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Development of Rotary Fixture on Laser Engraver Machine

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Rachmad Hartono[a, *], Farhan Ali Husaini[a]
[a]Program Studi Teknik Mesin, Fakultas Teknik, Universitas Pasundan
Bandung 40264, Indonesia

[*]E-mail: rachmad_hartono@unpas.ac.id

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Abstract

In the Mechanical Engineering Laboratory at Pasundan University, a laser engraver is available for performing the gravir process on flat surfaces. The laser engraver has the disadvantage of not being able to do the gravir process on cylindrical workpieces. To overcome this weakness, a workpiece holder designed explicitly for cylindrical workpieces is needed. The purpose of this research is to improve the laser engraving machine's ability, so a rotary fixture model is manufactured on the laser engraver. The rotary fixture is directly connected to a stepper motor. The stepper motor is controlled by the axis controller on the laser engraving machine. The rotary fixture has been successfully manufactured and tested. The letter gravir process on a cylindrical gravir surface, with a workpiece Ø66 mm and 6 mm thick, requires a power modulation of 250 and an engraving speed of 200 mm/min. It produces gravir with a letter width of 16 mm, a letter height of 5.50 mm, and a spacing distance of 9.50 mm, stated with ideal results. In general, the rotary fixture has been successfully developed and improves the performance of the laser engraver machine for the gravir process on cylindrical workpieces. From the test results, it can be concluded that the rotary fixture mechanical system can be operated to gravir letters, names, and batik motifs. With the rotary fixture, it is hoped that craftsmen can increase creativity in carrying out the gravir process using a laser engraver.

Keywords: Laser Engraver, Performance Enhancement, Rotary Fixture

Abstrak

Di Lababoratorium Teknik Mesin Universitas Pasundan terdapat mesin laser engraver yang mampu melakukan proses gravir pada material yang mempunyai permukaan rata. Laser engraver tersebut mempunyai kelemahan tidak mampu melakukan proses gravir pada benda kerja yang berbentuk silindris. Untuk mengatasi kelemahan tersebut perlu dibuat alat bantu pemegang benda kerja yang khusus untuk memegang benda kerja silindris. Tujuan penelitian iniadalah untuk meningkatkan kemampuan mesin laser engraver, maka dibuatlah model rotary fixture pada mesin laser engraver. Rotary fixture dihubungkan langsung dengan motor stepper.Motor stepper dikendalikan oleh pengendali sumbu yang ada pada mesin laser engraver. Rotary fixture telah berhasil dibuat dan telah mengalami proses pengujian. Proses gravir huruf yang dihasilkan pada permukaan silindris gravir dengan dimensi benda kerja Ø70 mm dengan tebal benda kerja 6 mm memerlukan power modulation 250 dan engraver speed 200 mm/min dan menghasilkan gravir dengan lebar huruf 5 mm, tinggi huruf 30mm dan jarak spasi 9,50 mm dinyatakan dengan hasil yang ideal. Secara umum rotary fixture telah berhasil dibuat dan meningkatkan kinerja mesin laser engraver dapat melakukan proses gravir pada benda kerja berbentuk silindris. Dari hasil pengujian dapat disimpulkan bahwa sistem mekanik rotary fixture dapat dioperasikan melakukan gravir huruf, nama, motif batik dan foto. Dengan adanya rotary fixture tersebut diharapkan pengrajin dapat meningkatkan kreatifitas dalam melakukan proses gravir menggunakan laser engraver.

Kata kunci: *laser engraver*, peningkatan kinerja, *rotary fixture.*

INTRODUCTION

Here, the tourism industry is underdeveloped, despite Indonesia having many tourist destinations that attract both local and international visitors. Tourists often purchase souvenirs or unique mementos from the regions they visit, making it essential to produce these items in a way that is both easy and affordable. One such souvenir product is wood engraving crafts [1].

