SVU-International Journal of Engineering Sciences and Applications (2025) 6(2): 204-211
Print ISSN 2785-9967 | Online ISSN 2735-4571
DOI 10.21608/svusrc.2025.425646.1303

CNC Machine Design and Manufacture for Laser Drawing and Engraving

Suha Hashim Ahmed[1,], Gaidaa Ibraheem Husain alsarraj[1], Ali Abdelhafeez Hassan[2]

Abstract In recent years, the integration of digital fabrication technologies has enabled the development of compact and cost-effective CNC laser engraving machines for small-scale applications. The present study aims to design and construct a two-axis CNC engraving system driven by an Arduino-based GRBL control platform. The proposed machine combines mechanical, electrical, and software components to achieve accurate and repeatable engraving on materials such as wood, leather, and linoleum. The methodology involves mechanical frame design, selection of stepper motors and linear motion systems, laser module integration, and GRBL firmware configuration for motion control. Experimental tests were carried out to evaluate engraving precision, operating stability, and cost efficiency. Experimental tests confirmed that the prototype achieves consistent engraving quality with a positional error not exceeding 0.2 mm, demonstrating its operational reliability for educational and small manufacturing environments. The system provides a low-cost and open-source alternative to conventional industrial engraving machines, promoting accessibility and innovation in digital manufacturing.

Keywords:. CNC engraving, G-code, Arduino GRBL, stepper motor, laser module, digital fabrication, low-cost design

1 Introduction

In today's manufacturing sector, Computer Numerical Control (CNC) systems have become a cornerstone of production because of their high precision, reliability, and automation features. These systems transformed traditional machining operations such as milling, cutting, and engraving by allowing direct computer control over the movement of tools and machine parts. Over the past few years, the demand for smaller and more affordable digital manufacturing solutions has encouraged many researchers and engineers to design compact, low-cost CNC machines that serve both educational goals and small-scale industrial needs [1–2]. Traditional CNC laser machines are expensive and require complex control systems, which limit their accessibility for beginners and small businesses. Therefore, there is a need to design a simplified and portable engraving system that provides acceptable accuracy and reliability without high production costs. The development of micro controllers such as the Arduino platform, combined with open-source firmware like GRBL, offers a flexible and low-cost solution for controlling multi-axis motion and executing G-code commands efficiently.

Several studies have explored low-cost CNC systems for drawing, cutting, and engraving, yet many of them face challenges in precision control, structural rigidity, and software optimization. Moreover, there is still a noticeable gap in integrating affordable hardware with reliable motion control for consistent engraving quality. This study addresses these gaps by designing and manufacturing a two-axis CNC laser engraving machine using an Arduino-based GRBL controller. The research focuses on the mechanical structure, electrical integration, and software configuration required to achieve accurate engraving on different non-metallic materials. The proposed system aims to combine functionality, cost efficiency, and simplicity of operation, making it suitable for educational environments, prototype workshops, and small creative industry [3-5].

2 Literature Review

Several researchers have explored the development of compact and affordable CNC engraving systems, aiming to balance precision, functionality, and low cost. For instance, Mahesh Raut (2019) designed a mini CNC machine for printed circuit board (PCB) drawing using Arduino control and G-code generation [1]. His work demonstrated the feasibility of using open-source software and low-cost hardware to automate simple drawing tasks. However, the design lacked adequate mechanical rigidity and precision analysis, which limited its applicability to more demanding engraving operations.

Received: 21 September 2025/ Accepted: 20 November 2025
Suha Hashim Ahmed, suabaumu@uomosul.edu.iq
Gaidaa Ibraheem H.alsarraj,ghaidaa.alsarraj2019@uomosul.edu.iq
Ali Abdelhafeez Hassan, ali.hassan@cumbria.ac.uk
1. Mechanical Engineering Department, College of Engineering, University of Mosul, Mosul, Iraq
2. University of Cumbria.

