DEVELOPMENT OF THIXO-LASER ENGRAVING PROCESS FOR PEWTER PRODUCT DEVELOPMENT FROM RECYCLING TIN

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MUHAMMAD SYAHIR BIN MAAROF

A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigeration and Air-conditioning Systems) with Honours

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled " Development of Thixo-laser Engraving Process for Pewter Product Development from Recycling Tin" 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.

Signature :

Name : *MUHAMMAD SYAHIR BIN MAAROF*

Date : 23/3/2022

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 Mechanincal Engineering Technology (Refrigeration and Air-conditioning System) with Honours.

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ABSTRACT

Laser engraving is a process that involves vaporising substances to generate a thin slotted groove. By removing material layers, the laser beam serves as a chisel to carve designs into the surface of the material. To achieve the high heat required for vaporisation, the laser directs large amounts of energy to specific regions, with the result varying according to the power generated or the strength of the material being vaporised. However, the high hardness of the majority of materials, especially metal, prevents the creation of surfaces with a smooth and fine texture when a high laser power is employed. This research includes an examination of laser engraving on a tin-based alloy, pewter, that is heated and then cast. The pewter will then be use to coat a plate before performing laser engraving on its surface. The plate that were used in this research were galvanize steel plate after performing test on 3 different type of plate to find efficiency of coating for the semi-solid pewter. The semi-solid pewter will then be engraved using a laser engraving machine with variable laser speed, laser power, and laser frequency. 12 samples were tested with different parameter to obtained excellent design quality. The results were determined and analysed and 4 best samples were selected from the 12. The first sample uses parameter of 20% power, 500 mm/s speed, 150kHz frequency with height and time set at 23cm and 1min respectively. Second sample uses parameter of 20% power, 1000 mm/s speed, 150kHz frequency with height and time set at 23cm and 1min respectively. Third sample uses parameter of 20% power, 1500 mm/s speed, 150kHz frequency with height and time set at 23cm and 1min respectively. Last and final sample, which produce the finest result uses parameter of 40% power, 1500 mm/s speed, 150kHz frequency with height and time set at 23cm and 1min respectively. The coating on the plate may not last long depending on the thinness of it applied on the plate surface.

ABSTRAK

Ukiran laser ialah proses yang melibatkan bahan mengewap untuk menghasilkan alur berlubang nipis. Dengan mengeluarkan lapisan bahan, pancaran laser berfungsi sebagai pahat untuk mengukir reka bentuk ke dalam permukaan bahan. Untuk mencapai haba tinggi yang diperlukan untuk pengewapan, laser mengarahkan sejumlah besar tenaga ke kawasan tertentu, dengan keputusan berbeza mengikut kuasa yang dijana atau kekuatan bahan yang diwap. Walau bagaimanapun, kekerasan tinggi kebanyakan bahan, terutamanya logam, menghalang penciptaan permukaan dengan tekstur yang licin dan halus apabila kuasa laser yang tinggi digunakan. Penyelidikan ini termasuk pemeriksaan ukiran laser pada aloi berasaskan timah, piuter, yang dipanaskan dan kemudian dituang. Piuter kemudiannya akan digunakan untuk menyalut pinggan sebelum melakukan ukiran laser pada permukaannya. Plat yang digunakan dalam penyelidikan ini adalah plat keluli tergalvani selepas melakukan ujian ke atas 3 jenis plat yang berbeza untuk mencari kecekapan salutan bagi piuter separa pepejal. Piuter separa pepejal kemudiannya akan diukir menggunakan mesin ukiran laser dengan kelajuan laser berubah-ubah, kuasa laser dan frekuensi laser. 12 sampel telah diuji dengan parameter yang berbeza untuk mendapatkan kualiti reka bentuk yang cemerlang. Keputusan telah ditentukan dan dianalisis dan 4 sampel terbaik telah dipilih daripada 12. Sampel pertama menggunakan parameter kuasa 20%, kelajuan 500 mm/s, frekuensi 150kHz dengan ketinggian dan masa ditetapkan masing-masing pada 23cm dan 1min. Sampel kedua menggunakan parameter kuasa 20%, kelajuan 1000 mm/s, frekuensi 150kHz dengan ketinggian dan masa ditetapkan masing-masing pada 23cm dan 1min. Sampel ketiga menggunakan parameter kuasa 20%, kelajuan 1500 mm/s, frekuensi 150kHz dengan ketinggian dan masa ditetapkan masing-masing pada 23cm dan 1min. Sampel terakhir dan terakhir, yang menghasilkan keputusan terbaik menggunakan parameter kuasa 40%, kelajuan 1500 mm/s, frekuensi 150kHz dengan ketinggian dan masa ditetapkan masing-masing pada 23cm dan 1min. Salutan pada plat mungkin tidak bertahan lama bergantung pada kenipisannya yang digunakan pada permukaan plat.