Currently, wood engraving is either manual or automated. Manual engraving uses a tool similar to a soldering iron, which is manually applied to the workpiece surface to create images or text. This process requires specialized skills and, while the tools are easy to obtain and inexpensive, it is time-consuming, and the results may vary in consistency, with a rougher texture compared to those created by automatic laser engravers.

The limitations of manual engraving have led to the development of automatic engraving machines, such as laser engravers, which are widely used in industries for making company logos, numerical patterns, cutting, embossing, stamping, and engraving [2].

At the Mechanical Engineering Laboratory of Pasundan University, there is a laser engraver machine. Its working principle is similar to that of a regular printer, but instead of ink, it uses laser combustion to create images or text by burning the material's surface. This process does not require a craftsman with special skills. However, the current laser engraver at the laboratory cannot engrave on cylindrical objects. Therefore, a rotary fixture is needed to rotate the workpiece during the engraving process.

This research focuses on the design and development of a rotary fixture for a laser engraver. The rotary fixture serves as a holding aid on the laser engraver, rotating cylindrical materials (particularly hollow ones) during the engraving process. The control for the rotary fixture is derived from one of the laser engraver's axes, with all axes controlled by Laser GRBL software. (last five years).

MATERIAL AND METHODS

Research Stages

The stages of designing and manufacturing the rotary fixture for the laser engraver are illustrated through a flowchart. The flowchart for the design and manufacturing stages of the rotary fixture for the laser engraver is shown in Figure 1.

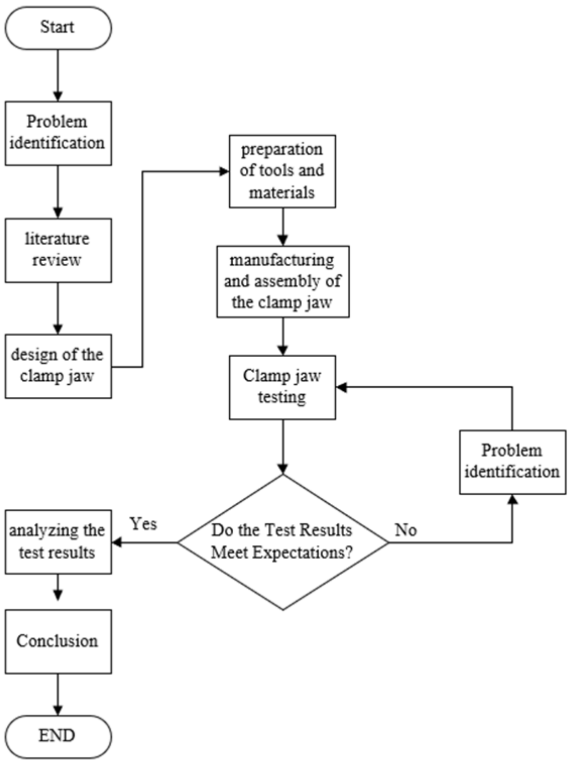

Figure 1. Flowchart of the Research Process

Problem identification is a part of the research process that can be understood as an effort to define the problem and make that definition more measurable as the starting point of the research. A literature review is the process of examining relevant studies related to the issue being investigated. This may involve reviewing established theories, analyzing personal or others' research findings, scientific journals, seminar results, discussions, field surveys, scientific magazines, library studies, including reputable internet sites, and consulting statements from

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authoritative figures in the relevant field based on the expertise derived from the research itself. The design of the clamp jaw involves developing a mechanical system to meet specific needs. Clamp-jaw testing is the process of verifying that the mechanical system meets the desired specifications. Some general steps in clamp jaw testing include visual inspection, functional testing, static testing, dynamic testing, performance testing, and final testing. After testing is completed, the next step is to analyze the test results. Some general steps in interpreting test results include reviewing, evaluating, identifying errors, and making corrections or modifications. The analysis of test results is the process of analyzing data obtained from testing or experiments to draw conclusions or make decisions. The conclusion represents the outcome of the tests conducted [3].