Similarly, Layth Fadhil (2018) proposed a computer-controlled schematic illustrator capable of immediate stop and restart functions. His model focused on portability and adjustable working areas, offering flexibility in different environments. Despite its practicality, the study did not include a comprehensive discussion of motion accuracy or system calibration, both of which are critical for consistent laser engraving results [6].

Aman Ismail Nsayef (2018) introduced a microcontroller-based three-axis plotter machine that simplified operation and reduced maintenance costs compared to conventional CNC machines. The design achieved good repeatability and stability, but it mainly targeted pen plotting applications rather than laser-based engraving, where thermal effects and material response require more precise control [7].

A.P. Kuldhar (2019) presented an automatic sketching machine with Arduino integration for 2D drawing tasks. Although the work successfully demonstrated coordinated motion between axes, it lacked quantitative evaluation of performance metrics such as positional accuracy, engraving depth, or repeatability [8].

From these studies, it is evident that most existing designs prioritize affordability and simplicity, often at the expense of precision and durability. Moreover, few have addressed the integration of reliable control firmware such as GRBL with suitable mechanical components to ensure both stability and engraving quality. Therefore, the current research builds upon these previous efforts by designing a two-axis CNC laser engraving system that improves structural design, control accuracy, and operational consistency, while maintaining a low overall cost suitable for small workshops and educational use.

3 Methodology

The design and construction of the proposed CNC laser engraving machine were carried out in several sequential stages that combined mechanical design, electrical integration, and software control. The main goal was to achieve a compact, stable, and low-cost system capable of performing precise engraving tasks on various non-metallic materials.

4 Hardware

4.1. Mechanical Design

4.1.1. Ball Bearing

Ball bearing is a type of winding element bearing that uses ball bearings to take care of the separation of the bearing races. The aim of a ball bearing is to minimize rotatory rub and backing radial and axial loads [9-10].

4.1.2 Lead Screw

Lead screws are threaded rods of metal and a threaded nut which is in prompt connect with the screw; this make gliding friction as opposite to rolling friction from other alternate instruments .They are used within motion control devices to transform rotary or turning movements into linear motion, Rotational movement will transmit the screw, causing the nut to shift straight in a linear motion , therefore, converts the movement from rotation to linear [11-12].

4.1.3 Linear rods (Shaft)

Linear rods are a solid, durable stainless steel shaft that is used to bear the load without affecting movement and supports linear motion [13] as shown in **Fig. 1.**

Fig. 1 shafts, screws, and ball bearings (12mm Diameter)

4.2 Electrical parts

4.2.1 Stepper motor

A stepper motor is used to check the exact situation via digital control. The motor works in exact coincidence with the pulse signal outputs from the control unit to the driver Their capability to produce increasing torque at low speeds with minimal oscillations makes them highly effective for cutting-edge short-range operations as shown in **Fig. 2**. The step circumference can range from 0.9 to 90 degrees and consists of rotor and stator. Step angle of a stepper motor is given by equation (1) [14-16]. Specification of Stepper motor (STP-43d2052-01) is shown in **Table 1**.

$$\text{step angle} = \frac{360^\circ}{\text{number of poles}} \quad (1)$$

Table 1 Specification of Stepper motor (STP-43d2052-01)

Parameter	Value	Unit
Step Angle	1.8	degree
Rated Voltage	12	V
Rated Current	1.1	A
Resistance	1.2	ohms
Holding Torque	40	N.cm
Shaft diameter	22	mm
Shaft length	39	mm
Motor Diameter	41	mm
Motor length	39	mm
Temperature Rise	80	°c

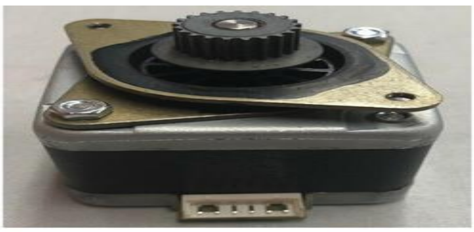

Fig. 2 Stepper motor (pulse motor)

4.2.2 Laser Module

The laser shown in **Fig. 3** extends the illumination by stimulating the release of radiation. The laser beam manufacturing process uses the thermal energy of the laser to engrave, heat and burn materials. The laser counter will include one or more laser diodes as well as some visual and electronic components that are used to power the diodes and discharge the beam. Usually all this is shaved into a sturdy container [16-17]. Specification of laser module used (5.5W laser) as shown in **Table 2**.

