Design and Fabrication of 3-Axis Computer Numerical Control (CNC) Laser Cutter

Rashid Khalid Hilal Al Habsi and G. R. Rameshkumar

***Abstract*—Nowadays with a digital control it's became more and more useful to use such a machine tools with simple a coded software. This paper will present the design and fabrication of Laser Powered 3-axis computer numerically-controlled (CNC) machine which comprise the use of a graphical-user interface (GUI) and Arduino micro controller to produce pulse-width modulation (PWM) outputs in order to run the stepper motors that will be used in this work. A simple mini 3-axis CNC is previously used precisely surfaced designed for snapping of wood, plastic sheet and thin sheet of metal alloy by using a rotating drill bit which its accuracy is much lesser than using a lesser cutter techniques this machine tool is portable and it's controlled by computer (PC). Design and Fabrication of mini CNC with workspace of 130mm x 130mm using a precision Stepper motors that combined with belt & pulleys help in moving the axis smoothly on linearity bearings that increases a more precisely results obtained.**

***Keywords*—Mini CNC, 3-Axix, Laser and Arduino**

I. INTRODUCTION

Computer numerical-controlled (CNC) Laser cutting is an industrial technology that uses a LASER (Light Amplification by Stimulated Emission of Radiation) to cut ferrous and non-ferrous materials. Mini CNC machine is the machine that is similar to usual CNC machine but it's limited by the area of machining. This machine is designed for small and precise measurement. CNC can be grouped into two types, which are rotary machine and milling machine. A rotary machine is basically a device that spins a material piece at a very high speed and the spinner moved back and forth and in and out until the preferred shape is complete. A milling machine is a machine that has spindle which consider as similar as the router, with a LASER tool that spines and cuts in various direction and moves in three directions along the X, Y, and Z axis [1]. Recently, the industrial world has become faster smaller and in highly advanced technology to make things smaller, thinner and portable. As well as now the things in engineering and technology world have microcontroller in NANO and micro size. This also goes to 3-axis CNC machine; these machines nowadays have range size in the open market. Every type of machine has its own function, even still the size are big or small. Depends of the machine specification CNC can machine a big work-piece or small work-piece which is to be considered as a mini CNC machine according to the specification of the design. This paper work is to overcome the problem of machining the small part. Where the mini CNC machine is going to give the small area of setup the work-piece and it will be easier to get the accurate result of the work-piece.

Over decades, industrial technology has transformed many aspects of daily life. Several studies has been carried out for the development of such a (CNC) machine on smaller thinner, lighter weighted and budget cost. From the related journal and research, the main idea in carrying out this work of CNC development. As the technology of CNC machine characterized by accessible price and technology so rip that even individuals can design and construct CNC controlled machine [2]. Advanced facility and precision of control of CNC tools, if it's compare with usual machine, has had a significant influence on the development of function components, frame body, stepper motors, and control circuits. Construction and evaluation of Low-cost table CNC milling machine by using low-price milling cutter for the main spindle due to a low voltage supply of the main cutting forces it is possible to use the tools of smaller dimension to machine materials like wood, aluminum and plastic materials. Design and Implementation of Three Dimensional CNC Machine [3] where it discusses the design of low cost three dimensional CNC. The main function is a microcontroller based CNC machine and it's communication between personal computer (PC) and CNC machine by Software sub system that gets a set of commands and fetch it to the mechanical sub system in order to be control the 3-axis. Software sub system that is a PC that provides easy to use interface for user to program commands in such a language that microcontroller accepts. The author conclude that using C++ as language on NET platform as an alternative of using any ROTS which is expensive and not user friendly and not possible to execute in general PC which user has to get a separate operating system. The design of this system is user friendly which give accurate results and flexibility to users.

Developing an 3D prototyping of customized device for CNC laser micro-machining that is determine by using a laser head of TRUMF TruPluse unit, so that complex surface to be

Rashid Khalid Hilal Al Habsi is with the Caledonian College of Engineering, Muscat, Oman, Phone: +968 93366436; fax: +968 24535675; (Email: rashid_al_habsi1@hotmail.com)

Associate Professor G. R. Rameshkumar is with the Caledonian College of Engineering, Muscat, Oman, Phone: +968 94889468; fax: +968 24535675; (Email: grrameshkumar@yahoo.com)

generated by various laser micro-machining producers. The strong requirement for highly performance modern products determining the progress of new and highly developed machining and, in particular, micro machining technologies that replace the usual CNC machining. The machining process are different once the main usual spindle which the cutting tool clamped is replaced by LASER device, so measuring to maintain right stiffness to be considered. The whole assembly should ensure a 0.015 mm positioning tolerance. Stepper motors are quite different from usual electrical machine. It can be regarded as brushless DC motor, whose rotor rotates in discrete angular increments when it stator winding are programmatically energized. Stepper motor drive for computer numerical control machine is general purpose stepper motors are rated with resolution as low as 0.9°. Precision, high end stepper motors are able to achieve up to 0.05°. It is importance to note that stepper motors weight and power ratio is high, from where occurs a maximum achievable power as well. Computer based controller reads G-code instructions, interprets them and performs numerically directed interpolation [4] of a cutting tool in the work piece of a machine to fabricate components. The traditional machine controllers employ PC based or embedded CNC systems, because of the overheads imposed by a very large G-code increase the hardware cost of the system which making it unaffordable for use by small industries. At the earlier developed microcontroller based CNC system had many drawbacks. The GRBL G-Code interpreter [5] for example, implemented only some of the many g-codes. Many projects like ROTS based Embedded CNC system and An Open Architecture Numerical control System Based on Windows CE [6] have implemented Operating system on the embedded system which decrease the processing and memory capacity of the system. Thus, these systems required high end and expensive microprocessors. The require for a G-code parser using an Arduino based microcontroller which is integrated part of the system, is offline, a huge reduction in the cost price is achieved, as a result making the system inexpensive for small scale industries and individuals.

Program commands are made up by words, CNC controls use a word address format for programming. By word address format, we mean that the CNC program is made up of sentence-like commands. Each command is made up of CNC words, each of which has a note address and a numerical value. The note address (X, Y, Z, etc.) tells the control the kind of word and the numerical value tells the control the value of the word. Used like words and sentences in the English language, words in a CNC command tell the CNC machine what it is we wish to do at the present time [7]. The CNC programmer must have an ability to visualize the operation of the machine and he says, in similar manner, a manual CNC programmer must be able to visualize the machining operations that are to be performed during the execution of the program [8]. Then, in step-by-step order, the programmer will give a set of commands that makes the machine behave accordingly.

