UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ANALYSIS AND OPTIMIZATION OF PROCESS PARAMETERS INVOLVED IN LASER BEAM MACHINING OF STAINLESS STEEL (6 MM AND 8 MM THICKNESS)

Thesis submitted accordance with the requirements of the National Technical University College of Malaysia for the Degree of Bachelor of Engineering Manufacturing (Honours) (Manufacturing Design)

By

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DECLARATION

I hereby, declare this thesis entitled "Analysis and Optimization of Process Parameters involved in Laser Beam Machining of Stainless Steel (6mm and 8 mm thickness)" is the results of my own research except as cited in the reference.

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APPROVAL

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DEDICATION

Specially dedicated to My beloved Father, Rahim bin Othman and My Mother, Mazeni binti Md Zain who are very concern, understanding, patient and supporting. Thanks for everything to My supervisor Mr Mohd Amri bin Sulaiman for his constructive guidance, encouragement and patience in fulfilling our aspiration in completing this project. To My Brothers and All My Friends, I also would like to say thanks. The Work and Success will never be achieved without all of you.

ABSTRACT

Stainless steel is an important engineering material that is difficult to be cut by oxy-fuel methods because of the high melting point and low viscosity of the formed oxides. However, it is suitable to be cut by laser. This work aims to evaluate the optimum laser cutting parameters for 6 mm and 8 mm thickness of stainless steel sheets by using laser beam and nitrogen as assistant gases. It was shown that the laser cutting quality depends on the cutting speed, gas pressure and focal distance. The optimum cutting was achieved during the gas pressure of 190 bar is applied for both sample thickness. Increasing the cutting speed and gas pressure decreased the burr height and the smoother surface cutting is obtained. However, regarding to those parameters, material is usable to cut because off high speed and low gas pressure. It is due to in sufficient time for heating diffusion and melting wider groove. This process occurs periodically and leads to development of the surface roughness and also on strias around the kerf edge.

ABSTRAK

Keluli tahan karat adalah satu bahan kejuruteraan yang penting dan adalah sukar untuk dipotong secara kaedah oxy bahan api kerana mempunyai takat lebur yang sangat tinggi dan kelikatan oksida terbina yang rendah. Bagaimanapun, ia adalah sesuai dipotomg dengan mennggunakan kaedah pemotongna secara laser. Objektif projek ini adalah untuk mendapatkan parameter yang paling optimum untuk pemotongan secara pancaran laser ke atas kepingan keluli dengan ketebalan 6 mm dan 8 mm. Melalui kaedah pemotongan pancaran laser ini, didapati bahawa kualiti pemotongan bergantung kepada kelajuan memotong, tekanan gas dan jarak fokus. Pemotongan optimum adalah dicapai semasa tekanan gas 190 bar dan diaplikasikan ke atas kedua-dua sampel ketebalan. Dengan menambahkan kelajuan memotong dan tekanan gas akan meyebabkan kurangnya ketinggian *burr* dan menghasilkan permukaan pemotongan yang lebih baik.. walaubagaimanapun, sekiranya kelajuan memotong sangat tinggi akan meyebabkan masa yang tidak mencukupi untuk pemanasan dan akan mencairkan alur yang lebih luas. Proses ini berlaku secara berkala dan akan meyebabkan kekasaran permukaan dan juga berlaku *strias* di sekitar *kerf* pinggir.

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CHAPTER 1

INTRODUCTION

1.0 LASER BEAM CUTTING

A laser beam is created by the introduction of gas and electric current in a sealed chamber. As the electricity breaks down the gas energy is released and it resonates between the mirrors within the chamber. While it resonates intensity of the energy increases and of its optimum is released through a partially transmissive mirror. The beam is then directed to a focusing lens and is further intensified. At this point the laser beam becomes a usable cutting device.

Some advantages of cutting with lasers include the ability to cut incredible complex shapes without tooling or set-ups. This makes it perfect to produce a huge variety of different products.

Laser beam cutting systems cut quickly and very accurately for a wide range of materials. In general, for steel, laser beam cutting process lies between cutting with wire EDM (which is more precise but slower) and plasma (which is less precise but faster). It goes well beyond the range of other methods as well as can cut anything within certain thicknesses.

