

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



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

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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.



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.

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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.

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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.

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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 (CO2), 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.

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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	- 14	Before Century
DOE	27	Design of Experiment
	A TEKN	
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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

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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 UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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

2.3.2 Fiber Laser

Fiber laser markers are perfect for marking black-annealed metal and deep engraving. It have a wavelength of 1090 nm, making them infrared (IR) lasers. Fiber lasers can mark a broad variety of materials, although they are best used for metal marking. Fiber laser markers ideal for annealing and engraving because of their enormous power, but they cannot mark clear things because IR light flows right through. Fiber laser markers are based on the same long-distance communication technology that is used in long-distance communication (optical fibers). When a laser travels via an optical fibre, it is amplified efficiently, allowing for the production of a high-output laser. Compared to traditional laser markers, fibre lasers offer a substantially higher output power. As a result, they can complete most applications far more quickly.(Genna et al., 2010)



Figure 2.3 Fiber Laser Engrave Machine

2.3.3 CO2 Laser

CO2 laser engraving devices produce a laser beam from a gaseous mixture of CO2 that has been electrically treated. The CO2 laser beam has a wavelength of approximately 10.6 microns. This wavelength can be used to engrave non-metallic materials like as wood, plastics, fabrics, paper, and glass. The CO2 laser is one of the most powerful and efficient lasers on the market today, and it can be used for a variety of medical, surgical, industrial, and military purposes. Because CO2 lasers are highly spectrally pure, they can achieve conversion efficiencies of 10% with a radiated line width of less than 1 kHz without sacrificing power. CO2 lasers can now handle new applications in the fields of material treatment and light detection because to their unique properties.(Mushtaq et al., 2020)



Figure 2.4 CO2 Laser Engrave Machine

2.3.4 Crystal Laser

2021).

Neodymium-doped yttrium orthovanadate and neodymium-doped yttrium aluminum garnet (Nd-YAG) are used in crystal laser cutting. Crystal lasers produce intense beams. Because their beams have a great intensity, they're ideal for cutting hard and thick materials. The fundamental disadvantage of this laser is that its increased power causes frequent failures. Metals, polymers, and even ceramics are among the materials sliced by this laser equipment. This type of lasers typically emits laser light with a wavelength of 1064 nanometers (nm) in the near-infrared part of the spectrum. It also absorbs laser light with wavelengths of 1440 nm, 1320 nm, 1120 nm, and 940 nm, among others. (Sriram et al.,



Figure 2.5 Example Mechanism of Nd-YAG Laser (Nd:YAG - Laser

Construction, 2007)

2.3.5 Master Oscillator Power Amplifier (MOPA) Laser

This type of laser can be defined as a laser system that includes a seed laser and a laser amplifier for increasing output power. MOPA can be made up of a solid-state bulk laser and a bulk amplifier, or it can be made up of a tunable external-cavity diode laser and a semiconductor optical amplifier. They are frequently employed to make high-contrast marks on other metals like titanium,nickel alloys and steels. A MOPA laser may produce a wide range of stainless steel annealing colours that are repeatable. It also provide benefits in terms of label lifetime during reprocessing. With the flexibility to modify the laser parameters flexibly, high-quality markings that are resistant to several passivation and sterilizing processes can be achieved. (Jiang et al., 2019)

Pulsed laser sources use MOPA structures as well. In that instance, the amplifier might be employed as a power source. The impact of gain saturation is crucial if a pulse from the seed laser removes a considerable fraction of the stored energy. The temporal pulse shape may be deformed as a result of this. In some circumstances, the seed source's pulse shape is modified to get the desired pulse form following amplification. (Chiang et al., 2010)



Figure 2.6 Schematic Diagram of MOPA Laser (Y. Panbiharwala et al., 2014)

2.4 Laser Engrave Parameters

Effect reference					
Speed(mm/s)	1000	1000	1000	1000	1000
Power(%)	45	45	80	25	45
Frequency (KHz)	400	300	400	350	200
Q Pulse Width (ns)	60	6	2	15	100
Line Distance (mm)	0.003	0.002	0.005	0.001	0.001

Figure 2.7 MOPA Laser Marking Colors Parameter

2.4.1 Power

The most essential settings in the material database are the laser power and speed parameters. They can be specified as a percentage ranging from 0% to 100%. The laser's output power is described by the Power laser parameter. Maximum power is 100 percent. High power is required for dark wood engravings or stamp engravings, whilst low power is required for materials such as paper.

In metal laser engraving, it is recommended to set up power at least 50 Watts. A fibre laser with a power of 40 or 50 Watts can be used for direct laser marking of metals, different to be compare with CO2 laser as it is suggested to use around 25-150 Watts of power. As a result, it is common to engrave metal in multiple passes. Permanent markings can be created using the laser engraving method, which are resistant to heat and wear. This determines the laser's percentage power. There is frequently a trade-off between speed and power. If the mark is too strong at full power, try increasing the speed before lowering the power to see if cycle durations may be reduced.

2.4.2 Speed

As be said in 2.4.1, speed and power are the most essential parameters in the material database. The laser head's movement is described by the Speed laser parameter. Short exposure times result from faster speeds, while long exposure durations result from slower speeds. Large-scale engravings of TroLase materials, for example, are etched at high speeds of 80 to 100%, whereas photo engravings with a lot of detail on wood should not exceed 10%. The quality of the laser cut is also affected by this option. (Lin et al., 2008)

The speeds of cutting and engraving are not comparable. Cutting, in general, is slower than engraving. A 10% cutting speed is considered "high."



Figure 2.8 Reference Chart for Speed vs Power in Engraving and Cutting (Test Your Material to Determine Laser Speed and Power Settings)

SLOMakerSpace, n.d.)

2.4.3 Frequency

During marking, the frequency (Hz) characteristic is utilised to show the QSwitch frequency in laser pulses per second. Various marking effects are provided by changing the frequency. This parameter is used to directly modify the laser output frequency using the Qswitch. The Q-Switch is an optical electric device that controls the opacity of the lens and allows the user to change the frequency of the laser beam. Gravure that is "spotted" is produced by a lower frequency, whereas gravure that is "lined" is produced by a higher frequency. Because frequency is inversely proportional to laser beam power, the marking process cannot be efficient if the frequency is too high. A shutter sluice that closes and disconnects the laser beam is connected to the Q-switch.