Mechanical System Design of the Rotary Fixture

Creating the rotary fixture design aims to determine the shape of the product or the construction of the rotary fixture that will be made. The rotary fixture design process consists of designing the clamp jaws and the bracket. The rotary fixture design is shown in Figure 2. The rotary fixture component illustrated in Figure 2 represents a compact rotary actuation assembly consisting of a stepper motor, a mounting bracket, and a rotary jaw mechanism. This assembly is designed to convert electrical control signals into precise rotational motion, which is subsequently utilised for mechanical gripping or positioning applications. The stepper motor functions as the primary actuator of the rotary system. It provides controlled and incremental rotational movement, allowing accurate angular positioning. The motor housing is typically manufactured from steel, ensuring durability and effective heat dissipation during operation. The mounting bracket, fixed to the motor body, serves as a structural support that ensures stable installation and alignment of the rotary assembly. This bracket is designed to minimise vibration and mechanical misalignment during motor operation, thereby enhancing the overall reliability of the system. The rotary jaw mechanism, shown in red, is directly coupled to the motor shaft. This component is responsible for transmitting rotational motion from the motor to the gripping or clamping mechanism. Its geometry is designed to ensure effective torque transfer while maintaining smooth rotational behaviour. The use of polymer-based materials, such as ABS plastic, reduces overall weight and facilitates manufacturing without compromising functional performance. The rotary component integrates actuation, support, and motion transmission into a single unit. This configuration enables precise rotational control, compact system integration, and reliable mechanical performance, making it suitable for automation, robotic gripping, and positioning applications.

The components to be used are listed in Table 1. The construction components listed in Table 1 represent the main mechanical and electromechanical elements used in the proposed system. Each component is specified in terms of material selection, dimensional characteristics, thickness, and quantity, which collectively determine the structural integrity and functional performance of the device. The bracket is manufactured from ABS plastic and serves as the primary supporting structure. With dimensions of 100 × 60 × 100 mm and a thickness of 10 mm, this component is designed to provide sufficient rigidity while maintaining lightweight characteristics. The use of ABS plastic contributes to ease of fabrication and resistance to mechanical stress. The main jawboring component, also made from ABS plastic, functions as the central housing for the jaw mechanism. It has dimensions of 70 × 70 mm and a thickness of 10 mm. This component is designed to ensure proper alignment and stability of the jaws during operation. The jaw components are fabricated from steel to ensure high strength and wear resistance. Three identical jaws are employed, each with dimensions of 70 × 10 mm and a thickness of 10 mm. The use of steel enables the jaws to withstand gripping forces and repetitive mechanical loading. The jawboring spiral, constructed from ABS plastic, is designed to convert rotational motion into linear movement for jaw actuation. This component has dimensions of 70 × 70 mm and a thickness of 10 mm, allowing smooth interaction with the jaw elements while reducing overall system weight. The snap ring component, also made from ABS plastic, acts as a locking or retaining element within the assembly. It has dimensions of 20 × 20 × 40 mm and a thickness of 20 mm, ensuring secure positioning of moving parts during operation. The stepper motor, manufactured from steel, serves as the primary actuator of the system. Withdimensions of 56 × 56 mm and a thickness of 1 mm, this motor provides precise rotational control required for accurate jaw movement and positioning. The combination of ABS plastic and steel materials reflects a balanced design approach, optimising structural strength, manufacturability, and operational efficiency of the system. The

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preparation of tools and materials is a crucial stage in carrying out various types of work, including the design of the clamp jaw. During the preparation of tools and materials, it is essential to ensure that all used tools and materials meet the required safety and design process quality standards. The manufacturing and assembly of the clamp jaw involve the precise and accurate installation and integration of mechanical components according to the previously developed mechanical system design.

