LASER PROCESSING OF LINEAR BEVEL CUTTING

BADR KAMOON DABIS

A thesis submitted

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

(Industrial Engineering)

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2013

DECLARATION

I declare that this thesis entitled "Laser processing of linear bevel 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 : Badr Kamoon Dabis

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 (Industrial Engineering).

Signature : ....

Supervisor : Prof. Madya. Ir. Dr. Sivarao Subramonian

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

PROFESOR MADYA IR. DR. SIVARAO SUBRAMONIAN
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
Durian Tunggal, Melaka.

بسم الله الرحمن الرحيم

يَرفَعُ اللّهُ الذِينَ آمَنُوا مِنكُم

وَالذِينَ أُوتُوا العِلمَ دَرَجات

صَدَقَ اللهُ العَظِيم

{سورة المجادلة-آية 11}

ABSTRAK

Tujuan kajian ini adalah untuk membangunkan satu model pemotongan laser proses yang boleh meramalkan hubungan antara parameter input proses dan maklumbalasnya; kekasaran yang dihasilkan, ciri-ciri lebar garitan dan prestasi. "Response Surface Methodology" (RSM) telah digunakan, ini merupakan salah satu teknik yang paling praktikal dan kos efektif yang berkesan untuk membangunkan satu model proses. Walaupun RSM telah digunakan untuk pengoptimuman proses laser, tetapi bahan yang membuktikan RSM sesuai untuk kerja model atas pemotongan laser proses berkurangan. Kajian ini sedang disiasat memotong keluli lembut ke pemotongan terbaikdengan menggunakan RSM teknik.The parameter input dinilai ialah tekanan gas, bekalan kuasa, dan kelajuan pemotongan; manakala maklumbalasnya adalahlebar garitan, kekasaran dan prestasi pemotongan. Untuk Lebar garitan dan kekasaran, pengesahan model dijalankan adalah dalam selang ramalan 95% daripada model dihasilkan. Kesilapan sisa dibandingkan dengan nilai-nilai yang diramalkan, dimana patut ditunjukkan kurang daripada 5%. Model juga kualitatif disahkan dengan dibandingkan dengan keputusan maklumbalas berdasarkan kepada parameter yang dimasukkan dan juga kepada kertas kerja yang dikaji oleh penyelidik-penyelidik sebelum ini. Kajian ini juga dikaji untuk mengenal pasti parameter penting yang mempengaruhi lebar garitan memotong dan kekasaran melalui analisis "ANOVA" semasa pembangunan model. Keratan garitan lebar telah dipengaruhi oleh tekanan, bekalan kuasa, dan kelajuan pemotongan; kekasaran permukaan dipengaruhi oleh tekanan oksigen dan bekalan kuasa dan prestasi memotong telah dipengaruhi oleh kelajuan.Penemuan ini adalah selari dengan kerja yang diterbitkan oleh penyelidik lain, analisis ANOVA juga mencadangkan bahawa terdapat interaksi yang signifikan antara oksigen dan bekalan kuasa yang tidak boleh diabaikan dan tidak pernah dilaporkan dalam jurnal yang diterbitkan.

DEDICATION

Special dedicate to all persons that help me in completing my final year project especially to my project supervisor Prof. Madya. Ir. Dr. Sivarao Subramonian.

To my beloved parents, my family you for your comfort and supported me…

And not forgotten, Thanks to my lecturers and friends…
This report I'm fully dedicate to all of you…

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ACKNOWLEDGEMENT

With the highest praise to God and thanks that I manage to complete the Master Thesis successfully. My deepest appreciation to Prof. Madya. Ir. Dr. Sivarao Subramonian as my project supervisor for his assistance, inspiring and guiding towards the progress of this project. He had provided not only his personal times to guide me in order to fulfil my report and my project but also provided his knowledge to solve the problem that I confronted.

I would also like to extend my gratitude to all the dedicated Ministry of Higher Education and Scientific Research of Iraq and Universiti Teknikal Malaysia Melaka, especially the Dean of Faculty of Manufacturing Engineering, Prof. Madya. Dr. Mohd Rizal Salleh and Deputy Dean, Prof. Madya. Dr. Mohd Warikh Abd Rashid.