As identified, “programs are prepared up of commands and commands are made up of words”. Each word has a letter address and a numerical value. The letter address tells the control the word type. CNC control manufacturers do vary with regard to how they determine word names (letter addresses) and their meanings. The beginning CNC programmer must reference the control manufacturer’s programming manual to determine the word names and meanings.

Laser engraving CNC machine can be categorized in three main parts: a Laser diode, a controller module and a working surface. As commonly known a laser is like a pencil, the different patterns which can be engraved by programming a control module to traverse a particular path of a laser beam in millimeter [9]. The trace of a laser beam is carefully regulated to achieve a consistent removal path of materials. The consideration of the speed movement across the engraving material to create an accurate patterns which increasing the intensity and spread of the beam which will allow flexibility of the design for example duty-cycle that the laser pulse during each turn what measured the power supplied to the engraving surface can be precise suitably for the material. The spot of the laser is known precisely by the controller, it is not needed to add obstacles to the surface to avoid the laser from conflicting from the prescribed engraving design. As a result, no resistive mask is needed in laser engraving. This is primarily why this technique is different from older engraving methods.

An axis is a path of motion controlled by the CNC machine control. It can be linear (motion beside a straight line) or circular (a rotary motion). The total of axes a machine has concludes its machining abilities. For machining centers, a three axis CNC machine will have three linear axes. A four or five axis machine will have three linear axes as well as one or two rotary axes.

The 3-Axis machine was aimed to provide an appropriate entry-level mechanism for testing with 3-axis machining and CAD/CAMM systems. It has not been planned to replace current, higher end machines such as those created by Manufacturing Corporation. The emphasis is on accessibility and allows the user to completely modify the in-built firmware on the machine [10]. In order to construct a three axis machine, there is a requirement to decide which the components have to use so that it can achieve smoothly and efficiency results.

The systems and component that transfer, hold, and guide loads move in linear directions. Also the duration used to describe computerized and semi-computerized mechanical systems that generate directions of x, y, z axes. Recent engineering process integrates the use of linear component to allow for rapid low-friction accuracy movement. A liner system combined with stepper motor, driver, and sensor makes filling these necessities conceivable. Gear motors and servomotors used as the driving and controlling instruments provide response, control, and power to the machine. Linear motion systems have three basic categorize as 1) The control, 2). The drive tool, 3). The support of components.

The drive or control devices include a selection of electric motors such as linear, stepper. The drive tool, in combining with the drive, offers the thrust and axial positioning precision of the load. The guidance machines of the systems control the travel direction and linear accuracy, as well as support the load.

Machines are presented with the traditional floor plate and the mobile gantry, as well as special gantry mills with integral turntable providing heavy duty turning capabilities. The milling head rides over two rails (often steel tubes) which lie at each side of the work surface.

For the gantry machine it have 5 type:

- Gantry type structure offers maximum structural height dynamic performance. X-axis travel can enlarge according to client requests, Y-axis can travel the prepared with untested as “Crossbeam Adjustment Mechanism” which it can reach of span at 7 m.
- X-axis has double ball screws, double servo motors and double linear scale synchronous that controlled driving system to ensure vital dynamic accuracy.
- Additional extraordinary rigidity roller style linear guide ways for Y-axis cartel the benefits of both box way and linear guide ways which make the unit can do a heavy duty cutting, fast movement and low abrasion capabilities.
- Z-axis have an extra-large size linear guide ways which along with larger saddle and high rigidity box structure headstock which provides best cutting rigidity.

As we all know that there is a bit of argument about the name of a particular axis and the direction it moves. Both sides of the argument have their merits [11]. The arguments begin when assigning axis to the device itself. Most people will call the axis holding the spindle (router) the Z-Axis. However, the X and Y axis becomes a debate. The X-Axis should be the longer of these two axis [12]. In other words the X-Axis is the axis you are facing as you face the machine during operation. Now this may be improper, but it makes it easy to visualize the coordinates as you look at the machine. It simply becomes a Cartesian coordinate system that used to in high school algebra with the Z-Axis moving up and down.

The main objective of this paper is to design and fabricate a mini CNC Machine and to use software to control the 3-axis machine. This project describes the design, fabrication and assembly requirement of the machine and the criteria required to build the machine sufficiently. And also to construct the whole system with a limited budget.

II. 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.

A. Structure Design

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 as shown in Fig. 1.

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 and Z axis that travels from one point to another. The X axis move left & right, Y axis move front & back, Z axis moves Up and Down. Travel length that is to be designed is X axis 10cm and Y axis 10cm and Z axis. This structure comes with less materials hence it’s very less expensive to build which it’s designed to cut papers, engrave leather, wood & plastic cards.

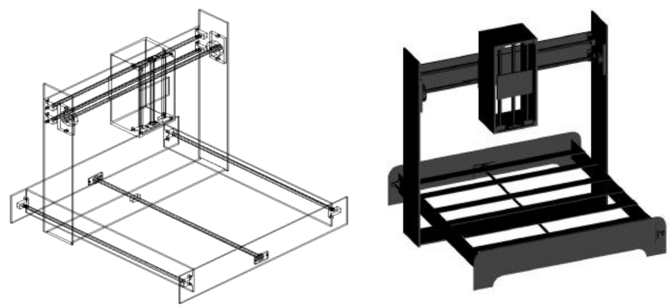

Fig. 1. Wireframe and solid model of the structure

B. Components

Stepper motor & Accessories: It’s a combination of stepper motor drive connected with GT2 pulley with Grub screw that is mechanical linear bar and linear bearings that drives rotational motion into liner motion with minimum friction. Traveling bar dimension 4mm X 250 mm for Y-Axis and 3 mm X 184 mm for X-Axis. Geared Stepper Motor with 1:30, 12V. The stepper motor as represented in Fig. 2 have 1/30 step angle and the speed is directly proportional to the pulse frequency where it stands of the higher the output voltage from the easy driver the more level of torque drive.

