PATTERN QUALITY ANALYSIS WHEN LASER ENGRAVING ILLUSTRATION ON STAINLESS STEEL

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

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DECLARATION

I declare that this Choose an item. entitled " Pattern Quality Analysis when Laser Engraving Illustration on Stainless Steel " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Anis Soraya Binti Zucafly

Date : 17 JANUARY 2022

APPROVAL

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

Signature :

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

Date : 17 JANUARY 2022

DEDICATION

This study is wholeheartedly dedicated to my beloved family especially my parents, who have been my source of inspiration and gave me strength when i thought of giving up, who have never left my side, who never stop provide their moral, spiritual, emotional and financial support.

I dedicate this study and give special thanks to my supervisor Prof. Madya Ir. Dr. Mohd Hadzley Bin Abu Bakar for all his guidance throughout the process.

I also dedicate this study to my lecturers and friends who always shared their words of advice and encouragement to finish this study.

ABSTRACT

In recent years, laser engravings have risen as one of the most promising technologies for engraving or branding an object. The current research will be concentrating on analysing the pattern quality when laser engraving illustrations on stainless steel with the goal of improving it. According to the results of this experiment, the effect of surface roughness and microstructure will be evaluated using the basic parameters of laser engraving, which are laser power, laser speed, laser frequency, and the number of loops in the engraving pattern. To begin, the software packages ImagR and EzCad will be utilised to generate a specific illustration. This was accomplished by engraving a stainless steel workpiece using the Master Oscillator Power Amplifier (MOPA) Fiber Laser employing a combination of specified settings to achieve efficiency on stainless steel for laser engraving colour. An investigation into the relationship between laser engraving on stainless steel and a mixture of factors revealed that a combination of parameters, including frequency, power, speed, and loop count, was critical in getting the best colour finish. A low speed combined with the best feasible number for frequency and power will have a significant influence, as no burn scars will occur and a golden-brownish colour will be attained as a result of using these parameters. In the following step, a surface roughness test will be performed to analyse the surface roughness and microstructure of a stainless steel that has been engraved using a stylus profilometer Mitutoyo Surftest SJ-301 and a digital USB microscope will be performed. The measurement of surface roughness was carried out in order to acquire the roughness value (Ra). The optimal Ra value for laser engraving illustrations on stainless steel is 0.093 (µm) at a speed of 4000 mm/s. After that, microstructure observation was carried out with the help of a Nikon Eclipse LV100 Digital Microscope. When there are no burn traces on the surface, it is considered to have a good surface quality.

ABSTRAK

Pada masa kini, ukiran laser telah meningkat sebagai salah satu teknologi yang paling menjanjikan untuk mengukir atau menjenamakan objek. Penyelidikan semasa akan menumpukan pada menganalisis kualiti corak apabila ilustrasi ukiran laser pada keluli tahan karat dengan matlamat untuk memperbaikinya. Menurut keputusan eksperimen ini, kesan kekasaran permukaan dan mikrostruktur akan dinilai menggunakan parameter asas ukiran laser, iaitu kuasa laser, kelajuan laser, kekerapan laser, dan bilangan gelung dalam corak ukiran. Untuk memulakan, pakej perisian ImagR dan EzCad akan digunakan untuk menjana ilustrasi tertentu. Ini dicapai dengan mengukir bahan kerja keluli tahan karat menggunakan Master Oscillator Power Amplifier (MOPA) Fiber Laser menggunakan gabungan tetapan tertentu untuk mencapai keberkesanan pada keluli tahan karat untuk warna ukiran laser. Penyiasatan ke dalam hubungan antara ukiran laser pada keluli tahan karat dan campuran faktor mendedahkan bahawa gabungan parameter, termasuk kekerapan, kuasa, kelajuan, dan kiraan gelung, adalah penting dalam mendapatkan kemasan warna terbaik. Kelajuan rendah digabungkan dengan nombor terbaik yang boleh dilaksanakan untuk kekerapan dan kuasa akan mempunyai pengaruh yang ketara, kerana tiada parut terbakar akan berlaku dan warna keemasan-coklat akan dicapai akibat menggunakan parameter ini. Dalam langkah berikut, ujian kekasaran permukaan akan dilakukan untuk menganalisis kekasaran permukaan dan mikrostruktur keluli tahan karat yang telah terukir menggunakan profilometer stylus Mitutoyo Surftest SJ-301 dan mikroskop USB digital akan dilakukan. Pengukuran kekasaran permukaan telah dijalankan untuk memperoleh nilai kekasaran (Ra). Nilai Ra optimum untuk ilustrasi ukiran laser pada keluli tahan karat adalah 0.093 (μm) pada kelajuan 4000 mm/s. Selepas itu, pemerhatian mikrostruktur dijalankan dengan bantuan Mikroskop Digital Nikon Eclipse LV100. Apabila tiada kesan terbakar di permukaan, ia dianggap mempunyai kualiti permukaan yang baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