At this juncture, it is only logical for me to pay tribute to my family. Their undivided love and support are the beacons that have continued to motivate me through the harshest of situations and I believe it will also spur me on to greater achievement in the future.

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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 AluminumGarnet
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

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CHAPTER 1

INTRODUCTION

1.1 Background

This research project is part of a programme funded by the Iraq Government to enable the laser cutting of the materials industry among small and medium enterprises (SME's) in Iraq. One of the "help needed areas" identified is to develop a method for practical and cost effective laser cutting process optimization that potentially gives cost competitiveness and process flexibility advantages.

1.2 Laser Cutting

Control a wide range of materials can be cut in this way although today they tend to be mainly metals Laser cutting is a process whereby material is cut to shape using a laser beam under computer with other non-metals such as plastics and ceramics being cut by high pressure water jet and other method as the show in Figure 1.1.

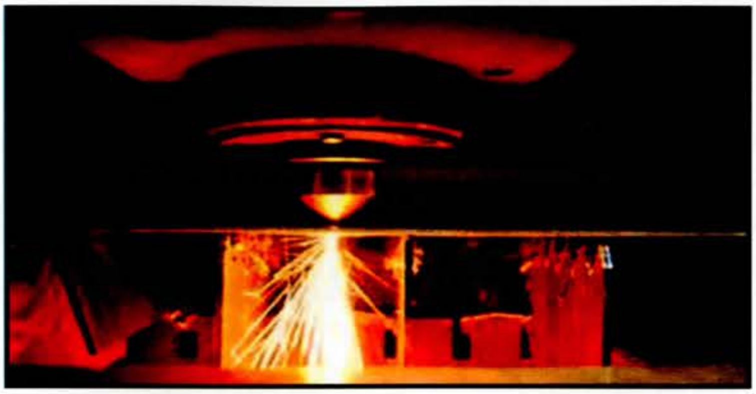

Figure 1.1 Bevel Cutting Laser, the Laser Mat from LVD Cutting Systems Offers Bevel Cutting in Stainless Steel That Fulfils your Highest Requirements.

CO_2 Laser fulfills highest requirements, The Laser Mat from LVD Cutting Systems offers bevel cutting in stainless steel that fulfills your highest requirements. In mild steel, besides straight cuts, also V and Y cuts are possible. Bevel cutting in principle is a process that shows sophisticated control especially when two cuts along one contour are made. Maximum angles of 45° and maximum thicknesses of 5/8" (15 mm) are possible. Equipment training is available to make bevel cuts in stainless steel, easy to cut, key features: Bevel cuts in mild steel and stainless steel with high precision (+/- .004" (.1 mm) for straight cuts, +/- .020" (5 mm) for bevel cuts) Maximum thickness: 5/8" (15mm) Maximum angle: 45°,infinitely rotatable bevel unit. The laser cutting process uses a strong focused laser beam, produced by a laser diode. The high energetic laser beam heats the surface of the material and melts rapidly a capillary in the material. The diameter of the capillary responds to the diameter of the used laser. During the cutting process, an assistant gas is used to eject the molten material from the kerf. As a result, the cut quality and speed are very high compared with other cutting technologies (Myer et al., 2010).

1.2.1 Types of Laser Cutting

With Sublimation Cutting, the laser beam brings the material to its vaporization point directly (Sublimation). An inactive (inert) cutting gas such as Nitrogen forces the molten material out of the cut. Typical materials are, amongst others, wood and plastic. Thin metals can also be cut in this way. Flame Oxygen Cutting by contrast, is characterized by the fact that the material is only heated to its ignition temperature. Oxygen is used as cutting gas, so that the material burns and forms an oxide which melts through the additional energy from burning. The cutting oxygen then forces the slag out of the cut. Typical material is, for example, low alloy steel (Mild Steel). For Fusion Cutting, the material is melted directly by the laser beam. As with sublimation cutting, an inert gas, usually nitrogen, is also used here to force the molten material out of the cut. This process is typically used for alloyed steels (Stainless Steel) (Berkmanns and Faerber, 2008). All processes have in common that, because of the narrow focus of the laser beam, the width of cut (kerf width) is very small compared to the other thermal cutting processes. Thus minimum material is melted and the laser energy is used very efficiently. The heat input into the material is thus relatively low so that even small geometries can be cut. In addition, the cut edge is relatively straight which in all gives very high component accuracy from the cutting process (Eltawahni et al., 2011). This means that laser cutting is used in the most diverse areas, specifically wherever high accuracy for the component geometry and the cut edge is required. The preferred range for steel sheets is up to a material thickness of 0.375" (20 mm) under certain circumstances up to 1" (25 mm). For this application mainly the CO2 Laser and Fiber Laser are used. For greater thicknesses, laser cutting only makes sense for special applications as show in Figure 1.2, more usually other cutting processes (Oxyfuel or Plasma Cutting) are used here (Gok et al., 2012).

