EFFECT OF LASER ENGRAVING PARAMETERS ON SURFACE MORPHOLOGY AND QUALITY OF LOW CARBON STEEL

RUDI AKTAR ALI BIN HUSSAIN
B091810132

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

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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

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this report entitled “Effect of Laser Engraving Parameters on Surface Morphology and Quality of Low Carbon Steel” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : Rudi Aktar Ali Bin Hussain

Date : 14 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 : Associate Professor Ir. Dr. Mohd Hadzley Bin Abu Bakar

Date : 14 January 2022

DEDICATION

I would like to dedicate my thesis to my beloved parent whom always supported and motivated me throughout my life. This research is lovingly dedicated to my family member my beloved mother Zaharah binti Mohamad, to my father Hussain bin Ali and my sister Naomi Ashraf binti Hussain and my brother Redza Akbar Ali bin Hussain, who was constant source of inspiration. A gratitude of thank you to my supervisor Profesor Madya Ir. Dr. Mohd Hadzley Bin Abu Bakar and all my lecturer that have been helping and supporting me throughout this project. They have given me the drive and disciple to tackle any task with enthusiasms and determination. Last but not least, to all my friends that have been there for me. Without their support this project would not been made possible.

ABSTRACT

Laser engraving is a machining process that is using laser to engrave the material. In recent year, Master Oscillator Power Amplifier (MOPA) Fiber Laser have been introduced for laser engraving. This research objective is to use Master Oscilator Power Amplifier (MOPA) Fiber Laser Engrave Machine to conduct laser engraving and surface cleaning on Low Carbon Steel. This research is to study the surface morphology and quality after laser engraving process on Low Carbon Steel. The experiment utilises two sample which the first sample conducted laser engraving directly on low carbon steel surface while sample 2 perform surface cleaning by using laser cleaning method before laser engrave on the sample.The design is done using Adobe Illustrator to design the square boxes to represent different laser parameters then transfered to the Laser Engraving Machine software that is EzCAD software to complete the engraving . The influence of the important laser parameters such as laser power, laser speed and pulse frequency of the laser beam is studied in this research. The laser engraving process requires certain important parameters that is needed to complete the laser engraving process and to determine the best laser parameters needed to achieve the best quality of laser engravement on the low carbon steel surface. In order to identify the quality of the laser engrave on the surface of low carbon steel, the results of the laser engraving with the surface morphology and quality are analysed to determine the microstructure and surface roughness of the low carbon steel. The microstructure of the material is analysed through a Nikon Eclipse Lv100 to observe the microscopic structure on the laser engraved region. Plus, the surface roughness of the engraved boxes is analysed with Mitutoyo Surftest SJ-410 stylus profilometer to obtain the roughness value (Ra).

ABSTRAK

Ukiran laser adalah proses pemesinan yang menggunakan laser untuk mengukir bahan. Pada tahun kebelakangan ini, Laser Fiber Master Oscillator Power Amplifier (MOPA) telah diperkenalkan untuk ukiran laser. Objektif kajian ini adalah menggunakan Master Oscillator Power Amplifier (MOPA) Fiber Laser Engrave untuk menjalankan ukiran laser dan pembersihan permukaan pada Keluli Karbon Rendah. Penyelidikan ini adalah untuk mengkaji morfologi permukaan dan kualiti selepas proses ukiran laser pada keluli karbon. Eksperimen menggunakan dua sampel yang mana sampel pertama menjalankan ukiran laser secara langsung pada permukaan keluli karbon rendah manakala sampel 2 melakukan pembersihan permukaan dengan menggunakan kaedah pembersihan laser sebelum mengukir laser pada sampel. Reka bentuk dilakukan menggunakan Adobe Illustrator untuk mereka bentuk kotak persegi untuk mewakili parameter laser yang berbeza kemudian dipindahkan ke perisian Mesin Pengukir Laser iaitu perisian EzCAD untuk melengkapkan ukiran . Pengaruh parameter laser penting seperti kuasa laser, kelajuan laser dan frekuensi nadi pancaran laser dikaji dalam penyelidikan ini. Proses ukiran laser memerlukan parameter penting tertentu yang diperlukan untuk melengkapkan proses ukiran laser dan untuk menentukan parameter laser terbaik yang diperlukan untuk mencapai kualiti ukiran laser terbaik pada permukaan keluli karbon rendah. Untuk mengenal pasti kualiti ukiran laser pada permukaan keluli karbon rendah, hasil ukiran laser dengan morfologi permukaan dan kualiti dianalisis untuk menentukan struktur mikro dan kekasaran permukaan keluli karbon. Struktur mikro bahan dianalisis melalui Nikon Eclipse Lv100 untuk memerhati struktur mikroskopik pada kawasan terukir laser. Selain itu, kekasaran permukaan kotak berukir dianalisis dengan profilometer stylus Mitutoyo Surftest SJ-410 untuk mendapatkan nilai kekasaran (Ra).

