

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



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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# Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

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

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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.



#### 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.

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#### **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 (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 (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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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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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 nonconventional, 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.
- 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.



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

ALAYS/

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. Laserbased 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 of an oxide layer on the surface. The visual appearance of laser-marked surfaces was adjusted in this work by adjusting different laser parameters. (Laakso et al., 2008).

#### 2.3 Laser Engraving on Various Material

The most pressing issue in the manufacturing industry is high-strength material machining (Leunda et al., 2012). If there is a high expectation for good surface quality, minimal tool wear, and tool-based tooling, the processing of such materials might increase machining cost and surface roughness (Ding et al., 2010). The most significant requirement is the machining strategy for a certain material. Because a high-quality surface is wanted in molds and parts used in electronics, biomedical sectors, and automotive, a high-quality surface is required. The working forming tool and material have the greatest impact on the machining of complex shapes with good surface quality. (Gaitonde et al., 2009).

Engraving can be done on any type of wood. Due to seasonal growth of the wood, it is dependent on the presence of large varied density values, which prevents smooth etched surfaces and consideration of wood structure (Leone et al., 2009). Laser engraving has acquired increased interest in the use of bamboo material for handcraft industry in other material selection in the laser engraving process. It is highly suited for high-volume automated manufacturing because of its high processing speed, high engraved product quality, precision of operation, and little waste (Lin et al., 2008).

Some materials, such as high-strength steels and high-chromium alloys, are nevertheless difficult to machine. It is a demanding task that has garnered little consumer attention. Laser assisted machining must be considered for materials such as metallic alloys and ceramics. Cutting tools and standard computer numerical control machines cannot easily adapt to such materials, resulting in extremely expensive tooling costs for rough machining and finishing processes (Masood et al., 2011). According to the manufacturer, it is possible to produce the required contrast for barcode marking on base metals, which are a high-strength material (Wendland et al., 2005).

When opposed to steels whose chemical composition is manufactured using a traditional casting technique, powder metallurgy steels have a number of advantages (Hnilica et al., 2004). These alloyed steels have superior mechanical qualities over traditional standard steels, such as wear resistance, hardness, and toughness (Arslan et al., 2011).

It is critical to check the surface texture since defects in the microstructure lead materials to be weak and pitiful. Microscopy demonstrates that some surfaces with good surface roughness include microstructure defects such wavy surfaces, burning, and melting. As a result, the materials will suffer in terms of strength (Noor et al., 2010).

The machinability of hard metal created by powder metallurgy is investigated in a new technique to laser engraving of P/M metals. The major goal of this research is to see how laser engraving affects the Vanadis 10 material (Kasman, 2013). However, Vanadis 10 was described as a material with excellent dimension stability and wear resistance. Vanadis 10 is also one of the high vanadium alloyed powder metallurgy tool steels, according to him (Hatami et al., 2012).

#### 2.4 Laser Engraving Parameters

A taguchi orthogonal analysis of the impact of factors on the process response for laser engraving. The most successful technology for cutting hard materials with complex geometry is laser engraving. The research investigates the machinability of powder metallurgy-produced hard metals and proposes a novel way to laser engraving of P/M metals. The major goal is to see how the laser engraving process affects Vanadis 10, a powder metallurgy cold work tool steel. On the surface roughness and engraving depth, three process factors such as effective scan speed, frequency, and laser effective power are important. In this study, taguchi and linear regression were used. Surface roughness and engraving depth were measured using a L9 orthogonal array based on the S/N ratio. Scanning speed was discovered to have a statistically significant effect on surface roughness and engraving depth. For the two performance qualities, the scan speed showed to be the most important effective metric. According to the findings, increasing scan speed lowers both Ra and D. The scan speed should be set to a high level (800 mm/s) to reduce Ra, while the scan speed should be set to a low level (200 mm/s) to maximize D. A mathematical model for surface roughness and engraving was also developed and evaluated using regression analysis. (Kasman, 2013).

Using a grey relational technique, metric optimization of the laser engraving process for various materials was achieved. Laser engraving is a non-conventional machining process that can be used to mark or engrave practically any material that can't be marked with a traditional machining process. The surface of the material is heated in laser engraving procedures, which causes the material to evaporate. Multiple input parameters such as spot diameter, laser power, laser frequency, different wavelengths, and so on can be used to vary output parameters such as material removal rate, surface finish, and indentation. Based on grey relational analysis, to optimize all these parameters with multiple performance characteristics. It will be determined which parameter has the most impact on the input parameter's responses to the output parameter. Finally, it will be concluded that increased laser power or a lower feed speed ratio resulted in a deeper laser etched depth (Review & Patel, 2014). Influence of process parameters on material removal rate and roughness in fiber laser machining of C45 steel. Using C45 carbon steel and Q-switched 20WYb, the goal of this research is to see how process parameters affect material removal rate and surface roughness during engraving. The fundamental wavelength of a YAG fiber laser is 1070mm. The pulse frequency, beam speed, distance between the linear patterns of two consecutive laser scans, number of geometric pattern replications, and scanning strategy were all investigated. The findings of the experiment reveal that the Yb: YAG fiber laser can successfully process C45 carbon steel. The rate of material removal and the roughness of the surface are both highly dependent on the process parameters. Based on the findings provided in this paper, a Qswitched Yb: YAG fiber laser was used to laser engrave C45 steel (Genna et al., 2010).

The influence of process factors on machined surface quality in laser engraving in industrial applications. The process removes material layer by layer, with each layer being only a few microns thick. The purpose of this study is to look at the effect of process parameters on surface quality when laser engraving is used. The parameters that were investigated included pulse frequency, beam speed, and layer thickness. Surface roughness was used to determine the surface quality for each set of characteristics. The surface roughness of Al7075 material was found to be dependent on the frequency and scan speed utilized in the experiment. It can be concluded from the current paper's experimental work in laser engraving Al7075 using a Q-switched Yb: YAG fiber laser that the surface roughness is substantially dependent on the frequency and scan speed utilized. Furthermore, it was demonstrated that the resulting roughness is less affected by layer thickness. When all of the trial data from the current experimental plan was taken into account, the best surface roughness was obtained when a frequency of 20kHz, a scan speed of 600-700mm/s, and a layer thickness of 4 and 6m were used. (Agalianos et al., 2011).

Following that, various laser output power levels and feed speed ratios were used to etch bamboo lamina. The goal of this research is to determine the impact of laser output power on engraved depth, color difference, and feed speed ratio impacts. As a result, it was discovered that for higher laser power or a lower feed speed ratio, the etched depth increased. The engraved depth difference values ranged from 0.69mm to 0.86mm on average. Furthermore, with a greater power and lower feed speed ratio, the color difference values rose, resulting in a brownish color in the engraved zone region. Meanwhile, regression analysis could forecast and estimate the average color difference values, which ranged from 46.9 to 51.9 pixels. According to the author, it is critical to match laser power and speed for cost-effective and useful engraving. Because of the varying engraving depths sought and product color discrepancies, this is the case. The laser etched depth got deeper with either higher laser power or a lower feed speed ratio, as shown in Figure 2.1.(Lin et al., 2008).



Figure 2.1: above show that the laser engraved depth became deeper for either higher laser power or a lower feed speed ratio.

The influence of the feed speed ratio on the engraved depth and color difference was substantial when laser power interaction regimens were used. As a result, as shown in figure 2.2, the engraved depth and color difference grew as the laser output power increased, while the feed speed ratio decreased.



Figure 2.2: Color difference under various feed speed ratios and laser output power level for with and without steam treatment.

#### 2.5 Laser

AALAYSIA

Laser is Associate in Nursing abbreviation for light-weight Amplification using accelerated Emission of Radiation. It differs from conventional light in that it is made up of photons with the same frequency and section. Light is emitted by an optical maser using a method of optical amplification based on the stirred-up emission of non-particulate radiation. Lasers differ from other types of light in that they emit light in a coherent manner. Abstraction coherence enables an optical maser to be centered on a precise point, allowing applications such as optical maser reduction and lithography to take place (Siegman & Anthony, 1986). Abstraction coherence also enables a beam to measure thin at long distances, allowing for optical maser pointer applications.

Laser light is quite distinct from the type of light that a well-known bulb emits. Lightweight gauge bosoms are emitted with no pattern, but optical maser mild is prepared in such a manner that each photon takes the same path due to the contrary, similar to how well-prepared troops travel. Furthermore, unlike light from an optical maser, which is small and directed with a high-quality beam, contemporary light is dispersed with no precise route. Because it is all one wavelength as specified by the variety of energy free, the optical maser lightweight is monochromatic (all one hue).

The optical maser allows for the smooth reproduction of a computer-generated shape or image onto a material without physically touching it. This enables hard shapes to be imprinted or cut from delicate and flexible materials such as paper and thin plastics, allowing for the creation of complex shapes with ease (Steen, 1998). It's commonly used for subject version development or possibly material reducing/engraving. An optical maser cutter has the disadvantage of having no bodily slicing tool to sharpen or replace. It has the potential to reduce sharply at any time if the optics are swish and focused.

Lasers are commonly used to reduce metals and other tough materials, but the strength required is enormous. It has the capability to reduce wood and plastic up to spherical 10mm with sixty watts of power. This varies based on the consistency of the fabric; some woods produce low-quality outcomes due to the release of sap and resins within the timber burning and charring the surface (Zhou & Yusoff, 2006).

