UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CO_2 LASER CUTTING OF POLYPROPYLENE POLYMER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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APPROVAL

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ABSTRACT

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications. Laser cutting works by directing the output of a high power laser, by computer, at the material to be cut. The material then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high quality surface finish. This study is focusing on CO_2 laser cutting process on Polypropylene (PP) polymer. By cutting this type of polymer, the quality of cutting surface is evaluated. Through this study, the parameters that involved in laser cutting are examined. The laser parametric that affects the result and machining characteristic of surface roughness on the cutting surface will be studied. There are three parameters that want to be evaluated in this experimental study, which are the cutting speed, focal length of the lens, and gas pressure. A two-level full factorial is used to examine the combinations of these three parameters during the experiment. Two levels full factorial design means, there are two levels (high and low) of the value of each parameters that will be used in this process. Through this experimental study, there is only one response that will be evaluated, which is surface roughness, Ra. The value of Ra will be determined by using portable roughness measuring machine. Then, the result will be generated by using Minitab v14 software by entering all the measurements data and some graph will be plotted in order to find the main effect which is significant. From these three parameters, the factors that gives the main effect in cutting quality will be determined. This result will be used to find the suitable values or level combination to produce the good quality in laser cutting.

ABSTRAK

Pemotongan melalui kaedah laser adalah teknologi yang menggunakan laser untuk memotong bahan kerja, dan biasa digunakan dalam industri pembuatan. Kaedah pemotongan melalui laser adalah dengan mengarahkan output kuasa laser yang tinggi menggunakan komputer, kepada bahan yang ingin dipotong. Bahan yang dipotong itu sama ada akan melebur, terbakar, mengewap, atau meletup dengan menggunakan jet gas, dan akan menghasilkan kesan pemotongan pada bahagian tepi bahan yang dipotong iaitu hasil yang berkualiti tinggi. Kajian ini bertumpu kepada pemotongan melalui kaedah laser ke atas Polypropylene (PP) dengan menggunakan gas Karbon Dioksida. Melalui kajian ini, parameter-parameter yang terlibat akan dinilai. Kajian akan dibuat terhadap kesan parameter yang digunakan berdasarkan nilai kekasaran permukaan yang dipotong. Terdapat tiga parameter yang digunakan dalan kajian ini iaitu kelajuan pemotongan, panjang tumpuan lens, dan juga tekanan gas. Kombinasi ketiga-tiga parameter ini akan dikaji dengan menggunakan kaedah “two-level factorial design”. 2-level bermaksud setiap parameter yang digunakan mempunyai dua nilai (tinggi dan rendah). Hanya satu tindak balas sahaja yang dinilai dalam kajian ini iaitu kekasaran permukaan yang dipotong. Nilai ini diperoleh dengan menggunakan mesin pengukuran kekasaran permukaan yang mudah alih. Keputusan akan dijana dengan perisian Minitab v14 dan graf-graf yang berkenaan akan diplotkan untuk mencari kesan utama yang signifikan. Berdasarkan ketiga-tiga parameter yang digunakan dalam kajian ini, salah satu parameter yang akan memberikan kesan utama akan ditentukan. Keputusan ini akan dugunakan dalam mencari nilai atau kombinasi yang sesuai untuk menghasilkan qualiti yang baik dalam kaedah pemotongan melalui laser ini.

DEDICATION

To my beloved father, Hasan bin Saman and mother, Che Esah binti Abdullah for all support that you have given to me.
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Laser cutting has developed into state- of- art technology over the past decade. There are so many cutting systems that used for the high- power cutting of metals and non-metals material. By the using of low power applications, this system is used widely in plastics cutting and paper cutting.

Many lasers can be used for laser cutting by providing their beam which focused on a small spot with sufficient intensity to melt the material and their specific wavelength is absorbed in the material. CO_2 gas lasers, Nd: YAG solid-state lasers and Excimer gas lasers are those most commonly used in the field of materials processing. However, knowing the strengths and weaknesses of laser processing is the key to determining whether or not a laser is the right choice for cutting. While lasers are not the answer for every application, they can provide flexibility, efficient material use, a repeatable and controlled process.

