OPTIMIZATION OF LASER CUTTING PARAMETERS ON SURFACED CUTTING

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OPTIMIZATION OF LASER CUTTING PARAMETERS ON SURFACED CUTTING

Submitted in accordance with the requirement of the Universiti Teknikal
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by

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Date :

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee is as follow:

....

(Dr. Mohd Amri bin Sulaiman)

ABSTRAK

Laporan ini menekankan kajian mengenai mengoptimumkan parameter pemotongan laser pada pemotongan permukaan untuk besi tergalvani. Besi galvanis digunakan secara meluas dalam projek-projek pembinaan dan juga peralatan permainan kanak-kanak seperti rak basikal dan set swing kerana ciri anti-karatnya. Adalah penting untuk mengetahui kualiti permukaan bahan yang menggunakan proses pemotongan laser kerana ia membawa kepada isu keselamatan. Oleh sebab fakta ini, tujuan penyelidikan ini adalah untuk mencari kesan kedudukan tempat tumpuan dan tekanan gas dibantu dalam memotong laser. Parameter-parameter ini kedua-duanya diperoleh daripada analisis skrining. Kedudukan tempat tumpuan dibahagikan kepada tiga titik yang berada di atas, di bawah dan pada permukaan material. Bagi tekanan gas yang dibantu, julat diperolehi daripada ujian perintis iaitu 1 bar hingga 8 bar. Kekasaran permukaan adalah tindak balas proses yang akan diperoleh pada akhir eksperimen dengan menggunakan penguji kekasaran permukaan mudah alih. Kelajuan pemotongan dan kuasa yang dimakan laser ditetapkan untuk menjadi sama bagi kedua-dua parameter. Mesin yang digunakan dalam kajian ini adalah model Mitsubishi Electric ML2512HV2-R PLUS. Design of Experiment (DoE) digunakan untuk merancang keseluruhan kajian. Reka bentuk faktorial tahap dua dengan menggunakan Perisian Design-Expert® digunakan untuk merekabentuk eksperimen. Berdasarkan analisis ANOVA, tekanan gas yang dibantu lebih ketara daripada kedudukan tumpuan dari segi pemotongan permukaan. Malah, model matematik dibangunkan dari analisis ANOVA dan peratusan kesilapan telah diverifikasi antara nilai model dan nilai eksperimen yang adalah sekitar 2.67%. Pada akhir kajian, tindak balas optimum diperolehi pada kedudukan fokus pada -1 mm dan tekanan gas dibantu pada 8 bar. Kesilapan pengoptimuman antara eksperimen dan model adalah 3.7%.

ABSTRACT

This particular report emphasizes a study on optimizing the laser cutting parameters on surfaced cutting for galvanized iron. Galvanized iron is widely used in construction projects and even children's playground equipment such as bicycle racks and swing sets due to its anti-rust feature. It is crucial to know the surface quality of the material that used laser cutting process as it leads to the safety issue. Due to this fact, the purpose of this research is to find the effect of focal spot positioning and assisted gas pressure in laser cutting. These parameters are both attained from the screening analysis. The focal spot positioning is divided into three spots which is at above, below and on the material surface. As for the assisted gas pressure, the range is obtained from the pilot testing which is 1 bar until 8 bar. The surface roughness is the process response that will be obtained at the end of the experiment by using a portable surface roughness tester. The cutting speed and the consumed power of the laser are set to be constant for both parameters. The machine that is utilized in this study is Mitsubishi Electric model ML2512HV2-R PLUS. Design of experiment (DoE) technique was applied to plan the whole study. two level factorial design by using Design-Expert® Software is used to design the experiment. Based on ANOVA analysis, the assisted gas pressure is more significant than focal positioning in terms of surfaced cutting. In fact, a mathematical model is developed from the ANOVA analysis and the percentage of error had been verified between the model value and experimental value which is around 2.67%. At the end of the study, the optimum responses are obtained at focal positioning at -1 mm and assisted gas pressure at 8 bar. The error of optimization between the experimental and model is 3.7%.

