UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

LASER PROCESSING OF NON-LINEAR INCLINE CUTTING

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LASER PROCESSING OF NON-LINEAR INCLINE CUTTING

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in fulfilment of the requirements for the degree of Master of Manufacturing Engineering

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DECLARATION

I declare that this thesis entitled "Laser Processing of Non-Linear Incline Cutting" is the results of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Turki Diwan Hussein

Date : ...5../..9../...2013

APPROVAL

I hereby declare that I have read this thesis and in my opnion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering).

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ABSTRACT

This research is to find the optimal parameters of machining process. The research conduct based on Design of Experiment DOE analysis. In this research the experiment designed to find out the interaction between the variables to evaluate the high performance responses of machining process. The experiment is design based on the objectives that want to be achieved in this research. The analysis is run by using the Minitab Software. In this research, Response Surface Methodology and factorial design used to compared in term of modeling capabilities. The input parameters evaluated were gas pressure, power supply, and cutting speed; meanwhile the output responses being kerf width and surface roughness. The laser cutting process is one of the widely used techniques for cut various thickness of material for many applications such as fiber, steel, wood etc. In the area cutting material, it can be improved drastically with the application of difficult cutting material. Application of cut on mild steel for various machining techniques, such as bevel linear and bevel non-linear cutting, requires different cut characteristics. From that, being highly dependent on the process parameters under which they were performed. To efficiently optimise and customise the kerf width and surface roughness characteristics, machining of laser cutting conduct via modelling using RSM methodology was proposed. In this research, non-linear incline cutting is done on critical laser processing of mild steel materials optimization . This research predominantly focuses to investigate the correlation between laser machining parameter with the responses kerf width and surface roughness. This research also highlights the experimental control parameters of mild steel laser processing with the responses.

ABSTRAK

Kajian ini adalah untuk mencari parameter optimum dalam proses pemesinan. Kajian penyelidikan ini berdasarkan "Design of Experiment". Dalam kajian ini "DOE" bertujuan untuk mengetahui interaksi antara pembolehubah untuk menilai respons prestasi tinggi dalam proses pemesinan. Analisis ini dijalankan dengan menggunakan perisian Minitab itu. Dalam kajian ini, "Response Surface Methodology" dan "Factorial Design" akan digunakan untuk dibandingkan dari segi keupayaan model. Parameter input dinilai ialah tekanan gas, bekalan kuasa, dan kelajuan pemotongan; sementara itu maklumbalas adalah lebar garitan dan kekasaran permukaan. Proses pemotongan laser adalah salah satu teknik yang digunakan secara meluas untuk pelbagai ketebalan potong bahan untuk banyak aplikasi seperti serat, besi, kayu dan lain-lain Dalam bidang memotong bahan, ia boleh diperbaiki secara drastik dengan permohonan memotong bahan yang sukar. Pengunaan pemotongan pada keluli lembut untuk pelbagai teknik mesin, seperti serong linear dan memotong serong bukan linear, memerlukan ciri-ciri yang berbeza dipotong. Dari itu, Proces paramter memainkan peranan penting dalam menentukan potongan terbaik. Dengan mengoptimumkan dan menyesuaikan lebar garitan dan ciri-ciri kekasaran permukaan, pemesinan pemotongan dijalanakan melalui model dengan menggunakan kaedah RSM telah dicadangkan. Dalam kajian ini, pemotongan serong bukan linear dilakukan di laser pemotongan. Kajian ini terutamanya memberi tumpuan untuk menyiasat hubungan antara parameter pemesinan laser dengan maklumbalas lebar garitan dan kekasaran permukaan. Kajian ini juga menunjukkan parameter kawalan eksperimen untuk pemotongan keluli lembut

DEDICATION

I would like to present my work to those who did not stop their daily support since I was born, my dear mother and my dear wife. They never hesitate to provide me all the facilities to push me foreword as much as they can. This work is a simple and humble reply to their much goodness I have taken over during that time. I don't forget my brothers, sisters, son, daughter, uncle and those entire how I love. Also to my father, grandfather, aunt and uncle (Allah's mercy them).