Figure 2.9 Frequency vs Speed Effect on Laser Engrave

2.4.4 Loop Count

The loop count is the number of times the laser will pass over your target. The more loops there are, the more depth there is. Depth can be improve by raising the power of the laser, slowing down the marking speed, or lowering the frequency, or a combination of all three. However, this produces a lot of heat and might leave a black, uneven mark.(Kasman, 2013)

The mark depth, width, and contrast have all been measured in relation to the pulse frequency, according to (Patel et al., 2015). The mark depth reaches its maximum when the pulse frequency is around 3 kHz, although the mark breadth remains virtually constant at different pulse frequencies. Material evaporation slows and oxidation increases as the pulse frequency rises, resulting in increased mark contrast. The maximum mark contrast was observed when the laser pulse frequency was around 8 KHz.

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2.5 Process of Laser Engraving

Laser engraving is a method of etching permanent, deep marks by vaporizing materials into fumes. The laser beam acts like a chisel, eroding layers from the material's surface to create incising marks. To achieve the high heat required for vaporization, the laser beams large amounts of energy at specific locations. Typically, laser engraving is used to engrave metal workpieces that will be subjected to various types of wear or surface treatments. Steel and aluminum are used in metal engraving including die-casting and anodized aluminum. The capacity of this method to etch 2D codes with good readability rates following post-process treatments is its most notable characteristic. Shotblasting, e-coating, and heat treatments are some of the procedures that can be used to handle the most difficult traceability challenges.

Laser engraving sublimates the material surface to create deep fissures, whereas laser etching melts the material surface to change its roughness. This means the surface absorbs enough energy to go from solid to gas without ever becoming a liquid. The laser engraving equipment must generate enough energy to allow the material's surface to reach its vaporization temperature within milliseconds to achieve sublimation. Laser engravers are extremely powerful tools, especially considering the high temperatures required for sublimation. The removed material layer thickness and the rate of material removal were the measured criteria used to assess the performance of the process.(Nikolidakis et al., 2018)

2.6 Laser Engraving Applications

Laser engraving is one of the most versatile and easily accessible types of marking. As a result, many manufacturers use this method for a range of applications in many industries. Some applications of laser engraving:

1. Annotations that are decorative or commemorative.

Some jewelry or any valuable things nowadays are more likely considered to engrave words on it such as some phrases or date. Many stores allow you to personalize a present with a decorative or commemorative inscription.

2. Trophies and Awards.



3. Signage.

The most typical application of laser engraving is in long-lasting signs. There are numerous advantages to engraving maps, directions, and other sign information instead of painting or printing them.

4. Creation of Barcode.

Most of the items have a barcode on their body to represent of a selling item. Most barcodes are printed on paper or directly on the object. These conventional barcodes, however, will not work on objects with properties. To avoid complications such as surfaces that are resistant to adhesion, engravers cut barcodes directly into these items.

2.7 Mild Steel

2.7.1 Introduction

Mild steel, commonly known as "low carbon steel," is a form of carbon steel having a low carbon content. The quantity of carbon present in mild steel is typically 0.05 percent to 0.25 percent by weight, whereas heavier carbon steels are typically stated as having a carbon content of 0.30 percent to 2.0 percent, depending on the source. The steel would be classified as cast iron if any more carbon were added. (Arslan et al., 2011)

Mild steel is not an alloy steel; thus, it does not have a lot of other elements in it besides iron. It is difficult to find a lot of other alloying elements in mild steel. Due to its low carbon and alloying element content, it possesses several characteristics that set it apart from higher carbon and alloy steels.

Mild steel has less carbon than other steels, making it more ductile, machinable, and weldable; yet it is difficult to harden and strengthen through heating and quenching. Because of the low carbon content, there is not much carbon and other alloying elements to block dislocations in the crystal structure, resulting in lower tensile strength than high carbon and alloy steels. Mild steel is magnetic due to its high iron and ferrite content.

If not properly coated, the iron in mild steel is susceptible to oxidation or rust because mild steel lacks alloying components like those found in stainless steels. However, the small number of alloying elements in mild steel makes it comparatively inexpensive when compared to other steels. The price, weldability, and machinability of this steel make it a popular customer choice. (Laakso et al., 2008)

2.7.2 Properties of Mild Steel

2.7.2.1 Physical Properties of Mild Steel

Its outstanding characteristics have led to an increase in its use across a wide range of sectors. Some physical properties of mild steel are:

- Magnetic metal based on its ferrite content.
- Exceptional tensile strength
- High impact resistance
- Heat treatment to improve characteristics is not recommended.
- Weldability and ductility are both good.
- Good malleability and cold-forming capabilities.

2.7.2.2 Chemical Properties of Mild Steel MALAYSIA MELAKA

Because of its low carbon concentration, this steel is extremely machinable. Without adding corresponding stresses to the workpiece, it can be cut, machined, and molded into complicated designs. It also improves the weldability of the material. A wide range of alloying elements can help to improve chemical characteristics. These ingredients will have a positive impact on the physical and chemical qualities of the finished product, making it appropriate for the application.

For example, chromium imparts corrosion resistance and increases the toughness of mild steel. Mild steel, in its pure form, is prone to rusting owing to oxidation. Unlike iron
oxide, when exposed to the atmosphere, chromium metal creates a solid layer of chromium oxide that does not flake off and protects the metal beneath from further corrosion. Copper, in small amounts, acts similarly to chromium oxide. Galvanizing mild steel pipes improves their resistance to the elements. To improve wear resistance, ultimate tensile strength, and heat resistance, further components may be added.

2.7.3 Mild Steel Engraving

Steel is the most used material, both as a raw material and as a component of industrial parts, especially in the automobile industry. Anodized steel, mild steel, carbon steel, and other new forms of steel with improved mechanical qualities are now available.

Steel laser engraving does not require any pre- or post-treatment and does not require any contact with the part. The result is a durable, high-contrast marking with a highdefinition finish that does not damage the steel. Steel laser engravers are versatile and offer a wide range of marking options, including engraving, etching, and annealing marking, from the rawest to the most polished steel. It is the ideal high-speed technology for marking and surface engraving on steel.

When the heat from a laser beam melts only the surface of a material rather than penetrating it completely, laser engraving happens. Laser marking a few millimeters deep is possible with this method. A steel laser engraver's high power generates a lot of heat, which melts the material's surface. In carved regions, oxides can form, making the marks brighter and more noticeable.