Microcontroller Board: Uno r3 it’s an Arduino Board it’s selected to be the control unit in this project, which it’s used as a motion control board. The Arduino Uno is a microcontroller board based on the ATmega328 as shown in Fig. 3. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

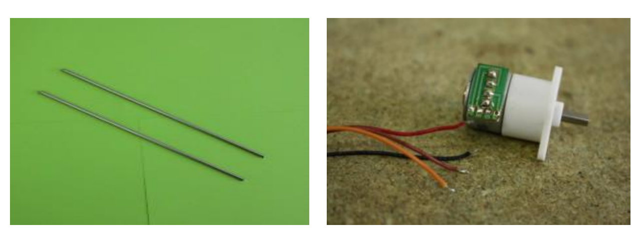

Fig. 2. Steel shaft and stepper motor

Power Supply: 12V SMPS (Switch mode Power Supply) is used for stepper motor driver. 2V SMPS is used to power the microcontroller board (Arduino Uno3).

The microcontroller is flashed with GCODE interpreter firmware written in optimized 'C' language.

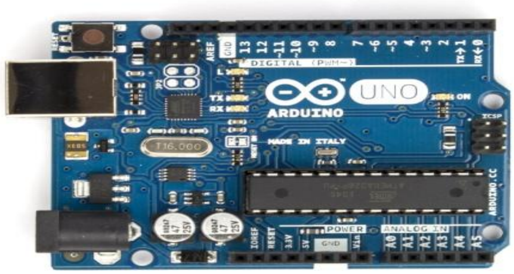

Fig. 3. Arduino Uno r3 board

Stepper Motor Drivers: It's kind of driver that receive steps signal from microcontroller and convert it into voltage electrical signals that turn the motor. This driver is called Easy Driver V4.5 as shown in Figure.4 that required 6V – 30V supply to power the motor which can power any type of step motor.

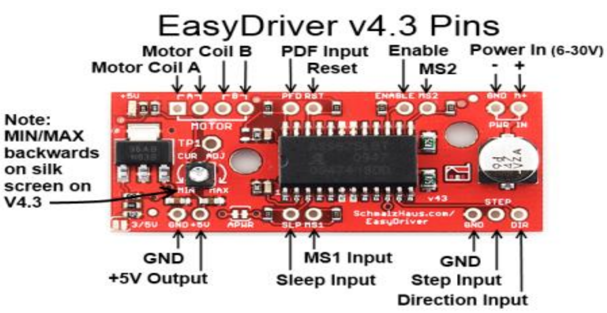

Fig. 4. Easy Driver v4.3 Pins

Laser diode system: This system is the vital component used for cutting and engraving purpose attached at the machine. It consist of three elements: (Lesser diode, leaser module housing, Adjustable constant current laser diode driver and Glass leaser lenses) -Laser Diode: its 500mw 405 nm blue Ray laser module BDR-S06J Laser Diode shown in Figure.5. Adjustable current laser diode driver: capable with up to 1000 mw output and a variable power rate rang to the laser diode which can be adjusted by pot on the driver board as shown in Figure.5, 5-10V input required to power up.

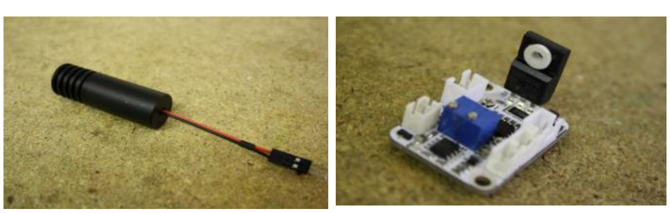

Fig. 5. Laser Diode and Adjustable current laser diode driver

C. Software development

The CNC machine uses Grbl v0.9 software which is shown in Figure.6 for motion control of the axis. Grbl converts G-code into certain commands that Easy driver stepper motor will understand. Also required another program to send the G-code to Grbl.

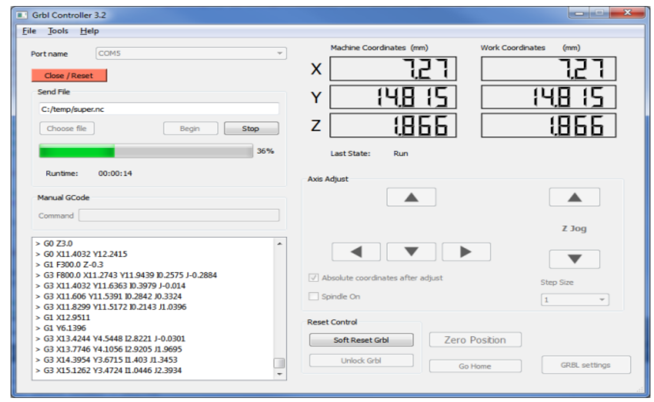

Fig. 6. The Grbl Software

In order to begin programming it's required for IDE Arduino software shown in Fig. 7.

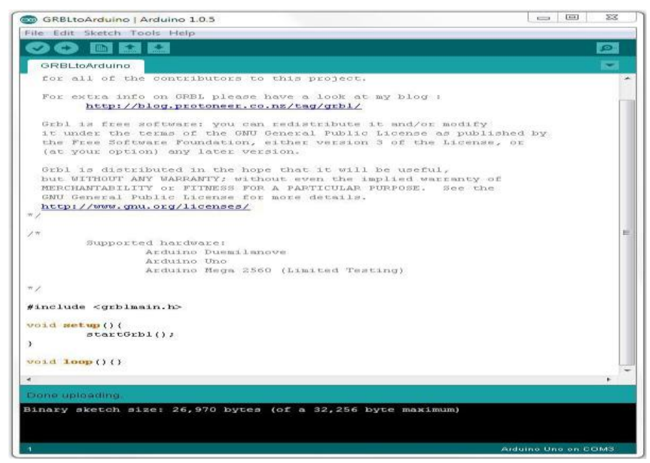

Fig. 7. IDE Arduino software

To make it easier and friendlier to generate G-code the best way is to use "Inkscape" as shown in Fig. 8 combined with laser engraver plug-in which is an open source graphical editor.