Turki diwan Hussein

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قال تعالى في محكم كتابه الكريم

وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ

صدق الله العلي العظيم

الاية ١٠٥سورة التوبة

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LIST OF SYMBOLS

K/W	-	Kerf Width
CO_2	-	Carbon Dioxide
I,V,Y	-	Type of Bevel
DC	-	Direct Current
RF	-	Radio Frequency
Nd:YAG	-	Neodymium-Doped Yttrium Aluminum Garnet
K=1	-	For an ideal Gaussian
$K < 1$	-	For real laser radiation.
CW	-	Continuous Wave
Psi	-	Pounds per square inch
RSM	-	Response Surface Methodology
LBC	-	Laser Beam Cutting
XRD	-	X-Ray Diffraction
SEM	-	Scanning Electrical Microscopy
OP	-	Optical Microscopy
ANOVA	-	Analysis of Variance
CCD	-	Central Composite Design
O_2	-	Oxygen
N_2	-	Nitrogen

LIST OF APPENDICES

CHAPTER 1

INTRODU CTION

1.1 Background

This Laser light amplification by stimulated emission of radiation is basically a cohesive, convergent and monochromatic electromagnetic radiation beam. Its wavelength ranges from ultra-violet to infrared. It can provide very low to very high power with a precise spot to any substrate type through any medium. Laser is differed from other electromagnetic radiation especially in terms of its cohesion, spectral purity and its straight line propagation. Therefore, it plays an important role in different industries, and used in many applications such as communication, military, medical and others. It is used in wide applications due to several properties such as spatial and temporal coherence, low divergence, and high continuous or pulsed power density and mono - chromaticity (Majumdar and Manna, 2003). One of its main applications is his ability to act as a heat source LMP. This feature helps to utilize it in Forming, joining, machining, manufacturing, coating/ deposition and surface engineering.

Due to the advantages of laser over the traditional cutting processes, it is commonly used in machining various types of materials, especially very hard materials in many industrial applications. The fundamental advantages of laser cutting are: no vibration because it is non- contact process, low heat input that leads to less distortion and its ability to be controlled numerically. The parameters of laser cutting process play a main role on the cutting edge quality features. The commercially available lasers for material processing by Eltawahni et. al., (2010):

i. Solid state crystal or glass laser – Nd:YAG, Ruby
ii. Semiconductor laser – AlGaAs, GaAsSb and GaAlSb lasers
iii. Dye or liquid lasers solutions of dyes in water/alcohol and other solvents
iv. Neutral or atomic gas lasers – He–Ne laser, Cu or Au vapor laser
v. Ionized gas lasers or ion lasers – argon. ArC / and krypton .KrC / ion lasers
vi. Molecular gas lasers – CO_2 or CO laser
vii. Excimer laser – XeCl, KrF, etc
viii. Fiber laser- ytterbium

However, there are main obstacles that limit the lasers extensive use in applications of routine material processing such as beam size limitation, high cost of installation and replacement, additional and costly accessories, and need for skilled workers (Majumdar and Manna, 2003).

1.2 Laser Parameters

The laser cutting process quality and the response in terms of cut edge quality is controlled by a number of parameters linked to the laser system, used material, and the cutting process. The laser system parameters are summarized in Figure 1.1 below.

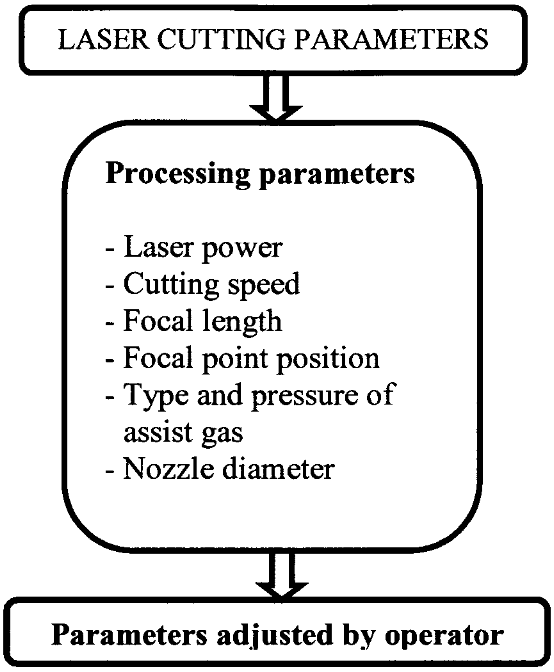

Figure 1.1 Laser Parameters (Wandera, 2010)

Researchers studied the impact of different lasers parameters on cut edge quality, kerf dimensions, roughness and surface finish. Kar et. al., (1996) studied the process parameters impacts such as laser power, spot size and dimensions, and cutting speed on the resulting kerf size. Yilbas (2008) studies on the effect of laser power and oxygen gas pressure on the kerf width variation. Researchers Ghany and Newishy (2005) indicated a positive relationship between laser cutting quality and the laser power, pulse frequency, cutting speed and focus position.

1.2.1 Laser Cut Quality Characteristics

The laser cut edge characteristics, which can be used to measure the laser cut quality include: the cut kerf width, dross attachment on the lower cut edge, cut edge squareness deviation perpendicularity, cut edge surface roughness, and boundary layer separation point.