Laser engravings must be put deeper into the steel when marked components still require reworking or extra painting and the material is rough. During the engraving process, the steel laser engraver generates a lot of heat, which causes the material to evaporate. This forms a visible and tactile hollow in the surface. As a result, it is especially recommended when there is post-process stress in the laser marking.

2.8 Ceramic

2.8.1 Introduction

A ceramic is a non-metallic material composed of heated and cooled metal or nonmetal compounds. The oldest subject of materials science, ceramics is also one of the topics that materials scientists are interested in. They are often brittle, rigid, and resistant to corrosion.

Both manufactured and man-made non-metallic inorganic solid materials are referred to as ceramic. Since ancient times, heat treatment has frequently been utilized in the manufacturing of ceramics. As a result, the term ceramic is used to describe items made of ceramic like pottery and porcelain that have undergone high-temperature processing in furnaces. The phrase also refers to the science and technology used in their production. Since ancient times, the bulk of potteries, porcelains, refractories, cement, and glasses have been created from naturally occurring silicate-based materials. These items are frequently referred to as traditional ceramics or classical ceramics. Both traditional and classical ceramics have evolved in response to societal demands and the use of latest technology.

Ceramics produced by humans have been found that date to at least 24,000 BC. These ceramics were created using a mixture of fine clay-like substance, bone ash, and animal fat and bone. The pottery was formed, then burnt in loess-walled, domed, and horseshoe-shaped kilns at temperatures ranging from 500 to 800 degrees Celsius. Although the purpose of these

ceramics is unknown, it is believed that it was not a practical one. It is believed that practical ceramic containers were first used around 9,000 BC, where grain and other foods were held and stored in these jars. Ceramics technology and uses have developed steadily from those prehistoric times. We frequently take for granted the significant contribution that pottery has made to the advancement of humanity.

Commercial items made using ceramic processing range widely in terms of their size, shape, level of detail, complexity, and cost. The evolution of ceramic processing into an applied science is a logical outcome of advances in the development, characterization, and refinement of ceramic materials. To create a rigid product, processed clays and other natural raw materials are often heated in the production of ceramics. Purity, particle size, particle size distribution, and heterogeneity must all be controlled in ceramic products that start off with naturally occurring rocks and minerals. These characteristics have a significant impact on the final characteristics of the ceramic material. Some ceramic products also begin with powders that have undergone chemical preparation. It is possible to manipulate these synthetic materials to create powders with exact chemical make-ups and particle sizes.

2.8.2 Properties of Ceramic

Like other materials, the properties of ceramic materials depend on the kinds of atoms that are present, the kinds of bonds that exist between them, and how tightly they are packed. The atomic scale structure refers to this. Most ceramics have two or more components. It's referred to as a compound. For instance, alumina (Al2O3) is a substance consisting of oxygen and aluminum atoms.

Chemical bonds hold the atoms of ceramic materials together. Covalent and ionic connections are the two that ceramic materials encounter the most frequently. The metallic

bond is the name given to the chemical bond between metals. Compared to metallic bonds, covalent and ionic bonds have substantially stronger atom-to-atom bonds. Because of this, metals are typically ductile while ceramics are typically brittle. Ceramic materials are employed in a wide variety of applications due to their vast range of characteristics. Most ceramics are typically:

- brittle,
- nonmagnetic,
- hard,
- electrical insulators,



2.8.3 Ceramic Engraving

CO2 laser devices are typically used to laser engrave ceramic materials. When it comes to laser engraving, it can be stated that it is a highly flexible technology that enables us to work with various materials on the same piece of machinery. Ceramic is one of the materials that capable of being engrave based on their properties. A ceramic piece of appearance can be dramatically altered by engraving. Ceramic mugs, dishes, vases, pots, and even flooring components can all be engraved. The optimal time to engrave something made of ceramic is just before the lustrous glaze is applied. It is simple to engrave on the rough ceramic, thus, easily add glaze to cover up the new engraving after that.

Hard and brittle are both properties that included in ceramic components. Additionally, it is frequently used to colorize them to provide the desired answer. In this instance, it must endure high temperatures while being prepared. The Master Oscillator Power Amplifier (MOPA) Fiber Laser and CO2 Laser Engraving Machine are suitable for engraving ceramic and porcelain. They are distinguished by their exceptional precision, which makes it possible to laser engrave the finest writing and the most accurate images. Non-contact laser machining safeguards the material and reduces breakage. This procedure creates a surface with a light texture that can be utilised to construct complicated patterns and finely detailed images.



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the entire methodology clarification process for this project and in a mixed method theoretical study, this chapter focuses on proposed research approaches for the qualitative and quantitative effects of laser engraving parameters on surface morphology and quality on ceramic. This could be to ensure that the goals are met with success. The major approach started with the style and material selection. It is vital to choose the proper style and substance when utilizing a laser engraving to engrave a design on the plate. Effect on the workpiece plate can facilitated a thorough understanding based on the parameters used such as speed, power, and frequency. This chapter discusses the importance of grounded theory and takes a constructivist approach to it.

Condition of the ceramic must be considered to avoid any unwilling incident happens to the workpiece. This study will use laser engraving technology to create a laser etched on the workpiece. A unique pattern design will be created utilizing Adobe Illustrator/ImagR and EzCad Software. The laser engraving procedure uses this result as the primary input.

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3.2 **Project Planning**

To identify all information and requirements, such as hardware and software, planning must be done correctly. Two significant components in the planning stage are data collecting and the utilization of hardware and software requirements. The most important component of the planning process should be created before the procedure is completed to ensure that the project runs smoothly and easily. This planning strategy is critical in project management since it ensures that the project is completed on schedule. Process planning can also be guided to guarantee that the process is carried out in a systematic manner.

The introduction, literature review, and methodology chapters are the focus of the project's first phase. The issue description, objectives, scope, and project-related information are all being gathered at this point from various sources. This is a flow chart that will be used to demonstrate the flow of procedures in this project from beginning to end. The flow chart will outline the procedures that must be taken to ensure that the project's objectives are reached. The procedure for completing this project is depicted in the flowchart. This flow chart serves as a guide for putting together this project utilizing the system outlined in the PSM1 flow chart in concept.

