UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF PATTERN ON CERAMIC SURFACE WITH PARAMETERS MANIPULATION FOR LASER ENGRAVING PROCESS

MUHAMMAD HAFIZ BIN MOHAMAD ROSLI
B091910089

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

DEVELOPMENT OF PATTERN ON CERAMIC SURFACE WITH PARAMETERS MANIPULATION FOR LASER ENGRAVING PROCESS

Muhammad Hafiz Bin Mohamad Rosli

Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

2022

DEVELOPMENT OF PATTERN ON CERAMIC SURFACE WITH PARAMETERS MANIPULATION FOR LASER ENGRAVING PROCESS

MUHAMMAD HAFIZ BIN MOHAMAD ROSLI

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Development Of Pattern On Ceramic Surface With Parameters Manipulation For Laser Engraving" 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	:	Muhammad Hafiz Bin Mohamad Rosli
Date	:	08/02/2023

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 Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature : ....

Supervisor Name : Profesor Madya Ir. Dr. Mohd Hadzley Bin Abu Bakar

Date : 08/02/2023

DEDICATION

This research is dedicated to my dear family, particularly my parents, who have always been a source of inspiration and strength when I felt like giving up, who have never left my side, and who never cease to provide moral, spiritual, emotional, and financial support.

I dedicate my work to my supervisor, Prof. Madya Ir. Dr. Mohd Hadzley Bin Abu Bakar, and express my gratitude for all of his help throughout the process.

I also dedicate my study to my teachers and friends, who have always provided me with sound advise and motivation in order to complete this project.

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 utilised in extremely delicate operations such as eye surgery, it is reasonable to assume that it can also be used in the creation of extremely delicate art pieces. Many new approaches are being used to get fruitful effects using the engraving procedure. Because ceramic is an excellent 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 different types of business lasers are used for laser engraving, including carbon dioxide (CO2) 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 (power, speed, and frequency) on material removal rate, engraving depth, and surface microstructure. 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 were used to evaluate the method's performance.

ABSTRAK

Hari ini, laser biasanya digunakan dalam industri kesihatan, grafik dan pengiklanan, serta pelbagai bidang industri lain. Ia juga sesuai untuk eksperimen artistik. Oleh kerana laser digunakan dalam operasi yang sangat halus seperti pembedahan mata, adalah munasabah untuk mengandaikan bahawa ia juga boleh digunakan dalam penciptaan karya seni yang sangat halus. Banyak pendekatan baru sedang digunakan untuk mendapatkan kesan yang membuahkan hasil menggunakan prosedur ukiran. Kerana seramik adalah medium yang sangat baik untuk mengukir, teknik ukiran laser digunakan pada badan jubin seramik, menghasilkan kesan yang produktif. Ukiran laser ialah teknik pemesinan di mana bahan terukir menggunakan laser. Pendekatan paling mudah untuk memotong bahan yang telah habis adalah ukiran laser, yang menghilangkan lapisan bahan demi lapisan. Banyak jenis laser perniagaan yang berbeza digunakan untuk ukiran laser, termasuk laser karbon dioksida (CO_2), laser yttrium aluminium garnet (Nd: YAG) doped neodymium, laser gentian dan laser semikonduktor. Melalui ukuran eksperimen, matlamat kajian ini adalah untuk menilai pengaruh parameter teknik (kuasa laser, kelajuan imbasan, dan kekerapan laser) terhadap kadar penyingkiran bahan, kedalaman ukiran, dan permukaan struktur-mikro. Reka bentuk yang dihasilkan secara digital diukir pada badan jubin seramik semasa kajian ini. Ketebalan lapisan bahan yang dikeluarkan dan, akibatnya, kadar penyingkiran bahan digunakan untuk menilai prestasi kaedah.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, praise to Allah, the Almighty, the Most Gracious, the Most Merciful, on whom we ultimately rely for protection and direction. I'd like to thank Almighty Allah for allowing me to pursue my studies, for my dedication, and for my courage.

Next, I'd like to offer my heartfelt gratitude to Associate Professor Madya Ir. Dr. Mohd Hadzley Bin Abu Bakar of the Faculty of Manufacturing Engineering at Universiti Teknikal Malaysia Melaka (UTeM) for his unwavering support, advice, and inspiration. His invaluable help throughout the research, in the form of constructive remarks and recommendations, has contributed significantly to the research's success.

Furthermore, I dedicate everything to my family, who has always supported, prayed for, inspired, and motivated me throughout my personal and academic life, and who want to see this achievement come true. In my heart, there will always be a particular place for them.