#### **UNIVERSITI TEKNIKAL MALAYSIA MELAKA** 2.6 Type of laser

#### 2.6.1 Fiber Laser

Because of its capacity to cut, etch, and otherwise manipulate a variety of materials often used in industry, this laser was an excellent instrument for industrial use. Fiber laser, as the name implies, is a laser with an active medium made of optical fiber doped with a rare earth element such as erbium (Er), neodymium (Nd), or ytterbium (Yb) and pumped by a diode laser. This laser's output power can reach hundreds of watts while maintaining good efficiency. This laser has several advantages, including a compact construction, a highquality beam, the generation of ultra-short pulse laser beams, a wide tuning range, and a high output efficiency of roughly 50% when compared to CO2 and Nd: YAG, which have output efficiencies of 10-30% and 2%, respectively. The difficulty of aligning the pump beam to the core of a single mode optical fiber is also a disadvantage of this laser. Because high pumping damages fiber, the output power was limited to hundreds of watts. It also requires a considerable cavity length since absorption per unit length of fiber is limited. Cutting, welding, engraving, drilling, and surface treatment are just a few of the industrial applications for this laser. The value of this laser is in the materials it can cut, such as Mild Steel, Stainless Steel, Nonferrous Metal, Precious Metals, and Titanium, which are not impacted by CO2 lasers. It can also cut glass, plastic, wood, and other organic materials. So that it was used for marking or engraving different material and its effect has been studied for different researchers as will show.

#### 2.6.2 Gas laser

Density volatilized materials are used as active media in gas lasers. In compared to solid state, dye, and semiconductor lasers, line widths are much shorter. The Doppler shift way to thin line widths is the main widening process, and optical pumping might be ineffective. Instead, continuous, RF, or pulsed electric pumping is used. Fuel lasers are made up of neutral atoms (He-Ne, metal vapor, and so on), ions (for example, Ar+), or molecules (example; CO2).



Figure 2.3: Gas laser

#### 2.6.3 Semiconductor optical

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Semiconductor optical masers are one of the most often used optical tools nowadays. They may be employed in applications straight away, as well as on pump stable US lasers. To function as optical device active media, semiconductors must have a precise band gap, else components like Si and Ge would not function. Emission wavelengths vary from 630 to 1600 nm in duration. Compounds of III-V components (Al, Ga, In... – N, P, As, Sb...) are used in most semiconductor optical tools. Several compounds are uncommon, although they are attainable. Shorter wavelengths are produced by II-IV compounds, whereas longer wavelengths are produced by IV-VI compounds.



Figure 2.4: Semiconductor optical

#### 2.6.4 Solid state laser

Excessively dense stables are used as spirited laser material in solid state optical devices. Ions are introduced to host material, which might be crystalline or glass, as a supporting impurity. When you consider that their strength stages are so completely different, semiconductors are ruled out. The most often employed dopants are transition component ions that dramatically grouping elements or transition bronze. They're usually electric steam-powered jackets that aren't allowed since they require extremely long lifespans. Although glasses are easier to make, crystals offer superior thermal characteristics.



Figure 2.5: Solid state laser

#### 2.7 Laser Engraving

By burning the material to be treated, laser engraving is accomplished. Mirror, lens, tube, laser head, ventilation machine, and water-cooling components are all part of it. The first phase of the equipment is to create an icon-based virtual representation of the blueprints and save it as a file with the Dfx extension. The engraving/cutting power and speed charges are entered in accordance with the material to be treated. The optical tool head and, as a result, the laser is focused on the appliance stand, and the ventilation system is activated. The distance between the optical tool head and the fabric should be 1.5 inches (approximately 4 cm). These figures may change in accordance with the running principles and, as a result, the approach.

The machine should be cooled with water or air since it warms up at some point in the equipment. In an optical tool engraving device, there are mirrors that reflect the beams, and as a result, the shaft of light that emerges from the mirrors begins to approach the material by way of the laser head. A specific fuel is used in the optical tool engraving device's tube. The optical device's technology is completed with gasoline and, as a result, water that circulates in those glass tubes, the diameters of which are governed by the device's speed. The glass tubes are projected to last between 3000 and 6000 hours. Later, it's continued to be used by re-pumping gasoline into the same tube. Optical tool machines are expected to last a long time if they are operated according to the instructions and maintained properly.



Figure 2.6: Laser tube (AYKA, 2017)

#### 2.7.1 Laser engraving process

A targeted laser beam is scanned over the work in the optical device engraving procedure. Every optical device pulse's energy is absorbed by the piece of work, which warms the fabric, producing melting and, eventually, vaporization to a gas. Ablation is a term used to describe the transition from solid to vapor phase. Because the gaseous substance is evacuated, a fabric removal occurs, resulting in the thickness of the only layer eliminated. A 3D formed surface structure is made by eliminating many layers of cloth using a particular scanning pattern for everyone.

# The optical device engraving process is schematically illustrated in Figure 2.9(a).

During a specific, preset approach (scanning strategy), the light beam spot searches the work material surface, and random light pulses are created, inflicting ablation, and thereby removing the target material.

The qualities of the beam of light, the attributes of the item of work, and the technique they each move all affect the material removal. The density, melting-vaporizing temperatures, heat energy capability, heat physical phenomena, heat of melting-evaporation transition, and absorption-reflectivity in solid-melting states are all factors that affect the piece of work's qualities. The optical device machine parameters, such as optical device kind,
wavelength, optical device spot diameter, pulse duration, and technique parameters, such as average output power P, repetition rate F, and scanning speed V, are used to describe the shaft.



Figure 2.7: Laser engraving process

(a) Schematic illustration of the laser engraving process; and

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(b) Engraving depth of 14 successive laser beam pulses in ceramic tile workpiece.

2.8 Tiles

A tile is a thin, square, or rectangular item with a variety of shapes. Tile is a factoryproduced hard-wearing cloth composed of ceramic, stone, metal, baked clay, or glass that is commonly used to cover roofs, floors, walls, and one-of-a-kind things such as tabletops. Tile, on the other hand, refers to comparable wall and ceiling products constructed of lightweight materials such as perlite, wood, and mineral wool. A tile might also refer to a manufacturing tile or any comparable item, such as square counters used in games (see tileprimarily based game). The term "tile" comes from the French word "tile," which comes from the Latin word "tegula," which means "lay-off clay roof tile." Tiles are commonly used for wall and floor coverings and come in a variety of shapes and sizes. To add complexity, use tiles or mosaics. Ceramic tiles are the most common, with glazed interiors and unglazed exteriors, although other materials such as glass, cork, concrete, and unique composite materials, as well as stone, are also commonly employed. Marble, onyx, granite, or slate are commonly used as masking stones. Dilatant tiles are more suited for dividers than for floors that require more durable surfaces to withstand impacts.

#### 2.8.1 Manufacture of common tiles

Within the overall technique to producing the uncommon tiles, the following four incredible activities are concerned:



The chosen clay is taken and made free of any impurities such as grit, stones, and so on. In Canis familiar's mills, such clay is ironed and regenerated into a suitable powder.

An excessive amount of clean water is added to the powdered clay for superiorquality tiles, and it is thoroughly mixed in a completely tank. After that, the combination is quietly squared. The extreme gritty dirt settles to the tank's rock bottom. The good particles are then transferred to different tanks, and the water is allowed to dry. As soon as this process for making tiles was hired, the vast clay vanished. A mixture of floor glass and pottery-ware is added to the clay of the tiles in the required proportion to make the tiles tough and moth proof.

b) Moulding

The clay is placed in a mold that creates the pattern or shape for the tile. Molding is also done using a wood mold, mechanical means, or a potter's wheel.

The wooden mold should be made from high-quality wood. As soon as the clay is pulled out of the mold, it is pressed into the mold, and the tiles are ready for drying. During the mold eradication process, special care must be given to maintain the form of the tiles. A wooden mold is used to mold tiles that do not have an equal portion lengthwise.

The availability of machines and thus the clay is ironed into such machines to induce tiles of desired segment and form is referred to as molding with mechanical help. For tiles with the same segment running the length of their length, this molding process is used. With the aid of a great wire, it is possible to cut tiles in the required length of time. Molding with a potter's wheel corresponds to 1 and is used in the production of ceramic ware vessels by potters. When the tile is in an entirely circular shape on the wheel, this way is used. Its diameter, on the other hand, will change with time.

c) Drying

The tiles, as they come out of the mold, are laid flat one on top of the other in a proper pattern. The numerous lots are formed in this manner. With a flat wood mallet, the irregularity of tiles that leads to distortion is repaired after two days. The tiles are then upraised as needed with the use of a hand-hardening agent. The surfaces on the sides and bottom are cleaned. They're heaped haphazardly beneath a color to dry for about two days. The drying underneath a color prevents the tiles from being distorted and cracked due to rain and sunlight.

d) Burning

Kilns are used to bake the tiles. Figure 2.10 depicts a typical oven, known as the Sialkot oven, which can hold between 30000 and 40000 tiles and is enclosed by a shed. At the rows of long, thin flues, a layer of bricks is laid down flat. The firewood placed in the flues is used to fuel the combustion. The bricks are laid out in the most practical way possible, with free spaces between them. Dry tiles are positioned jumpy layer with the help of layer above the brick layer. The last door is afflicted with mud-caked stonework. The top of the oven has a layer of new tiles that are in excellent shape.