DEDICATION

I dedicate this final year project to:

My beloved parents;

Mohd Raman Zubri & Faridah Rosnan

My Supervisor,

My Friends,

For giving me infinite moral support, cooperation, encouragement and understandings

Muchas gracias and may Allah bless all of you.

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By The Name of Allah the Most Merciful and Gracious

Alhamdulillah, all the praises to The Mighty Allah SWT. With his Blessing, this Final Year Project have been successfully completed even though there are many ups and downs along the way. I'd like to express my deepest and sincere gratitude to my supervisor, Dr. Mohd Amri bin Sulaiman for his guidance, continuous moral and research support throughout this research. His infinite technical advice and suggestions on improvements helped me to overcome hurdles and kept me enthusiastic which made this research an astounding experience. I would like to give a special thanks to both of my parents for their unconditional love, support and guidance. They have always been supportive to my academic pursuits and stood by every step of the way regardless of my decisions. Not forgotten, a million thanks to the assistant engineers, Mr. Mohd Ghazalan bin Mohd Ghazi and Siti Aisah binti Khadisah for being cooperative and provide all the relevant information and technical knowledge to fulfill my research on laser cutting. Both of them had been very kind and helpful throughout the research period. To all my fellow friends who involves directly or indirectly that always stay vigorous beside me in giving opinions and supports throughout this research, I really thankful and appreciate it very much. May Allah bless all of your kindness.

Thank You

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LIST OF ABBREVIATIONS

ANN	:	Artificial Neural Networks
ANOVA	:	Analysis Of Variance
ANSI	:	American National Standards Institute
AWJM	:	Abrasive Water Jet Machining
CCD	:	Central Composite Design
CO2	:	Carbon Dioxide
DF	:	Degree of Freedom
DoE	:	Design Of Experiment
EDM	:	Electrical Discharge Machining
ELM	:	Extreme Learning Machining
FD	:	Factorial Design
GI	:	Galvanized Iron
GP	:	Genetic Programming
HAZ	:	Heat Affected Zone
MRR	:	Material Removal Rate
N_2	:	Nitrogen
Nd: YAG	:	Neodymium-Doped Yttrium Aluminium Garnet
RSM	:	Response Surface Methodology
WL	:	White Layer

CHAPTER 1

INTRODUCTION

This chapter will be covering the whole introduction about this study. It started out with the background that gives a brief explanation of this study. It is then followed by the problem statement that occurred. Next, the objectives that need to be achieved in this study are outlined. The rest of this chapter revealed the scope that narrows down the area of study, significant of study and also the thesis outline.

1.1 Background

Laser cutting is one of the machining techniques that is highly utilized in industry. This advantageous technology are well-known utilized in laser welding, laser cutting of steel, hybrid welding and so on (Salminen *et al*., 1996 and Salminen 2010). Laser cutting is a popular process that is utilized to cut sheet metals in industry (Riveiro *et al.,* 2011). It is noticed that the used of laser cutting machine is widely increase in industry year by year. In terms of performance, laser cutting machining is economical and yet has the ability to cut materials with high precision and excellent finishing quality compared to other conventional cutting methods

According to (Boujelbene, 2018), laser cutting contributes to the minimization of operating time and has a high level of automation. In laser machining, materials will be melted in rapid heating by the power density which is relatively high. Madic *et al.* (2012) discussed that the working principle in laser cutting as a thermal and non-contact. In addition, it was found that laser cutting process is a highly automated process and suitable for different manufacturing industries that involves mass production who requires a high dimensional accuracy and surface finish. Figure 1.1 illustrated the working principle of laser cutting where the high power density beam is focused in a spot and it melts and evaporates material in a fraction of second. The evaporated molten material is removed by a coaxial jet of assist gas from the affected zone.