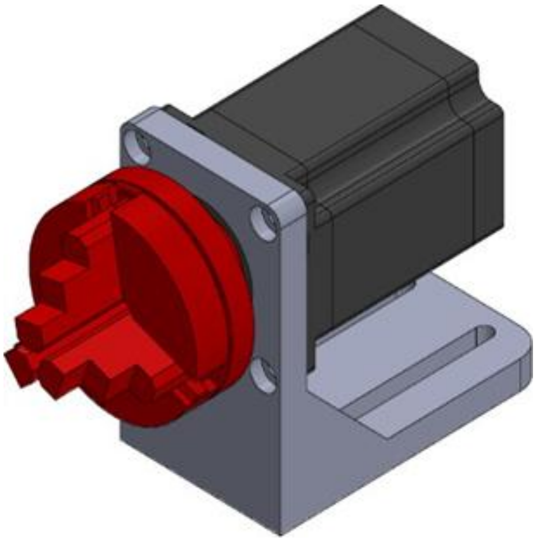
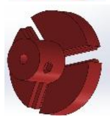
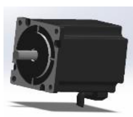


Figure 2. Rotary Fixture Design

Table 1. Components to be Used in the Rotary Fixture

No	Construction Component	Design	Spesification	Total
1	Bracket		Material: Plastik ABS Dimension:100x60x100 mm Thickness: 10 mm	1
2	Main Jawboring		Material: Plastik ABS Dimension: 70x70 mm Thickness: 10 mm	1
3	Jaw		Material: Steel Dimension: 70x10mm Thickness: 10 mm	3
4	Jawboring Spiral		Material: Plastik ABS Dimensi: 70x70 mm Thickness: 10 mm	1
5	Snapring		Material: Plastik ABS Dimensi: 20x20x40 mm Thickness: 20mm	1
6	Stepper Motor		Material: Steel Dimensi: 56x56 mm Thickness: 1 mm	1

RESULTS AND DISCUSSIONS

Engraving Test of a Square on a Wooden Cylinder

Engraving Test of a Square on a Wooden Cylinder. This test aims to determine the relationship between the Y-axis calibration factor and the workpiece diameter. The test is intended to determine the number of steps required by the stepper motor for both the X-axis and Y-axis for every 1 mm of length. This test is conducted to ensure that the device created functions properly and to identify any advantages or limitations in the rotary fixture's movement. The rotary fixture's control is derived from the Y-axis control, which was previously linear and has been converted to rotary motion. The test is performed by determining the calibration factor and then comparing the engraving results with the planned design. The testing steps are as follows: a) Prepare the laser engraver machine, b) Prepare the rotary fixture, c) Prepare the Laser GRBL software and control system, d) Connect the motor to the control system derived from one of the axes on the laser engraver machine, e) Operate the motor on each axis of the laser engraver machine and connect one axis of the motor to the rotary fixture, and f) Observe, and the test is completed.

Table 2. Calibration Factor of Wood Diameter to Y-Axis

Wood Diameter	Y-axis step
10	40000
20	25000
25	20000
30	13000
40	10000
70	5500

The engraving test of a 2x2 cm square is performed to assess the rotary fixture's movement and determine whether it functions correctly. This test is repeated several times with the stepper motor set to 30,000 steps on the X-axis and the Y-axis adjusted according to the diameter of the wooden cylinder. The calibration factor for the wood diameter relative to the Y-axis is shown in Table 2.