This experiment was carried out in the Manufacturing Laboratory of the Faculty of Manufacturing Engineering at Universiti Teknikal Malaysia Melaka (UTeM) to gain a better understanding and documentation of ceramic laser engraving using the MOPA fiber laser engrave equipment. In this study, the parameters of the laser machine's speed, power, and loop count were examined to obtain good grooves patterns on the workpiece for ceramic. To undertake this study, a flowchart was designed for the overall project, as shown in Figure 3.1. This flow chart depicts the laser engraving procedure from the literature review through the experiment and finally to the analysis and reporting of the results.



Figure 3.1 Flow Chart of Methodology Process

3.2.1 Project Period

This curriculum is divided into two semesters, each of which lasts 15 weeks. As a result, the student has 30 weeks to complete their senior project, or Projek Sarjana Muda (PSM). PSM1 comprises a complete analysis and examination of the proposed project, as well as a better understanding of it. The Introduction, Literature Review, and Methodology reports must be submitted from Chapter 1 to Chapter 3. PSM2 comprises experimental testing with a limited number of tests to produce a scissoring gait device employing 3D printing as a result. According to the facts, the project will require meticulous planning and task organization. To get a degree, a student must complete this project and meet the prerequisites.

3.3 Selection Material, Machine and Software

The materials and qualities needed to complete this project are discussed in this chapter. This chapter discusses the machines that were employed during the experimentation phase to get the desired results in this study. Aside from that, the software utilized in the experiment was also covered in this section.

3.3.1 Type of Material

The workpiece or specimen that will be used to analyse the entire laser engraving process will be the mild steel and ceramic.

3.3.1.1 Mild Steel

Table 3.1 shows the mechanical properties of mild steel.

Properties	Value
Phase at STP	Solid
Density	7850 kg/m3
Ultimate Tensile Strength	400-550 MPa
Yield Strength SITI TEKNIKAL	MAL 250 MPaMELAKA
Young's Modulus of Elasticity	200 GPa
Brinell Hardness	120 BHN
Melting Point	1450 °C
Thermal Conductivity	50 W/mK
Heat Capacity	510 J/g K

 Table 3.1 Mechanical Properties of Mild Steel

When it comes to laser engraving, there are numerous benefits to employing mild steel as it has a lower carbon content opposed to carbon steel because the higher the carbon content, the harder for the edge laser cut. Mild steel also a good decorative material to be engrave using laser engraving as the design of the surface are not to metallish to be seen by eyes. Furthermore, mild steel also a potential material to be applied for laser engraving as it is a good heat conductor.

3.3.1.2 Ceramic

Ceramic specimen are suitable for engraving as the hardness and brittleness of their properties. Some of the mechanical properties for ceramic are as follow:

- They exhibit very little to no yielding due to their tremendous stiffness and rigidity.
- Fragile and have poor thermal shock resistance.
- Ceramic have weak impact resistance. AYSIA MELAKA
- Strong compressive strength.
- Ceramic contain little fissures of varied diameters that lead to brittle fracture and localised stress concentrations.
- Ceramic items have a high temperature strength.

There are numerous benefits to employing ceramic as it can sustain at high temperatures easily. Despite the laser engraving on ceramic may only focusing on cutting, it is also proven that the sustainability of ceramic at high temperatures can be develop to designing any shapes on it. Some of the cutting tools use in machining process may be made of ceramic, such as the lathe machine cutting tools. In term of a long period, the cutting tools may be defects or wear, and most of us surely just discarded and replace it with a new one. By using the laser engraving process, the wear on ceramic cutting tools can be reshape or redesign, thus, further analysis may be made to ensure either it is suitable to be use as the cutting tools or not.

3.3.2 Type of Machine

In the Manufacturing Laboratory at Universiti Teknikal Malaysia Melaka's Faculty of Manufacturing Engineering (UTeM), the Master Oscillator Power Amplifier (MOPA) Fiber Laser was used in this research as it is available there. Figure 3.2 depicts the Master Oscillator Power Amplifier (MOPA) Fiber Laser.



Figure 3.2 Master Oscillator Power Amplifier (MOPA) Fiber Laser in UTeM

The Master Oscillator Power Amplifier (MOPA), which generates a pulse frequency with a broader fiber, can be used to supply a power source for the laser. This enables MOPA laser to provide distinct engraving results in diverse polymers and metal materials when compared to other fibre engrave laser technology. Furthermore, laser MOPA can engrave several colours on stainless steel, titanium, and aluminium, as well as produce a darker colour effect and a better gloss than fiber laser.

3.3.3 Type of Software

EzCAD2.76 Software was the chosen software on designing pattern on ceramic surface through the Master Oscillator Power Amplifier (MOPA) Fiber Laser. The software was used to design the laser engrave region, and a vector image was created in the engraving element's arrangement. If the design has small lines and curves, vectors are the way to go. This method is known as 'scoring,' and it is also known as 'line engraving' or grooving. Figure 3.3 show the EzCAD2.76 Software where all the setting of parameters will be conduct there before the engraving process can start operating. Adobe Illustrator Software interface can be seen on the figure 3.4 below.



Figure 3.4 Adobe Illustrator Software

3.4 Identification of Engraving Parameters

Any conducted experiment needed parameters to produce more outcomes from the activities. This laser engraving research, laser strength, engrave speed, pulse frequency, and laser loop counts are the four factors studied. The laser frequency and speed were fixed parameters, while the laser strength and laser loop count were variable parameters, as shown in Table 3.2. Table 3.3, on the other hand, showed the suggested constant settings that were used throughout the trial.

Designation	AYSIA Parameters	Recommended	Units
LEKIN	AMA	Data	
Ceramic	Power	20,40,60,80,100	%
ملاك	Speed	500,1000,1500	وني Mm/s
UNIVE	RSITI TEKNIKAI Frequency	- MALAYSIA MELA 80	KHz
	Loop Count	1,2,3,4,5	-

 Table 3.2 Ceramic Engraving Parameter

Designation	Parameters	Recommended Data	Units
Mild Steel	Power	20,40,60,80	%
	Speed	500,1000,1500	Mm/s
	Frequency	40	KHz
AL MA	Loop Count	3,4,5	-

Table 3.3 Mild Steel Engraving Parameter

Table 3.4 Recommended Constant Parameters for Laser Engrave

Constant	ليسيا ملا	Recom	mended Data	ونيومرسي	Units
Parameters	IIVERSITI	TEKNIKAL	MALAYSI	A MELAKA	
Speed	1000	2000	3000	4000	Mm/s
Power	20	40	60	80	%

3.5 Specimen Microstructure

To examine the grain size of the microstructure on the graved region and base metal, the sample microstructure was observed using a digital USB microscope, as shown in Figure 3.5, The etched zone and base metal micrographs of the workpiece were obtained using microscopy examination.