Figure 2.8: Circular kiln for burning tiles

To get greater results, the law of heat is critical. In the beginning, the fire is kept to a low level. Wetness is removed. After that, it's heated to around 800 degrees Celsius. It was slowed for about a half-dozen hours before being heated to 1300°C once again. For a total of three hours, this temperature is kept constant. The practice of relaxing in front of the fire for 6 hours and then raising the temperature to heat is a common one. The temperature is kept at a constant temperature for four hours. Finally, the flues are full of fuel, and the doors are sealed with mud brickwork. The oven is then gradually allowed to cool. Burning the tiles takes around seventy hours to complete. The tiles have been removed from the oven. The bottom-burned tiles are sorted out and placed on the top of the oven during the subsequent tile-burning process. This oven is a visible intermittent kiln.

A new automated approach known as one firing generation has been discovered, which has resulted in a significant decrease of the firing cycle from 72 hours in the existing double firing standard methodology to a surprising average of just one hour.

This next generation uses less fuel and costs less to produce. As a result of the new generation's expansion of tile standard, fashion, and versatility, the ceramic trade has entered a new chapter of discovery.

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# 2.8.2 Characteristic of a good tile

Following are the characteristic of a best tile:

- i) Must be free from any cracks, flaws, or bends
- ii) Should be ordinary in shape and size
- iii) Has to be sound, onerous, and sturdy
- iv) Has to be burn
- v) It must slot in properly, once placed in position.
- vi) It must offer a clean ringing sound once affected with hand or with every different or with lightweight hammer.
- vii) It must offer a terrific and compact structure once visible on its damaged surface.
- viii) It has to possess uniform colour.

#### 2.8.3 Types of tiles

i) Drain tiles

These tiles are designed to maintain a porous texture after they have been burned. As a result, when such tiles are placed in wet regions, they allow water to work beneath their skeleton. Round, semi-circular, or segmental drains are all possibilities. They're also known for delivering water for agriculture. In today's environment, such drain tiles are uncommon.

ii) Floor or paving tiles

Square or hexangular floor or pavement tiles are additional options. The thickness of these flat tiles ranges from twelve to fifty millimeters. sq. in dimensions the size of the tiles ranges from 150mm to 300mm. The floor tiles must be tough and compact to endure wear and tear over time. The thin-section ground tiles can be used for both the floor and the ceiling.

The coloring material is added to the clay during the preparation process to make colored floor tiles. For wall solutions, less energy-intensive floor tiles might be used. Despite their high price, ceramic floor or paving tiles offer the following significant advantages:

- a) Supplied in an infinite vary of colours and styles.
- b) Easier to get as they're tiny in size.
- c) More lighter than both mosaics and marbles.
- d) They're scratch-resistant, stain-resistant, and damp-proof, as well as anti-slip.
- e) They may not require sharpening, and as a result, the ground is ready for use the next day.
- iii) Roof tiles

They may not require sharpening, and as a result, the ground is ready for use the next day. Their important sorts are as follow:

a) Corrugated tiles

These tiles have corrugations, and when they're in place, they produce a component lap of one or two corrugations. The appearance of wrinkled iron sheets is achieved by using such tiles on a roof. Although these tiles are attractive, they will be blown away by a strong wind.

b) Allahabad tiles

These tiles are composed of high-quality clay. Clay molding is performed with the help of machineries. Those tiles are finished burning in such a way that they get more power. These tiles have projections on them so that when they're in place, they'll interlock with one

another. The hip, ridge, and valley components of the roof are made up of special-shaped tiles. These tiles are widely used in the North-Western Asian country.

c) Flemish tiles

These tiles are in the shape of the letter's,' with measurements of 350 millimeters by 225 millimeters by 12 millimeters, and they're made with the use of a mold. These tiles do not form a genuine covering like the visible tiles, and thus are only suitable for usage in sheds.

d) Flat tiles

These are some of the most often used ground tiles. Two or more holes are provided on their surface to allow them to be repaired on battens. The best laps are found near the corners and edges.

e) Guna tiles

These are burned clay tiles with a hollow tapering shape. They have a 100millimeter-diameter base on the wider end and 75-millimeter-diameter base on the smaller end. The circular ring has a thickness of 1/2 dozen millimeter. These tiles may be created in a factory on a potter's wheel and then put one into another on a kind a hoop of Guna tiles due to their form shape. The ring can also be created in a suitable form, such as round, elliptical, or parabolic.

f) Mangalore tiles

These tiles have a flat design and are equipped with proper projections so that, once in place, they interlock with one another. These red tiles have a double channeled city Mission Mangalore pattern and are manufactured of double channeled city Mission Mangalore pattern. The Mangalore tiles are available for the hip, ridge, and valley of the roof. It's been calculated that about fifteen Mangalore tiles are required to cover one square meter of roof space.

These tiles are mass-produced in South Asian countries, particularly in Mangalore, Fowl, and Calicut. German missionaries developed this economic operation in the early nineteenth century. In 1951, the first manufacturing plant for Mangalore sample tiles was established in Morsi, Saurashtra, and today, almost two hundred machines are in operation in this area. As a result, Morsi has become Gujarat's Bengaluru, and several such devices, numbering in the hundreds, can be seen throughout the Gujarat districts of Bulsara and Surat.

The Mangalore sample roofing tiles are becoming increasingly popular in rural and semi-urban regions, and they may be used by people in the medium and lower income brackets for a variety of reasons, including test results, the scarcity and cost of alternative substitutes, population expansion, and so on. The life expectancy of these roofing tiles is estimated to be around twenty-five years, with an annual growth rate of around 5%. The Mangalore sample tiles are separated into two groups, according to the Bureau of Indian Standards (BIS): 654-1962: class AA and sophistication A.

No	Item	Class AA	Class A
1	Maximum water absorption percentage	19	24
2	Maximum average breaking load	1.00kN (102kg)	0.80kN (82kg)
3	Minimum individual breaking load	0.89kN (91kg)	0.67kN (68)

 Table 2.1: Classification of Mangalore tiles

Effective length	Effective width	
320	210	
340	215	
350	220	

Table 2.2: Dimension of Mangalore tiles

# g) Pot tiles

These are standard half-round country tiles, as well as safety tiles. They are made on a potter's wheel and shaped by a potter's damp hands. A wet textile or a wetted strip of animal skin is used to finish the sprucing of both indoor and external surfaces.

These tiles have a semi-circular shape and taper to a diameter of about 230 mm at the larger end and about 200 mm at the smaller end over a 300mm period. They can also be placed on the roof with their copulate and convex facets on top, resulting in self-locking. As soon as these tiles are employed, a minimum of 80mm companion overlap is provided at the margins.

Because these tiles are prone to breaking, they must be replaced and repaired on a regular basis, which can be time-consuming.

### 2.8.4 The benefits of tiles

- i) Much less susceptible to being displaced by birds.
- ii) Can also be used as a sole masking to the roof.
- iii) Even if the slope of the roof is minor, the pitched roof may be made completely leak resistant due to the fact that intelligent draining is assured by those tiles.

# 2.8.5 Application of ceramic tiles

Ceramic tiles are a popular choice for interior décor because of their inexpensive cost and attractive appearance. These tiles are usually created with a mixture of purple or white clay and chance goods before being glazed. The coloring and sample of the tile are controlled by this glaze, which gives sturdiness to the tile. As a result, ceramic tiles are commonly employed for decorative purposes and in places with low visitor density. These tiles can be used for a variety of purposes, including:

# 2.8.5.1 Flooring

Ceramic tiles are most used in flooring, and most residential structures price ceramic tiles in flats more distinctively. They're ideal for this because of the inexpensive cost, ease of use, and large variety of shapes and sizes available.



Figure 2.9: Flooring

#### 2.8.5.2 Walls

Ceramic tiles can also be utilized on dividers, whether interior or external. On internal walls, they'll be utilized to produce patterns or fast change the color of a space, whilst on external partitions, they'll be used to provide a cooling effect because they don't absorb heat. This will be especially beneficial during the hot months.



Ceramic tiles are a good choice for counter tops since the glaze makes them water and stain resistant, and they can be cleaned very easily on a regular basis. Those tiles, UNIVERSITITEKNIKAL MALAYSIA MELAKA however, are prone to splintering, so caution is required.



Figure 2.11: Kitchen counter tiles

#### 2.8.5.4 Patios

Ceramic tiles are a popular choice because of the wide range of colors and designs available, as well as their relative affordability when compared to stone tiles. In addition, their water-resistant characteristics make them stronger and lasting in humid conditions; nevertheless, care should be made to avoid water buildup.



Figure 2.12: Patios tiles

2.8.5.5 Walkways

Because of the variety of designs available on the market, paths through gardens and parks are frequently made with ceramic tiles, allowing the pathways to be fresh and non-repetitive.

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Certain types of ceramic tiles are created with certain qualities in mind; as a result, you must ensure that the tile you're purchasing is appropriate for your needs. For example, ceramic tiles made for indoor use are often more expensive and less durable than those designed for outside use, so be sure you know what you're obtaining.