Fig. 3 5.5W 450nm laser module

Table 2 Specification of laser module

Parameter	Value	Unit
Working Voltage	12	V
Electrical Power	20	W
Optical Power	5	W
Wave length	450	nm
Engraveing distance	3-5	Cm

4.2.3 Arduino nano

Arduino nano is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button - and turn it into an output - activating a motor, turning on an LED [18].

4.2.4 GRBL Board

The Board chosen for research is "3 Axis GRBL Control Board" as shown in **Fig. 4.** This board is used because of these features:

- Use Atmel 328P (Arduino nano).
- Support XYZ axis, double Y-axis.
- Support XYZ limit switch
- Support 2pin/3pin/4pin laser (all the types of laser in Market).
- Use 5.5mm*2.5mm DC Power Interface.
- Connect by USB Mini B.
- Input voltage: 7-36V.
- Prop pulse motor: 12V, ultimate stream of 2A or minim is within 1.5A.
- Support stepper motor driver (A4988) and (8825)
- Can work of Offline controller.
- Support Bluetooth
- Stepping subdivision
- Support connects servo(writing)
- Support voltage: 0-48v (300W/400W/500w spindle).

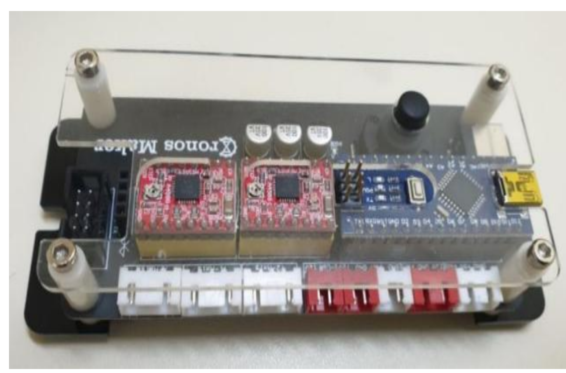

Fig. 4 GRBL board

4.3.5 Power Supply

For electrical equipment to be stable and effective, the power supply unit is essential. It is in charge of controlling the input voltage, shielding the gadget from power spikes, and delivering a steady output to avoid variations that can damage delicate parts [19-21]. To improve safety and dependability, advanced power supply units frequently include features like thermal regulation, short-circuit prevention, and overcurrent protection. These units are made to be small and energy-efficient for use in contemporary applications, which lowers heat production and energy loss while in use. Rectification and filtering procedures are used to convert alternating current (AC) to direct current (DC), guaranteeing a steady and smooth output. Power supply units are built to handle a range of input voltages. They must deliver a precise 12V DC output for devices as shown in **Fig. 5** that require it to operate at their best. This is particularly important in systems where even small voltage variations can cause faults or decreased performance. Because they directly affect the accuracy and endurance of the machinery, high-quality power supply units are essential to the dependable functioning of CNC machines, laser engravers, and other precision devices [22].

Fig. 5 Power supply (12V and 8.5 A)

5 The Software

GRBL is a widely-used open-source firmware specifically developed for controlling CNC machines via microcontroller platforms like the Arduino Uno [19-20]. Its primary function is to process G-code commands—a standardized language used to direct the precise movements of stepper motors enabling CNC machines to carry out tasks such as cutting, engraving, and milling with remarkable accuracy. When installed on an Arduino board, GRBL serves as an intermediary between G-code instructions produced by CAD / CAM (Computer - Aided Design/Computer - Aided Manufacturing) software and the CNC machine's hardware [21].

