linear motion (along the V-Slot). They have a special profile with rounded teeth which reduces backlash.

They are often used for precision 3D printers and CNC machines.They are made up of high quality rubber.

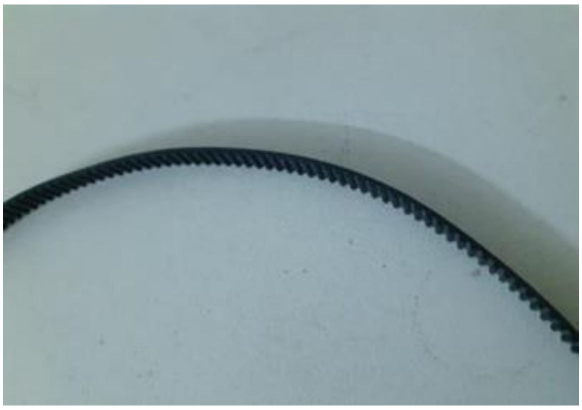


Figure 6- Timing Belt

VI. Working Construction

We designed the body of this machine using v-groove aluminum profile and acrylic material. DC current is mandatory for this type of machine and it resist 12V (10A) of current.

Firstly, the aluminum profiles were cut into desired length, then the body frame was assembled as per the 3D model using caster corner brackets with bolts and screws.

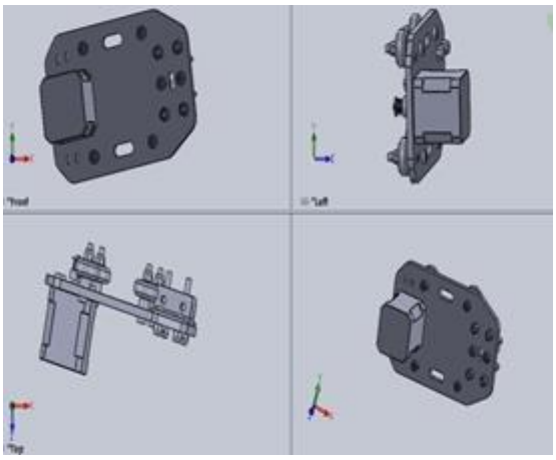
On the other hand, the stepper motors were attached to the acrylic cut out. To the stepper motor the Pulleys were also fixed in a precise manner. Then, the laser module is fixed on the acrylic body, which then slided along the X-Axis profile.

Thirdly, the timing belt is fastened along the both Y-Axis profiles and the X-Axis profile with the pulleys taking hold of the belt. The foot brace are then fixed to the machine for a proper distance between laser module and the work piece.

Lastly, the control board (MakerBase) is fixed to the body, the connections to the stepper motors and the laser module is done accordingly. The control board is switched on after supplying DC current and it then it is connected to the computer. The software (LaserGRBL) is installed which detects the control board connection and then engraving instruction can be given to the machine via the software.

Figure 7- Assembling of Body

8(a) Acrylic with wheels Assembly



8(b) 3D model of the assembled part

Figure 8- Assembly of wheels

9(a) Assembled body

9(b) 3D model of assembled body

Figure 9- Assembled Body with Caster Connectors

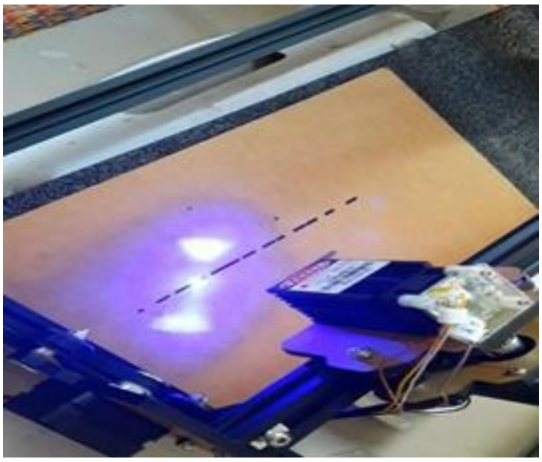


Figure 10- Laser Engraving Machine

VII. Working Principle and Working

A laser engraving machine consists of three main parts: a laser, a controller, and a surface. The laser is a drawing tool. The beam emitted from Laser allows the controller to trace patterns onto the surface. The controller determines the direction, intensity, speed of movement, and spread of the laser beam aimed at the surface. During the process of laser engraving, the laser beam impinges on the material, exposing it to a great deal of heat. Depending on the exposure time, the color changes and creates a contrast, or the material evaporates or burns. The resulting laser engraving is permanent and very resistant to abrasion. The point where the laser beam touches the surface should be on the focal plane of the laser's optical system and is usually synonymous with its focal point. In this laser engraving machine, the work piece (surface) is stationary and the laser optics move around in two dimensions, directing the laser beam to draw vectors. Laser engraving is as simple as printing. The working can be explained in steps.