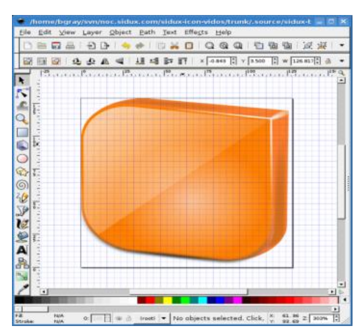

Fig. 8. Inkscape

There are three easydrivers in this project electronic cuircut each driver are connected individually to the Arduino PWM output on teriminial number 3,5,6 which according to Arduino Uno r3 datasheet and is shown in Fig. 9.

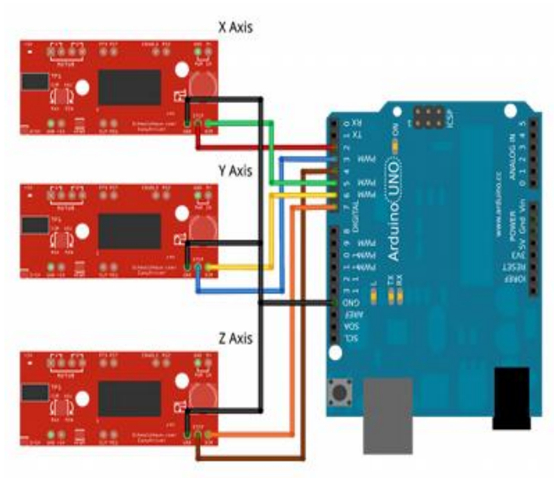

Fig. 9. Easy Driver wiring

Stepper motor that is used in X, Y and Z axis in this project uses with 4 wire connections that is each stepper motor are connecter to one easydriver respectivly as shown in Fig. 10.

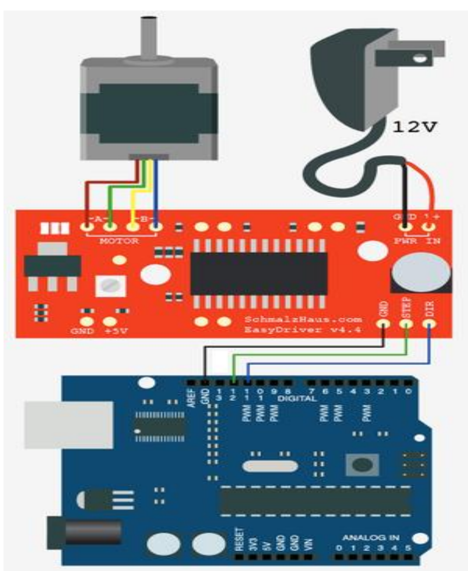

Fig. 10. Stepper Motor wiring

The wirirng of the components are reprsented in Fig. 11 and Fig. 12.

The microcontroller board is connected to PC trough USB port. Stepper motors Driver board PULSE , DIR of every board is connected to Arduino Uno r3 terminals 3,5,6 respectivly. A+,A- B+,B- of 4 wire stepper motor Drive are connected directly. Power Supply is for each componant of this cuircut are provided.

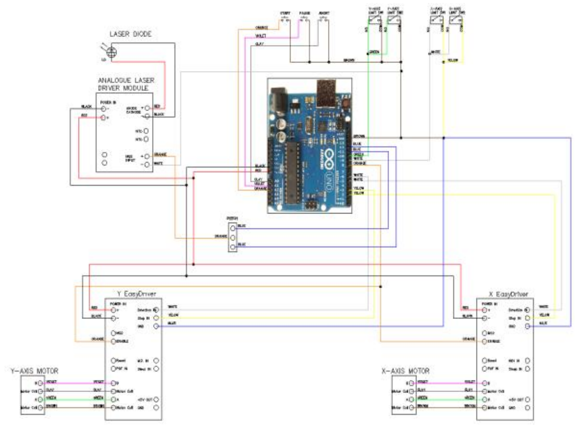

Fig. 11. Components wiring

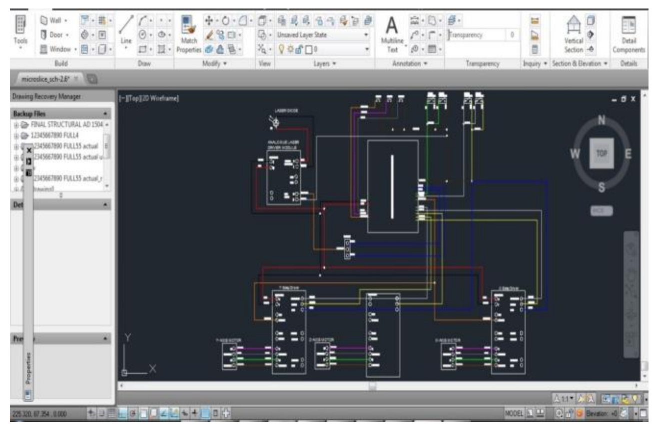

Fig. 12. Components wiring

D. CNC Structure Assembly

After gathering all required parts and accessories for assmbly, step by step procedure for making the cnc is noted below. Each step has a corresponding figures and final assembly is as shown in Fig. 13.

a) Start from lower-deck which is the base.
b) Install 4x rubber feet.
c) Assemble the upper-deck which is Y-axis base.
d) Slid 2x 4mm X 250mm bars into rear of upper deck for Y-axis
e) Assembly The Frame using 50mm brass stand offs.
f) Complition of the Frame.
g) Assemble the gantry which is X-axis support.
h) Fix 4x 4mm ID linear Bearings into the gantry
i) Assemble the gantry into the Frame.
j) Slid 2x 3mm Bars into gantry
k) Assembly the Cutting-Head Slider which is a laser mount.
l) Fix 4x 3mm ID linear bearing into the cutting-Head Slider.
m) Assembly the diod moduel mounting.