Figure 1.2 Laser Bevel Head Bevel Head for Vertical and Bevel Cuts From 0° - 50°.

1.2.2 Laser Characteristics

Typically, plate thickness is 10 mm up to 20 mm and 5 mm up to 20 mm. Bevel cutting requires an exact knowledge of the laser machine and the cutting processes. Corners, lead-ins and run-outs have to be cut with special sequence if the required quality is to be achieved (Kratky et al., 2008; Madic and Radovanovic, 2012a; Madic et al., 2012). Bevel cutting also places high demands on the programming of the cut parts. Special auxiliary functions are needed to set the units up for laser bevel cutting (Majumdar and Manna, 2003).

For example, with plasma bevel cutting, cuts must be repeated if the preparation consists of multiple bevels. It may be necessary to offset the cutting contour to a parallel one or the unit may have to be offset laterally. Depending upon the cutting process, special start of cut geometries may be required. Additionally, the optimum technology parameters such as drive speed and cutting energy has to be matched to the bevel to be cut. Sounds complicated, and it is. But these are exactly the small specialities which characterize a "LVD Machine".

Messer Cutting Systems offers a variety of bevel cutting units, perfectly suited for your cutting applications. You choose out of Oxyfuel, Plasma and Laser beveling options, in both automatic and manual systems. The automatic systems are fully controlled, with no manual adjustments necessary.

1.2.3 Significant Reason for Selecting Laser Cutting

The virtues of laser cutting have been promoted fairly rigorously since the process started to take off as a sub contract service around twenty five years ago. However, there is still a misconception in some quarters that laser cutting is a high-tech process for high-tech applications. It is true that laser cutting is being used more and more in areas such as aerospace, motor sport and other highly technical and high precision industries but the fact remains that a large percentage of work passing through job shops (laser cutting subcontractors) is of a fairly mundane nature, without a requirement for tolerances measured in microns. A of laser cutting work would, at one time, have been carried out by gas cutting. It has large amount often been said to potential customers, in the past, that if they were buying gas cut components and were happy with them then they should stay with them, because laser cutting would never compete on price, but if they had to flatten them, dress the edges or machine in holes and cut outs then laser cutting would offer a better and more economical alternative. Laser cutting does not cause distortion through heat, it leaves a clean edge and is able to include holes and cut outs of (almost) any shape and size. Laser cutting provides customers with a consistent product that can, in most cases, be integrated immediately into their product. The fact that standard tolerances for laser cutting are around 20 percent of those for gas cutting is an added bonus to many customers and not a strict requirement.

One of the more important advantages of laser cutting is that of time and therefore cost saving. The need for hard tooling is eliminated and this can save many thousands of pounds and several weeks delay. Modifications can be made instantly and samples produced within hours. Stock levels can be reduced significantly because the quantities required to make a pressing operation viable do not apply to laser cutting and reduced lead times give manufacturers more control over their scheduling (Sivarao et al., 2010a).

Another popular misconception about laser cutting is that it is too expensive. The growth in the number of machines sold and in the number of job shops belies that. It is true that the machines are not cheap, with a typical machine from one of the market leaders costing in excess of $300,000 but improvements in the process capabilities of these machines mean that they are now able to produce items at a lower cost than was possible 25 years ago (Sivarao et al., 2010b).