3.6 Surface Roughness

Surface roughness was measured with a Mitutoyo Surftest stylus profilometer for all test runs, as shown in Figure 3.6. The Mitutoyo Surftest stylus profilometer was used to measure the material's surface roughness quickly and accurately. The Mitutoyo Surftest stylus profilometer shows the estimated roughness depth (Rz) in microns or micrometres (μ m), as well as the mean roughness value (Ra). A 5mm measuring field was used to determine the Ra values of all of the samples. Three measurements were taken for each

engraved piece to eliminate the impact of measuring errors. The mean value was used to compute the final Ra value. Surface roughness is a crucial factor that influences how surfaces behave tribologically.(Korakana et al., 2020)



Figure 3.6 The Mitutoyo Surftest Stylus Profilometer

3.7 Preliminary Finding

3.7.1 Expected Result

The expected output of laser engraving on mild steel and ceramic are shown in Figure 3.7 and Figure 3.8. The result allows for surface characterisation following lasering at precise parameters. Furthermore, the look of the surface on the mild steel workpiece revealed which surface was preferable for product marking.



Figure 3.7 Engraved mild steel surface profile with appropriate surface



Figure 3.8 Engraved ceramic tile with appropriate parameters use

The distribution of surface roughness for an mild steel is shown in Figure 3.9. When the laser parameters are changed, surface roughness graphs like this can be used to predict surface quality. From a practical engineering standpoint, determining the roughness of a surface is crucial. Surface roughness enables designers to assess the precision of processed components by predicting characteristics such as friction and vibration between two contact surfaces. Furthermore, the surface roughness value allows engineers to predict a component's ability to provide lubrication as well as estimate the component's life.



Figure 3.9 Surface Roughness of Mild Steel Engrave

In addition, the goal of this research is to provide the results of laser engraving selected material with the best specifications. Figure 3.10 illustrates a laser-marked product with the best parameter used during the laser engraving process.



Figure 3.10 Best Chosen Parameters of Surface Appearance

3.8 Summary

Throughout the experiment, the type of material utilised, engraving parameters, and machine type were all addressed in the methodology section. Mild steel and ceramic were utilised as the engraving sample, and the engraving operation was conducted utilising a Master Oscillator Power Amplifier (MOPA) Fiber Laser equipment. Furthermore, surface roughness was determined using a Mitutoyo Surftest stylus profilometer, and the microstructure of the specimens was examined using a digital USB microscope.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter explain more onwards about the result and discussion of the engraved ceramic by using different types of parameters. The engraved ceramic is marks with a few grooves according to the different parameters for each one. The engraved grooves are made using the Master Oscillator Power Amplifier (MOPA) Fiber Laser, with various types of parameters such as frequency, power, speed, loop count, and the wobble diameter. Three experiments are conducted by develop grooves design on the ceramic with different parameters use. The depth and the microstructure of the engraved ceramic will then be characterized before analyzing the result.(Lahoz et al., 2011)

The grooves on the ceramic pieces are made to relate the suitability of grooves microstructure with the capable of trapping lubrication liquids around the gap. Some parts such as cutting tools, are made of ceramic for the advantages of the material properties. These heavy cutting machining processes are necessary of having the lubricant system. The trap of the lubrication liquids around the gap may help the cutting tools to prolong the life expectancy as it provides smoothness operating with the lubrication.(Zhang et al., 2020)

4.2 Material Used



Figure 4.1 shows one of the ceramic pieces that are used to engrave the grooves on it. These ceramics comes in a diamond shape with the length of each side of 1.1cm, and 0.45cm for the height (1.1cm×1.1cm×0.45cm). Brittle, rigid, and resistant to corrosion are

the properties of this ceramic, which make it the chosen material for this research.

As the size of this ceramic piece are quite small, it is suitable for engraving grooves on the surface to ease the depth analysis process. Each of the ceramic pieces are marked with specified numbers to facilitate the identification of one and another. The ceramic substance is delicate before heating. Due to the high temperature of the laser, the ceramic body reacts in a variety of ways when exposed to the laser beam.

4.3 Trial Result

Various types of parameters are taken as trial, which strongly depends on the characteristics of the material. The trial parameters used are focused on ensuring the best design formed on the ceramic surface. Table below shows the trial parameters, consists of three different speed and power, with a constant value of 80KHz for frequency.



Table 4.1 Trial Parameters of Laser Engrave on Ceramic

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Figure 4.2 Graph of Power VS Speed 44

Figure 4.2 shows the graph of power vs speed for the trial process. Three different speed and power were tested, which consists of 9 etches on the material surface. Based from the trial result. The best power used for the engraving process is 100 as the other values of power produces unsatisfied design. Parameters used for the experiment may differs for the speed, or loop count, while the power may constant at 100.

4.4 Experimental Result



Figure 4.3 Engraved Ceramic Pieces

The ceramic pieces were engraved using a Master Oscillator Power Amplifier (MOPA) laser engraving. For the experiment, there were 6 samples of ceramic pieces used. There are 5 grooves portion in 1 sample of the experiment, each with a distinct laser power, speed, loop count, and wobble diameter. The experiments are conducted with 3 different types of parameters use. Frequency for this experiment will remains constant at 80KHz. The first experiment, consist of two ceramic pieces, was conducted with a manipulated variable of speed, as the power and frequency are stable at 100% and 80KHz. The speed value was chosen by taking the lower range value and adding it from 100mm/s to 1000mm/s.

The second experiment, which also consist of two ceramic pieces, was conducted with a manipulated variable of the loop count, from 1 to 10. Power and frequency remain the same such as the first experiment. The speed value was chosen by taking the higher range and the suitability for the ceramic pieces, which is 1000mm/s.

The third experiment was conducted with a manipulated variable of the wobble diameter, from 0.1mm to 1.0mm. The speed value remains constant such as the second experiment, which is 1000mm/s. Power is constantly applied at 100%. The loop count for this experiment is chosen to be 5, as more loop count would produce a better groove on the ceramic pieces. It is also consisting of two ceramic pieces for the third experiment.