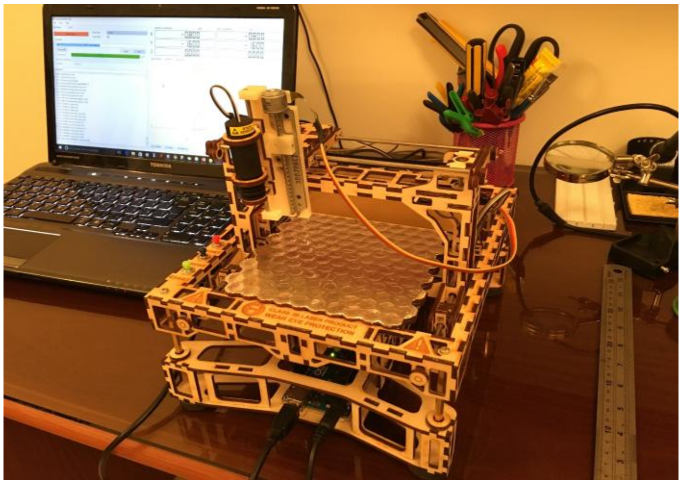

Fig. 13. Final assembly of CNC Laser Cutter

While fabrication of CNC is done, alingment of Y, X axis carried out, smoothness of working surface, and straightening up of Z axis are all correctly checked by phisically. Several issue occurred during the assembly is the screws missing and miss alingment of proper position of y-axis. This issues has perfectly covered to a proper alingment whike adding spacers at end of gantry holder.

After ensuring all parts availibilty for fixing all electronic parts together as shown in Figure.14 and Figure 15 to meet the wiring schematic requirment showen in Fig. 11 and Fig. 12. There are three axis x, y and z all are equiped with stepper motor hooked up with easydrives to direct the positions respectivly each easydrive required a power supply connected to arduino pin Vin and GND and below listed the remaining connection of easydriver:

- ENABLE pin is connect to pin ~8 (y & x-axis).
- Direction is connected to pin ~6 (y-axis) pin ~5 (x-axis).
- Step N is connected to pin ~3 (y-axis) pin ~2 (x-axis).
- GND are connected together in arduino to pin GND.
- B B+ A A+ are connected respectivly to 4 wire stepper motors.

E. CNC Structure Assembly

GRBL 0.9v:

To begain with software configuation is to setup the GRBL controller to PC that it's used to send G-code to CNC it is user friendly and free open source to Arduino to give a virtual commands to controll movment of machine using easydriver, and the interface of the GRBL software connected to Arduino. For compilation the GRBL to Arduino it's required to download a Grbl source code to be added into Arduino library folder by following the steps from GRBL website. After having grbl library setted up into Arduino IDE next is flashing the CNC.hex file Firmware to arduino using Xloader application which required to be download and open to select the COM port connected to arduino with correct baud rate for arduino uno: 115200 to uplod the .hex file.

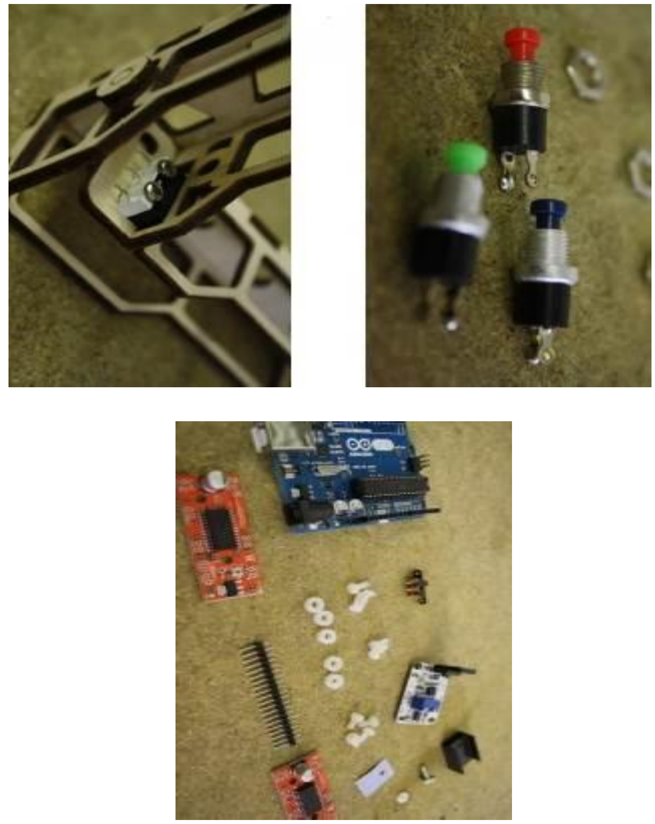

Fig. 14. Electronics parts

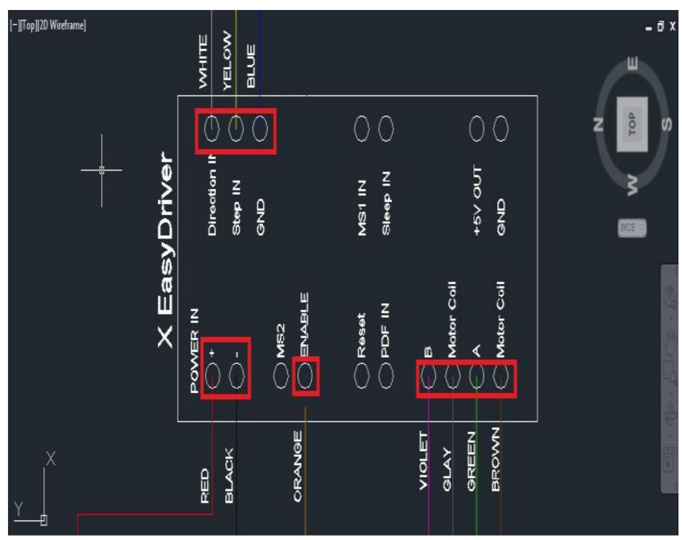

Fig. 15. Pins of Easy Driver

Configuration and testing Of GRBL:

Software configuration is required to test the system respondings for home position and switches feedback which can all be obtained in single software GRBL controller V3.0. this application is a guidance of cnc machin settings include machine axis positioning, homing cycle, feedrate, acceleration, hard limits.

