ASSESSMENT OF SURFACE MORPHOLOGY OF LASER ENGRAVED STAINLESS STEEL

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DECLARATION

I declare that this Choose an item. entitled "Assessment of Surface Morphology of Laser Engraved 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 : Muhammad Haziq Zafrin Bin Alwi

Date : 8/6/2022

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 : 22 Februari 2023

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. Laser machines are spesifically designed for engraving on different types of materials, cutting, ethcing, and marking. The parameters in this process play a significant role as the parameters changed, the output changes. The current research will be concentrating on analysing the line pattern surface when laser engraving on stainless steel with the goal of finding the best parameter. According to the results of this experiment, the effect of surface 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 line. To begin, the software packages ImagR and EzCad will be utilised to generate a specified line. 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 best parameter on stainless steel for laser engraving line. 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 parameter. Its purpose is to determine how laser parameters influenced the structural and metallurgical characteristics of stainless steel. It is also useful for analysing the microstructure of the heat affected zone, which is where the material has been damaged by laser heat during the engraving process.A high speed combined with the best feasible number for looping count and speed will have a significant influence. In the following step, a microstructure observations of a stainless steel that has been engraved using a Elecronic Microscopic digital USB will be performed. Microstructure observations of engraved lines in stainless steel resulting in information about the material's response to the laser engraving process. Graining size, microhardness, heat impacted zone, and phase transitions are among the observations recorded during microstructure study of engraved stainless steel.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, ukiran laser telah meningkat sebagai salah satu teknologi yang paling menjanjikan untuk ukiran atau penjenamaan objek. Mesin laser direka khusus untuk mengukir pada pelbagai jenis bahan, pemotongan, pengikisan dan penandaan. Parameter dalam proses ini memainkan peranan penting kerana parameter berubah, output berubah. Penyelidikan semasa akan menumpukan pada menganalisis permukaan corak garisan apabila ukiran laser pada keluli tahan karat dengan matlamat mencari parameter terbaik. Mengikut keputusan eksperimen ini, kesan mikrostruktur permukaan akan dinilai menggunakan parameter asas ukiran laser, iaitu kuasa laser, kelajuan laser, frekuensi laser, dan bilangan gelung dalam garisan ukiran. Untuk memulakan, pakej perisian ImagR dan EzCad akan digunakan untuk menjana talian tertentu. Ini dicapai dengan mengukir bahan kerja keluli tahan karat menggunakan Master Oscillator Power Amplifier (MOPA) Fiber Laser menggunakan gabungan tetapan tertentu untuk mencapai parameter terbaik pada keluli tahan karat untuk garis ukiran laser. Siasatan terhadap hubungan antara ukiran laser pada keluli tahan karat dan campuran faktor mendedahkan bahawa gabungan parameter, termasuk kekerapan, kuasa, kelajuan dan kiraan gelung, adalah kritikal dalam mendapatkan parameter terbaik. Tujuannya adalah untuk menentukan bagaimana parameter laser mempengaruhi ciri-ciri struktur dan metalurgi keluli tahan karat. Ia juga berguna untuk menganalisis struktur mikro zon terjejas haba, yang mana bahan telah rosak oleh haba laser semasa proses ukiran. Kelajuan tinggi digabungkan dengan nombor terbaik yang boleh dilaksanakan untuk kiraan dan kelajuan gelung akan mempunyai pengaruh yang ketara. Dalam langkah berikut, pemerhatian struktur mikro keluli tahan karat yang telah diukir menggunakan USB digital Mikroskopik Elecronic akan dilakukan. Pemerhatian struktur mikro garis terukir dalam keluli tahan karat boleh menawarkan maklumat tentang tindak balas bahan terhadap proses ukiran laser. Saiz butiran, kekerasan mikro, zon kesan haba, dan peralihan fasa adalah antara pemerhatian yang direkodkan semasa kajian struktur mikro keluli tahan karat terukir.