The core functionalities of GRBL include:

1- Command Interpretation: It processes G-code inputs that dictate motion, speed, and acceleration.

2- Motion Planning: GRBL calculates the movement paths for the X, Y, and Z axes, ensuring precision and efficiency.

3- Motor Control: It generates control signals for stepper motors, regulating their motion and positioning accurately.

Interaction Between GRBL and CNC Machines [24-26]: When G-code is transmitted to GRBL, it transforms these commands into motor control signals. The typical commands involve:

1- Axis Movement Commands (e.g., G0, G1): Define the motion of the machine along the X, Y, and Z axes.

2- Speed Settings (F): Specify the movement speed of the axes.

3- Tool Commands: Instruct tool changes or position adjustments.

GRBL's integration with Arduino allows users to tailor its settings to suit different CNC systems [22-29], including laser engravers, milling machines, and 3D printers. This adaptability makes GRBL an excellent choice for makers, small-scale businesses, and DIY enthusiasts [30-31]. Steps to convert the drawing to the program laser GRBL are shown in **Fig. 6**.

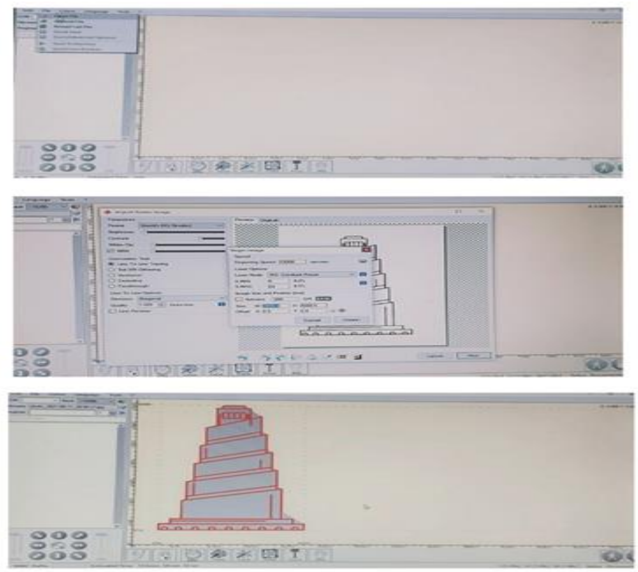

Fig. 6 Steps to convert the drawing to the program laser GRBL

6 Assembly and Building

The machine shown in **Fig. 7** consists of several components that are assembled to form the final configuration. The actual shape of the device from the front and back is shown in **Fig. 8**.

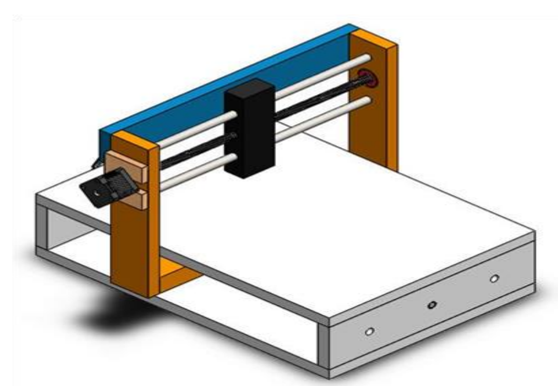

Fig. 7 The frame of machine draws in AUTOCAD program

Fig. 8 The actual shape of the device from the front and back

7 Results

(Laser Engraving Steps)

A[Start] --> B[Prepare Design File (e.g., rose, logo)]
B --> C[Convert Design to G-code (using CAM software)]
C --> D[Load G-code to GRBL Board via Arduino]
D --> E[Calibrate Axes (X, Y) and Stepper Motors]
E --> F[Set Laser Power and Speed]
F --> G[Start Engraving Process]
G --> H[Monitor Engraving for Accuracy]
H --> I[End Process / Turn Off Machine].

CNC Laser Engraving Process shown in **Fig. 9**.