Figure 2.13: Walkway tiles

### **CHAPTER 3**

#### METHODOLOGY

#### 3.1 Introduction

During this project, this chapter discussed the entire methodology explanation. This might be done to ensure that the goals are met. First and foremost, this approach began with a flow chart to provide a clear and transient comprehension from the beginning to the end. Style and material selection were the first steps in the main procedure. When using an optical instrument to engrave a design on a tile, it's critical to choose the right style and substance. To begin the planning and development process, a survey was designed to collect the necessary data and input to choose the best style and material. A variety of parts are enforced in this design, which may be separated into many different ceramic tile materials. In addition, the kind of ceramic tile half relates to the structure's surface, size, and material type, among other things.

Each type of ceramic tile has its own set of characteristics that must be considered while planning. For instance, the most important characteristic in ceramic tile is the protective feature, as well as the type of ceramic tile used for pattern design and any half that could build ceramic tile style, such as sharp edges. Furthermore, the mechanical half's size is significant since this project is particularly made for people who want to buy souvenirs, and it shouldn't be too big, or the people would feel worthless when shopping for them. This chapter will provide a concise overview of how the project will be executed. The project is divided into many stages, starting with a content flow chart, then a customer survey, a HOQ, a conceptual style, the Pugh approach, and material selection, followed by model production, testing, and analysis.

# 3.2 **Project planning**



Figure 3.1: Flowchart of methodology process

The first phase of the project concentrates on the three chapters of introduction, literature review, and methodology. At this stage, the issue description, objectives, scope, and project-related information are being gathered from a variety of sources. This is a sequence diagram that will be used to show the flow of processes involved in this project from start to finish. The flow chart will show the steps that must be followed to guarantee that the project's goal is met. The flowchart below depicts the procedure that will be utilized to complete this project. This flow chart is used as a reference for putting this project together using the system that is clearly specified in the FYP 1 to FYP 2 flow chart in concept.

To comprehend the crucial and fundamental facts about this project, it is necessary to conduct some study on the design to limit the risk of errors in the construction of patterned tile by laser engraving. As a result, the first step is to hunt for a previous study of literature or case studies on how to create a design on ceramic tile using the laser engraving technique. For this project, the goal of this research is to create a three-dimensional pattern on ceramic tile using the laser engraving technology. The first chapter, which identifies the project's issues, objectives, and scope, is the emphasis of this phase. The aim and scope of the title should be clearly defined to ensure that it is understood. Literature studies use books, journals, papers, and websites to obtain more extensive information on this issue.

### **3.2.1** Period of the project

The duration of this curriculum is two semesters, with each semester lasting 15 weeks. As a result, the student gets 30 weeks to finish his or her Projek Sarjana Muda (PSM), or senior project. FYP 1 entails a thorough examination and investigation of the proposed project, as well as a greater understanding of the project. From Chapter 1 through Chapter 3, you must submit the Introduction, Literature Review, and Methodology report. FYP 2 entails experimental testing that will entail a limited number of tests to develop an outcome

that is a scissoring gait device using 3D printing. Based on the facts, the project needs careful planning and effective task organization. Before a student may receive a degree, they must finish this project to meet the prerequisites.

### 3.3 Literature review

A literature research was conducted to better understand the nature of this project and past work in order to provide ideas and designs for new scissoring gait devices that would meet the demands of clients. This project's literature studies have been compiled from a variety of sources, including journals, essays, and books. It will be easy to design new concepts and choose materials for prototype development with these resources. This will serve as a roadmap for making additional development and ensuring that this product can benefit everyone.

### 3.4 Data Collection

Data gathering and analysis are the approaches employed in this research to interpret it. Data collection refers to the process of determining the information gathered regarding the technique employed. Qualitative data and quantitative data are the two forms of data collected. In this study, both sorts of data are employed to get such information. For data collecting, there are two types of sources: primary and secondary sources. Primary sources include observation and inquiry, whereas secondary sources are newspapers, books, and the internet.

## 3.4.1 Observation field

An observation was carried out at the UTEM FTK laboratory to understand more about laser engraving of ceramic tile. The speed, power, and loop count of the laser machine were all monitored in this project to achieve a decent design of 3D and 2D patterns on ceramic tiles. Furthermore, because there are many different types of ceramic tile surfaces on the market, the ceramic tiles utilized in this project were also noted. As a result, several observations must be made to obtain an appropriate ceramic tile surface and the process method for obtaining a final design on ceramic tile utilizing the laser engraving technique.

#### **3.4.2** Design specification

It should transform the customer's need into a technical phrase known as a product design specification after recognizing and understanding the restriction of the patterned on ceramic tiles using laser engraving process. The challenge of employing a laser engraving on ceramic tile to get 3D or 2D patterns to build a pattern on the surface of the tile is investigated through observations and interviews.

## 3.5 Pattern development

Customized pattern design necessitates the following steps: 3D scanning of the design, 3D surface reconstruction, recap model pattern and conversion to STL file, and lastly, design utilising a laser engraving machine

### **3.6** Methods and materials

#### 3.6.1 Laser engraving

Engraving is a technique for carving a design into a hard, typically flat surface. The surface design is permanent and cannot be changed. A beam of light is used to ablate a solid mass in this technique, which follows predetermined patterns. A laser is a device that can generate light via an optical implication technique that is supported by the stimulated emission of electromagnetic waves. A suitable laser must be picked to carry out the required operation to be able to use it for engraving. This method is repeated on each thin layer until

the desired design is achieved. A low-power laser was employed as the main component element in this project to etch the surface of a wooden object. In this project, a desktop laser engraving kit machine with a diode laser and wavelength was utilized to engrave the product's surface. It's the medium for converting the appearance into an actual design that will be tweaked and tested. The laser will be moved in the x-axis and y-axis directions by three stepper motors on this equipment. The YMMarker 2.14.9 program will be used to understand and control hardware instructions. It is a collection of data that includes various studies on the laser engraving process, including input parameters such as laser power, frequency, pulse duration, spot diameter, number of passes, air/gas pressure, and engraving speed for various work piece materials including ceramic, aluminum, alloy, acrylic, semiconductor, and wood. It is discovered what changes occurred because of adjusting all input parameters to output parameters such as surface polish, material removal rate, and depth.

#### 3.6.2 Engraving method

When printing something, you must usually use ink and paper. Laser engraving, on UNIVERSITTEEKNIKAL MALAYSIA MELAKA the other hand, is the opposite. When using a laser to remove material, the substance will be sliced away from the surface with apparent depth and texture. It may engrave at varied depths or even cut all the way through the material for a distinctive edge or die cut effect by adjusting the intensity of the beam.

A laser engraving machine is a machine that performs a comparatively transferring information from a design file onto an item using intricate components and techniques. The laser, the controller, and the surface are the three major components of a laser engraver. The laser, like the pen, is the device that really generates the planning by focusing high-powered light into the cloth. The surface of the cloth that I was attempting to engrave was ceramic tile for this project.

The controller is the portion of the engraving machine that controls the laser—it's arm that moves the pen over the surface and directs the laser's ability to follow your design guidelines. The information in the design file you produced controls the motions of the controller as well as the power of the laser. When the laser engraving machine's software translates your design into a vector map with X and Y axes, the magic happens. The controller, as well as the laser, will then scan the vector map and move appropriately to create your design.

#### 3.6.2.1 Idea on engraved

It is the most crucial and initial phase in the laser engraving process. Ceramic, stone, glass, plastics, coated or non-coated metals, and natural substrates like wood may all be engraved with a laser, and the possibilities for what can be engraved are only limited by your imagination. If you're having trouble coming up with project ideas, consider looking for inspiration in nature or on the internet.

### 3.6.2.2 Design the desired text or image

The picture concept in this project is either a 3D or 2D design. Most of the art line design is based on the internet or software. If you're using the software technique, you'll need to edit the image with Adobe Insulator or another program to achieve the right pattern to engrave. If the design is based on the internet, utilize "paint" software to correct any flaws in the design. Computer programs are used to create optical device printers, but it's important to make sure that the laser engraving machine you want to use is compatible with the files generated by your design software. Some laser engraving machines come with their own

software, while others, such as Adobe Creative Person, are designed to work with current software systems. Once the design is complete, the printer dialogue will send it to the laser engraver.

#### 3.6.2.3 File format

Depending on the laser engraver and software, the laser's power, depth of cut, speed, range of passes, line thickness, and other characteristics must all be controlled. The depth of the laser cut, the speed, the number of passes, the line thickness, and other factors. It is suggested that you try the materials under a range of scenarios to see what settings produce the best results. We employ the ai file format, which includes.ai,.bmp, cdr, dwg, dxf, eps, jpg / jpeg, pdf, png, scad, svg, and xps.

#### 3.6.3 Procedures

Engraving using a laser is as basic as printing. These are the easy methods to engrave the artwork you choose.

- Create the engraving layout with a graphics application like Adobe Illustrator, CorelDraw, Photo-shop, Auto CAD, or Inks cape.
- ii) The graphic is then sent to the laser via the printer driver.
- iii) The chosen material is laser etched with the hold on settings at the touch of a button.
- iv) Advanced options, such as the depth of engraving design and the various colour tones, may be created if needed to make the picture more appealing.
- v) Process types saved in the printer driver make day-to-day tasks much easier by streamlining graphically needed procedures automatically.