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Last but not least, I am eternally grateful to my loving parents, for their encouragements, endless support, prayers and who have been my backbone. My eternal love also to all my siblings, for their patience, love and understanding. Finally, thank you to all the individual(s) who had provided me the assistance, constantly supported and for always being there throughout my journey.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
MOPA	-	Master Oscillator Power Amplifier
CO2	-	Carbon Dioxide
Nd: YAG	-	Neodymium-doped Yttrium Aluminium Garnet
mm	-	milimitre
kHz	-	kilohertz
GPa	-	gigapascal
MPa	-	Megapascal
W	-	watt
mm/s	-	Milimitre / second
°C	-	celcius
µm	-	micrometre
SiC	-	silicone carbide SiC
Al2Si2O5(OH)	-	potassium
ZrO2	-	zirconia

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CHAPTER 1

INTRODUCTION

1.1 Background

In recent decades, lasers have become increasingly popular for cutting and welding tasks. By introducing laser sources with shorter and shorter pulses ranging from nanosecond to femtosecond, this approach has recently been used in different industrial processes such as marking, selective removal, and processing of various materials. Engraving is a method of creating product identifiers such as time stamps, component labels, and barcode tagging. Tin marking, mechanical engraving, and electrochemical engraving are just a few examples of engraving methods.

Laser engraving is a subtractive manufacturing process that involves changing the surface of an object with a laser beam. This method is mostly used to create images that are displayed at eye level on the material. The laser produces a lot of heat, which causes the substance to spray and show the holes that make up the final image. The laser is used to mark the surface of a metal workpiece. According to (Haron & Romlay, 2019), the working concept of laser engraving is based on vaporisation, in which the contact of a laser system with a material through a focusing lens (convex lens) results in the vaporisation and melting of the materials employed in the operation. It's also a great example of how a fundamental theoretical concept can persist until a technology application is rediscovered. As a result, material is removed from the workpiece in layers by an ablation mechanism.

(Mehta et al., 2015) found that laser engraving has various advantages over other engraving methods because it does not require the use of inks or tool bits. Also, the primary advantages of laser engraving include non-contact working, which reduces the rate of product damage, high precision, faster scanning speed, and great flexibility and automation.

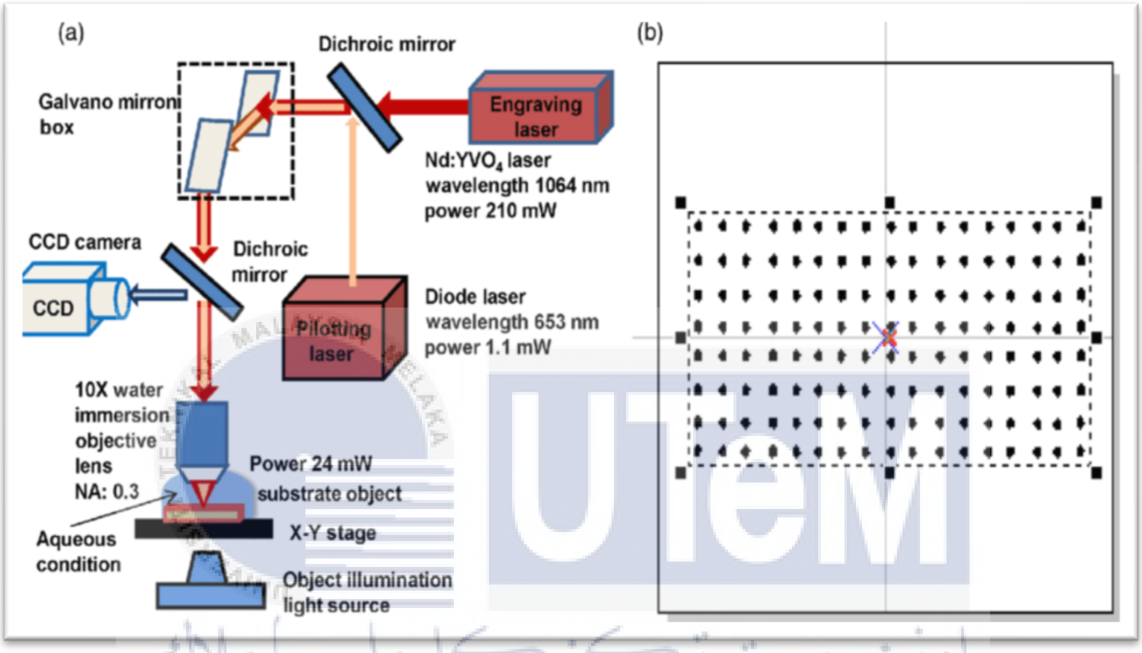

Figure 1.1 Schematic Laser Engraving System (Deka et al., 2013)