Finally, I'd like to express my gratitude to my close friends for their unwavering support, input, conversation, and motivation during my research. All the adversity we experienced together will be remembered for the rest of our lives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
MOPA	-	Master Oscillator Power Amplifier
2D	-	Two-dimensional
kW	-	KiloWatt
Nd-YAG	-	Neodymium-doped Yttrium Aluminum Garnet
Hz	-	Hertz
nm	-	Nanometer
CO2	-	Carbon Dioxide
BC	-	Before Century
DOE	-	Design of Experiment

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, lasers have become increasingly popular for cutting and welding tasks. This approach has lately been applied in many industrial processes such as material processing, marking and selective removal by introducing laser sources with shorter and shorter pulses. Time stamps, component labels, and barcode tagging are all examples of identifiers product created through engraving. Some of engraving processes can be included mechanical engraving, tin marking and electrochemical engraving. Laser engraving is a subtractive manufacturing process that involves changing the surface of an object with a laser beam.(Dubey & Yadava, 2008). This method is mostly used to create images that are displayed at eye level on the material. The laser produces a lot of heat, which causes the substance to spray and show the holes that make up the final image. The laser is used to mark the surface of a metal workpiece.(Agalianos et al., 2011)

Laser marking has various advantages over traditional marking methods, including the fact that it does not require tool wear due to its high level of automation, as well as free programming and character selection. (Singh et al., 2012)

The working concept of laser engraving is based on vaporisation, which occurs when a laser system interacts with a material through a focusing lens (convex lens) and causes the vaporisation and melting of the materials employed in the work(Kaldos et al., 2004). It's also a great example of how a fundamental theoretical concept can persist until a technology implementation emerges. As a result, the material is abated from the workpiece in layers by an ablation process.

Laser engraving is used to engrave a specific image or trademark onto a chosen material. It's a subtractive method of production. However, before the engraving process can begin, a file from a computer must be transferred to the machine's controller, which then sets the laser. When the process begins, the beam generates a large amount of heat, which burns or evaporates the surface in accordance with the image in the file. Direct laser engraving is not affected by chemical gravure methods' instability or limitations.(Hennig et al., 2008). There are two types of engraving: surface engraving and line engraving. The first type vaporises the material to embed an image or give the design a three-dimensional appearance, while the second employs vector images to follow routes or lines.

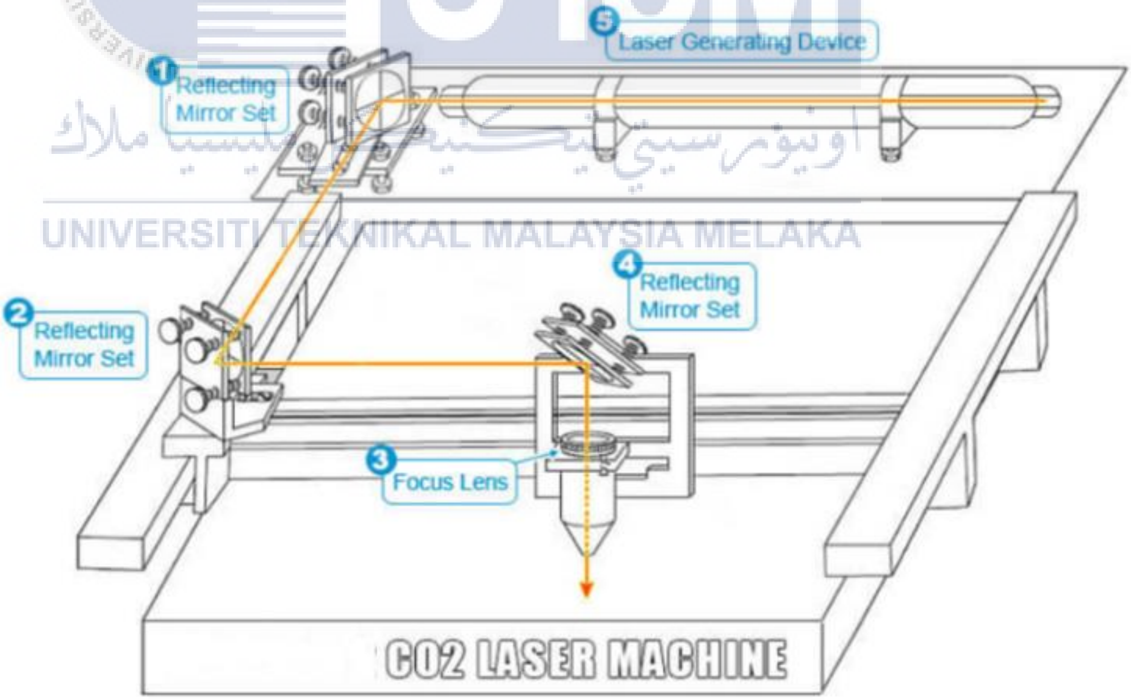

Figure 1.1 Schematic Laser Engraving System (RaymondLaser, 2022)