The word "Laser" stands for "Light Amplification by Stimulated Emission of Radiation". Laser cutting machines are more powerful and also easier to operate.

Programmed lasers are easier than ever. Modern machines are capable to adjust their parameters to cut a given material of a defined thickness and also to adjust itselves to machine for a difficult geometry.

Nowadays, laser programming systems have comprehensive material databases for carbon steel, stainless, and aluminum, which helps a new user to begin the production rapidly with minimal training. When given a clear geometry file and the definition of the material type, the computer will generate machine codes automatically.

Lasers no longer require daily adjustments to set their cutting parameters. A job that runs one day can run just next day, a week, or a month later. The scientific image of lasers can be a bit daunting. Some working knowledge of computers, basic math skills, a little bit of logical, and some training by the machine manufacturer are needed.

Laser cutting operation is both dynamic and stochastic process for the laser operators to handle it easily, with fluctuations in absorbed power, material composition and optical integrity. It is beneficial to develop steady-state modeling for obtaining the approximate order of magnitudes for various parameters. But there are clearly limitations when such models are used as controls. Consequently, an experimental investigation into the laser cut quality is essential to predict the actual control parameters.

Almost all engineering materials are machine by laser beam cutting process. However, material properties such as absorption to electromagnetic wave length, thermal conductivity and electrical conductivity, melting point and surface conditions govern the selection of laser and optics systems.

Weather in the Asian countries has higher humidity and hence stainless steel replaces mild steel which is used as a common building and decorative material. Stainless steel cannot be cut using traditional oxy-fuel cutting equipment because of its higher melting point and due to the viscosity of the oxide formed.

1.1 STAINLESS STEEL

'Stainless' is a term coined early in the development of these steels for cutlery applications. It was adopted as a generic name for such steels and now covers a wide range of stainless steel types and grades for corrosion or oxidation resistant applications.

Stainless steels are iron carbon alloys with a minimum of 10.5% chromium content in it. Other alloying elements are added to attain favorable micro structure and enhance the properties such as formability, strength and cryogenic toughness. These include metals such as nickel, molybdenum, titanium, and copper. Non-metal additions are also added such as carbon and nitrogen.

The main requirement for stainless steels is that it should be corrosion resistant for a specified application or environment. The selection of a particular type and grade of stainless steel must initially meet the corrosion resistance requirements. Additional mechanical or physical properties are also needed to be considered to achieve the overall service performance requirements.

Stainless steel is characterized primarily by their corrosion resistance, high strength and ductility due to high chromium content. Chromium is a ferrite stabilizer; hence the addition of chromium tending to increase the temperature range over which ferrite forms stable structure. Stainless steels are classified into five types. They are:

- Austenitic stainless steel
- Ferritic Stainless Steel
- Martensitic Stainless Steel
- Precipitation-hardenable Stainless steel
- Duplex structure Stainless steel

- Austenitic – These steel are generally composed of chromium, nickel and manganese in iron. They are nonmagnetic and have excellent corrosion resistance, but they are susceptible to stress-corrosion cracking. Austenitic stainless steel are hardened by cold-working. These steel are used in a wide variety of applications, such as kitchenware, fittings, welded construction and also in lightweight transportation equipment.
- Ferritic – These steel have a high chromium content-up to 27%. They are magnetic and have good corrosion resistance, but they have lower ductility than austenitic stainless steels. Ferritic stainless steels are hardened by cold-working and are not heat-treatable. They are generally used for nonstructural applications such as kitchen equipment and automotive trim.
- Martensitic – The steel of this type do not have Nickel content and are hardenable by heat treatment. Their chromium content may be as much as 18%. These steels are magnetic, and they have high strength, hardness, and fatigue resistance, good ductility, and moderate corrosion resistance. Martenistic stainless steels are typically used for cutlery, surgical tools, instruments, valve and springs.
- Precipitation-hardenable – These steels contain chromium and nickel, along with copper, aluminum, titanium, or molybdenum. They have good corrosion resistance and ductility, and they have high strength at elevated temperatures. Their main application is in aircraft and aerospace structural components.
- Duplex structured – These steels have a mixture of austenite and ferrite. They have good strength, and have higher resistance to both corrosion (in most environments) and stress corrosion. Typical applications are in water-treatment plants and as heat-exchanger components.