#### 3.6.4 Type of laser used

#### 3.6.4.1 Fiber laser

The solid-state laser cluster includes fiber optical equipment. They create a beam of light using a seed optical device and then enhance it in specially engineered glass fibers that are supplied with energy via pump diodes. Fiber lasers produce a relatively small focus diameter with a wavelength; therefore, their intensity is up to a hundred times more than that of a greenhouse gas optical device with an equivalent output average power. The fiber optical device is best suited for hardening metal marks, metal engraving, and high-contrast plastic markings. Fiber optical devices are usually maintenance-free and have a minimum service lifetime of 25000 optical device hours.

# 3.6.5 Type of machine

This research made use of a Fiber Laser Machine at the Manufacturing Laboratory at University Technical Malaysia Melaka's Faculty of Manufacturing Engineering (UTeM).



Figure 3.2: Engraving machine and specification

# **3.6.6** Type of software

In this experiment, Adobe Illustrator from Adobe Inc. was used to design the required pattern that would be etched by the Fiber Laser Machine. The laser engraving region was drawn in Adobe Illustrator, and the etched part's arrangement was developed as a vector picture. The Adobe Illustrator interface is seen in Figure 3.3. Because the Fiber Laser Machine is compatible with the format of the chosen graphic software, it was easier to utilize Adobe Illustrator. As demonstrated in Figure 3.4, the intended picture or design was a basic 2D model that was then loaded into the YMMarker 2.14.9 program. This is the standard software that comes pre-installed on the laser engraving machine. The program analysis vector line shapes in an Adobe vector picture and converted them to laser vector movement.



Figure 3.4: YMMarker software

# 3.7 Parameters

In this experiment, Adobe Illustrator from Adobe Inc. was used to design the required pattern that would be etched by the Fiber Laser Machine. The laser engraves A parameter is a numerical or other quantifiable element that serves as one of the hard and fast rules that defines a system or establishes the conditions under which it operates. A parameter may also be defined as a constraint or barrier that limits the scope of a system or activity. Cloth is removed according to the necessary measurements and the parameters that the laser

engraves device requires in laser engrave. Adobe Illustrator was used to create the graving area.

The etched surface's perfect finish is determined by the specifications entered. The engraving outcome is influenced by the machine's settings being set correctly. To be able to price the engraved result, the desired result must first be identified. Energy and speed parameters, PPI, and Hertz's parameters, pass parameter, Z-off parameter, and lastly air-assist parameter are all involved in laser engraving.

The most important settings in the fabric database are the laser power and velocity parameters. They can be specified as a percentage ranging from 0% to 100%. The laser's output strength is described by the Power laser parameter. The highest strength is 100 percent. Excessive energy is required for dark ceramic engravings or stamp engravings, whilst low values are employed for materials such as paper. The laser head's movement is described by the Speed optical device parameter. Fast speeds result in shorter exposure durations, whereas sluggish speeds result in longer publicity times. Massive scale engravings of ceramic substances, for example, are etched at excessive rates of between 80% and 100%, while the rate for metal engravings should no longer surpass 100%.

This positioning also has an impact on the quality of the laser engraving. It's worth noting that the speeds of lowering a portion of the material and engraving are not similar. In general, reducing a portion of a material takes longer than engraving. A high engraving speed range from 80% to 100%.

The PPI (pulses per inch) parameter specifies how many optical device pulses per inch are utilized for engraving. This might be an equivalent or multiple of the dpi selected in the print option to provide an accurate outcome. When this option is set to machine, a computer program selects the optimal resolution of the optical device pulses mechanically. The Frequency parameter is crucial throughout the etching procedure and is expressed in Hertz (=Hertz). The number of optical device pulses per second is specified. The value for a carbon dioxide optical device will be set between 1,000 and 60,000 Hz. For example, if you want a smooth edge when cutting acrylic, you'll need higher temperatures, which means this value should be between 5,000 and 20,000 Hz. On the other hand, a low frequency of one thousand Hertz cutting wood is necessary to realize, for example, the brightest possible leading edge.

The number of engraving or cutting passes is determined by the Pass parameter. For some materials, for example, it may be preferable to engrave at a low power and high speed, then repeat the process several times. This indicates that the cloth is under less stress per pass. This method, for example, is suitable for relief engraving.

In addition, there is the Z-offset parameter. The focus setting is described by the z-offset. It operates "in focus" if the z-offset is close to zero, which implies the focus is only on the cloth surface. There are some cases, however, where purposeful refocusing is desirable. For example, when engraving large regions on Tirolese, we recommend focusing the laser 2 mm for a more equal engraving finish. The following z-offset values can be used: - 5 millimeters up to 127 millimeters (table rises higher, bringing it closer to the material) (table moves down, i.e., additional far from the material).

Finally, there's the air assist parameter. The availability of compressed gas will have a significant impact on and improve the outcomes of optical device engraving and laser cutting. Furthermore, Air Assist protects the lens from damage by preventing debris from clinging to it in the first place. However, there are some applications where the Air Assist is modified on purpose. While not using Air Assist when engraving Tirolese engraving materials, for example, an additional tempting engraving effect is created. In this situation, the lens should be inspected for contamination more frequently than when using Air Assist.

Use default param						
Current pen	0					
Loop Count	1					
Speed(MM/Secon	100	-				
Power(%)	80	10				
Frequency(KHz)	20	-				
Start TC(US)	-80	THE.				
Laser Off TC(US)	250					
End TC(US)	300	+				
Polygon TC(US)	30	+				

Figure 3.5: Laser engraved parameters

# **3.8** Effect of laser engraving on ceramic tile

Although laser technology is mostly used in engineering sectors, it has also been used in various branches of the arts, such as graphic and plastic arts. Ceramics is one of these disciplines. Before heating, the ceramic substance is delicate. It's water semipermeable after bisqued, yet it's fairly resistant to breakage. Following the glaze firing, the body/surface has a water-proof and long-lasting characteristic. Due to the intense temperature of the laser, after the irradiation is given to the ceramic body, the ceramic body exhibits a variety of responses. In agreement with the author's earlier investigations, which provided light on the current study;

- a) Wherever irradiation is used, white clay has transformed to a single cream or brown colour as a result of the warmth. A cavitation of around 0.2-.03mm depth has also formed on each surface. These applications are tested on both glazed and unglazed bisque bodies.
- b) Clay has turned black whenever irradiation is used as a result of the iron chemical complex it contains coming into touch with heat.

This technology, which has found a home in the ceramics industry, may be employed efficiently in decorative approaches such as dishware. This technology, which is also quite popular in other countries, speeds up the application process and makes the craft simpler. Because laser engraving is such a delicate process, it is much simpler to create incredibly intricate designs. The application technique of laser engraving on several items of an organization in South Korea has been ascertained on-site, as illustrated in Figure three, and many diverse visuals are presented below. Initially, the design is created digitally and then submitted to a laser engraving equipment after being saved as a dxf file. The final appearance of the optical maser etched and glaze laid-off ceramic ware body (decorative tile) is shown.

When several samples are examined, it becomes clear that the machine's effects are applicable to the ceramic industry, disciplines of ceramic design, and practice, and that it allows for the creation of unique practices that are open to new ideas.

# 3.9 Microstructure specimen

To determine the grain size of the microstructure on the graved region and base metal, the sample microstructure was examined using a digital USB microscope, as shown in Figure 3.6.



Figure 3.6: Digital microscope

# 3.10 Surface roughness machine

For all test runs, the surface roughness was assessed with a Mitutoyo Surftest stylus profilometer, as illustrated in Figure 3.7. The surface roughness of the material was readily and precisely assessed using the Mitutoyo Surftest stylus profilometer. The estimated roughness depth (Rz) in microns or micrometres (m) is displayed on the Mitutoyo Surftest stylus profilometer, as well as the mean roughness value (Ra). All of the samples' Ra values were determined using a 5mm measuring field. To eliminate the influence of measuring mistakes, three measurements were made for each engraved section. The final Ra value was calculated using the mean value.



Figure 3.7: Surface roughness machine

# 3.11 Summary

Throughout the experiment, the type of material utilized, engraving settings, and machine type were detailed in the methodology section. Ceramic tiles were utilized as the engraving sample, and the engraving operation was done utilizing a Fiber laser equipment. Furthermore, surface roughness was measured using a Mitutoyo Surf test stylus profilometer, and the microstructure of the specimens was examined with a digital USB microscope.



# **CHAPTER 4**

### **RESULT AND DISCUSSION**

# 4.1 Introduction

This chapter describes and tests the preliminary results of the Ceramic Tiles without any coating or spray. Laser frequency, laser strength, engraving speed, and loop count were all used in this experiment. For this experiment, the laser frequency and engraving loop count were kept constant. The purpose of this project was to create a design utilizing laser engraving on ceramic tiles and to analyses the engraving parameters. Following that, according to this testing, characterize the structural and microstructure alterations caused by laser engraving. The test was then conducted, and the results were analyzed.