- First, the layout of the engraving is created in usual graphics program (Laser GRBL). The dimension should be taken according the work piece.
- The machine is started by switching a plug as it requires electricity to work.
- The computer is connected to the laser engraving machine controller by USB or other connecting medium.
- Then the driver is used to send the graphic to the laser.
- At the push of a button, the selected material is laser engraved or laser cut with the stored settings.
- If required, advanced settings can be set, provided by many different type of laser software.
- Process types stored in the printer driver make everyday work much easier by automatically optimizing graphically required processes.

A laser can remove material very efficiently because the laser beam can be designed to deliver energy to the surface in a manner which converts a high percentage of the light energy into heat. The beam is highly focused and collimated in most non- reflective materials like wood and plastic. Different patterns can be engraved by programming the controller to traverse a particular path for the laser beam over time. The trace of the laser beam is carefully regulated to achieve a consistent removal depth of material.

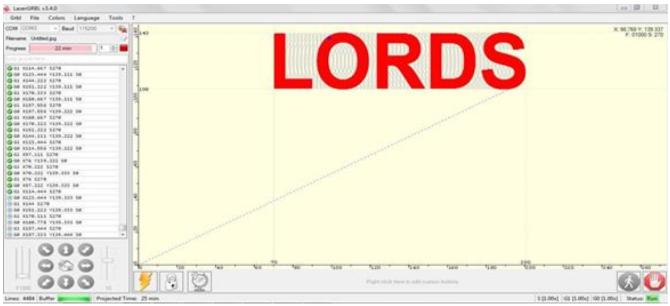


Figure 11- Snap Shot of Laser GRBL software in function.

For example, criss-crossed paths are avoided to ensure that each etched surface is exposed to the laser only once, so the same amount of material is removed. The speed at which the beam moves across the material is also considered in creating engraving patterns. Changing the intensity and spread of the beam allows more flexibility in the design. For example, by changing the proportion of time (known as "duty-cycle") the laser is turned on during each pulse, the power delivered to the engraving surface can be controlled appropriately for the material.

Figure 12(a)- Name of our Institution engraved on a wood piece

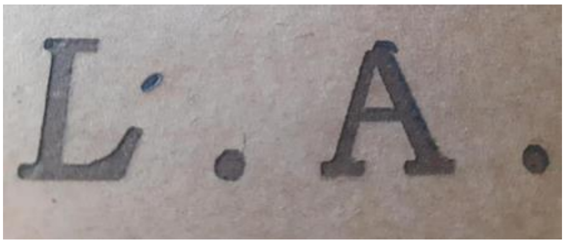


Figure 12(b)- Result of Engraving on wood piece.

VIII. Applications

Laser marking or engraving machine become more and more popular in handcraft and gift making field. With the development of Laser marking or engraving machine, also the Personal engraver become easier and easier.

Now let us see some common laser marking or engraving application around our life.

8.1 Phone case

Mobile phone have become irreplaceable communication tools in our life, but the common model is limited. We can saw many people use all same phone with ourselves. If we add one personal phone case, everything will be different.

These phone case engraving are of two types:

- ABS plastic phone case photo marking
- Anodized aluminum phone case making

Now most phone brand use anodized aluminum on the mid-to- high price range, including IPHONE, HUAWEI, Samsung etc brand.

8.2 Key chains

Key chains is so popular in our life, check your key chains, if you find its surface have some drawing, letter, photo etc. Yes it is laser marking or engraving machine product. Most key chains are stainless steel or coated non-metal material, both of them could do laser marking or engraving processing.

8.3 Stainless steel Cup and Tumbler

In winter, stainless steel vacuum cup is very convenient to carry. One simple stainless steel cup may seems monotonous. But if we mark some drawing on the surface, all will be different Except above common product in our life, nearly all small piece could saw the laser marking or engraving. such as pen, notebook, necklace etc. All of these product will use laser marking & engraving machine.

IX. Advantages

- Low weight-

The machine frame is designed by aluminum metal so the machine is of low weight, because of the machine's low the machine can be carried easily from one place to another.

- Economic production or low cost –

Money invested in production of machine is less due to cheap but strong type of the materials like aluminum and acrylic is used. The production of individual pieces or small series, as well as large series, is cost-effective and economically feasible.

- Easy to setup and User friendly –

The working of machine is made simple that it can become used easily by anyone, and no extra skills are required.

