# EFFECT OF LASER ENGRAVING PARAMETERS ON SURFACE MORPHOLOGY AND QUALITY ON CERAMIC TILES


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# Faculty of Mechanical and Manufacturing Engineering Technology

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**A thesis submitted**
**in fulfillment of the requirements for the degree of**
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**2021**

## DECLARATION

I declare that this thesis entitled "EFFECT OF LASER ENGRAVING PARAMETERS ON SURFACE MORPHOLOGY AND QUALITY ON CERAMIC TILES" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *MOHD ZULKARNAIN AZWAR BIN ZULKIFLI*

Date : 18/1/2022

## APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name : *PROFESOR MADYA IR DR MOHD HADZLEY BIN ABU BAKAR*

Date : 18/1/2022

# DEDICATION

Alhamdulillah, praise be to Allah for the strength and guidance He provided me in completing my study. My humble endeavour's I devoted to my loving family, deserves special recognition whose affection, devotion, support, and day-and-night prayers make me capable of the achievement and the honour.

# ABSTRACT

These days, laser is commonly used in the health, graphic, and advertising industries, as well as a variety of other realms of industry. It is also appropriate for artistic experimentation. Because laser is employed in extremely delicate operations such as eye surgeries, it occurs to me that it could also be used in the creation of extremely delicate art creations. Many new approaches are being used to get fruitful effects using the engraving procedure. Because ceramic is an acceptable medium to engrave, the laser engraving technique is used on ceramic tile bodies, resulting in productive effects. Laser engraving is a machining technique in which material is etched using a laser. The easiest approach for cutting exhausted materials is laser engraving, which eliminates the material layer by layer. Many types of business lasers are used for laser engraving, including carbon dioxide ($CO_2$) lasers, neodymium-doped yttrium aluminium garnet (Nd: YAG) lasers, fibre lasers, and semiconductor lasers. Through an experiment measure, the goal of this study is to assess the influence of technique parameters (laser power, scanning speed, and laser frequency) on material removal rate, engraving depth, and surface roughness. Digitally generated designs are carved on the bodies of ceramic tiles during this study. The removed material layer thickness and, as a result, the material removal rate was used to evaluate the method's performance.

# *ABSTRAK*

Hari-hari ini, laser biasanya digunakan dalam industri kesehatan, grafik, dan periklanan, serta berbagai bidang industri lain. Ia juga sesuai untuk eksperimen artistik. Oleh kerana laser digunakan dalam operasi yang sangat halus seperti pembedahan mata, saya berpendapat bahawa ia juga dapat digunakan dalam pembuatan ciptaan seni yang sangat halus. Banyak pendekatan baru digunakan untuk mendapatkan kesan yang membuahkan hasil menggunakan prosedur ukiran. Oleh kerana seramik adalah media yang boleh diterima untuk mengukir, teknik ukiran laser digunakan pada badan jubin seramik, sehingga menghasilkan kesan yang produktif. Ukiran laser adalah teknik pemesinan di mana bahan terukir menggunakan laser. Pendekatan termudah untuk memotong bahan habis adalah ukiran laser, yang menghilangkan lapisan demi lapisan bahan. Banyak jenis laser perniagaan digunakan untuk ukiran laser, termasuk laser karbon dioksida (CO2), laser garnet aluminium yttrium-doped neodymium (Nd: YAG), laser gentian, dan laser semikonduktor. Melalui ukuran eksperimen, tujuan kajian ini adalah untuk menilai pengaruh parameter teknik (daya laser, kecepatan imbasan, dan frekuensi laser) terhadap kadar penyingkiran bahan, kedalaman ukiran, dan kekasaran permukaan. Reka bentuk yang dihasilkan secara digital diukir pada badan jubin seramik semasa kajian ini. Ketebalan lapisan bahan yang dikeluarkan dan, sebagai hasilnya, kadar penyingkiran bahan digunakan untuk menilai prestasi kaedah.