ACKNOWLEDGEMENTS

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

I would like to express my deep and sincere gratitude to my supervisor, Associate Professor Ir. Dr. Mohd Hadzley Bin Abu Bakar from Faculty of Manufacturing Engineering for all his continuous support, advice and inspiration. The dynamism, vision, sincerity and motivation have deeply inspired me. His constant patience for guiding and providing priceless insights will forever be remembered.

Furthermore, I dedicated everything for my beloved family for their love, prayers, caring and sacrifices for educating and preparing me for my future. My family, at every point of my personal and academic life, supported, prayed, inspired, and motivated me and longed to see this achievement come true. There will always be a special place for you in my heart.

Last but not least, I am extremely thankful to all my best friends and classmates for their endless support, feedback, discussion, and motivation over the course of my research. All the hardness that we shared will be remembered forever.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
W	-	Watt
mm	-	Milimeter
Nm	-	Newton meter
CO^2	-	Carbon dioxide
mm/s	-	Milimeter per second
SD	-	Standard deviation
Ghz	-	Gigahertz
µm	-	Micron meter
CW	-	Continuos wave
FL	-	Fiber laser
kHz	-	Kilohertz
Ra	-	Roughness value
Λ	-	Lambda value
Wt%	-	weight percent

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CHAPTER 1

INTRODUCTION

1.1 Background

Laser engraving is a laser machining process that utilizes laser to engrave on the surface of a material. Laser represents as “Light Amplification by Stimulated Emission of Radiation”. Laser engrave machining consist of a computerized laser machine that uses concentrated beam on a material to engrave the surface with image or text. The process of engraving on a material by using laser beam is to remove the surface of the material to form an image or text according to the customization of user needs. In addition, laser cleaning is a method of laser ablation where the process of laser machining that removed undesired layer The laser creates heat that is high in temperature to make engravement process on a material which causes the material to vaporized and to develop cavities that is visible to eyes and physical touch. Laser engraving is type of technology that reduce human effort as engraving in traditional method requires a lot of human effort but in laser engraving, it reduces human effort and improve the engrave quality. Also, laser engrave machining provide a more efficient ways to engrave by using advance laser engrave machining in which the laser is used to engrave an object or material in a faster and precise manner. Laser engraving is a non-contact, non-conventional machining technology that is continue to evolve into a much better laser machining mechanism since the creation of conventional laser to more advance laser machine because to its capacity to do high-precision laser engrave on a variety of materials and even complicated design (Nikolidakis et al., 2018).

The application of laser technology contributes many advantages towards the industries because of durable process, non-contact technology, precise beam focusing, high speed machining, high contrast, quality of the treatment, high productivity, low operation cost, good portability, even if the surface is hard to be engrave, it can easily produce a high precision engravement (Lazov et al., 2015). Laser engraving has high accuracy and does not create chips or wastewater (Yuki et al., 2016). Laser engrave machine have many types of machines that contain different types of lasers such as Carbon Dioxide (CO2), fiber gas, Neodymium-doped Yttrium Aluminum Garnet (Nd Yag), direct diode laser, MOPA (master oscillator power amplifier), etc. There are various types of lasers are because the application of the lasers is depending on the type of materials that need to be engraved. According to (Jeyaprakash et al., 2020), the common properties that brought many advantages for the laser are coherence, highly monochromatic, intensive radiance and directionality. These optical properties can be quantified for analyzing the laser properties.

The success of laser application leads laser technologies to be practiced in various application in the industries such as laser engraving, laser marking, laser cleaning, etc. Common application of laser technology in laser machining in the industries as the result of the accuracy and efficiency of the laser engraving process which can be done with complex design on various materials such as metal, plastic, wood, ceramic, leather and glass while producing a higher quality of precision and accuracy for the engravement.