Further the experiment process, the engraved ceramic pieces were analyzed by using the Digital USB Microscope to examine the microstructure appearance and depth.

4.4.1 Experiment 1



Figure 4.4 Ceramic "7" and "10"

Figure 4.4 shows two ceramic pieces used for this experiment are marked with number 7 and 10 representatively. As the dimension of the ceramic piece is 1.1cm×1.1cm×0.45cm, that make it quite small, each piece was engraved with 5 grooves on the surface according to the different parameters. With frequency of 80KHz and only set to 1 loop count, the parameters used for this experiment are shown in the Table 4.2 and Table 4.3.

Before engraving both ceramic pieces, the laser lens with 100mm focusing lens, had been configured to decide the efficient height for the process. The height of the laser lens is different according to the different height of any materials. In this case, it is dependent on the height of the ceramic piece from the base. The suitable height for engraving ceramic piece is 130mm as shown in the Figure 4.5.



Figure 4.5 Laser Lens of 130mm Height

4.4.1.1 Ceramic "7"

Each engraved grooves on the surface of the ceramic are different in the value of the manipulated variable, which is the speed. Figure 4.6 shows the engraved grooves on the ceramic piece with a marked "7".



Figure 4.6 Engraved Ceramic "7"

Based on the Figure 4.6, the numbering from 1 to 5 coordinated the different values of speed. The numbering represents of:

- 1 = 1000 mm/s.
- 2 = 900 mm/s.
- 3 = 800 mm/s.
- 4 = 700 mm/s.
- 5 = 600 mm/s.

Parameters in this experiment are shown in the Table 4.2.

Table 4.2 Parameters Use for Engraving Ceramic "7"

Numbering	Speed, mm/s	Power,%
U 1.	NIVERSITI TEKNIKAL MAL 1000	AYSIA MELAKA
2.	900	
3.	800	100
4.	700	
5.	600	

4.4.1.2 Ceramic "10"

Ceramic piece with a marked "10" is the continuous of the experiment 1. Each groove on the ceramic surface is different in the value of speed. Figure 4.7 show the ceramic with a marked "10".



From the Figure 4.7, the number 6 to 10 refers to the different values of speed as the same concept with the ceramic "7". Those numbers represent the speed value of:

- 6 = 500 mm/s.
- 7 = 400 mm/s.
- 8 = 300 mm/s.
- 9 = 200 mm/s.

• 10 = 100 mm/s.

Parameters use in this experiment are shown in the Table 4.3.

Numbering	Speed, mm/s	Power, %
6.	500	
7.	400	
8.	AN WALAYSIA 300	100
9.	200	
10.	Mon 100	اونىۋىرىسىتى تىغ

 Table 4.3 Parameters Use for Engraving Ceramic "10"

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4.4.2 Experiment 2



Figure 4.8 Ceramic "19" and "25"

Figure 4.8 show the ceramic pieces of marked "19" and "25" representatively. Each piece was engraved with 5 grooves on the surface according to the different parameters. With a constant value of frequency and power, which is 80KHz and 100%, the parameters used for this experiment are shown in the Table 4.4 and Table 4.5.

The height of the laser lens also had been configured before conducting the engraving process. Same goes to the experiment 1, the suitable height for engraving ceramic pieces is 130mm from the base.

1.0

1.00

14

a Ceramic "19"



Figure 4.9 Engraved Ceramic "19"

Figure show the ceramic "19" which consist of 5 grooves represented by the numbering, from 1 to 5. For experiment 2, the manipulated variable is the loop count. Power and frequency remain constantly, while the speed was taken by the higher range values that was conducted in the experiment 1, the 1000mm/s.

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The numbering of grooves on the ceramic surface are referred to the different values

of loop count. The different values of loop count use in this experiment are:

- 1 = 1 loop count.
- 2 = 2 loop count.
- 3 = 3 loop count.
- 4 = 4 loop count.

• 5 = 5 loop count.

Parameters use in this experiment are shown in the Table 4.4.

Numbering	Loop Count	Speed, mm/s
1.	1	1000
2.	2	1000
3.	NALAYSIA 40.3	1000
4. July 4.	4	1000
5.	کنیکل ملیسیا ملا	1000
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Table 4.4 Parameters Use for Engraving Ceramic "19"

4.4.2.2 Ceramic "25"

Ceramic piece with a marked "25" is the continuous of the experiment 2. Each groove on the ceramic surface is different in the value of loop count. Figure 4.10 show the ceramic with a marked "25".



Figure 4.10 Engraved Ceramic "25"

From Figure 4.10, the number 6 to 10 refers to the different values of loop count, which is the same as the engraved ceramic "19". Each number stand for:

- اونيونر،سيني تيڪنيڪل ملين واقع واقع •
- U7 = 7 loop count. EKNIKAL MALAYSIA MELAKA
- 8 = 8 loop count.
- 9 = 9 loop count.
- 10 = 10 loop count.

Parameters use in this experiment are shown in the Table 4.5.

Numbering	Loop Count	Speed, mm/s	
6.	6	1000	
7.	7	1000	
8.	8	1000	
9.	9	1000	
10.	NALAYSIA 10	1000	
4.4.3 Experim		لونیوم سیت ته איז או אויד איז או אויד	

 Table 4.5 Parameters Use for Engraving Ceramic "25"

Figure 4.11 Ceramic "31" and "23" 56
Figure 4.11 show two ceramic pieces, which had a marked of "31" and "23" beneath them. For the experiment 3, the parameters use is quite unique as the manipulated variable is the diameter of the wobble. Wobble is a different marking method that can speed up marking and give more control over the lettering weight. By using continuous wobbling frequencies for material removal, etching can profit from laser wobble.

Other parameters were configured. The constant value of power and frequency, which is 100% and 80KHz, remains the same for the experiment 3. The parameters for this experiment are shown in the Table 4.6 and Table 4.7.



Figure 4.12 Engraved Ceramic "31"

Figure 4.12 shows the engraved grooves on the ceramic piece with a marked "31" beneath it. Each engraved grooves on the surface of the ceramic "31" are different in the

value of the manipulated variable, which is the diameter, mm, of the wobble. From the experiment 2, the loop count value of the data was taken as the constant variable, which is the 5-loop count.