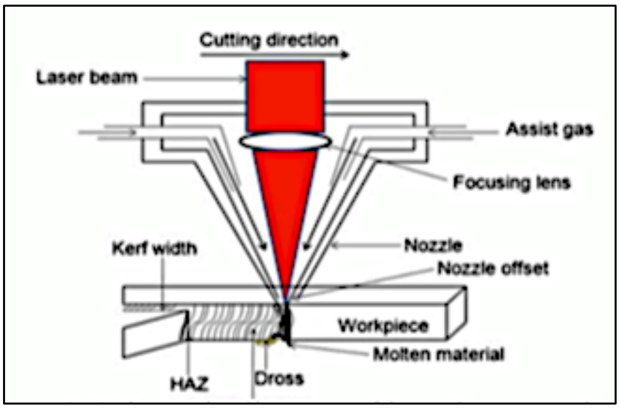

Figure 1.1 Schematic Diagram of Laser Cutting (Senthilkumar et al., 2015)

Just like the other advanced machining such as Abrasive Waterjet Machining (AWJM), Electric Discharge Machining (EDM) and Plasma Arc Cutting, Laser Cutting one of the advanced process that co-related with few parameters which leads to the performance of the finishing quality (M Boujelbene, 2018). The processing parameters must be emphasized and well identified as it contributes to the performance of the cutting surface's microstructure. Both internal and external parameters should be well optimized as they are associated well with each other. Specified parameters on laser cutting includes; gas pressure, cutting speed, power consumed to perform the laser cutting machining, focal positions in the laser cutting, frequency duty and also the height of the nozzle from the workpiece.

In laser cutting, it is crucial to emphasize and maintain on the focal length as the right position of the laser focal length will produce a high surface quality of laser cut. It is proven that the most effective focal length of the beam is the one that is emitted by an 8 kW multimode fiber laser (Reitemeyer *et al.,* 2010). Focal distance happened when a laser beam is reflected through a series of mirrors and straight to the focus lens. Just like a magnifying glass experiment, when it is moved up from the leaf, the spot will increase in size and in contrary, as it moved nearer to the leaf, it will decrease in size and creates a bright point that looked like an hourglass shape. The narrower the size of the spot of the laser, the higher the precision of the cutting edge. However, according to Neumeier and Landsiedel (2014), damaged workpiece and nozzle could happen if the process windows are very narrow for materials like brass or aluminum. These conditions can promote to the rupture of the cut. Figure 1.2 illustrated how a focus lens narrows the laser beam to a relatively small and precise spot that will be engraved or cut with a high accuracy of cutting performance. Once the laser beam leaves the focus lens, an hourglass shape will be formed with ideal focal distance within the center of the hourglass shape.

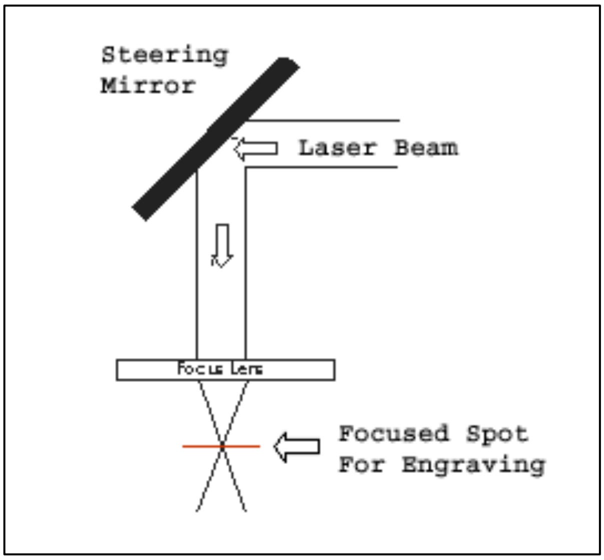

Figure 1.2 Illustration in the focus lens (Retrieved from: http://support.epiloglaser.com/article/8205/42831/focus-lens-101)