1.2 Problem Statement

Master Oscillator Power Amplifier (MOPA) Fiber Laser is a new technology that is currently developed in recent years. The application of MOPA Fiber Laser is rarely seen in engraving low carbon steel due to its newly found technology. Moreover, there is not much research on studying the effect of laser engraving on laser cleaned surface especially on low carbon steel. The result of laser engraving on laser cleaned surface is still unknown and the result produced on surface morphology and surface roughness is yet to be determined. Carbon steel is a type of steel that has a higher concentration of carbon than other types of steel. Almost all types of steel have a relatively low carbon content around 0.05% to 0.38%. While the carbon content of carbon steel is up to 2.5%. The high content of carbon in carbon steel compared to the other types of steel makes carbon steel is better in strength. Although carbon steel has a higher content of carbon in it and the strength of the material is quite high, the surface quality after laser engraving can still be affected by the high output power from laser engraving. Because MOPA Fiber Laser is among one of the most innovative and technologically advanced system in the market today. However, the quality of the engraved surfaces is the critical factor that need to be observed. The ideal parameter to produce a quality engravement on the surface of low carbon steel need to be analyze as the laser engravement will affect the surface roughness and microstructure properties of the low carbon steel. Laser engraving parameters that need to be consider include engraving speed, laser power, pulse frequency, work piece thickness and amount of loop count. Moreover, laser engrave uses laser beam to micro-melt the material surface or remove the surface of the material to form a pattern. From the laser engravement process, the temperature of the heat produced from the laser can affect the surface quality of the material. The absorption of heat from the laser into the metal is different with every type of metal. Also, the effect of laser engraving on laser cleaned surface also can be different with normal surface as the laser

cleaned surface already get absorbed by heat from laser that changed the surface appearance. The consideration of laser speed, laser frequency and laser power can contribute to the significant changes of the surface properties of the carbon steel. Moreover, the shaping of the cavities that produced from the engravement will increase the surface roughness of the material. Nowadays, low carbon steel is widely used in many industries to be part of their products main material. However, low carbon steel is not likely been used in the industry that conduct laser engrave machining on their product. So, it is important to produce research on how laser engraving can affect the surface quality of the low carbon steel on normal and laser cleaned surface in order to increase future demand to laser engrave on low carbon steel. In addition, the aim of producing the best surface quality on low carbon steel need to identify the correct parameters that is suitable at the machine to produce a higher quality engraving quality on low carbon steel that provide minimal changes towards the surface roughness and microstructure properties.

1.3 Research Objective

The main objective of this research is to analyze the effect of laser engraving parameters on surface morphology and quality on carbon steel. The objectives are as follow:

i. To use MOPA Fiber Laser Engrave machine to laser engrave on normal surface and laser cleaned surface of low carbon steel.

ii. To identify the effect of laser engraving with different parameters on surface quality of low carbon steel.

iii. To observe the characteristic of structural and microstructure changes produced by laser engraving on low carbon steel.

1.4 Scope of Research

This research project will focus on the laser engraving on the low carbon steel, the result of laser engraving using a Master Oscillator Power Amplifier (MOPA) Fiber Laser engrave machine on a low carbon steel and to determine the characteristic of structural and microstructure changes produced by laser engraving on the normal and laser cleaned surface of carbon steel. The experiment is conducted in the laboratory at Universiti Teknikal Malaysia Melaka (UTeM) by using Laser Engrave Machine (MOPA) Fiber Laser as the main equipment for laser engraving process of the low carbon steel material plate. MOPA Fiber Laser Engraving Machine have been chosen to be used in the experiment purpose because parameter introduced by the machine where it proposes many advantages such as high output power of 60 W, maximum application flexibility, elevated optical quality and long pulse durations that can permit the engraving to a more high speed aggressive marking and deep engraving applications. The laser engraving process was carried out by laser engraving on normal surface and laser cleaned surface of low carbon steel plate to determine the changes on morphology and quality of the low carbon steel plate after engraving process by using surface roughness test and microscopic observation. Plus, the effect of laser engraving parameter such as laser speed, laser power, loop count and pulse frequency were analyzed to identify the changes on the surface of the carbon steel plate for its surface morphology, microstructure appearance and quality of laser engraving.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Laser

The first invention of a practical laser was Albert Einstein's invention in 1916 where he proposed that photons could stimulate emission of identical photons from excited atoms. In addition, laser mechanism that contribute to the first principle of laser was initially developed by Albert Einstein in the early 20th century in the year of 1917 but the time taken required is a long time of almost 50 years to finally able for an operational laser to be developed (Jeyaprakash et al., 2020). Albert Einstein became the foundation for the innovation of the laser throughout the many years after his finding of laser principle where he introduced stimulated emission of radiation could occur that later on a German scientist named Rudolf Ladenburg found a new theoretical idea for the invention of laser where he discovered an accidental evidence of energized emission in 1928. Then, during that era most physicists called the idea for the laser as the effect "negative absorption," and considered it of low practical importance. In 1940, a famous physicist named Valentin A. Fabrikant recommended that stimulated emission that is contained in a gas discharge can stimulate light but under a suitable requirement in order to generate the laser. Nevertheless, Valentin A. Fabrikant did not present any resonator in his recommendation and not able to propose any proposal of his idea for years so later on the idea was disbanded. Then, Willis Lamb, Jr. and R. C. Retherford discovered that nuclear magnetic resonance can probably cause population inversions after World War II, and Edward M. Purcell and Robert V. Pound uses the idea of the phenomenon to witness and generate a stimulated emission of 50 kHz radio waves.