The numbering of grooves from the Figure 4.12 are refer to the different diameters of the wobble, which each one is refers as:

- 1 = 0.1mm.
- 2 = 0.2mm.



Table 4.6 Parameters Use for Engraving Ceramic "31"

Numbering	Diameter, mm	Loop Count
1.	0.1	5
2.	0.2	5
3.	0.3	5

4.	0.4	5
5.	0.5	5

4.4.3.2 Ceramic "23"

Ceramic piece with a marked "23" is the continuous of the experiment 3. Each groove on the ceramic surface is different in the diameters of the wobble. Figure 4.13 show the ceramic with a marked "23" beneath it.



Figure 4.13 Engraved Ceramic "23"

From Figure 4.13, the number 6 to 10 refers to the different diameters of wobble, which is the same as the engraved ceramic "31". Each number stand for:

• 6 = 0.6mm.

- 7 = 0.7mm.
- 8 = 0.8mm.
- 9 = 0.9mm.
- 10 = 1.0mm.

Parameters use in this experiment are shown in the Table 4.7.

Numbering	Diameter, mm	Loop Count
б.	0.6	
7.	Value 0.7	م م م م
8. UN	IVERSITI TERNIKAL MAL	AYSIA MELAKA
9.	0.9	5
10.	0.1	5

Table 4.7 Parameters Use for Engraving Ceramic "23"

4.5 Microstructure Analyze

Continuation of the experimental process, all the ceramic pieces, which consists of 9 pieces, were undergo the microstructure testing and analyzing. The structure of the etched

sections and the characteristics of the ceramic surface were clarified through microscopic inspection. Understanding the relationship between the laser parameters and the precision of the depth marks is vital for defending the value of the engraving depth marks.

This process was conducted using the Digital USB Microscope for more effective and quicker macro view evaluation. The Digital USB Microscope are connected to monitor device such as laptop, and been viewed through an Open Broadcaster Software (OBS) app.



Figure 4.14 Open Broadcaster Software (OBS)

All the results from engraving process were taken and analyzed through OBS app as shown in Figure 4.14. To determine the optimum outcome of the laser engraving test, each ceramic surface was tested using a digital microscope to see how it altered from the initial depth to a deeper or normal surface. How crisp the engraved part is and how thick or thin the carved layer is may both be examined with a digital microscope. Observations made with a Digital USB Microscope produce clear visual findings.

4.5.1 Digital Microscopic Observation (Experiment 1)

Based on the experiment 1, which consist of the different values of speed, both ceramic pieces "7" and "10" were analyzed. The grooves on both ceramic surfaces are examine during the observation. Two side were analyzed from each piece of the ceramics, which is the surface microstructure and the depth microstructure.

4.5.1.1 Surface Microstructure

Experiment 1 had the manipulated variable for the values of speed, and each different values were engraved as each groove on the ceramic surface. The surface microstructure observation for ceramic "7" are shown in the Table 4.8. Other parameters such as power, frequency, and loop count are remains constant in each engraved groove.

Table 4.8 Surface Microstructure of The Grooves on Ceramic "7"







4.5.1.2 Depth Microstructure

The depth microstructure observation for ceramic "10" are shown in the Table 4.9. Other parameters such as power, frequency, and loop count are remains constant in each engraved groove.

Table 4.9 Depth Microstructure of The Grooves on Ceramic "10"







melted ceramic was fully covered the entire groove. No gap formed along the groove as the 100mm/s was too slow for engraving groove on the ceramic, which produce continuous heat towards the melted ceramic before it hardened.

4.5.2 Digital Microscopic Observation (Experiment 2)

Based on the experiment 2, which consist of the different values of loop count, both ceramic pieces "19" and "25" were analyzed. The grooves on both ceramic surfaces are examine during the observation. Two side were analyzed from each piece of the ceramics, which is the surface microstructure and the depth microstructure.

4.5.2.1 Surface Microstructure

Experiment 2 had the manipulated variable for the values of loop count, and each different values were engraved as each groove on the ceramic surface. The surface microstructure observation for ceramic "19" are shown in the Table 4.10. Other parameters such as power, frequency, and speed are remains constant in each engraved groove, which is 1000mm/s for speed.

Loop	Surface Microstructure Observation (Ceramic "19")
Count	

Fable 4.10 Surface Microstructure of The	Grooves on	Ceramic	"19"
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The surface of the 5-loop count groove under the Digital USB Microscope. The hardened melted ceramic was spotted, but most of the gap are long compared to the hardened melted ceramic.

4.5.2.2 Depth Microstructure

The depth microstructure observation for ceramic "25" are shown in the Table 4.11 below. Other parameters such as power, frequency, and speed are remains constant in each engraved groove.



Table 4.11 Depth Microstructure of The Grooves on Ceramic "25"





The depth microstructure of 10-loop count groove (left), with a comparison to the 9-loop count groove (middle), and the 8-loop count groove (right), under the Digital USB Microscope. The depth for the 10-loop count groove is the deepest than the both of 9 and 8-loop count grooves, constantly. It is because the groove was consecutively engraved for 10 times.

4.5.3 Digital Microscopic Observation (Experiment 3)

Based on the experiment 3, which consist of the different diameters of wobble, both ceramic pieces "31" and "23" were analyzed. The grooves on both ceramic surfaces are examine during the observation. Two side were analyzed from each piece of the ceramics, which is the surface and the depth microstructure.

4.5.3.1 Surface Microstructure

Experiment 3 had the manipulated variable for the diameters of the wobble, and each different diameters were engraved as each groove on the ceramic surface. The surface microstructure observation for ceramic "31" are shown in the Table 4.12. Other parameters such as power, frequency, and speed are remains constant in each engraved groove. The loop count for each groove is set to 5.

Diameter,	Surface Microstructure Observation (Ceramic "31")
mm	

 Table 4.12 Surface Microstructure of The Grooves on Ceramic "31"





 Table 4.13 Surface Microstructure of The Grooves on Ceramic "31"

4.5.3.2 Depth Microstructure

The depth microstructure observation for ceramic "23" are shown in the Table 4.13 below. Other parameters such as power, frequency, and speed are remains constant in each engraved groove, while the loop count was set to 5 for each of the groove.