1.2 Problem statement

Laser engraving is a common technology that can engrave almost any material that can't be engraved with older methods. The laser engraving process is enabled by the heat-up mechanism that vaporises the material surface. In recent years, the laser process has become one of the most widely recognised technologies. Fiber Engraving Lasers are extensively employed in a variety of applications, including the electronic industry. Despite this, a laser engrave technique using a Master Oscillator Power Amplifier (MOPA) Fiber Laser is still fairly rare in Malaysia's market due to distinct specific needs, and this technology is much more expensive than fibre engraving laser.

Because of its corrosion resistance, durability, temperature resistance, and high specific strength, stainless steel is widely employed in industrial applications. It is well-known for its ductility, traceability, corrosion resistance, thermal conductivity, and electrical conductivity. As a result, metal material parameters such as laser power, beam speed, and frequency should be measured in relation to the mechanical properties of the material itself, in order to aid in the reduction of overburning materials during the engraving process, while at the same time determining the best combination of parameters to produce laser engrave colour when laser engraving illustration.

Due to various advantages such as non-contact, no cutting force, and a small area of heat effect, laser engraving is commonly utilised for a variety of metals. However, there are several drawbacks to laser engraving, such as very poor ablation surface roughness and a certain number of microcracks on the surface, which have a significant impact on treatment quality. As a result, basic laser parameters such as laser power, laser speed, and laser frequency values must be evaluated so that they can be applied to a stainless-steel workpiece to generate high-quality products.

1.3 Research Objective

The general purpose of this research is to analyze the effect of laser engraving parameters on a microscopic 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 straight line engraving using a Master Oscillator Power Amplifier (MOPA) Fiber Laser on stainless steel.

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

c) To analyze the microscopic observations of stainless steel when undergo laser engraving.

1.4 Scope of Research

The scope of this research is to create a design utilising laser engraving on a metal workpiece. The next step is to assess the impact of laser engraving parameters on stainless steel pattern quality, such as the speed, frequency, and power of the laser engrave equipment used during the procedure. Finally, a study of the impact of laser engraving on structural and microstructural alterations in stainless steel. The experiments were carried out in the Manufacturing Laboratory of Universiti Teknikal Malaysia Melaka's Faculty of Manufacturing Engineering (UTeM). The following are the research areas:

- 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 conclusions of the experiment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

"Laser" is a term for "light amplification by stimulated emission of radiation." A laser is a process that causes atoms or molecules to emit light at specific wavelengths, which is then amplified to produce a very tiny beam of radiation. The emission covers a very narrow wavelength range of visible, infrared, and ultraviolet wavelengths. As technology evolved, lasers were able to mark or engrave materials, allowing them to make barcodes, serial numbers, 2D codes, UDI codes, labels, patterns, and more. In the 1970s, Bill Lawson of LMI began working with the potential and capabilities of laser engraving in order to develop then computerized engraving machines. Lawson's approach, which includes scanned black and white artwork, information, or designs, engraving either the white or black component, depending on user option, significantly improved the finished product. (Lin et al.,2008)

Figure 2.1 Laser Engraving Machine

Laser Engraving, also known as Laser Etching, is a process that includes using a laser beam to change the surface of an object. This approach is mostly used to generate eye-level representations of content. To perform this, the laser generates a high level of heat, which vaporizes the matter, revealing cavities that will be used to create the final image. A laser is used to mark the surface of an object. The CO2 laser, which generates long-wave infrared light by combining carbon dioxide and other gases, is now the most popular laser used among engravers. CO2 lasers are useful for engraving and cutting heat or electrical conductors such as glass and ceramics. Another common type of laser is the YAG laser. The device allows use of a Yttrium Aluminum Grenet and tiny amounts of light from the uncommon element neodymium. YAG lasers are well-suited for graving both metal and nonmetal materials, and they work well with tough stainless-steel grades.

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