# 4.2 Ceramic tiles sample



Figure 4.1: Final product of laser engrave ceramic tile

The outcome of laser engraving is shown in Figure 4.1. This ceramic tile has the property of being a tougher tile with a smooth and rough surface. Many various types of tiles

are available on the market, including soft and light weight tiles, hard and highly reflective tiles such as mirrors, and many more. As a result, the only option for this project is to use the hard and heavy tile indicated in the image above.

Power	Speed mm/s(RPM)				
80%	200	400	600	800	1000
60%	200 <sup>YS/4</sup>	400	600	800	1000
40%	200	400	600	800	1000
20%	200	400	600	800	1000

#### 4.3 Result 1

Table 4.1: Parameters for ceramic tiles laser engraving



Figure 4.2: Graph of parameters used for engraved ceramic tiles

The graph of speed vs power (parameter) utilized for Laser Engraving Testing is shown in Figure 4.2. There are five samples, each with the same speed but different power was used.

# 4.4 **Result of the experiment**

The ceramic tiles were engraved using a fiber laser machine. For the experiment, there were two samples. The first sample contains 20 engraved portions with various laser speeds and powers, while the second sample contains 5 engraved parts with various laser loops. The laser power value was chosen by going from the lowest range value to the highest range value with a 20W increment, while the laser speed value was chosen by going from the lowest range value to the highest range value with a 20W increment, while the laser speed value was chosen by going from the lowest range value to the highest range value with a 500mm/s increment. Two tests followed the experimentation phase: microstructure inspection and surface roughness testing. The surface roughness was measured using a Mitutoyo Surf test stylus profilometer that passed ISO standards. The test was piloted utilizing a Digital Microscope Nikon SMZ-745T IMTCam3 for microstructure examination.



Figure 4.3: First sample of laser engraving test on ceramic tile

Figure 4.3 above depicts 20 laser engraving test samples on a ceramic tile, each with a distinct color of result after the tile has been engraved. The sample's result then reveals the varying color and showing rough surface to the 20 parameters that were employed throughout the test. The higher the parameter the brighter the color and the lighter the color the lower the parameter employed during the laser engraving process.



Figure 4.4: Second sample of laser engraving test on ceramic tile

Figure 4.4 depicts five samples of laser engraving tests on a ceramic tile, with the results demonstrating the various types of images produced by the five distinct parameters utilized throughout the test, the most important of which is speed. Because it employs low speed and high power, the initial image produced by the laser engraving does not generate a picture. The ceramic surface burns and produces an uneven surface as a result. We may deduce from this that if the power is higher, the picture will not be engraved clearly. Due to the high-power parameter employed, the picture clear vision changes to deeper, and the design will not be correct for the outcome.

## 4.5 Result of best parameters used

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On a ceramic tile, there are 20 examples of outcomes carved using laser engraving techniques. The research was carried out on the first 20 samples of laser engraving using a

digital microscope, and the best 5 laser engraving results were chosen. Then, for the second sample of five laser engraving, the best 2 laser engraved were chosen.

# 4.6 Result 2

### 4.6.1 Second sample

Constant loops count 5

i) Effect of laser speed and laser power on the surface quality of laser engraving tiles for constant loops count 5.



**4.**7

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4.8 Result of microscopic observation

The ceramic surface was described and the structure of the etched sections was clarified using microscopic inspection. The observation is necessary to justify the engraving mark quality and, as a result, to understand the link between laser parameters and mark accuracy.

# 4.8.1 Analysis result of digital microscopic observation

For a faster and more accurate macro view evaluation, the digital microscopic observation was performed utilizing a digital USB microscope. The microstructure was

discovered in the etched field's center. The surfaces of the engraved parts were classified into three categories:

- i) Parts with burn marks engraved on them. The respected oriented fields appear to be black-burned.
- ii) Parts with no burn marks engraved on them. Since the coating material was totally burned, the respected aligned fields generated parallel regions and were completely square.
- iii) Parts that were not damaged by the laser were engraved. The bubble of the covering substance could be seen in the orientated fields.

#### 4.8.2 Digital microscopic observation

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To determine the best result of the laser engraving test, the Digital Microscope was used to test the surface of the Ceramic Tile to see how it changed depth from original depth to deeper or normal to original surface after testing. It may be viewed how crisp the engraved section is and how thick or thin the carved layer is using a digital microscope. Because this procedure can be observed more carefully on the ceramic surface using a digital microscope, the visual results are crisp.

Microscope observation or analysis based on a comparison of laser speed and power, with microscopes used on the 5 best laser designs on tile and the 5 worst laser designs on tile.

#### 4.8.2.1 Best image for speed 1000



Figure 4.6: Best selection image for speed 1000

Figure 4.6 illustrates the outcome of engraving a ceramic tile using a 1000 RPM speed and an 80 percent power setting. When compared to other power for continuous speed, the depth after engraving is a little inside and the surface looks nicer. The time taken for this parameter is 1:40.97 min:sec, which is smaller than the time taken for other parameters such as speed 1000 rpm and power 80 percent.



Figure 4.7: Not best selection image for speed 1000

Figure 4.7 illustrates the outcome of engraving a ceramic tile with a speed of 1000 RPM and a power of 20%. In comparison to other powers such as 40 percent, 60 percent, and 80 percent, the engraving of power 20 percent does not etch the tile deeper and only engraves light the upper surface. The engraving design took 1:42:43 min:sec to complete with this engrave parameter. Even though this parameter takes less time to complete, the
engraving depth is not very clear and deep. For a speed of 1000 rpm, the power setting of 20% is insufficient.

## 4.8.2.3 Best image for speed 800



Figure 4.8: Best selection image for speed 800

Figure 4.8 depicts the outcome of engraving a ceramic tile with a speed of 800 RPM and an output of 80% power. The depth after engraving is more than the first best parameter on figure 4.7, and the surface appears to be superior when compared to other powers. In comparison to other parameters, this parameter takes 2:14.49 min:sec. The time taken for speed 800 rpm and power 80% is a fraction of a second longer.

4.8.2.4 Not best image for speed 800



Figure 4.9: Not best selection image for speed 800

Figure 4.9 illustrates the outcome of engraving a ceramic tile with a speed of 800 RPM and a power of 20%. In comparison to other powers such as 40 percent, 60 percent, and 80 percent, the engraving of power 20 percent does not etch the tile deeper and only

engraves light the upper surface. The engraving design was completed in 2:10.40 min:sec using this engrave setting. Even though this parameter takes less time to complete, the engraving depth is not very clear and deep. The 20% power setting is incompatible with a speed of 800 rpm.





Figure 4.10: Best selection image for speed 600

Figure 4.10 illustrates the outcome of engraving a ceramic tile using a 600 RPM speed and an 80 percent power setting. The depth after engraving is deeper than the first best parameter on figure 4.6 and the second-best parameter on figure 4.8, and the surface seems brighter and better in comparison to other power. The time taken for this parameter is 3:13.03 min:sec, which is somewhat longer than the time taken for speed 600 rpm and power 80 percent in pictures one and two.

### 4.8.2.6 Not the best image for speed 600



Figure 4.11: Not best selection image for speed 600

Figure 4.11 illustrates the outcome of engraving a ceramic tile with a speed of 600 RPM and a power of 20%. In comparison to other powers such as 40 percent, 60 percent, and 80 percent, the engraving of power 20 does not etch the tile deeper and only engraves light the upper surface. The engraving design was completed in 3:10.02 min:sec using this engrave setting. Even though this parameter takes less time, the engraving depth is not as deep, but the color is a little clearer than the 1000 rpm and 800 rpm parameters. The 20 percent power option is not suited for a speed of 600 rpm.

#### 4.8.2.7 Best image for speed 400



Figure 4.12 illustrates the outcome of engraving a ceramic tile using a 400 RPM speed and an 80 percent power setting. On figure 4.6, figure 4.8, and figure 4.10, the depth after engraving is deeper than any of the above best parameters, and the surface seems brighter and better when compared to other power. When compared to other parameters, the time taken for speed 400 rpm and power 80 percent is a little longer than other parameters, but it is still a decent parameter when compared to other photos.

#### 4.8.2.8 Not the best image for speed 400



Figure 4.13: Not best selection image for speed 400

Figure 4.13 illustrates the outcome of engraving a ceramic tile with a speed of 400 RPM and a power of 20%. In comparison to other powers such as 40 percent, 60 percent, and 80 percent, power 20 engraving does not etch the tile deeper and just engraves light the upper surface. The engraving design took this engrave parameter 6:13.99 min:sec to complete. Even though this parameter takes less time, the engraving depth is not as deep as the others, but the color is a little clearer. For a speed of 400rpm, the power setting of 20% is insufficient.

4.8.2.9 Best image for speed 200 UNIVERSITI TEKNIKAL MALAYSIA MELAKA



Figure 4.14: Best selection image for speed 200

Figure 4.14 depicts the outcome of engraving a ceramic tile at a speed of 200 RPM and an intensity of 80%. On figure 4.6, figure 4.8, figure 4.10, and figure 4.12, the depth after engraving is deeper than any of the aforementioned optimum parameters, and the

surface seems brighter and better in comparison to other power sources. When compared to other characteristics, the time taken for speed 200 rpm and power 80 percent is a little longer, but it is still one of the better parameters when compared to other photos.