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LIST OF SYMBOLS AND ABBREVIATIONS

mm	-	Milimeter
UV	-	Ultra Violet
nm	-	Nanometer
ns	-	Nanosecond
ps	-	Picosecond
kHz	-	Kilohertz
MHz	-	Megahertz
W	-	Watt
Nd:YAG	-	Neodymium-Doped Yttrium Aluminum Garnet
mm/s	-	Milimeter per Second
CO2	-	Carbon Dioxide
LASER	-	Light Amplification by Stimulated Emission of Radiation
MASER	-	Microwave Amplification by Stimulated Emission of Radiation
μm	-	Micrometer
SSM	-	Semi Solid Material
CFD	-	Computational Fluid Dynamics
Mg	-	Magnesium
Cu	-	Copper
Y	-	Yttrium
Al	-	Aluminium
Si	-	Silicon
°C		Celcius

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CHAPTER 1

INTRODUCTION

1.1 Background

Laser engraving is a process that eliminates a few millimetres of material layer by layer (Agalianos et al., 2011). This technology is a non-traditional machining procedure used to engrave virtually any material that normal machining processes cannot engrave. In the engraving process, the material's surface will be gradually heated and evaporated to create a design (Patel, 2014). Currently, laser engraving is the most practical method for engraving an object. Laser technology has been disseminated in countless ways and implemented in numerous areas, including design, medicine, communication, defence, and environmental protection. The use of laser for engraving has simplified this procedure in comparison to traditional engraving methods, which are considered to be complex.

In addition, Genna et al. (2010) have enumerated the advantages of laser engraving over conventional machining. These include the precision of the machining, the absence of mechanical contact with the material's surface, the high quality of the finished goods, and the decrease of industrial effluents. In addition, the laser engraving process is more environmentally friendly than conventional engraving processes. On the other hand, Alexander et al. (2013) state that the adoption of the new technology will unquestionably cut the operational costs of small businesses and boost their entrepreneurial and artistic production.

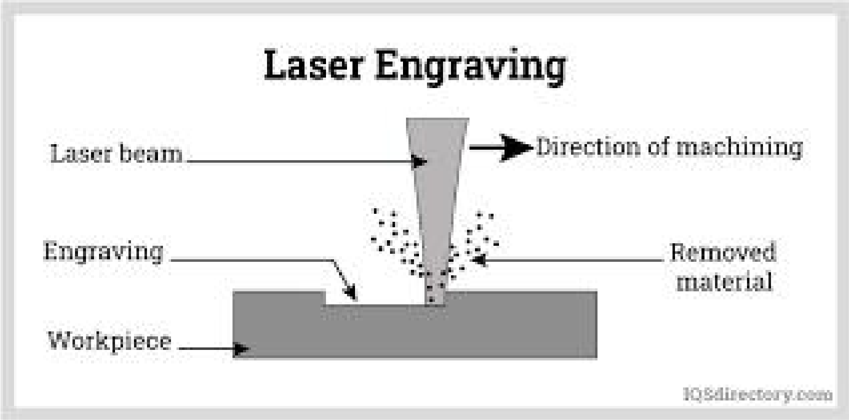

Figure 1.1 : Laser engraving process

1.2 Problem Statement

In practical laser engraving applications, the quality of the engraved surfaces is the determining factor. Recently, methodologies for analysing the effect of the most important process variables on quality have been devised, with the aim of enhancing quality rather than elucidating the engraving mechanism. The common engraving depth of laser varies between 0.5mm (0.02") and 3 mm (0.12") in metals or tougher materials and as deep as 0.3mm (0.01") with acrylic. It can be used to engrave practically any material, although metal, plastics, wood, leather, glass, and acrylic are the most frequently utilised. Severe penetration into the material increases the possibility of unfavourable effects such as warping (in acrylic) and excessive scorching (in timber).