1.3 Problem Statement

The common metal machining is performed by using a laser machine with vertical cutting head. The literature did not explain clearly the impact of the nonlinear incline cutting process parameters on the surface quality, and did not compare this effect with the linear cutting.

The nonlinear incline cutting is very important in assembling parts or appliances or in welding pieces together as some of the parts and by design must have incline surfaces for ease of their linking and assembling. Therefore, incline cutting laser machine should be available, but this machine probably not is available, in addition to being expensive. For this reason, will use the available vertical cutting machine to address this problem, where we will be control the incline degree of the work piece usually at an angle of 22° under the vertical head to get the incline cutting. After that test process on the impact of incline cutting process parameters in term of surface quality will conduct. This project focuses on research on alternative process acetylene oxygen cutting material in machine CNC because of their defects on the metal surface and the changing characteristics at mechanical physical and safety of the surface and transactions thermal and other. Therefore, the existence of machine laser CNC using oxygen gas best for the safety of the surface and the characteristics of mechanical and other through literature review of cutting mild steel, stainless steel, crystal steel, duplex steel.

1.4 Research Objectives

The main objective of this research is to conduct a comprehensive study on the processing parameters effects during incline laser cutting of thin sheet mild steel. The effect of processing parameters is evaluated in terms of surface finish and kerf width. The research aims to achieve the following objectives:

i. To identify the significant laser material processing that affecting inclined cutting parameter.

ii. To establish significant design parameters for high cut quality of non-linear inclined cutting.

iii. To model the optimal laser processing of non-linear inclined cutting

1.5 Research Scope

The aim of this research is to identify which parameters in incline laser cutting process play the major role in producing very low roughness cuts and surface finish, which improve the end product quality. The laser oxygen assist will be used for non-linear incline cutting process of a thin sheet of mild steel of 6 mm thickness.

The response surface methodology RSM will be applied to construct a mathematical relationship between the laser cutting process parameters, laser power, speed and pressure and between the quality of the responses namely quality of cut edge and surface roughness during an incline cutting process. The potential impact of each laser cutting parameter on the responses will be defined by the verified mathematical models to identify the optimal cutting conditions that lead to the highest quality.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of the laser and laser-cutting machine. The principles of the laser beam generation and the technology involved in the laser cutting machine is presented. Previous studies conducted on lasers and laser-cutting machines were reviewed and suggestions and recommendations from those studies were used in the current study.

2.1 Introduction

The conventional machining use has been restricted because of sophisticated shape and unusual size of the work material, rigorous design need and the emergence of advanced engineering materials. Thus, the need for nonconventional machining methods becomes an urgent demand which lead to the emergence of advanced machining processes AMPs (Choudhury and Shirley, 2010).

Laser machining is one of the AMPs utilized to cut various types of materials economically. Laser beam machining has wide application because it gives a finer finish to the end product as compared to conventional cutting methods (Choudhury and Shirley, 2010). Lasers are commonly used to cut or machine different types of materials, especially difficult-to-cut materials, in many industrial applications, due to its advantages over the conventional cutting processes (Eltawahni et al., 2010). Compared with other conventional mechanical processes, laser cutting removes little material, involves highly localized heat input to the workpiece, minimizes distortion, and offers no tool wear. Laser cutting is a thermal, non-contact, and highly automated process well suited for various manufacturing industries where a variety of components in large numbers are required to be machined with high dimensional accuracy and surface finish (Madic et al., 2012).

2.2 Metal Cutting Process

Metals are one of the structural materials. Metals are strong, cheap and tough; they are chemically reactive, heavy and have limitations on the maximum operating temperature (Samant and Dahotre, 2009). Metal working is the process of working with metals to create individual parts, assemblies, or large scale structures. It therefore includes a correspondingly wide range of skills, processes, and tools. Cutting is a collection of processes wherein material is brought to a specified geometry by removing excess material using various kinds of tooling to leave a finished part that meets specifications. The net result of cutting is two products, the waste or excess material, and the finished part. In cutting metals the waste is chips and excess metal. These processes can be divided into chip producing cutting, generally known as machining. Burning or cutting with an oxyfuel torch is a welding process not machining.

There are also miscellaneous specialty processes such as chemical cutting. Using an oxy-fuel cutting torch to separate a plate of steel into smaller pieces is an example of burning. Chemical turning is an example of a specialty process that removes excess material by the use of etching chemicals and masking chemicals (Tulasiramarao et al., 2013). Emergence of advanced engineering materials, stringent design requirements,