Table 2 presents the calibration factor values that define the relationship between wood diameter and the number of stepper motor steps required along the Y-axis. These values are not experimental outcomes, but predefined calibration factors used to adjust the motion control system in accordance with variations in workpiece diameter. For a wood diameter of 10 mm, a calibration factor of 40,000 steps is applied, representing the highest correction value required by the control system. As the wood diameter increases to 20 mm and 25 mm, the calibration factors decrease to 25,000 and 20,000 steps, respectively. A further reduction is assigned at a diameter of 30 mm, where the calibration factor is set to 13,000 steps. At larger diameters, namely 40 mm and 70 mm, the calibration factors are reduced to 10,000 and 5,500 steps, respectively. This decreasing trend indicates that larger workpiece diameters require fewer motor steps to achieve an equivalent positional adjustment along the Y-axis. The use of diameter-dependent calibration factors enables the system to compensate for non-linear mechanical characteristics and geometric variations in the rotary mechanism. Consequently, these calibration factors play a critical role in ensuring accurat positioning, consistent motion control, and stable system performance across a wide range of wood diameters. The test graph for the wooden cylinder is shown in Figure 3. The test results are shown in Figure 4.

Figure 3 illustrates the relationship between wood diameter and the number of stepper motor steps required to achieve a 1 mm movement along the X-axis. The horizontal axis represents the wood diameter in millimetres, while the vertical axis indicates the corresponding number of steps. It can be observed that the number of required steps decreases significantly as the wood diameter increases. For smaller diameters, such as approximately 10–20 mm, a relatively high number of steps is required, indicating finer motor resolution and higher mechanical resistance. Conversely, at larger diameters, particularly above 40 mm, the required number of steps decreases and stabilises, suggesting a more efficient transmission of rotary motion into linear displacement. The relationship between wood diameter and step count is well approximated by a third-order polynomial regression, expressed as

$$y = -0.2377x^3 + 43.499x^2 - 2702.9x + 63{,}128,$$

with a coefficient of determination $R^2 = 0.994$. This high R^2 value indicates an excellent fit between the experimental data and the regression model, confirming a strong correlation between the two variables. The non-linear trend reflects the mechanical characteristics of the rotary-to-linear conversion mechanism, where variations in contact geometry and effective radius influence the required step resolution. Overall, the graph shows that increasing the wood diameter reduces the number of motor steps required for a fixed linear displacement, highlighting the adaptability and precision of the rotary system across different workpiece size.

Engraving Test of a Square on a Wooden Cylinder

The batik engraving test on a 70 mm wooden cup was conducted after determining the parameters and adjusting the stepper motor driver settings to 30,000 steps on the X-axis and 5,500 steps on the Y-axis. The test parameters are shown in Table 3.

Based on Table 3 above, the difference/error in the batik engraving on a wooden cup with a diameter of 70 mm was observed in the first, second, and third trials. Although there was a difference/error of up to 8% between the planned design and the engraving result, the outcome was considered satisfactory. The results of the batik engraving test on the wooden cup are shown in Figure 5.

After tests with different parameters were completed, the differences among the three wooden cups that underwent the engraving process became apparent. Once the parameters used in the wooden cup engraving process were determined, further testing was conducted with a different image.

Landscape Photo Engraving Test on Wooden Cups

The landscape photo engraving test on a 70 mm wooden cup was conducted after determining the test parameters and adjusting the stepper motor driver settings to 30,000 steps on the X-axis and 5,500 steps on the Y-axis, with an engraving speed of 500 mm/min and power modulation of 250. The test parameters are shown in Table 4.

Based on the table above, the difference/error in the landscape photo engraving was 5%. An error of 5% is considered very small, and the resulting engraving is quite satisfactory. The landscape photo engraving on the wooden cup is shown in Figure 6.

The mechanical system of the rotary fixture has been tested, and the test results have been obtained. The data from the mechanical system test of the laser engraver needs to be analyzed. The following are some of the test result analyses: a) The mechanical system of the laser engraver and the rotary fixture can operate well, with all X and Y axes moving smoothly and being capable of performing text engraving, batik engraving, and photo engraving, b) The rotary fixture clamp can be operated to secure wooden cups and wooden cylinders, c) To produce clear and stable images, the engraving parameters used are an engraving speed of 250 mm/min and power modulation of 500, d) Calibration steps need to be performed to determine the number of stepper motor steps for a 1 mm shift on each axis to ensure that the results meet expectations, and e) The rotary fixture construction is equipped with legs to keep the rotary fixture balanced when clamping workpieces with larger diameters and workpieces that exceed the expected weight.