MOPA	-	Master Oscillator Power Amplifier
CO2	-	Carbon Dioxide
Nd: YAG	-	Neodymium-doped Yttrium Aluminum Garnet
mm	-	millimetre
kHz	-	kilohertz
GPa	-	gigapascal
MPa	-	megapascal
W	-	watt
mm/s	-	millimetre / second
°C	-	celcius
µm	-	micrometre
SiC	-	silicone carbide SiC
Al2Si2O5(OH)	-	potassium
ZrO2	-	zirconia

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Laser has been utilized frequently for cutting and welding activities in recent decades. Recently, this technique was utilized in various industrial processes such as marking, selective removal and processing of diverse materials by introducing laser sources defined by shorter and shorter pulses ranging from nanosecond to femtosecond. Engraving is a process which a product identifying mark was produced such as time stamps, component labels and barcode marking. There are several ways of engraving, such as tin marking, mechanical engraving and electrochemical. Based on (Qi et al., 2003), for comparison with typically marking methods, there are several benefits to laser marking, such as this marking method will not use tool wear because it has a high level of automation and also have a free programming and the choice of characters.

Laser engraving is a subtractive production process using a laser beam to change the surface of an object. This procedure is used mostly to make pictures that are displayed at eye level on the material. The laser generates great heat, which sprays the substance and so reveals the holes that comprise the final picture. The laser is used to mark a metal workpiece surface.

Based on (Haron & Romlay, 2019), the operating principle of laser engraving is focused on the vaporization, whereby the interaction from a laser system through a focusing lens (convex lens) between material and laser beam results in the vaporization and melting of the materials used in the work. It is also an excellent example of how a core theoretical notion might remain until a technological application may be rediscovered. The material is therefore removed by an ablation mechanism from the workpiece in layers.

(Mehta et al., 2015), investigated that there are several advantages of laser engraving method compared than commonly used engraving method since that this laser engraving process does not use of any kind of inks and also it does not implied a tool bits. Furthermore, the main advantages of laser engraving method is this process are non-contact working which can minimize the rate of damage to the product, high precision, higher scanning speed, as well as high flexibility and automation.

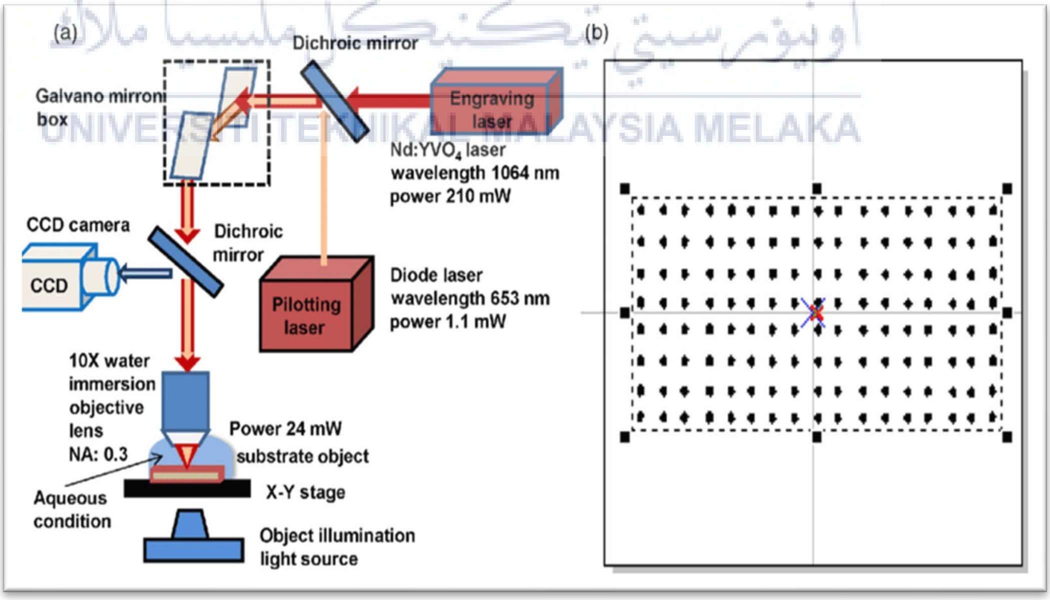

Figure 1.1 Schematic Laser Engraving System (Deka et al., 2013)