4.8.2.10 Not the best image for speed 200



Figure 4.15: Not best selection image for speed 200

Figure 4.15 illustrates the outcome of engraving on a ceramic tile with a speed of 200 RPM and a power of 20%. When compared to other powers such as 40 percent, 60 percent, and 80 percent, the engraving of power 20 does not etch the tile deeper and simply engraves the upper surface. The engraving design took 7:10.55 min:sec to complete with this engrave setting. Even though this parameter takes less time, the engraving depth is not as deep, but the color is a little clearer than the parameters 1000 rpm and 800 rpm, 600 rpm and 400 rpm. The 20% power option is not suited for a speed of 200 rpm.

# 4.8.2.11 Best and poor image view from Digital Microscopic

Best Image View	Poor Image View	
Power 80%, Speed 200rpm	Power 20%, Speed 200rpm	
Power 80%, Speed 400rpm	Power 20%, Speed 400rpm	
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Power 80%, Speed 600rpm	Power 20%, Speed 600rpm	



Figure 4.16: Zoom in part using Digital Microscopic

Figure 4.16 shows the engraved sample with a zoomed-in view to determine the surface microstructure following the Laser Engrave procedure. Under a digital microscope, the finest and worst images were seen. After the graving process is done, each angle has the best performance.

### 4.9 Result of surface roughness test

The surface texture of the sample was determined using a surface roughness test. The mean roughness value (Ra) in micrometres (m) was displayed on the roughness tester. The data was organised into four graphs, each representing a different speed (RPM) and power ( percent ). With the combination of laser power and speed, the surface roughness of each material was extremely important. As the speed increased, the surface roughness of most of

the materials decreased. The surface roughness value calculated for each material would be modest if the power was low. The maximum and minimum roughness values for each parameter are compared in Table 4.2.

Speed (RPM)	Power (%)	Surface Roughness Test		
		Reading 1	Reading 2	Reading 3
200 rpm	80%	1.303	1.202	1.853
	60%	1.395	1.766	1.787
	40%	1.630	1.748	1.855
	20%	1.079	1.231	1.181
400 rpm	80%	1.603	1.476	1.943
	60%	1.882	1.836	1.946
	40%	2.181	1.326	1.605
	20%	0.404	0.580	0.315
600 rpm	80%	1.856	1.670	2.460
	60%	3.021	2.102	1.819
	40%	0.878	1.114	1.566
~	20%	0.201	0.204	0.149
800 rpm 🔬	80%	3.234	3.026	2.904
N.	60% Ş	3.068	2.687	1.823
	40%	1.556	1.395	1.541
E	20%	0.160	0.131	0.140
1000 rpm 📎	80%	1.715	2.652	2.937
	1/mn 60%	3.580	3.132	2.412
de la	40%	1.280	0.819	1.161
2)	ل ما%20 ما	0.075	0.070	0.068

Table 4.2: Ra value for speed and power

The value of power was modified for both the lowest and maximum roughness values, as indicated in Table 4.2. Some materials were impacted by the maximum power at the lowest roughness, whereas others were influenced by lesser power. The greatest power, which is 80 percent, impacted most of the materials at maximum roughness. As a result, the power value had little impact on the surface roughness value. The power value that must be optimal is determined by the material's characteristics. An optimal power value combined with a higher speed combination will result in a superior surface finish, whereas an inappropriate and unsuitable power value combined with a lower speed count would result

in an increase in surface roughness. Oxidation can also induce an increase in surface roughness. The Ra value is high because to the oxidation-induced rusting look.



#### 4.9.1 Surface roughness reading speed 1000rpm

Figure 4.17: Surface roughness for speed 1000rpm

For the first reading Ra1, the maximum average value is 3.580µm at 60W power, while the lowest average value is 0.075µm at 20W power. In the second reading, Ra2, the Ra values are growing and falling as the laser power is increased. At 60W power, the maximum average value is 3.132µm, while at 20W power, the lowest average value is 0.070µm. While we get to the third reading, Ra3, the Ra values remain the same as the values decrease in power. At 80W power, the maximum average value is 2.937µm, while at 20W power, the lowest average value is 0.068µm. Finally, in power 80W, the Ra value increases for each trial, but in power 60W, the Ra value decreases for each trial. On the graph, show increasing and decreasing Ra values for 40W and a decreasing Ra value for 20W. For the

three measurements, the highest Ra average value is 3.580m at 60W and the lowest Ra value is at 20W power which is  $0.068\mu m$ 



#### 4.9.2 Surface roughness reading speed 800rpm

Figure 4.18: Surface roughness for speed 800rpm

For the first reading Ra1, the maximum average value is 3.234µm at 80W power, while the lowest average value is 0.160µm at 20W power. In the second reading, Ra2, the Ra values are falling as the laser power increases. At 80W power, the maximum average value is 3.026µm, while at 20W power, the lowest average value is 0.131µm. The Ra values show no trend in the third reading Ra3, with the greatest average value of 2.937µm at 80W power and the lowest average value of 0.068µm at 20W power. Finally, the Ra value decreases in power 80W and 60W for each trial, although the power in 40W increases and decreases as seen in the graph. Show the growing Ra value for the 20W. For the three measurements, the maximum Ra average value is 3.234µm at 80W power, while the lowest Ra value is 0.131µm at 20W power.

#### 4.9.3 Surface roughness reading speed 600rpm



Figure 4.19: Surface roughness for speed 600rpm

For the first reading Ra1, the maximum average value is 3.021µm at 60W power, while the lowest average value is 0.201µm at 20W power. In the second reading, Ra2, the Ra values are growing and falling as the laser power is increased. At 60W power, the maximum average value is 2.102µm, while at 20W power, the lowest average value is 0.204µm. The Ra values show a declining trend in the third reading Ra3, with the maximum average value of 2.460µm at 80W power and the lowest average value of 0.149µm at 20W power. Finally, for each trial, the Ra value is increased or decreased at a power of 80W. The power for 60W is dropping, as seen in the graph, whilst the power for 40W is growing. Finally, the Ra value for the 20W has increased from reading 1 to reading 2 and decreased in reading 3.



#### 4.9.4 Surface roughness reading speed 400rpm

Figure 4.20: Surface roughness for speed 400rpm

For the first reading Ra1, the maximum average value is 2.181m at 40W power, while the lowest average value is 0.404µm at 20W power. In the second reading, Ra2, the Ra values are growing and falling as the laser power is increased. At 60W power, the maximum average value is 1.836µm, while at 20W power, the lowest average value is 0.580µm. As we get to the third reading, Ra3, the Ra values show a downward trend, with the maximum average value of 1.946µm at 60W power and the lowest average value of 0.315µm at 20W power. Finally, as seen in the graph, the Ra value increases and decreases in every power for each trial. At 40W power, the greatest Ra average value for the three measurements is 2.181µm, while at 20W power, the lowest Ra value is 0.315µm.





Figure 4.21: Surface roughness for speed 200rpm

The Ra values for speed 200 rpm are varied increasing and decreasing with respect to laser power. For the first reading Ra1, the maximum average value is 1.630µm at 40W power, while the lowest average value is 1.079µm at 20W power. In the second reading, Ra2, the Ra values are growing and falling as the laser power is increased. At 60W power, the maximum average value is 1.766µm, while at 20W power, the lowest average value is 1.202µm. As we get to the third reading, Ra3, the Ra values show a growing and falling trend, with the maximum average value of 1.855µm at 40W power and the lowest average value of 1.181µm at 20W power. Finally, as seen in the graph, the Ra value increases and decreases in every power for each trial. At 40W power, the lowest Ra average value for the three measurements is 1.855µm, while at 20W power, the lowest Ra value is 1.079µm.

#### 4.10 Discussion

Laser engraving is a type of interaction that tends to influence the pulsed laser's interaction with materials. Laser ablation happens when the amount of energy absorbed by the material is high enough to cause vaporization and ejection of the substance's outer layers. The irradiance must be greater than the irradiated material's ablation threshold to produce material vaporization. Surface damage rises as a function of irradiance as a rule; hence an ideal balance must be achieved to maximize process throughput (increasing irradiance) while minimizing damage (decreasing irradiance and or decreasing pulse width).

According to the research, the irradiance influence on ablation rates can discriminate between two regimes. Laser radiation transmits significantly more energy into the sample's surface when irradiance levels are modest but beyond the typical ablation threshold of the substance irradiated, where strong temperature and pressure gradients form an intense plasma plume. These circumstances result in visible craters that have a noticeable impact on the mass of the material. Rejected species produce a rebound pressure that throws away the burned surface layer while also creating a mechanical shockwave that aids in the ejection process.

A laser ablation approach based on a Q-switched Nd:YAG laser operating in pulse mode was used to demonstrate high quality deep engraving of industrial ceramic tiles. The number of lasers passes or cycles over the same region of the ceramic tile surface has a significant impact on the ablation rate. Furthermore, the high irradiation levels attained were associated with two separate ablation regimes, one below critical value and the other above them. The processes of vaporization (vapor plume) and species breakdown (plasma plume), both dependent on photothermal type ablation mechanisms, are discovered. Furthermore, structural and microstructural analysis revealed that the ablation of clay and porcelain tiles occurred through distinct processes. As the number of laser cycles and irradiance levels were raised, the effectiveness of ablation was lowered due to the existence of higher volumes of surface melts in clay tiles. Thermal shock aided grain removal is used in the ablation of porcelain tiles. Despite the low ablation rates, a good resolution finish was produced in both cases.