Economy in the use of material has been a major promotional point for laser cutting from the beginning but this probably has more relevance today than it ever has. Steel prices are rising almost daily and some items are beginning to become scarce. We are told that this situation is going to get much worse before it gets better (if, indeed it ever does). Laser cut components can, depending on shape, be nested very closely to obtain maximum yield and therefore minimum cost (Tezuka et al., 2005; Powell et al., 2011; Physics and Astronomy department, 2013).

Has allowed designer to think 'outside the box' and to design specifically for the process. Many items are produced, by laser cutting, which would not have been possible by other methods or which would have been prohibitively expensive to produce. Bevel cutting requires an exact knowledge of the laser machine and the cutting processes.

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a) Types of bevel I, V, Y
b) Material thickness for bevelling up to 5/8 inch (15 mm)
c) Material thickness for vertical cuts up to 1 inch (25 mm)
d) Max. Angle 45°
e) Infinite rotation of the cutting head about its own axis
f) Interpolation of the bevel angel (change on the fly from minimum to maximum torch inclination while cutting)
g) Positive and negative bevel angles in one part are possible
h) Collision protection.

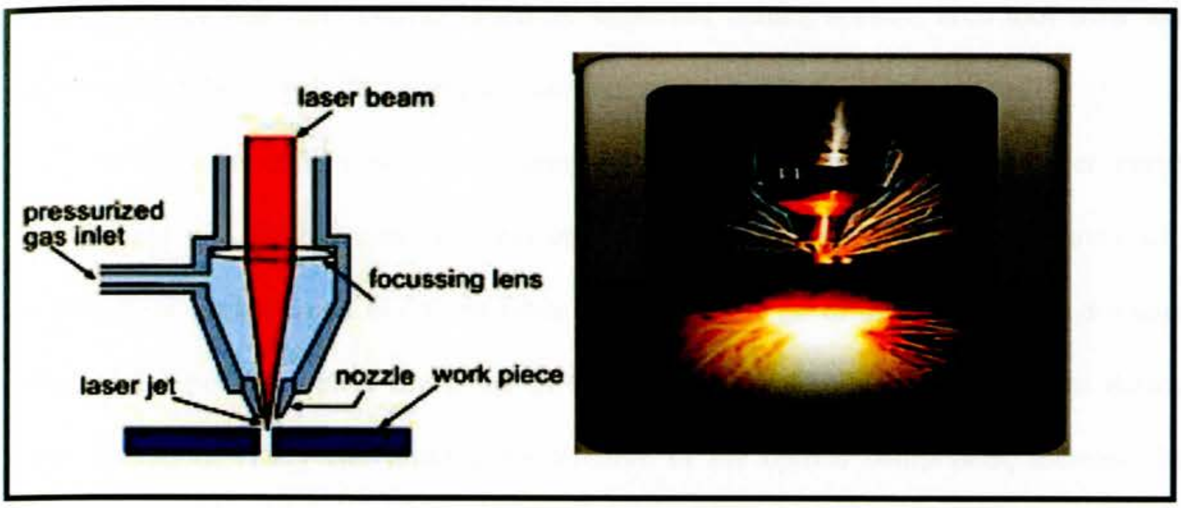

Figure1.3 Laser Cutting Systems Laser (Sivarao, et al., 2012)

Laser cutting technology with a streamlined design to offer an intelligent, cost-effective solution for today's laser processing needs. Figure 1.3 shows the schematic of laser cutting. With the laser cutting technologies, it will maximize the production. The reason of why using laser cutting is because it is simple, compact design, high flexibility to process a high volume of dissimilar parts. We are providing laser cutting for stainless steel < 16mm thickness, mild steel < 22mm thickness. Over the past decade, laser cutting has developed into state-of-the-art technology (Stournaras et al., 2009; Sharma and Yadava, 2012). It is estimated that more than 40,000 cutting systems are used for the high-power cutting of metals and non-metals worldwide (Yilbas and Sahin, 1995). When including low-power applications, such as plastics cutting and paper cutting, the numbers are even higher. Impressive examples of modern laser cutting applications are: Cutting of hydro-formed parts and tubes, high-speed cutting of thin-sheet metal, cutting of thick section-material. Developing lasers with higher output powers without sacrificing beam quality has been one important goal in the past. Other efforts focused on improving the drive technology of the motion system and enhancing material handling around the cutting table.