1.2 Problem Statement

Laser engraving is a typical technology used to engrave practically every material that traditional methods cannot engrave. The heat-up mechanism that vapors the material surface allows the laser engraving process to be done. The laser process is one of the most widely recognized technologies in many years. A Fiber Engraving Laser is commonly been used for various applications such as in electronic industries. Even so, a laser engrave technique using the Master Oscillator Power Amplifier (MOPA) Fiber Laser is still quite rare in Malaysia's market because of the different specialty need and this technology is highly expensive compare than fiber engraving laser.

Stainless steel have been commonly used in industrial applications because of its corrosion resistance, very durable, temperature resistant and high specific strength. In generally known as it is very ductile, traceable, resistant to corrosion, thermal conductivity and electrical conductivity. Hence, the metal material parameter such laser power, speed of the beam and frequency should be measured by refer to the mechanical properties of the material itself, in order to help in the reduction of over burning materials during the engraving process, in the mean time can evaluate the best combination of parameter to produce laser engrave colour when laser engraving illustration.

Laser engraving process is been widely used for multiple type of metals due to its several benefits such as non contact, non cutting force and tiny region of heat effect. However, there are still some downsides during the laser engraving process including very poor ablation surface roughness and certain number of microcrack on the surface that substantially impacts treatment quality. Thus, there is a need to evaluate on the basic parameters laser such as laser power, laser speed and laser frequency values so that it will be suitable to be applied on the stainless steel workpiece to produce a good quality products.

1.3 Research Objective

The general purpose of this research is to analyze the effect of laser engraving parameters on a microstructure and pattern quality on the stainless steel in laser engraving process. In order to accomplish the main objective, below shows the sub-objectives of this study:

a) To develop a illustration using a Master Oscillator Power Amplifier (MOPA) Fiber Laser on stainless steel.

b) To evaluate the effect of the process parameter on the surface of the stainless steel.

c) To analyze the surface roughness and microstructure of stainless steel when undergo laser engraving.

1.4 Scope of Research

The scope of this research is to develop a design using laser engraving on a workpiece metal material. Next, to evaluate the effect of laser engraving parameters on pattern quality on stainless steel, such as speed, frequency and power of the laser engrave machine running during the process. Finally, a research on the effects of laser engraving on stainless steel structural and micro-structure changes. The experiments were conducted Manufacturing Laboratory at the Faculty of Manufacturing Engineering in Universiti Teknikal Malaysia Melaka (UTeM). The research scopes are as follows:

- The testing or measuring of the materials used in this experiment is in the little and low depth.
- Adjust laser engrave machine's differences parameter.
- Study structural and microstructure changing characteristics of the plate at the conclusion of the experiment

CHAPTER 2

LITERATURE REVIEW

This section is focusing on the laser engraving process and the parameter used in this research. It described on the effect of laser parameters in surface morphology on a metal workpiece. In addition, types of a laser engrave, parameters involved, and other additional information were defined. All the information gained from multiple resources which were reference book, journal and online article

2.1 History of Laser

The word "laser" itself stands for "light amplification by stimulated emission of radiation”. A laser is a mechanism that induces atoms or molecules to release light at certain wavelengths and then amplifies that light to create a very small beam of radiation. The emission usually spans a very narrow spectrum of visible, infrared, and ultraviolet wavelengths.

Figure 2.1 Laser Engraving Machine

In 1916, Albert Einstein point out a idea involving the laser that under the right conditions, which is atoms could emit excess energy as light, either naturally or when induced by light. Rudolf Walther Ladenburg, a German physicist, discovered stimulated emission in 1928, though it seemed to have little practical use at the time. Laser technology is at the center of the larger scope of nanotechnology that leading to a range of unique properties of laser light. Many different types of lasers have been produced, each with a unique set of characteristics.

Figure 2.2 The Laser Engrave Table in 1981 (*History Part 5*, n.d.)

Lasers proceeded to be able to mark or engrave materials as technology advanced, allowing them to produce barcodes, serial numbers, 2D codes, UDI codes, labels, patterns, and more. In the 1970s, Bill Lawson of LMI started to work with the potential and possibilities of laser engraving in order to develop the then-popular computerized engraving machines. Lawson's system that are include a scanned black and white artwork, information, or designs, engraving either the white or black part, based on user preference, greatly enhanced the end result.