Although it can be used on practically any material, laser engraving has several limitations. The majority of metals have a high level of hardness and endurance, limiting the ability to engrave deeply and create fine grooves. For in-depth engraving, the laser's power and the scanning speed must be increased, which could eliminate the protective oxide layer that prevents corrosion or blacken the surface due to the laser's high heat, resulting in a product of inferior quality. Therefore, the purpose of this proposal is to determine the efficacy of laser engraving on a semi-solid metal by preheating pewter, a tin-based material, at a high temperature and testing a range of laser power and scanning speed.

1.3 Research Objective

The objectives of this project are presented as follows :

i. To find the optimal plate surface coated with semi-solid material for developing design using laser engraving.

ii. To evaluate the effect of laser engraving parameters on surface quality of semi-solid material.

1.4 Scope of Research

This research project will stress on the application of laser engraving on semi-solid material and the capabilities of laser engraving machines to create designs on such surfaces. This research will also study the factors that should be set appropriately in order to achieve the desired engraving depth. Experimentation will take place at Universiti Teknikal Malaysia Melaka. Tin-based material, mainly pewter is used as the engraving medium because it has a very low melting point compared to other alloys, making it a good casting material and achieve its semi-solid state.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Literature review provides the scope for the present study. The literature review plays an essential function in gathering material for the dissertation. It acts as a guidance for conducting this analysis. Literature review includes various studies on laser engraving processes for improved surface finish with different paramenter of lasers. Relevant book, journal, article, and website sources are utilised for the theory's sources.

2.2 Study on Laser Engraving

A. R. Khan et al. investigated the impact of laser power, number of layers removed, laser frequency, and scanning speed on surface roughness and marking time by using the Taguchi Method. In the laser marking of AISI 316L Stainless Steel, a TruMark station 5000 UV laser beam was utilised. A convex lens with a focal length of 163 mm was utilised to focus a laser beam with an input voltage of 230 volts on the workpiece. In multi-layer machining cycles, it has been claimed that surface roughness can be minimised by merely reversing the scanning direction, hence a mix hatching mode scanning method has been implemented. It was determined through experiments that the primary factor in marking time was the number of layers removed, followed by scanning speed and layer thickness. The most important characteristic for Surface Roughness is scanning speed, followed by laser power. The statistical significance of mathematical modelling was determined to be high at a confidence level of 95 % , with error contributing just 1.08 %

to the model generated for marking time and 3.16 % to the model developed for surface roughness. Through the use of a confirmatory test, the similarity between experimental and expected outcomes was examined.

Laakso et al. stated that fibre laser permits independent tweaking of different laser settings and that the marking process may be adjusted to produce colours of higher quality and aesthetic appeal. Color marking of stainless steels as a method has been proposed for some time, although it is not commonly employed in the industry.

Cheng-Jung et al. noted in their study that Moso bamboo lamina was engraved utilising different feed speed ratios and laser output power levels in order to comprehend the effects of feed speed ratio and laser output power on etched depth and colour difference. The results demonstrated that the engraved depth increased as laser power or feed speed ratio decreased. Moreover, with a lower feed speed ratio and higher power, the colour difference values rose, resulting in a brownish hue in the engraved zone. By varying engraving parameters, the average engraved depth and colour difference ranged from 0.69 to 0.86 mm and 46.9 to 51.9 pixels, respectively. The results of an investigation into the effects of varied feed speed ratios and laser output power levels on the etched depth and colour difference of Moso bamboo laminae are as follows. With an increase in laser power or a reduction in feed speed ratio, the laser engraving depth increased deeper. Under a lower feed speed ratio and higher power, colour difference values rose, resulting in a brownish hue in the engraved zone. Significant effects of the feed speed ratio by laser power interaction regimes were seen on the etched depth and colour difference. Therefore, the values of the engraved depth and colour difference grew as the laser output power increased; nevertheless, the feed speed ratio decreased. Using regression analysis, the engraved depth and colour difference values of Moso bamboo may be predicted and estimated. This prediction of two engraving performances enables laser engraving to fulfil a variety of requests in the décor and gift industries.