The configuration settings used for this project is listed below:

$0=159.999 (x, step/mm)
$1=159.999 (y, step/mm)
$2=255.000 (z, step/mm)
$3=10 (step pulse, usec)
$4=250.000 (default feed, mm/min)
$5=500.000 (default seek, mm/min)
$6=192 (step port invert mask, int:11000000)
$7=25 (step idel delay, msec)
$8=50.000 (acceleration, mm/sec^2)
$9=0.020 (junction deviation, mm)
$10=0.100 (arc, mm/segment)
$11=25 (n-arc correction, int)
$12=3 (n-decimal, int)
$13=0 (report inches, bool)
$14=1 (auto strat, bool)
$15=0 (invert step enable, bool)
$16=1 (hard limits, bool)
$17=1 (homing cycle, bool)
$18=96 (homing dir invert mask, int:01100000)
$19=250.000 (homing feed, mm/min)
$20=250.000 (homing seek, mm/min)
$21=100 (homing debounce, msec)
$22=1.000 (homing pull-off,mmm)

Mentioned settings are corrisponding to x,y and z-axis motors which required to adjusting the easydriver current outout using GRBL controller.

Easydrivers has an adjustment potentiometer

- Point No.3 in Figure 16 is the potentiometer adjustment to turn clock-wise = less current and anti-clock-wise = higher current. In order to identify the adjusted current in stepper coil is using a multimeter to
- measure the voltag in points 1 & 2
- measur resistance in points 4 & 5

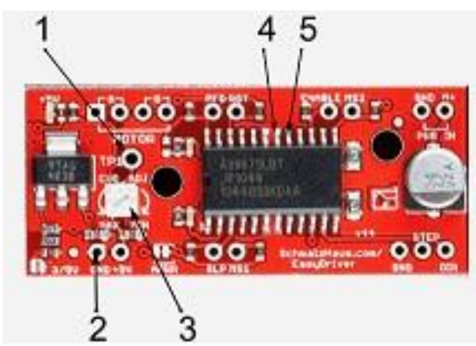

Fig. 16. Easy Driver current adjustment

Analogue Laser Driver Moduel ALDM: It is a high power laser driver is designed for laser as well as LEDs. With a powersupply built-in with protection of eddy current & polarity reversal.included with an over tempretur shutdown protection.

ALDM Configuration and Calibration for 500mW Diod

The analouge laser driver moduel is factroy configured with 200 mW Diod. In order to reconfigure the moduel to 500 mW it's required to use a multimeter to measure mA.

Step by step procedure shown in Fig. 17:

a) Using a multimeter conection in series between Anode + & Cathod GND pins. "to measure the current been supplied to the moduel from microcontroller.
b) Open GRBL controller software in command box typing : Z255 "to read the maximum power from ALDM" by default it should show 200mW
c) Refering to Laser Diod test Data to set a correct value.
d) Adjusting the potentiometer GAIN on ALMD. "to increase the power output to 500mW and multimeter should read ~310mA with making sure not to go beyond this value which may cause damaging the diod.
e) Turn the laser off using a command Z0 into Grbl controller.

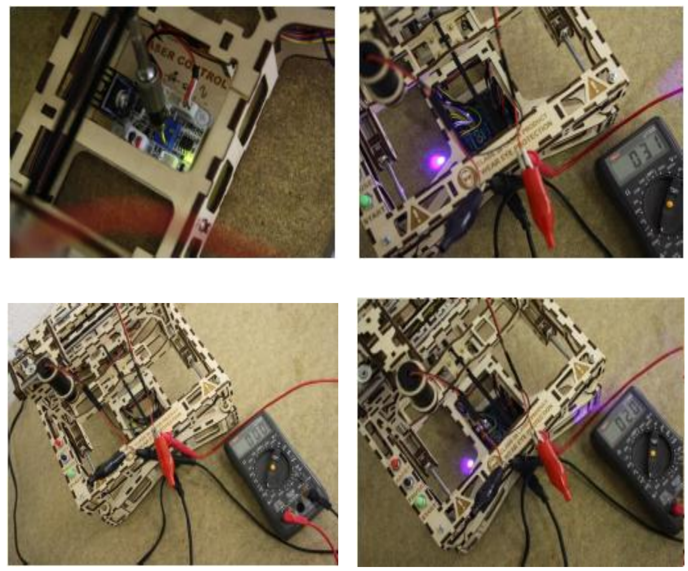

Fig. 17. Configuration of ALDM

Referring to the Figure 16 to follow an accurate adjustment for diode current output depend on the optical power/mW. In this project I have set the current of the diode is not more than 310 mA and if more the diode will be damaged and it is shown in Fig. 18.

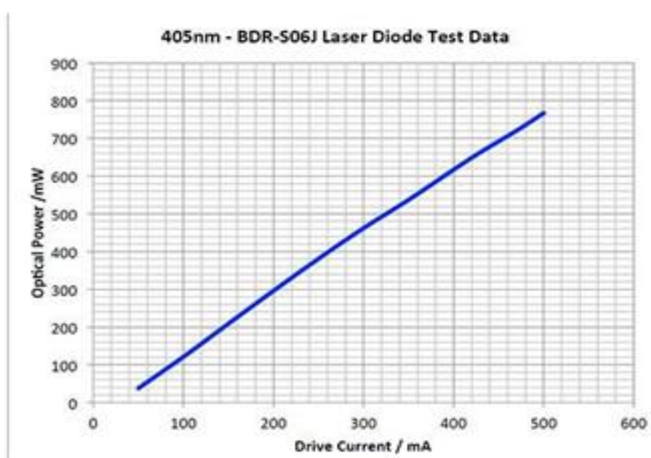

Fig. 18. Laser Diode Test Data

The final finished cutting samples are shown in Fig. 19.