1.2 Problem Statement

The quality of the engrave surfaces is the most important component in practical laser engraving applications. Recently, approaches for analysing the impact of key process variables on quality have been developed, with the goal of improving quality rather than explaining the engraved mechanism. In this research, laser engraving of ceramic surface using Master Oscillator Power Amplifier (MOPA) Fiber Laser is done at various levels of laser engraving parameters, such as engraving speed, power, and loop count. Waviness, flatness, and metallurgical changes at the engrave surface are all regarded measurable criteria in assessing the overall engrave quality. A factororial analysis is used to identify the parameters that affect engraving quality, and a neural network is used to classify the striation patterns that arise.

Ceramic characteristics should be measured to reduce the consumption of materials during the engraving process due to overburn. The time it takes to create a sculpture on ceramic parts is rather brief, especially when compared to the hand tools used by people in ancient times to engrave on any materials, which took days or month, to finish a single engraving. It is because of the rough and abrasive surface.

Furthermore, this engraving machine, known as the laser engrave machine, is capable of facilitating the process of carving on small pieces of work and taking only a short amount of time for one piece of work. In addition, the sector is able to create vast numbers of things in a short amount of time while conserving energy.

1.3 Research Objective

The main aim of this research is to analyze the surface pattern on the ceramic which results from the engraving process. Specifically, the objectives are as follows:

a) To develop grooves design using a Master Oscillator Power Amplifier (MOPA) Fiber Laser on ceramic.

b) To determine the impact of laser engraving parameters on ceramic surface quality.

c) To analyze how different characteristics affect depth.

1.4 Scope of Research

The scope of this research is to create some grooves for a workpiece using laser engraving. The thickness of the workpiece plate, which uses a different measurement, such as speed and power of the machine running during the operation, is then used to evaluate the effect of laser engraving parameters on surface quality of the workpiece. The material will be harmed if the speed and power are exceeded, and the substance will be burned. Finally, a study of the impact of laser engraving on structural and microstructural alterations in ceramic. The tests were carried out at the Universiti Teknikal Malaysia Melaka. The scope of this research are as follows:

- Modify a laser engrave machine's differences parameter.
- The materials utilized in this experiment or testing are measured on a small scale and depth.
- To examine the structural and microstructural alterations on the surface.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The history of laser engraving, process, the effect of different laser power, wavelengths, frequency, speed, and other parameters that may affect surface pattern, material removal rate, and engraving indentation are all discussed in this chapter.

2.2 History of Laser Engraving

While lasers are prominent in pop culture, numerous companies employ laser technology to cut and engrave materials as part of their manufacturing processes. In reality, we have virtually likely come across a product that was created with laser cutters. Although laser cutting appears to be cutting-edge technology, it has a long history that must be remembered. The early lasers had their origins in Einstein's theoretical work and followed a fascinating route before evolving into the higher-power lasers that are now employed in numerous industries.(Bernatskyi & Khaskin, 2021)

Figure 2.1 Laser Engraving Machine

The history of laser cutting dates back to 1917, when Albert Einstein proposed the "stimulated emission of radiation" idea, which is the basis for today's laser. When electrons absorbed enough energy to go up an energy level within an atom, he believed, they may release photons. Gordon Gould, a scientist, elaborated on Einstein's idea in 1959. He proposed that light may be amplified by stimulating the emission of radiation. Light Amplification by Stimulated Emission of Radiation, or LASER for short, was his theory to be dubbed.(Hecht, 2010)

In 1960, Theodore Maiman in a California laboratory built the first-ever functional laser. Although many of his contemporaries couldn't find an application for his ruby laser, he employed synthetic ruby to make a deep red beam. In fact, the device was dubbed "a solution seeking for a problem" by the public, who viewed it with scepticism and even mistrust. Many members of the scientific community, particularly experts at Bell Labs in New Jersey, realised the potential in Maiman's concept.