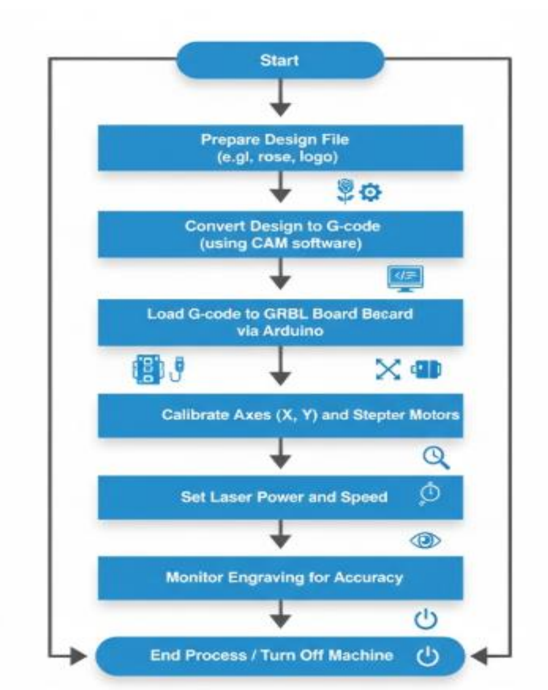

Fig. 9 CNC Laser Engraving Process

A hardware and software component device, as it connects the mechanical parts to the electronic parts to be engraved. A pulse motor is installed on the X-axis and another on the Y-axis, both connected to the Arduino board via wires. Each motor moves 1.8° per step. The laser is powered with 12V through the Arduino and controlled using an A4988 driver. A dedicated power supply is required, equipped with a shutdown switch and a key for locking and unlocking. The program sends commands to the motors, enabling linear movement. The laser moves along the shaft and bearings to draw the desired shape [32-35].

1-The Malwiya shown in **Fig. 10** was engraved on a wooden model using the GRBL software , completing the task in two hours. The laser intensity was set to 60, with engraving dimensions of 4000 in height and 4000 in width. The settings included a resolution of 1 line per millimetre and an engraving speed of 1000 mm/min. The engraving process utilized a 450 nm wavelength laser with a power output of 5.5W, ensuring precise detailing. The GRBL software optimized the movement paths for the X and Y axes, maintaining consistent accuracy throughout the engraving. This setup allowed for smooth operation and high-quality results, showcasing the machine's capability to handle intricate designs efficiently [32-35].

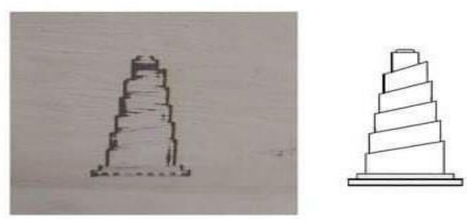

Fig. 10 The Malwiya engraved on wood

2- The rose design shown in **Fig. 11** was engraved on wood using GRBL software, completing the process in approximately 6 hours. The engraving dimensions were 3530 mm in height and 4000 mm in width. Key settings included a laser intensity of 70, a resolution of 1 line per millimeter, and an engraving speed of 2000 mm/min. GRBL software precisely optimized the movement paths for the X and Y axes, ensuring consistent accuracy throughout the operation. The laser was finely adjusted to a suitable wavelength and intensity, providing detailed and sharp engraving results. Despite the large dimensions and intricate design, the process was executed smoothly and efficiently. The final result showcased exceptional detail and precision, with a clean and flawless surface. This highlights the machine's ability to handle complex and large-scale designs effectively while maintaining high-quality output [32-35].