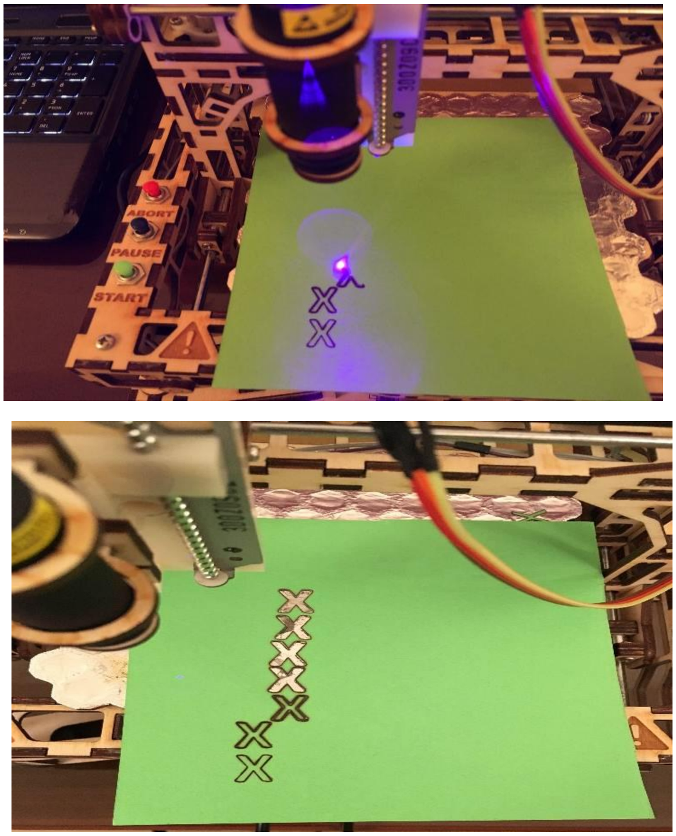

Fig. 19. Finished samples

III. RESULT AND DISCUSSION

Software results

The machine process is using a graphical user interface (GUI) e.g., “Inkscape” which is graphical software that runs into a PC for creating and desiging an image to be convert itinto G-Code .nc file which used to run the design into GRBL Controller.

Mechanical results

Being a Mechatronics engineer I have some difficulties in testing the CNC machine mechanically which it required a surface flatness test and perpindicularity test as well as the repetation accuracy of the axis movment. It is clearly to understand the accuracy of the geared stepper motor selected in this project to run the axis is by using a quick calculation in order to obtain the accurate results.

$$\frac{360\ Degree/1\ revolution}{degree/step} = \frac{360°/1}{12°/1} = 30\ \frac{Step}{Revolution}$$

The first thing is to have Step/ inch required for the stepper to move an inch which drives from a stepper motor and the driver which is the Easydriver. Typically stepper motors uses different steps per revolution as per the steping angle.

That stands for if the stepper motor turns 360° it steps 30 times.

Where ther driver is capabible increasing the number of steps, now the driver has been set to 1/16 microstepping which will equal to $30 \times 16 = 480\ steps$

To get the pich circumference =

$distance\ between\ teeth\ \times number\ of\ teeth\ = 3\ mm$

that mean in one revolution we will able to travle 3 mm so to find out how many steps it takes to travle one inch $\frac{480}{3} = 160\ mm$ which will get the thioritically number in the real world numbers.

Table 1 shows the pulley specification used in this project which the number of teeth is the core of calculation.

Table 1: Pulley specifications

Teeth profile	GT2
Teeth number	15
Bore Diameter	Ø3
Belt Width	3mm
Angle per Step	12°

Axis Acuracy and repeatability

Using a stepper as an accurate movement for CNC is is role of machining success. A machining measuring tool is used to measure how accurate is the stepper motor precision to get it to run. An experiment is held with controlling a stepper using an arduino connected with an easydriver which it has a built in parameters for dacceleration and acceleration.

Using a G-code to move the axis’s is the way what measures the repeatability and this code are impleneted through GRBL application which been compiled with arduino. In order to get into the experment the requirments are : DTI dail test indicator as shown in Fig. 20, Stpper motor, Arduino, Easydriver, GRBL application.

The results are in each repeated measurment been held is not only testing the stepper motor accuracy but it is the whole system is perfectly accurate.

In this Fig. 20 will show how was the axis’s are accurate in each repeat the X axis readings are given in Table 2 and the accuracy of the y-axis has been promissing the prcision values that in each repeat the value was fixed every time testing the values of Y-axis shown In this Fig. 21 will show how was the axis’s are accurate in each repeat the y axis readings are given in Table 3.

Table 2: x-axis repeated data

No of Rep	Values
1st repeat	0.38 inch
2nd repeat	0.38 inch
3rd repeat	0.379 inch
4th repeat	0.38 inch
5th repeat	0.38 inch

Table 3: y-axis repeated data

No of Rep	Values
1st repeat	0.3935 inch
2nd repeat	0.393 inch
3rd repeat	0.393 inch
4th repeat	0.393 inch
5th repeat	0.393 inch

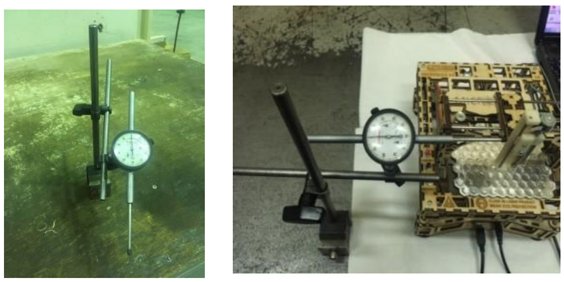

Fig. 20. Dial Indicator and x-axis experiments

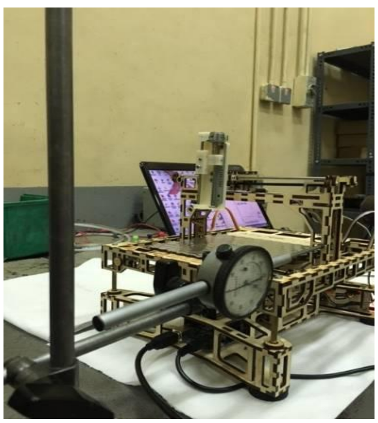

Fig. 21. y-axis experiments

The graphical representation of x-axis and y-axis experiments results are shown in Fig. 22 and Fig. 23.