Table 4.14 Depth Microstructure of The Grooves on Ceramic "23"







4.6 Depth Measurement TEKNIKAL MALAYSIA MELAKA

Depth measurement was conducted by using the Digital Tread Depth Gauge. Method of using the device is simple as placing the tip of the gauge on the depth surface, before ensuring the digital result shown on the screen is correct. The measurement of the depth is taken in millimeter, mm.

Based on all 6 pieces of the ceramic, the ceramic "19" and "25" are the specimens that shows a significant difference about the depth of engraved grooves, rather than the other ceramic pieces. The different values of loop count with the constant value of other parameters, which is the experiment 2, had produced a better depth for both ceramic pieces.

Table 4.15 Depth Measurement

Specimen	Groove	Depth, mm
Lunge Court	1-Loop Count	0.12
First and last groove of the ceramic "19".	5-Loop Count	0.36
UNIVERSITI TEKNIKA	6-Loop Count	اونيوم 0.39
Torroot	10-Loop Count	0.50
First and last groove of the ceramic "25"		

4.7 Best Parameters Used

4.7.1 First Best Parameters



Figure 4.15 First Selection of Best Parameters Used

Figure 4.15 shows the engraved groove which refer to the 0.9mm diameter of wobble. This groove was chosen as the best parameters used because of the nearly perfect U-shape was formed at the bottom of the depth. The groove also had a wobble diameter of 0.9mm, which widen the above part of the surface. The parameters used in engraving this groove are shown in the Table 4.15.

Table 4.16	First Bes	st Parameters	Used
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Wobble Diameter, mm	Power, %	Frequency, KHz	Speed, mm/s	Loop Count
0.9	100	80	1000	5

4.7.2 Second Best Parameters



Figure 4.16 Second Selection of Best Parameters Used

Figure 4.16 shows the engraved groove which refer to the 8-loop count. This groove was chosen as the second-best parameters used because of the depth formed. The consecutive

engrave of the groove was resulted with a deeper depth. The shape of the groove was appeared sharp to the bottom during undergo the microscopic observation. The parameters used in engraving this groove are shown in the Table 4.16.

Table 4.17 Second Best Parameters Used

Loop Count	Power, %	Frequency, KHz	Speed, mm/s	Wobble Diameter, mm		
8	100	80	1000	0.1		

Both best parameters used were examine their microstructure. The unsatisfied characteristics such as the sharp design formed at the bottom of the depth, are capable of being remove with another different types of parameters.

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

The project's outcome was discussed in this chapter, along with recommendations for additional research. This study examined the impact of laser engraving parameters on ceramic surface quality and depth. To see what effect the engraving parameters of laser power, speed, and loop count had on the responses of microstructure, these parameters were modified. The inquiry was successfully concluded with the aid of experiments on ceramic surface. Two topics discussed in the conclusion section are an overview of the inquiry and a summary of the results. The recommendations section consists of additional study and development of this subject.

5.1 Conclusion

The purpose of this study is to investigate the development of grooves design with various parameters use in ceramic surface laser engraving. As stated in the introduction, the **UNVERSITITEKNIKAL MALAYSIA MELAKA** initial objective of the project is to create a design using laser engraving on the surface of ceramic pieces. The impact of laser put on ceramic surface has produced positive results in terms of pattern engraving and quality. The ceramic surface is crucial to getting the best laser engraved design. The engraved groove on the ceramic surfaces helps to understand better and further about the laser engraving process.

The second objective is to examine the effects of laser engraving settings on the properties of ceramic surface. Combining the laser power, speed, and loop count was essential for characterizing the surface properties of the materials. A higher surface characteristic will emerge from a loop count combined with the ideal amount of laser power

since the ceramic components were eliminated. A proper material surface will yield acceptable surface characteristics in all possible combination of elements. The findings of the experiment show that different surface properties exist for each type of ceramic pieces.

Final investigation related with the microstructure and depth alterations brought on by laser engraving on ceramic surface. Each laser material's surface microstructure will change when the settings are changed. If the laser loop count is increased and the laser power is optimized for the material, surface microstructure will either be scattered of hardened melted ceramic or fully covered the entire groove. 80KHz of frequency is the maximum uses for the ceramic pieces. Superior groove depth is achieved by using a higher loop count and ideal laser power to create a microstructure on the ceramic surface.

5.2 **Recommendation for Future Research**

Recommendation for the future research include the following:

- 1. Conducting an experiment with additional settings to examine the burn marks engrave on the surface of the material use.
- 2. Use a different material with different properties for the specimen of the experiment such as wood, titanium, and stone.
- 3. Carrying out an additional experiment including hardness test, roughness test, and corrosion analyzation to determine the accuracy of the burn marks.

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APPENDICES

APPENDIX A Gantt Chart PSM1

		Semester 6 (2022)													
Ν	Activities							We	eks				-		
0.		1	2	3	4	5	6	7	8	9	1	1	1	1	1
											0	1	2	3	4
1	PSM 1 briefing														
2	Meeting with supervisor														
3	Article Review														
4	Web Research														
5	Writing Chapter 1: Introduction		T					T	T		T				
6	Background														
7	Objective														
8	Problem statement														
9	Scope of Research														
10	Writing Chapter 2: Literature review				_										
11	History of Laser Engraving					4									
12	Types of Lasers														
13	Laser Engrave Parameters					Ś	7								
14	Process and Applications														
15	Material (Mild Steel/Ceramic)														
16	Writing Chapter 3: Methodology	-	5.1	\leq	-	1				1					
17	Introduction and Project		-		-	0	1.0	V	1	2					
	Planning														
18	Materials, Machine, and	IK	AL	MA	LA	YS	IA I	IE	LAI	KA					
	Software														
19	Parameters and Expected														
	Results														
20	Chapter 1, 2, and 3 check by														
	supervisor														

APPENDIX B Gantt Chart PSM2

No	Activities	Semester 7 (2022- 2023) Weeks												
•		1	2	3	4	5	6	7	8	9	10	11	12	13
1	PSM 2 briefing													
2	Meeting with supervisor													
3	Material Survey													
4	Budget Calculation													
5	Engraving Process													
6	Experiment 1													
7	Experiment 2													
8	Experiment 3													
9	Microscopic Structure													
10	Writing Chapter 4:			•	•									
11	Introduction													
12	Result and Discussion													
14	Writing Chapter 5													
15	Conclusion/Recommendation													
16	Report checks by Supervisor													
17	Report submission				1									
18	Prepare the presentation													
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