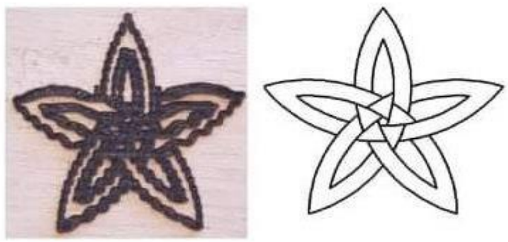

Fig. 11 The rose engraved on wood

3- The gear design shown in **Fig. 12** was engraved on linoleum using GRBL software, completing the task in 3 hours. The engraving dimensions were 4000 mm in height and 2250 mm in width. The process utilized a laser intensity of 70, with a resolution of 1 line per millimeter and an engraving speed of 1000 mm/min. The GRBL software effectively managed the movement paths of the X and Y axes, ensuring consistent precision and smooth operation throughout the process. The laser settings were optimized to deliver detailed and accurate engraving, accommodating the large dimensions and maintaining high-quality output. The results demonstrated the system's capability to handle precise and intricate designs on linoleum, showcasing the efficiency and reliability of the GRBL-controlled setup. This highlights the suitability of the machine for large-scale and high-detail engraving tasks [32-35].

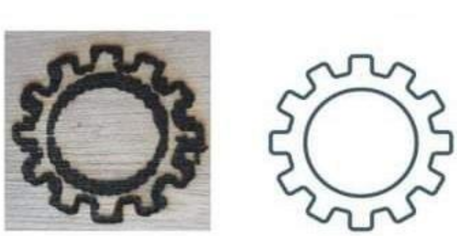

Fig. 12 The gear engraved on linoleum.

- The tiger design shown in **Fig. 13** was engraved on wood using GRBL software, completing the task with precision and efficiency. The engraving dimensions were 4000 mm in height and 3,867 mm in width, utilizing a laser intensity of 70. The settings included a resolution of 1 line per millimeter and an engraving speed of 2,000 mm/min. GRBL software ensured precise control over the X and Y axis movements, enabling accurate path optimization and maintaining consistent quality throughout the process. The laser settings were optimized to achieve sharp and detailed engraving, even at such large dimensions. The result highlighted the system's ability to handle complex designs with high accuracy, demonstrating the suitability of the GRBL setup for intricate and large-scale engraving tasks on wood [32-35].

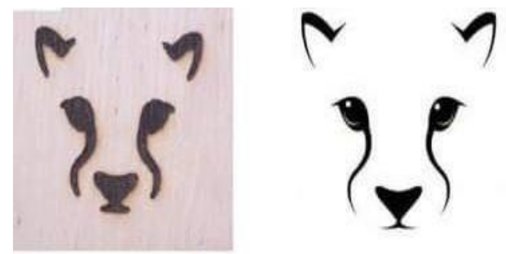

Fig. 13 The tiger engraved on wood

8 Conclusions

This study presented the design, construction, and testing of a low-cost, two-axis CNC laser engraving machine. The main findings and contributions of this work can be summarized as follows:

1- **Design and Manufacturing**: The CNC machine was successfully designed using a combination of mechanical and electrical components, including stepper motors, guideways, and a 20W laser module. The design process ensured compactness and stability, allowing precise motion control along the X and Y axes.

2- **Experimental Results**: The machine demonstrated reliable engraving performance on materials such as wood and linoleum. Quantitative observations indicated that the positioning error remained within ±0.2 mm over repeated tests, confirming the accuracy and repeatability of the system.

3- **Software Integration:** GRBL firmware was used to control the machine, and the Arduino-based system allowed smooth execution of G-code commands. Parameter tuning ensured consistent speed and laser intensity, achieving clear and detailed engraving patterns.

4- **Contribution and Novelty:** Compared to existing low-cost CNC systems, this study offers a compact and portable solution with simplified assembly and accessible software integration, making it suitable for small workshops and educational purposes.

5- **Future Work:** Potential improvements include implementing a higher power laser for broader material compatibility, adding a Z-axis for 3D engraving capabilities, and integrating automated calibration methods to further enhance accuracy and usability.

In conclusion, the developed CNC laser engraving machine provides a practical, affordable, and precise solution for small-scale engraving tasks. The study contributes to accessible digital fabrication by demonstrating a reproducible and modifiable design suitable for research, education, and small business applications.