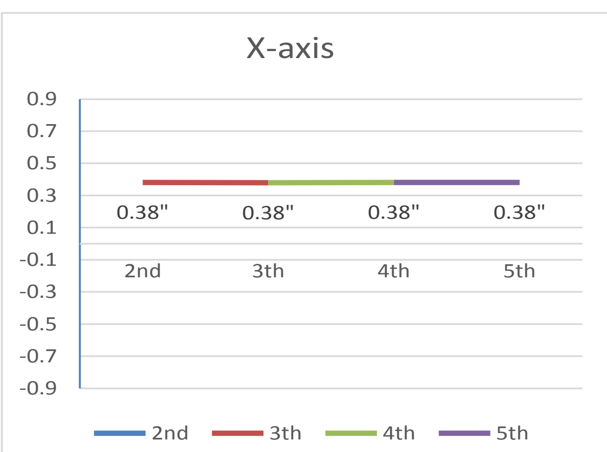

Fig. 22. x-axis repetition experiments

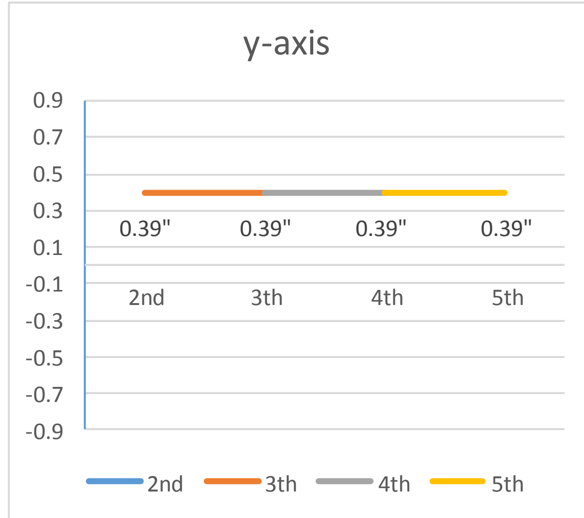

Fig. 23. y-axis repetition experiments

IV. CONCLUSION

Due to more demanded for mini scaled 3-axix CNC machine with highly accuracy parts in different industry, the retail for 3-axis mini CNC machine has noticably been increased. For fabrication small parts need to be provided both flexibilty and effeciently in the manufacture approaches and reduce total cost which is affordable for individuals and small business. Due to a success selection of a body parts and precision calibration, testing and assembling, the CNC machine has achieved the desired precision and accuracy.

In this work, a mini 3 axis cnc machine designed and fabricated with a low-priced of 150 omani rials. Throughout the structural design stage there was many common CNC structures been found and tested. The most appropriate structure is the gantry type structure was choosen and designed through a frenchiser in UK. Precarious componants such as liner guides, stepper motors, and microcontrollers and modules is precicly choosen among a huge different choises in order to feet the requirments. The best cost componants are selected to provide accuracy and simplicity and as well as budget limitation. The assembling of a mechanical parts and emerging it into an electronical componants are perfectly been considered. A model of a CNC machine is assembled inhouse using and in the lab to perform a testing cratiria of the machine componants befor assemblin it. The steps of building a wooden stucture are followed in detail from a cnc structures company has been followed to meet the accuracy while merging it into an electronic as well as mechanical parts together. The configuration and calibration steps are clearly given with all details. The complete machine functionality verified using a various of tests which flows from softwares test into a mechanically tests, the errors has been initially clarified and determaind to ensure relaibility of the machine.

In conclusion the accuracy of the mini 3-axis CNC machine body parts assembling has succeded to achieve the objectives of this project in precisionly and repeatability goal.

This work has haveliy increase a passion in future studies on the design of body structre that can holds an electrical and electronic platform with a cooling system hence in this project the tempreture of stepper motors and easydrivers in increasing after an 90 minutes of running condition while cooling would help to increase reliability of long term performance. Also in future improving the Z-axis of the machine to be able to automatically detect the thickness of the material to be engravied and replaces the laser to a rotary unit to perform a deeply engraving sketchs which will require an additional microcontroller to to perform the opration.

As well as finding a best possible solution in humen monitor interface (HMI) rether than using a PC to be mobalized is using a touchscreen from Raspberry Pi as computer. Since Raspberry Pi equiped with it's own embadded Operating system Linux, while the user can practically copy a machine code G-Code file hooked on the system using a simple USB driver which will help to stream the machine code to arduino Uno.

REFERENCES

[1] L. E. Chiang and j. Ramos, 1994. "CNC control of a laser cutting machine," 1994 IEEE International Symposium Industrial Electronics (ISIE), pp. 236-241.

[2] James Floyd Kelly, Patrick Hood-Daniel, 2009. *Build Your Own CNC Machine*. Volume 1. US: Apress L. P.

[3] Ivo Pahole, Igor Drstvensek, Mirko Ficko, 2001. *Programiranje numericno krmiljenih strojev.* Volum XXIII (ISS 1224-3264).

[4] V. V. Athani, *Stepper Motors: Fundamentals, Applications And Design*, 1st ed. Daryaganj: New AgeInternational, 1997.

[5] Ertell & Glenn G., 1969. *Numerical Control.* New York: Wiley-Interscience.

[6] Coll. Of Comput. Sci., 2010. The research of embedded CNC system component. In - *Computer Application and System Modeling (ICCASM), 2010 International Conference*. Volume 7 – 22-24 Oct. 2010. Taiyuan: Shaogan University.

[7] An Open Architecture Numerical control System Based on Windows CE", *IEEE International Conference on control and Automation*.

[8] Arduino Uno r3, 2015.Available from: http://www.arduino.cc/en/Main/ArduinoBoardUno. [25 may 2015]

[9] B. Jayachandraiah, 2014. *Fabrication of low Cost 3-axis CNC Router. [E-journal]. Volume 3 issue 6. Available from: http://www.ijesi.org. [Accessed: 30th march 2015.*

[10] Lynch,M. 2016. *mmonline*. [ONLINE] Available at: http://www.mmsonline.com/articles/key-cnc-concept-1the-fundamentals-of-cnc. [Accessed 24 May 2016].

[11] Nicloas correa. 2007. *Correa*. [ONLINE] Available at: http://www.correa.es/en/0-news-page/20-nicols-correa-sa-extends-its-presence-in-the-chinese-market-with-the-creation-of-an-industrial-subsidiary/. [Accessed 24 May 2016].

[12] Smid, P., 2007. CNC Programming Handbook. 3rd ed. washington: ISB.

Mr. Rashid Khalid Hilal Al Habsi is pursuing his Bachelor degree in Mechatronics engineering at Caledonian College of Engineering, Muscat, Sultanate of Oman. Her research interest is Mechatronic System Design and CNC Machines.

Associate Professor Dr. G. R. Rameshkumar is presently working as Senior lecturer at Caledonian College of Engineering, Muscat. He received his B.E (Mechanical) and M.Tech (PEST) degrees from Mysore University (India) in 1984 and 1995 respectively. He received his PhD degree from VIT University, Vellore, India. His research interests are in the field of Vibration Monitoring, Condition Monitoring, Mechatronics and Computer Aided Design & Manufacturing.