The main source of raw material for making stainless steels is the re-cycled scrap metal. This recycled processing route has been established for many years and the economy of the stainless steel manufacturing industry depends on recycling. Over 90% of new stainless steel is produced from recycled scrap.

Steel is melted electric arc furnaces and in most cases refined by using inert gasses, such as argon. Great care is taken to minimise fume and dust emissions.

As stainless steels are corrosion resistant alloys their life expectancy is usually long. A minimum of maintenance is needed and so, although more expensive initially, they offer attractive "life-cycle cost" benefits over alternatives such as carbon steels.

Stainless steels are easily cleansible and it is an obvious choice to make casting equipment by the food and beverage manufacturing industries. There are no proven health risks from the normal use of stainless steels. The possible risks from alloying elements such as nickel and chromium are under constant review by the experts.

1.2 PROBLEM STATEMENT

Many works have already discussed on the optimization of the cutting parameters of CO_2 laser on mild steel. However, parameters on cutting stainless steel have not yet discussed much. Therefore this experimental work discusses on the optimization of laser cutting parameters on stainless steel because, stainless steel is widely applied in industries.

Several thicknesses of stainless steel samples are used in this experiment. The parameters studied in this work are focal distance, gas pressure and cutting speed. Consequently, all the parameters are analyzed to get the best result.

The purpose of this experimental work is to optimize the process parameters on cutting stainless steel by laser beam machining technology. This optimization process reduces the time and cost.

1.3 OBJECTIVES

1. To understand the involved parameters of laser beam cutting process.
2. To study the effect of various parameters on the cutting of stainless steel having 6 mm thickness and 8 mm thickness.
3. To determine the optimized parameters of laser cutting process for stainless steel.
4. To get hands on practice on laser cutting process and operation.

1.4 SCOPE

This study focused on the cutting process of a series Helius 2513 Hybrid Laser Beam Cutting Machine which is located at machine shop Universiti Teknikal Malaysia Melaka. It is shown in the Figure 1.0.

Implementation of the laser cutting operation are depends entirely on the variable parameters according to material to be cut. In this work, stainless steel (thickness: 6mm and 8mm) is used as a cutting material. Since limited parameters are only controlled in this process and hence, the same are adjusted in the machine controller for optimization. A simple design and drawn by using CAD software and programming codes are created for the fabrication purpose.

Analyze on the machining parameters such as gas pressure, cutting speed and focal distance has been performed by some of project student during their past experimental implementation. So, optimization on parameters in the laser beam cutting operation of stainless steel having various thicknesses is considered as a significant work and the same is taken as a project problem.

Figure 1.0: LVD Helius 2513 Laser Machine

CHAPTER 2

LITERATURE REVIEW

2.0 HISTORY OF LASER

The first gas laser was developed in 1961 by A. Javan, W. Bennet, and D. Harriott of Bell Laboratories, using a mixture of helium and neon gases. At the same laboratories, L. F Johnson and K. Nassau demonstrated the first neodymium laser, which has since become one of the most reliable lasers available. This was followed in 1962 by the first semiconductor laser, demonstrated by R. Hall at the General Electric Research Laboratories. In 1963, C. K. N. Patel of Bell Laboratories discovered the infrared carbon dioxide laser, which is one of the most efficient and powerful lasers available today.

Later that same year, E. Bell of Spectra Physics discovered the first ion laser, in mercury vapor. In 1964 W.Bridges of Hughes Research Laboratories discovered the argon ion laser, and in 1966 W. Silfvast, G.R. Fowles, and B. D. Hopkins produced the first blue helium-cadmium metal vapor laser. During that same year, P. P. Sorokin and J. R. Lankard of the IBM Research Laboratories developed the first liquid laser using an organic dye dissolved in a solvent, thereby leading to the development of broadly tunable lasers. Beside, W. Walter and co-workers at TRG reported the first copper vapor laser.