#### 4.10.1 Optical microscopy and surface finish

With traditional processing techniques, high-definition engraving and machining of ceramics is difficult to produce. High-definition, customized graphics are deeply carved into ceramics using the laser process. Geometry, as well as the initial state and composition of ceramic tiles, are basically unrestricted. The mechanical resilience of these engraved tiles has been established in published studies, allowing for thermal treatments and glazing while maintaining their optical finish properties.

#### 4.10.2 Engraving rates

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If the damage threshold is not exceeded, the engraving depth is suggested as the most essential optimization parameter for the current ablation procedure. The damage threshold is defined as the lowest amount of irradiation that causes uncontrolled material removal or fractures inside the irradiated surface. The engraving rate was calculated using ablation rates, which are determined by the irradiance and the number of laser scans (passes or cycles) performed on the same region of the material's surface. All the data given here was gathered under settings that were set below each material's damage threshold.

#### **CHAPTER 5**

#### CONCLUSION AND RECOMMENDATION

This chapter described the project's result and recommendations for further study. This study looked at a few coating strategies for burn mark accuracy and depth in the laser engraving process for ceramic tiles. The engraving parameters of laser power, speed, and loop count were changed to see what influence they had on the responses of surface roughness and microstructure. Experiments on ceramic tile surfaces were used to effectively complete the investigation. An outline of the investigation and a summary of the findings are two elements covered in the section on conclusion. The recommendation section includes suggestions for further research and development of this topic.

#### 5.1 Conclusion

The goal of this study is to investigate several types of parameters and material methods for burn mark accuracy in the laser engraving of ceramic tiles. The study's initial goal, as mentioned in the introductory section, is to construct a pattern utilising laser engraving on ceramic tile. From the perspective of pattern engraving and quality, the effect of laser applied on ceramic surface has yielded positive results. The surface of the ceramic tile is very vital for getting the greatest laser engraving design. On tiles, laser engraving can be used as an alternative to printing other décor processes.

The second goal is to see how laser engraving settings affect the surface roughness and characteristics of ceramic tiles. In defining the surface characteristics of the materials, the combination of laser power, laser speed, and loop count was crucial. Because no burn scars formed and the ceramic components were completely removed, a loop count combined with the optimal amount of laser power will result in a superior surface characteristic. In all combinations of factors, a suitable material surface will produce acceptable surface characteristics. Each type of ceramic material has various surface properties, according to the results of the investigation. The existence of parallel lines in the majority of the etched fields demonstrated good surface characteristics in smooth and light weight ceramic material. To get a better laser engraving outcome, the materials need to be set up with the best settings possible.

The final goal is to investigate the structural roughness and microstructure changes caused by laser engraving on ceramic tile. When the settings are modified, the surface roughness of each laser material will occur. Surface roughness will be tougher or smoother if the laser speed is increased and the laser power is optimised for the material. Ceramic tile requires a maximum power of 80 watts. Because the depth is not created too deep on the surface, optimal laser power and speed with a greater loop count leads to superior surface roughness.

# 5.2 Recommendation for future research MALAYSIA MELAKA

- i) For more investigation, experiment with additional engraving settings including laser frequency and engraving speed.
- ii) Different materials to consider as experiment samples include other ceramics, aluminium, stainless steel, titanium, stone, and any other substance.
- iii) Other tests, including as engraving depth measurement, corrosion observation, and hardness test, are carried out to determine the burn mark accuracy.

#### REFERENCES

- Agalianos, F., Patelis, S., Kyratsis, P., Maravelakis, E., Vasarmidis, E., & Antoniadis, A. (2011). Industrial Applications of Laser Engraving : Influence of the Process
   Parameters on Machined Surface Quality. *Machine*, 1242–1245.
- Arslan, F. K., Altinsoy, I., Hatman, A., Ipek, M., Zeytin, S., & Bindal, C. (2011). Characterization of cryogenic heat treated Vanadis 4 PM cold work tool steel. *Vacuum*, 86(4), 370–373. https://doi.org/10.1016/j.vacuum.2011.07.066
- Ding, H., Ibrahim, R., Cheng, K., & Chen, S. J. (2010). Experimental study on machinability improvement of hardened tool steel using two dimensional vibrationassisted micro-end-milling. *International Journal of Machine Tools and Manufacture*, 50(12), 1115–1118. https://doi.org/10.1016/j.ijmachtools.2010.08.010
- Dubey, A. K., & Yadava, V. (2008). Experimental study of Nd:YAG laser beam machining-An overview. *Journal of Materials Processing Technology*, 195(1–3), 15–26. https://doi.org/10.1016/j.jmatprotec.2007.05.041
- Gaitonde, V. N., Karnik, S. R., Figueira, L., & Davim, J. P. (2009). Analysis of machinability during hard turning of cold work tool steel (type: AISI D2). *Materials* and Manufacturing Processes, 24(12), 1373–1382. https://doi.org/10.1080/10426910902997415
- Genna, S., Leone, C., Lopresto, V., Santo, L., & Trovalusci, F. (2010). Study of fibre laser machining of C45 steel: Influence of process parameters on material removal rate and roughness. *International Journal of Material Forming*, 3(SUPPL. 1), 1115–1118. https://doi.org/10.1007/s12289-010-0967-x
- Hatami, S., Shahabi-Navid, M., & Nyborg, L. (2012). Surface preparation of powder metallurgical tool steels by means of wire electrical discharge machining. *Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science*, 43(9), 3215–3226. https://doi.org/10.1007/s11661-012-1137-1
- Hnilica, F., C`makal, J., & Jurci, P. (2004). Changes to the Fracture Behaviour of the Cr-V
  Ledeburitic Steel Vanadis 6 as a Result of Plasma Nitriding. *Materiali in Tehnologije*, 38(5), 263–268.
- Jorge, A., & Lordelo, R. (2014). Study and development of a didactic engraving system using a low powered laser diode. September.
- Kaldos, A., Pieper, H. J., Wolf, E., & Krause, M. (2004). Laser machining in die making -

A modern rapid tooling process. *Journal of Materials Processing Technology*, 155–156(1–3), 1815–1820. https://doi.org/10.1016/j.jmatprotec.2004.04.258

- Kasman, Ş. (2013). Impact of parameters on the process response: A Taguchi orthogonal analysis for laser engraving. *Measurement: Journal of the International Measurement Confederation*, 46(8), 2577–2584. https://doi.org/10.1016/j.measurement.2013.04.022
- Laakso, P., Pantsar, H., Leinonen, H., & Helle, A. (2008). Preliminary study on corrosion and wear properties of laser color marked stainless steel. *ICALEO 2008 - 27th International Congress on Applications of Lasers and Electro-Optics, Congress Proceedings*, 405(2008), 212–221. https://doi.org/10.2351/1.5061314
- Leone, C., Lopresto, V., & De Iorio, I. (2009). Wood engraving by Q-switched diodepumped frequency-doubled Nd:YAG green laser. *Optics and Lasers in Engineering*, 47(1), 161–168. https://doi.org/10.1016/j.optlaseng.2008.06.019
- Leunda, J., Navas, V. G., Soriano, C., & Sanz, C. (2012). Improvement of Laser Deposited High Alloyed Powder Metallurgical Tool Steel by a Post-tempering Treatment. *Physics Procedia*, 39, 392–400. https://doi.org/10.1016/j.phpro.2012.10.053
- Lin, C. J., Wang, Y. C., Lin, L. D., Chiou, C. R., Wang, Y. N., & Tsai, M. J. (2008). Effects of feed speed ratio and laser power on engraved depth and color difference of Moso bamboo lamina. *Journal of Materials Processing Technology*, 198(1–3), 419– 425. https://doi.org/10.1016/j.jmatprotec.2007.07.020
- Masood, S. H., Armitage, K., & Brandt, M. (2011). An experimental study of laser-assisted machining of hard-to-wear white cast iron. *International Journal of Machine Tools* and Manufacture, 51(6), 450–456. https://doi.org/10.1016/j.ijmachtools.2011.02.001
- Noor, M. M., Kadirgama, K., Rahman, M. M., Zuki, N. M., Rejab, M. R. M., Muhamad, K. F., & Mohamed, J. J. (2010). Prediction modelling of surface roughness for laser beam cutting on acrylic sheets. *Advanced Materials Research*, 83–86, 793–800. https://doi.org/10.4028/www.scientific.net/AMR.83-86.793
- Review, G. R. T.-A., & Patel, D. K. (2014). *Parametric Optimization of Laser Engraving Process for different Material using*. 3(4).
- Wendland, J., Harrison, P. M., Henry, M., & Brownell, M. (2005). Deep engraving of metals for the automotive sector using high average power diode pumped solid state lasers. 24th International Congress on Applications of Lasers and Electro-Optics, ICALEO 2005 - Congress Proceedings, 1901, 934–940. https://doi.org/10.2351/1.5060456





# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

# TAJUK: EFFECT OF LASER ENGRAVING PARAMETERS ON SURFACE MORPHOLOGY AND QUALITY ON CERAMIC TILE

SESI PENGAJIAN: 2021/22 Semester 1

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