There are two essential actions that are needed to perform laser cutting. These two actions are including a laser beam to melt the particular material that followed the desired cut contour and a stream of gas which is typically nitrogen. The main purpose of nitrogen as the assisted gas is to blow the melted region away from the processing zone. Assisted gas in laser cutting contributes to the cutting quality due to its aerodynamic interactions that happened during cutting. In any way, this assisted gas also happened to be chemically react with the molten material. It can be categorized into two categories which are inert gas or reactive gas. Inert gas such as nitrogen is an ideal gas as it avoids a thin resolidified layer of metal oxides along the cutting edges. This reaction is due to the fact that nitrogen happened to provide mechanical action only in order to extract the molten material from the cutting zone. This explained the usage of nitrogen gas when a high quality edges in cutting steels are required.(Powell, 1998). It was proven that gas purity gives a high impact on the laser cutting efficiency and edge quality (Sun *et al.,* 2013).

It is understood that most of the work reviewed in the literature only contemplate with only one or two characteristics in laser cutting properties to describe quality (Mas *et al.,* 2003). Internal and external parameters contribute to a specific form unevenness of the surface (Radovanovic and Dasic, 2006). Grooved pattern will be formed at the edge of the workpiece. Surface roughness value determines the quality of the surface finishing. Every parameter is parallel with each other due to the importance of each parameters and how it leads to the performance of the surface quality. It is the aim of any project to know how the input parameters of the process contribute to the performance of the process in order to get an excellent product (Noor *et al.,* 2009).

1.2 Problem Statement

In laser cutting, the surface quality of the workpiece is highly depended on the number of associated parameters in which their correlation leads to the complex material behaviour. For instance, inert gas like nitrogen needs to go through the treatment zone by using appropriate pressure to ensure the quality of the processed surface. Galvanized iron is widely used in construction projects and even children's playground equipment such as bicycle racks and swing sets due to its anti-rust feature. Hence, it is crucial to know the surface quality of the material that used laser cutting process as it leads to the safety issue. A high purity of nitrogen must be used to achieve a high productivity during laser cutting. In fact, in order to maximize the effect of using assisted gas, it is recommended to optimize every parameter and not only the pressure. These parameters included the position of the focal lens in the laser cutting process and as well as the profile distance between the nozzle and the treated material. In other words, optimizing laser cutting parameters is complicated due to the fact that the large numbers of influencing parameters are in mutual nonlinear interaction. Besides, poor technological basis in a particular specific production condition occurs due to the non-optimal productivity in laser cutting.

In manufacturing industry, if the input settings are wrongly set up such as the focal positioning and assisted gas pressure level, it will lead to defects for the whole batch in the production. When defects occur, it will affect the whole production line and the productivity will be affected. Other than creating Work In Progress (WIP) which is a waste, the production schedule will be affected as many rework process need to be done to cover the defects which come from the human error in the setting stage. Defects such as burr will occur due to this error. When this issue occurs due to the setting of the input parameters, it will affect the lead time in manufacturing industry. Even worse, costumers might lose their trust towards the company.

Mathematical model is the best way to express the dependence of input and output parameter. In this situation, dependence input is independent variables while output parameter is dependant variable. Mathematical model can be shown in a multiple linear regression analysis. With mathematical model, the optimal process of laser cutting of galvanized iron shall be achieved along with attaining a maximum material saving, higher quality of the product and higher productivity of the laser cutting machine.

1.3 Objectives

a) To investigate the correlation between focal positioning and assisted gas pressure according to the effect on the surface roughness of cutting surfaced.
b) To develop mathematical model for surface roughness by using Two Level Factorial.
c) To determine the optimization cutting parameter towards surface roughness, Ra.

1.4 Scope

This study focuses on the surface roughness of the workpiece when different focal positioning is emitted on the workpiece with various level of assisted gas pressure. The machine that will be utilized in this study is from Mitsubishi Electric model ML2512HV2-R PLUS. The materials that will be used in this study is galvanized iron (GI). The thickness of galvanized iron 2.0mm.