References

[1] M. Raut, “Automatic mini CNC machine for PCB drawing using Arduino,” *Int. Res. J. Eng. Technol. (IRJET)*, vol. 6, no. 6, Jun. 2019.

[2] S. V. Deshpande, P. U. Karthik, N. K. D, V. Kumar, and K. S. Badrinaryan, "Design and fabrication of 3-axis CNC milling machine," *Int. J. Eng. Res. Gen. Sci.*, vol. 6, no. 4, 2018.

[3] A. Kumar, V. Prasath, B. Jambu, and M. F. Julia, "Operating CNC & laser machine everywhere using IOT," *Int. J. Trend Sci. Res. Dev. (IJTSRD)*, 2020.

[4] T. K. Patil and A. Kumar, "Optimization of manufacturing processes using modern automated CNC," *Int. J. Recent Technol. Mech. Electr. Eng. (IJRMEE)*, vol. 6, no. 11, Nov. 2019.

[5] A. Khan, “Design and fabrication of 3-axis computer numerical control (CNC) milling machine,” *IJCRT*, vol. 6, no. 2, Apr. 2018.

[6] L. Fadhil, “Implementation and manufacturing of a 3-axes plotter machine by Arduino and CNC shield,” in *Proc. Int. Conf. Eng. Technol. Appl. (ICETA)*, Al-Najaf, Iraq, 2018.

[7] A. I. Nsayef, “Microcontroller – based plotter machine,” *Al-Nahrain J. Eng. Sci. (NJES)*, vol. 21, no. 3, pp. 350–355, 2018.

[8] A. P. Kuldhar, “Arduino based automatic sketching machine,” *Int. Res. J. Eng. Technol. (IRJET)*, Feb. 2019.

[9] K. Rajaram, M. Khamkar, V. S. Gavali, T. D. Kadu, and A. S. Desai, “CD-ROM CNC plotter,” 2016.

[10] N. Chan, T. Z. Oo, and A. M. S. Hlaing, “Design and structural analysis of 3 axis CNC milling machine table,” *Int. J. Trend Sci. Res. Dev. (IJTSRD)*, vol. 3, no. 6, Oct. 2019.

[11] M. Pal, P. Behera, R. Chauhan, D. Sahu, and K. Dash, “Design and fabrication of laser engraving machine,” *Int. Res. J. Mod. Eng. Technol. Sci.*, vol. 5, no. 7, Jul. 2023.

[12] A. S. Putri, F. Firdaus, and A. H. Nasution, "Design and implementation of a mini CNC laser engraving machine using GRBL and Arduino," *J. Robot. Control (JRC)*, vol. 2, no. 5, pp. 384–389, 2021.

[13] K. Agalianos, S. Patelis, P. Kyratsis, E. Maravelakis, E. Vasarmidis, and A. Antoniadis, “Industrial applications of laser engraving: Influence of the process parameters on machined surface quality,” *World Acad. Sci., Eng. Technol.*, vol. 59, pp. 1242–1245, 2011.

[14] R. Ginting, S. Hadiyoso, and S. Aulia, “Implementation 3-axis cnc router for small scale industry,” *Int. J. Appl. Eng. Res.*, vol. 12, no. 17, pp. 6553–6558, 2017.

[15] J. Persad and S. Rocke, “A survey of 3D printing technologies as applied to printed electronics,” *IEEE Access*, vol. 10, 2022. [Online]. Available: https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=6287639. Accessed: Sep. 28, 2024.

[16] K. Prashant *et al.*, “Design and fabrication of laser engraving machine,” *Int. J. Sci. Res. Sci., Eng. Technol. (IJSRSET)*, vol. 7, no. 3, 2020.

[17] S. M. B. Ramadan, A. O. Houssein, and M. E. M. Abid, "Analysis and design of engraving machine movement," *Int. J. Eng. Inf. Technol.*, vol. 4, no. 1, 2024, doi: 10.36602/ijeit.v4i1.385.