Estimated at 1964, a Bell Labs scientist developed laser-based thermal cutting techniques. Kumar Patel developed a carbon dioxide-based gas laser cutting technology, which he discovered to be a faster and more cost-effective alternative to ruby laser cutting. Later that year, his Bell Labs colleague J.E. Geusic devised the crystal laser technique. The innovation sparked widespread interest.

The Western Engineering Research Center in Buffalo, New York, was the first to use laser cutting in 1965. The crew intended to figure out how to make electrical lines more efficiently. Manufacturers at the time employed diamond dies to extrude metal wire, and drilling the die holes was costly, complicated, and time-consuming. Scientists created the gas laser cutting method utilising carbon dioxide shortly after the Western Engineering

Research Center began employing laser cutting technology as a drilling tool. As a result of this advancement, laser cutting technology has become more adaptable. The discovery of lasers that could cut through metals like mild steel was especially important for the technology's broad adoption.

Another watershed milestone in the history of laser cutting occurred in 1979. Laser cutting had only been two-dimensional up until this time. Prima Industrie of Collegno, Italy, developed a 3D laser cutting technique that greatly increased the scope of laser cutting's potential applications.

Nowadays, laser power is widely used in a variety of industries. Because of advancements in laser cutting technology, the process may now be utilised on a wider range of materials, including metal, ceramic, and even paper. Fiber and CO2 laser cutting processes enable firms to cut materials more faster than prior methods, allowing them to increase production while reducing labour hours.

2.3 Types of Lasers Engrave

2.3.1 Direct Diode Laser

Direct diode lasers are lasers in which the output of laser diodes is used directly for a purpose such as laser material processing, such as laser cutting or laser welding. Using diode-pumped lasers, on the other hand, the diode laser radiation is used to pump another laser, whose output is then supplied to the application. Although some optical power is lost, the beam quality of the extra laser's output is so much better than the diode laser's that the brightness (radiance) is still higher. Increased optical intensities on workpieces are possible as a result of this.

Many applications for direct diode lasers necessitate high output powers. Diode stacks, which contain numerous diode bars and deliver powers of 1 kW or even several kilowatts, are used instead of single diode bars, which are suited for powers on the order of 100 W. With many diode stacks operating at slightly different wavelengths, spectral beam combining is also conceivable.

The increased brightness of high-power laser diodes can be attributed to a variety of factors. One factor is the continual improvement in the brightness of diode bars and diode stacks due to design advances. Tapered laser diodes and tapered amplifiers, for example, have significantly improved beam quality.(Wendland et al., 2005) Improved methods and components for beam combining the radiation of several laser diodes are another reason.

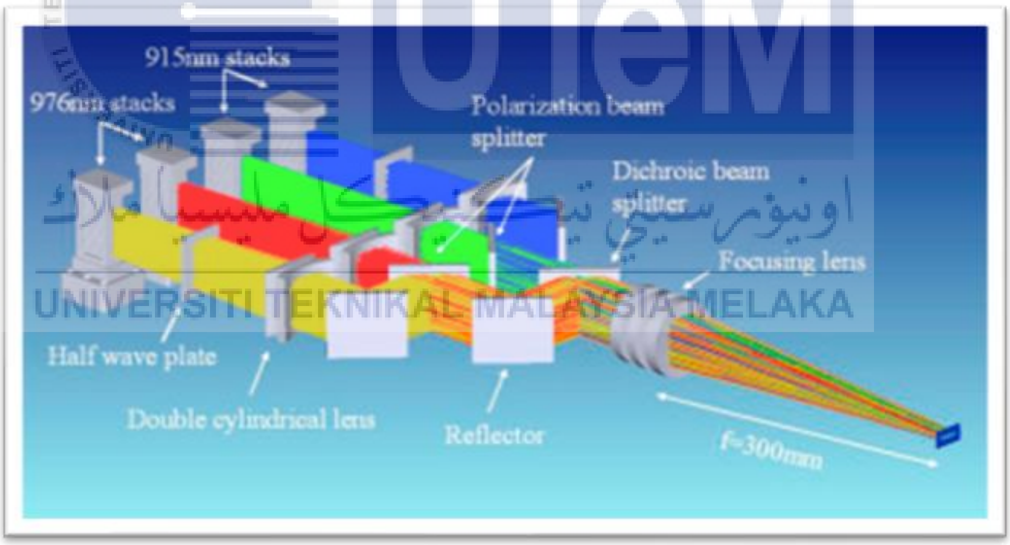

Figure 2.2 Mechanism of Direct Diode Laser