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Finally, I'd like to express my gratitude to everyone who has helped, supported, and inspired me to pursue my studies.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| UTEM | Universiti Teknikal Malaysia Melaka |
| Nd:YAG | Neodymium-doped Yttrium Aluminum Garnet |
| CO2 | Carbon dioxide |
| Rz | Roughness depth |
| Ra | Roughness value |
| FYP | Final year project |
| Mm | Millimeter |
| Nm | Newton meter |
| PC | Computer aide numerical |
| Mm/s | Millimeter per second |
| Etc | Extra |
| Al | Aluminium |
| Re | Reynold number |

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|---|---|---|

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Because of its capacity to execute high-precision machining of intricate geometries on a wide range of materials, the optical device engraving method may be a non-conventional, non-contact machining approach that is quickly evolving. As a result of the advantage of having no touch between a cutter and hence the work, optical device machining procedures are gradually gaining ground over traditional machining processes. This implies that difficulties such as cutting tool wear or failure, as well as the idea of replacing them on a regular basis, will be eliminated, hence increasing the assembly value. Furthermore, optical device machining techniques enable the small cutting of sophisticated geometries in work parts with small dimensions, which may be impossible in some situations with traditional machining due to accessibility and, as a result, the cutter's minimum size.

The optical device engraving method's primary operating principle is that the irradiation machine emits laser pulses that deliver an excessive amount of focused energy to the work to ablate the fabric that must be removed. By altering the essential method parameters, such as the irradiation average power, the irradiation scanning speed, and thus the repetition rate of the optical device pulses, the style and therefore the amount of warmth energy provided to the fabric by the irradiation pulses may be altered.

The main goal of this research is to conduct an experiment to see how the irradiation machining technique parameters (average output power, repetition rate, and scanning speed) affect the optical device engraving of ceramic tile by measuring the parameters and hence the material removal rate. Optical device machining procedures do not appear to be as common as traditional ones, since laser technology is still in its infancy, with its progress beginning in the early 1960s. However, a growing number of studies are being conducted on optical device machining to provide solutions for jobs such as improving the produced surface quality, lowering energy consumption, boosting cutting speed, and machining new materials, among others.

Engraving is a technique for imprinting a design on a tough surface by cutting grooves into it, usually on a flat surface perpendicular to the process beam axis. Engraving was a popular method of generating images on tiles for purposes such as artistic creation, map making, and souvenirs. Because of the difficulty in mastering the process, etching and other techniques can be used instead. Optical device engraving and engraving are two popular engraving techniques that have a variety of uses. Optical device engraving is one of the most acceptable technologies to use in the ceramic tile engraving process. Irradiation is used to permeate the solid substance in this approach. This optical device has the advantages of non-contact operation, fast scanning speed, versatility, and automation.



For the engrave process, ceramic tile is used. The appearance may be transferred to a laser engraving machine to style the art on ceramic tile once the design is finished or found from any resources and software system.

## 1.2 Problem Statement

The quality of the engrave surfaces is a significant aspect in practical laser engraving applications. Methods for analyzing the impact of the primary process factors on quality have recently been developed, with the goal of improving quality rather than explaining the engraving mechanism. In this study, laser engraving of ceramic tiles is done at various combinations of levels of laser engraving parameters, such as engraving speed, power, work piece thickness, and loop count. In assessing the overall engrave quality, waviness (striations), flatness, and metallurgical changes at the engrave surface are considered quantifiable characteristics. The factors that impact engraving quality are determined using factorial analysis, and the resultant striation patterns are classified using a neural network.

Manual procedures, on the other hand, are engraving speed and power, as well as engrave loop count. Internal and undercut profiles (with the potential exception of internal circles) are practically hard to construct with 3D and 2D patterns; more advanced approaches must be used to achieve these profiles. Traditional methods for creating complicated geometrical patterns in ceramic tiles include diamond sawing, hydrodynamic machining, and ultrasonic machining, however these methods are both costly and time consuming.

The most common problem that occurs after using the laser engraving technique to engrave ceramics tiles is a crack on the surface and a lack of clarity in the design, which is primarily caused by different loop count, speed, and power, as well as a high temperature gradient within the ceramic's tiles substrate during the engraving process. These issues can diminish the strength of the tiles and provide opportunities for significant fracture propagation, resulting in partial or full tile failure.