[18] T. G. Rao, "Design and fabrication of laser engraving machine," *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 13, no. 6, pp. 966–972, 2025.

[19] J. T. Beng, "Development of a training model on the use of laser engraving machines," *TEM J.*, vol. 14, 2025.

[20] H. Attar, A. S. Al-Shammari, and M. A. Alhazmi, “Control system development and implementation of a small-sized CNC portative laser engraver,” *J. Electr. Comput. Eng.*, vol. 2022, Art. no. 9140156, 2022.

[21] T. Thaweskulchai *et al.*, “A low-cost 3-in-1 3D printer as a tool for the fabrication ...,” *Mater.*, 2021.

[22] A. Tariq, T. Islam, M. J. Javed, and M. H. Sayyad, “Design and characterization of a 3D-printer-based diode laser engraver,” in *Proc. Second iScience Int. Conf.*, 2021, pp. 1–6.

[23] J. A. Kumar, W. Dsouza, and R. Kumar, “Design of CNC machine based laser engraver with Arduino UNO,” *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 10, no. 8, pp. 569–573, 2022.

[24] A. H. Al-Dhaher, M. A. Al-Badr, and M. W. Al-Tameemi, "Design and implementation of a low-cost CNC machine for engraving and drawing applications," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 928, no. 3, p. 032064, 2020.

[25] T. G. Rao, N. Naveen, Y. P. Kumar, K. J. S. C. Bose, and G. Gopalakrishna, “Design and fabrication of laser engraving machine,” *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 10, no. 8, pp. 569–573, 2022.

[26] R. U. Ahmed, M. N. Yasmin, A. Das, and S. M. Ahmad, “Design and fabrication of a low-cost customizable modern CNC laser cutter,” *Lect. Notes Inst. Comput. Sci., Soc. Inform. Telecommun. Eng.*, vol. 396, pp. 1–6, Jun. 2023.

[27] A. Pajaziti, N. Berisha, A. Lajqi, and L. Berisha, “Optimization of toolpath planning and CNC machine performance using hybrid algorithms,” *Machines*, vol. 13, no. 1, pp. 65–77, Jan. 2025, doi: 10.3390/machines13010065.

[28] V. Ráczi, B. Mikó, and Z. Tóth, “Laser engraving on a CNC milling machine,” Óbuda University, Budapest, Hungary, Aug. 6, 2025.

[29] J. Liao, C. Lu, C. Xiong, B. Qian, and X. Yang, “Multi-functional integrated 3D printer,” *SSRG Int. J. Mech. Eng.*, vol. 10, no. 5, pp. 8–10, May 2023.

[30] A. Durna, J. Fries, L. Hrabovsky, A. Sliva, and J. Zarnovsky, “Research and development of laser engraving and material cutting machine from 3D printer,” *Manuf. Syst. Prod. Eng.*, vol. 28, no. 1, pp. 47–52, Mar. 2020.

[31] S. Kannaki, S. Sooraj, and R. Vijeth, "Fabrication of multi-purpose 3D printer (3D printer, CNC & laser engraving)," in *Proc. 7th Int. Conf. Civ. Eng. Sustain. Dev. (ICCESD24)*, Jan. 2025.

[32] V. Attari, M. U. Ghori, and A. Shaikh, "Development of a low-cost open-source 3-axis CNC machine," in *Proc. Int. Conf. Innov. Eng. Manag. (ICIEM)*, 2021.

[33] S. Luhar, I. Luhar, and K. Patel, "Design and development of a low-cost 3-in-1 machine (3D printing, CNC milling, and laser engraving)," in *AIP Conf. Proc.*, 2020, vol. 2200, no. 1, p. 020063.

[34] U. C. Das, M. N. Yasmin, A. Das, and S. M. Ahmad, “Development of an automatic CNC machine with versatile control using Arduino,” *Procedia Comput. Sci.*, vol. 240, pp. 321–330, 2024, doi: 10.1016/j.procs.2024.03.045.