- Environmentally safe –

As the laser produces no chemical or toxic bi-products process such as with acid etching. It leaves very little waste behind as most is vaporised, but the waste that is left is typically in the form of particle dust. This is unlike the harmful waste that other processes leave

- Larger field of Application-

The laser beam is a universal tool for many materials such as wood, glass, MDF, textiles, cardboard, paper, foil, and much more.

- Non-Contact method –

One of the biggest benefits of laser engraving is that it's a non-contact process. This means that the laser beam isn't physically touching the material that it is being applied to, instead relying on heat to achieve the desired results.

- • No tool wear –

Due to the non-contact material processing of the laser, there are no tool costs for cutters and drills.

- Maximum precision and finest details –

The laser technology makes it possible to implement the finest motifs with maximum precision. Virtually everything that can be drawn can be engraved and marked using a laser.

- Used in many industries for many applications-

From creating electrical circuits in ceramics for semi-conductors to creating engravings in personal jewellery pieces, it's a process that benefits businesses and individuals alike. It is a process that dozens of industries around the world have adopted for hundreds of varying processes.

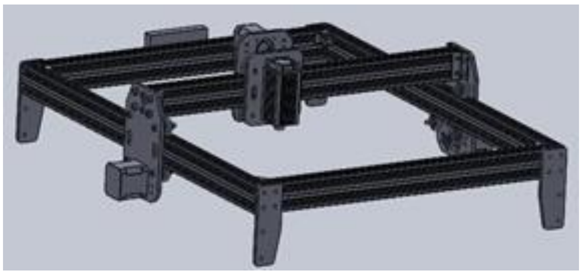
X. Disadvantages

- The working is only on the two-dimensional plane of the X, Y direction.
- It cannot be used for the processing of the highly hard or high melting point metals.
- If the metal is very much shine then the engraving becomes tough due the reflection characteristics of the metal.

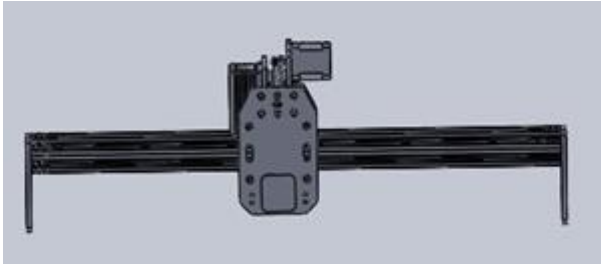
XI. Result

The machine was designed and fabricated successfully and during testing it worked well with the USB connection. A user friendly software was used and the machine proved to do the given work.

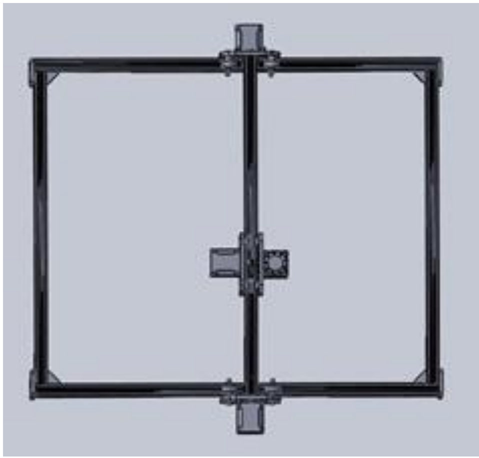
The design of the machine was done on Solid Works software, to get an idea of the layout. The 3D image which was designed on Solid Works helped out in accomplishing proper dimensions of the machine.



(a)Isometric view



(b) Side view



(c) Top View

Figure 13 - Different views of the 3D model (a), (b) and (c).

The 3D model of the machine helped in fabricating and fixing the final machine without any ease, the result of the fabricated machine was almost up the mark in lieu to the 3D model.

The maximum distance from the laser source tip and the work piece should be 96mm for a precise output of the work.

Figure 14 - Fabricated and Assembled perspective of the machine

XII.Conclusion

As globalization and industrial developments have been increasing, machines have gone from manual to a automatic control unit. the automatic control units have a very user friendly space, bringing in light to the our project is a perfect example of an automatic unit and a portable one too. The laser engraving machine works with a computer numerical control that writes and read G-codes instruction to drive to fabricate components with a proper material removal rate. G-codes are commands for machine given by the user to follow so that they can operate without much human control. The rate of work is fast and clear.

As we have made the machine portable and user friendly, it helped us to gain and approach more knowledge about CNC machines, it also gave us an idea on how the machines can be run by any person and can be transported easily elsewhere.

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