Mingwei Li et al. demonstrate that in recent years, laser micromachining of semiconductor materials such as silicon and sapphire has garnered a growing amount of interest, . Two Q switched and one mode-locked diode-pumped solid-state 355 nm lasers were utilised to scribe grooves on silicon and sapphire wafer substrates at varying pulse widths (10 ns, 32 ns, and 10 ps) and pulse repetition rates (10 ns, 32 ns, and 10 ps) in this study (30 kHz, 40 kHz, 50 kHz, and 80 MHz). Various pulse widths, power levels, and pulse repetition rates have been compared to their experimental outcomes. At the same average power and repetition rate, it has been discovered that the grooves scribed by the longer pulse width laser are deeper, whilst the shorter pulse width laser provides higher quality cuts.

Leone C et al. mentioned that laser deep engraving is one of the most promising in wood carving technologies. In this work the characteristics and performances of a 5W nominal power Q-switched diode-pumped frequency-doubled Nd: YAG green laser in the engraving of several types of woods are studied. The primary findings are that surface carbonization is dependent on the improper selection of process parameters and occurs at beam speeds of up to 10 mm/s for the laser used. For speeds greater than 40 mm/s, the engraving depth is extremely shallow, and numerous laser scans are required to achieve a deep engraving. The engraved depth is substantially controlled by the mean power, the pulse frequency, the beam speed, and the number of repeats. It is feasible to increase the speed to achieve engraving with a decreased frequency range close to the value at which maximum output power is reached. The maximum speed required for engraving is proportional to the mean power.

Mohd Ashraf B. Mohd Fauzan (2008) researched 304 stainless steel CO2 laser engraving.Using a typical CO2 laser machine to engrave 304-grade stainless steel, this study will investigate the effect of parameter on engraving characteristics and width size. In this study, engraving is performed on 304-grade stainless steel utilising eight tests and eight combinations of parameters. In this study, the process parameters helping gas, gas pressure, cutting speed, focal height, and focusing lens are identified. The experiment is repeated three times in order to achieve a more accurate result. Using a metallurgical microscope, the component is then evaluated and measured. The data are then qualitatively and quantitatively assessed. Minitab and Design of Experiment analysis are applied to the quantitative outcomes. In this experiment, it was determined that the engraving width is significantly affected by the cutting speed and the interplay between power and speed factor. Despite employing the same parameter combination, the qualitative analysis reveals a variety of distinguishing features. This study demonstrates that engraving width characteristics may be predicted using parameters from a standard CO2 laser unit.

2.3 Laser

LASER (Light Amplification by Stimulated Emission of Radiation) is one of the 20th century's most remarkable innovations (Patil & Dhami, 2008). In contrast to ordinary light sources, which emit incoherent photons at multiple frequencies, lasers produce coherent radiation at a wide range of wavelengths, from the metre region to the soft X-ray region. In the twenty-first century, laser technology penetrates practically every element of daily life. Due to the unique characteristics of lasers, including their directionality, coherences, monochromaticity, and high intensity, they are used in a vast array of applications ranging from communications to medical.

The cornerstone for laser technology is Einstein's atomic theories on controlled radiation. Einstein's 1917 work on the stimulated emission of radiant energy is recognised as the intellectual foundation for amplified light. Nearly four decades later, American physicist Townes increased microwave frequencies by the stimulated emission method, coining the term MASER (microwave amplification by stimulated emission of radiation). Schawlow and Townes considered extending the maser principle to the optical portion of the electromagnetic field in 1958, which led to the development of LASER. Maiman of Hughas Research laboratories created the world's first laser, a pulsed ruby instrument, in 1960. It emitted light with a wavelength of 0.694% m.

2.4 Characteristics of Laser

2.4.1 Coherence

All emitted photons exhibit phase coherence in both space and time. Coherence is a measure of the waveform's precision. A highly coherent laser beam can be focused more precisely.

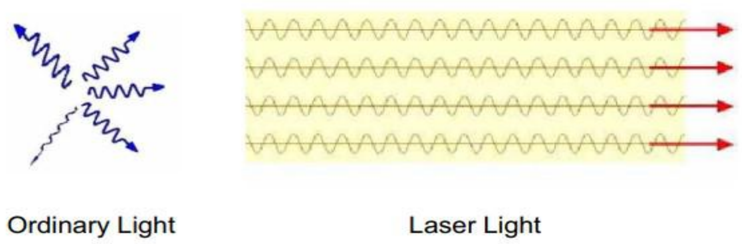

Figure 2.1 : Difference light waves between ordinary light and laser light