## 1.3 Research Objective

The main aim of this research is to:

i. To develop pattern using laser engraving on ceramic tile.

ii. To evaluate the effect of laser engraving parameters on surface roughness of tiles.

iii. To analyses the characteristic of structural and microstructure change produce by the laser

## 1.4 Scope of Research

This research project will largely focus on the use of laser engraving on ceramic tiles, the ability of laser engraving machines to generate designs on ceramic tiles, and whether this machine can engrave 3D and 2D designs on ceramic tiles. In addition, this project will look at the best values for parameters to select to obtain a nice depth of 3D and 2D design. The investigation will be carried out by evaluating the structural and microstructure changes caused by laser engraving on the surface of ceramic tiles, as well as identifying the laser parameters that impact ablation rates, engraving definition, and efficiency. Furthermore, the investigation will be conducted using the structural and microstructure changes caused by the laser engraving process on ceramic tiles. To utilize this engraving procedure, you'll need 2D and 3D files, such as vector drawings or an image drawing. The most often used formats for 2D and 3D processes are dxf and xtl.

## 1.5 Project Planning

When working on a project, it is critical to plan. The appropriate planning guarantees that the task is done on schedule. Project planning is a process that is conducted at the start of a project. From the beginning to the end of the project, the Gantt chart will show you where you are in the process. It refers to the amount of time that may be required to complete the job. Table 1.0 shows the Gantt charts for PSM Project 1.

| ACTIVITIES | | Degree Project 1 - 6th semester (weeks) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Selecting a topic and research planning | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |
| Understanding Topic<br>- Background<br>- Problem Statement<br>- Objectives<br>- Scopes | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |
| Literature Review | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |
| Research Methodology | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |
| Report submission | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |
| Presentation | P | | | | | | | | | | | | | | | |
| | A | | | | | | | | | | | | | | | |

P= Planning

A= Actual

Table 1.1: Gant charts timetable

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This review includes various studies on laser engraving processes for better surface finish with various lasers using parametric analysis, the effect of laser power, different wavelengths, pulse frequency, beam speed, and other parameters that may affect surface finish, material removal rate, and engraving indentation.

## 2.2 Laser Characteristic in Engraving

An extensive research of high-power diode laser applications for materials processing was conducted. Engraving, marking, machining, powder sintering, soldering, welding, scribing, paint stripping, synthesizing, brazing, sheet metal bending, and surface modification (hardening, cladding, glazing, and wetting modification) are all direct applications of high-power diode lasers for materials processing. Greater morphological properties, less heat-affected zone, better surface quality and beam absorption, fewer cracks, and less porosity development are among these features, with the result being more consistent and repeatable. The high-power diode lasers have some drawbacks. It includes work piece color-dependent beam absorption, the difficulty of producing very high-peak-power short-pulsed beams directly, and high beam divergence (thus difficult to focus to a small beam size) (Li, 2000). The laser is a high-power diode laser with a frequency-doubled Nd:YAG 5W green laser with a wavelength of 532 nm, and the testing results demonstrate that it can be utilized in deep engraving of various types of wood without carbonization of the surface. (Leone et al., 2009).

The photographs of the laser light have the same phase, frequency, and wavelength. As a result, they are distinguished from conventional light. In contrast to ordinary light, laser beams are highly directed, have a better focusing feature, and have a high-power density. Laser beams are important in material processing because of their unique features. Laser-based machining methods, in general, use a high-intensity beam as a cutting tool that does not make contact with the material surface (Dubey & Yadava, 2008). They had no problems with machine geometry or work piece material hardness on the cutting tools they used. (Kaldos et al., 2004).

In contrast to the higher-consumption CO2 tubes used by most other machines, this machine uses a low-powered diode laser for the engraving of soft materials. A TO-can package, blue (445 nm wavelength) laser diode was chosen as the diode laser device. Instead of turning off the current supply to the diode laser, the device was operated in a continuous mode when lasing. When the processing power of the work piece was not required, the current would be reduced to just above the laser threshold. The prototype could also process a variety of materials, including wood, synthetic foam sheets, and cardboard. Furthermore, the prototype was able to engrave on a 30 mm thick wooden block, demonstrating that work items of various sizes may be processed (Jorge & Lordelo, 2014).

The marking process using a fiber laser can be adjusted to provide better colors with better visual appearance and quality. It can also allow for independent tweaking of various laser settings. Laser processing of metal surfaces, on the other hand, results in the formation