In 1961, Fox and Li described the existence of resonant transverse modes in a laser cavity. That same year, Boyd and Gordon obtained solutions of the wave equation for confocal resonator modes. Unstable resonators were demonstrated in 1969 by Krupke and Sooy and were described theoretically by Siegman. Q-switching was first obtained by McClung and Hellwarth in 1962 and described later by Wagner and Lengyel. The first mode-locking was obtained by Hargrove, Fork, and Pollack in l964. Since then, many special cavity arrangements, feedback schemes, and other devices have been developed to improve the control, operation, and reliability of lasers.

2.1 PRINCIPLE OF LASER

The word LASER is an acronym and it stands for: (L) light (A) amplification (S) stimulated by the (E) emission of (R) radiation, and refers to the way in which the light is generated.

All lasers are optical amplifiers which work by pumping (exciting) an active medium placed between two mirrors. One of which is partially transmitting is shown in the Figure 2.0. The active medium is a collection of specially selected atoms, molecules or ions which can be in a gas, liquid or solid form and which will laser.

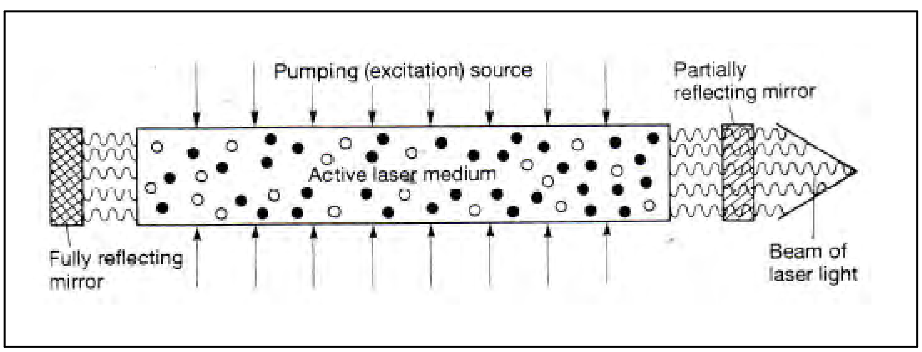

Figure 2.0: The basic elements of a laser.

Whatever the active medium consists of atoms, molecules or ions there are billions of them and they absorb energy when pumped, which they hold for a very short but random life time. When their life time expires they give up their energy in the form of a photon and return to their former state. The release of photons in this manner is called spontaneous emission. The photons released travel in all directions in relation to the optical axis of the laser, shown in the Figure 2.1.

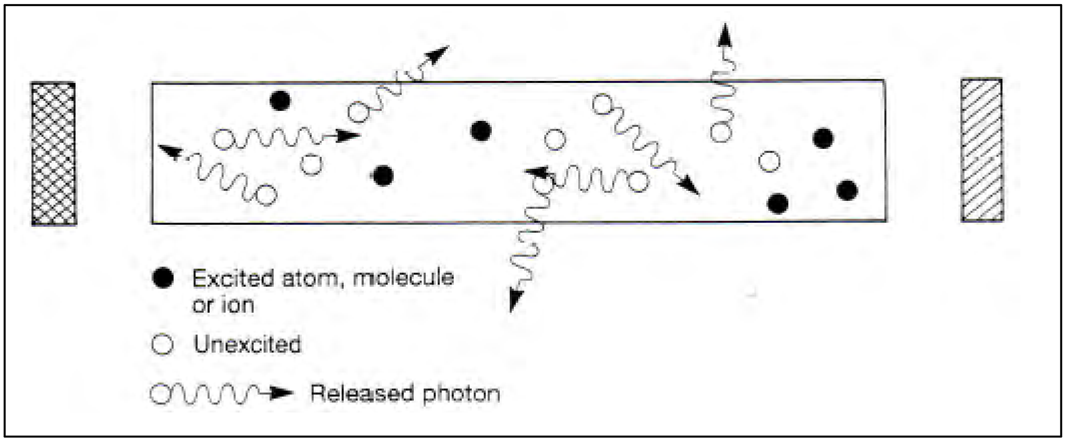

Figure 2.1: Spontaneous emission of photons from the excited active medium. There are billions of excited atoms, molecules and ions and they release their photons in all directions.

If a photon collides with another energized atom, etc. it causes it to release its photon prematurely and the two photons will travel along in phase until the next collision, thus building a stream of photons of increase intensity. It is illustrated in Figure 2.2.