CONCLUSIONS

The design and manufacture of the rotary fixture for use on a laser engraver have been completed, enabling controlled engraving and drawing on wooden cups and other cylindrical wooden workpieces. The developed rotary fixture has been demonstrated to securely accommodate workpieces with diameters ranging from Ø 10 × 100 mm to Ø 80 × 100 mm, with a maximum allowable mass of 500 grams. Experimental results have confirmed that the mechanical system can produce text, batik motifs, and photographic engravings with satisfactory consistency on cylindrical wooden surfaces.

The novelty of this research lies in the development of a compact, adaptable rotary fixture specifically designed to be integrated with a standard laser engraver, thereby extending its functional capability from planar to cylindrical engraving without substantial modification to the existing system. The primary contribution of this

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study is the provision of a practical mechanical solution that enhances the versatility of laser engraving equipment, particularly for small-scale manufacturing, educational laboratories, and creative industries utilising cylindrical wooden products.

Despite these achievements, several limitations of the developed system have been identified. The current rotary fixture is primarily optimised for lightweight wooden workpieces, and its performance may be constrained when used with denser or heavier materials. In addition, engraving accuracy is influenced by manual alignment and the lack of a closed-loop feedback mechanism, which may result in minor inconsistencies over prolonged operation. The rotational speed and synchronisation with the laser motion are also limited to predefined settings, reducing flexibility for complex or high-precision engraving tasks.

The implications of this work indicate that the proposed rotary fixture can improve production flexibility and broaden the application scope of laser engraving machines, potentially increasing efficiency and added value in the manufacturing of customised products. For future research, automated alignment, closed-loop control systems, and variable-speed control should be incorporated to enhance precision and reliability. Moreover, quantitative evaluation of engraving accuracy, assessment of long-term mechanical durability, and exploration of the fixture's applicability to other materials and larger or heavier cylindrical workpieces are suggested to strengthen its industrial relevance and scalability.

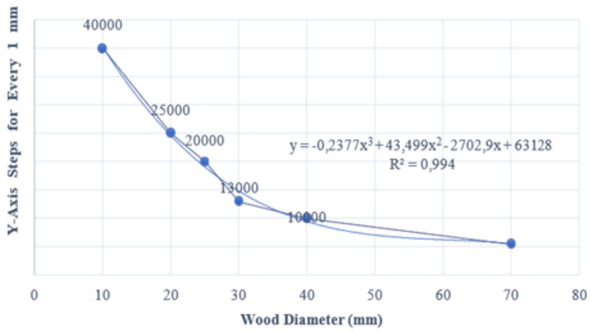

Figure 3. Wood Cylinder Testing Graph

Figure 4. Square Engraving Test on Wooden Cylinder

Table 3. Testing Parameters for Batik Engraving on a Wooden Cup

Testing	1	2	3
PWM	750	500	250
Engraving Speed	1000 mm/min	1000 mm/min	1000 mm/min
Engraving Plan	220 mm	220 mm	220 mm
Engraving Result	230 mm	225 mm	220 mm
Error	10 %	5 %	0 %

Table 4. Testing Parameters for Landscape Photo Engraving on a Wooden Cup

Testing Parameter	
PWM	250
Engraving Speed	200 mm/min
Engraving Plan	120x60 mm
Engraving Result	125x60 mm
Error	5 %

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Figure 5. Batik Engraving Test on Wooden Cylinder

Figure 6. Landscape Photo Engraving Test

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AUTHOR'S CONTRIBUTION

Rachmad Hartono: Designed and developed the rotary fixture mechanism for the laser engraver machine.
Farhan Ali Husaini: Wrote the manuscript.

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