The parameter that is emphasized in this study is the focal spot adjustment of the laser on a workpiece and level of assisted gas pressure that is used. Other parameters such as laser power, and frequency of the duty will not be covered in this study and these variables are set to be constant. The details of the variables are as shown in Table 1.1. During the laser cutting operation, the gas used is nitrogen (N2) and the focal lens material is 7.5 inch. The nozzle size is 2.5mm.

Table 1.1 Constant variables of the Input Settings

Parameter	Settings
Frequency, Hz	2000
Duty, %	70.0
Offset, mm	0.140
Pierce, sec	0.0
Nozzle Gap, mm	1.000

1.4 Significant/Important of Study

In manufacturing or any related industry atmosphere, it is believed that a good surface finishing of the products will boost up the excellence and performance of the product. However, surface roughness at the cutting surface depends on the application of the products itself. If this study can be proven to be much more effective and relevant compare to the typical process, it will consequently help other manufacturer to increase the quality of their products just by knowing the tolerance of the focal positioning. In addition, less time would be utilized in the inspection area due to the excellence and the effectiveness of the machining. When lesser time is consumed at the inspection area, the whole process would be much more economical yet productive. Hence, customer demands will also increase due to the improvement in quality of the surface finishing.

1.5 Organization of The Report

This section shows a detail information of the report that is covered for the Final Year Project 1 and Final Year Project 2. In FYP 1, it covers the primary stage of the project such as Introduction (Chapter 1), Literature Review (Chapter 2) and Methodology (Chapter 3). As for FYP 2, it covers the secondary stage of the project like Result and Discussion (Chapter 4) and Conclusion (Chapter 5). To have a better understanding on the structure of the report, Table 1.2 shows in detail the structure of the whole project report.

Table 1.2: The structure of the report for Final Year Project

Chapter	Content	Division
1	Introduction • Introduction consists of title, problem statement, objectives, scopes of the project and the significance of the study.	FYP 1
2	Literature Review • The research based on journal which related to the scope of the study. Normally more focus on books, and journal.	
3	Methodology • Basically focus on the method that is used to conduct the project.	
4	Result and Discussion • Collecting the data that has been gathered during conducted research. • Explaining the result of the project.	FYP 2
5	Conclusion • Conclude the overall project. • It also contains recommendation for the improvement of the project.	

1.6 Summary

Chapter 1 outlined the whole introduction of this study that includes background, problem statement, objectives, scope and the important of study. Upcoming chapter will be covering the literature review of this study.

CHAPTER 2

LITERATURE REVIEW

In this particular chapter, literature review or literally known as background study will be discussed to be acquainted with this study. Writing a literature review is very crucial for every researcher before starting any project analysis or study. This chapter outlined the theory that has been emphasized stage by stage in this study. Relevant sources like journals, articles, websites and books had been utilized well in order to script this chapter.

2.1 Laser Cutting Principle

Advanced Manufacturing Process like Laser Cutting is a widely used process in industry to cut sheet metal parts with specified contours. In laser cutting, it used a thermal concept which known as thermal separation process. The application of this process is broadly used in shaping and contour cutting. In fusion cutting process, the density laser beam, which has a relatively high energy is focused just like a small spot on a surface of the workpiece. This phenomenon will caused the thermal energy to be absorbed and those heats will transform the volume of work into a vaporized and molten conditions. These conditions can be easily eliminated by the flow of a high pressure assist gas jet (Dubey *et al.,* 2008).

However, Ready (1997), presented that the laser beam for fusion cutting can only be utilized by using two approaches which are; by melting a thin material film or by melting and vaporizing it. As a result, the trend of a narrow and clean-cut widths will be occurred with large depths. In laser cutting, the cut can be resulted by constantly moving the laser beam across the surface of the workpiece, or in another way, by moving the sample surface during the time where the nozzle deliver the laser beam with a constant gas jet.