In CO_2 laser gas-assisted cutting process, modeling of the interaction mechanism is important. An experimental will carried out to come out with findings to identify the relationship between the parameters used that influencing the cutting quality of the workpiece's surface. The method of Design of Experiment is used in order to get the optimum combination between the parameters involved in this project. Besides, through this finding, the main effect factors and the interaction between each factor also can be identified.

1.2 Problem Statement

The problem encountered in doing this project is to get the optimum combination of parameters in order to get the good quality of laser cutting process which will give the smaller value of Ra, which means that the cut quality is good.

Rajaram *et al.* (2003) said that, 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. Of particular interest to manufacturers using laser cutting are the maximization of the productivity and the subsequent quality of components made by the laser cutting process. Both aspects are governed by the selection of appropriate laser process parameters, which are unique for each material and thickness. These parameters include laser power, frequency, duty cycle, standoff height, and cutting speed and assist gas pressure. These parameters are usually adjusted and tuned to provide the quality of cut desired, but this consumes exhaustive amounts of time and effort, and still good quality cutting conditions may not be found. If a different type of material is to be cut, then the procedure has to be repeated.

Besides, according to Caiazzo (2005), the cutting of polymers through chemical degradation (when this is chosen as prevailing removal process) tends to produce smoke with carbonaceous particles which often results in a residue being deposited on the cut edges and faces. Chemical degradation is used to cut thermosetting materials. The process requires the use of a higher power level as compared to simple fusion cutting because a three-dimensional lattice needs to be broken and not merely a linear chain of monomers as in the case of thermoplastics.

By the laser cutting application, it can be seen that there are so many advantages of laser cutting over the mechanical cutting according to the situation. However, there are two important factors which are the lack of physical contact (since there is no cutting edge which can become contaminated by the material or contaminate the material), and to some extent precision (since there is no wear on the laser). There is also a reduced chance of warping the material that is being cut, as laser systems have a small heat-affected zone.

The other difference that lasers have over conventional processes such as stamping and punching is that they work with minimal contact. A typical cut width enables lasers to be used for small-radius cutting. This small kerf allows close nesting of parts and helps to minimize material waste. In addition, materials may be heat treated after cutting without the distortion that can occur with the grinding and reforming usually needed after processing by other methods.

This study is focusing on research to investigate the best combination of parameters that used in CO_2 laser cutting process in cutting the thermoplastic polymer which is polypropylene.

1.3 Objective of Study

The objectives of this project were:

1. to investigate the application of CO_2 laser cutting on Polypropylene (PP) polymer
2. to identify the effect of different parameters on final product according to its value of Ra by CO_2 laser cutting process
3. to investigate the optimum combination of parameters that will give the good result of cutting quality

1.4 Scopes of Study

This research project will focus primarily on application of CO_2 laser cutting on thermoplastic polymer (polypropylene), the effect of different parameters setting during the process, and also about the surface roughness of product that have been cut by using CO_2 laser cutting process. This project also to investigate which factors that give the optimum combination of parameter that can be used in laser cutting process to get the better result of surface roughness and burr appearance. The method used in conducting the study is based on the Design of Experiment (DOE).

CHAPTER 2

LITERATURE REVIEW

2.1 Principles of Laser Cutting

Petring (2001) in his research states that laser cutting is a thermal cutting process in which a cut kerf (slot) is formed by the heating action of a focused traversing laser beam of power density in combination with the melt shearing action of a stream of inert or active assist gas. The focused laser beam melts the material throughout the material thickness and a pressurized gas jet, acting coaxially with the laser beam, which blows away the molten material from the cut kerfs.

Laser technology is a technology which may be regarded as a device for producing a finely controllable energy beam, which, in contact with a material, generates considerable heat. The heat energy is supplied by a laser beam that allows tool-free machining with active heat energy. The energy of light contained in the laser radiation is absorbed by the workpiece and transformed into thermal energy. The laser cutting is performed with a coaxial current of the assist gas which is gas assisting laser cutting in order to remove the evaporated and molten material from the affected zone as soon as possible. In gas assisted laser cutting, the gas is usually introduced coaxially with the focused laser beam into the cutting area. The gas cools the cut area, thus lowering the heat affected zone, and also removes molten dross from the cut. (Petring, 2001)

The basic principle of laser cutting is shown in Figure 2.1 and Figure 2.2, and the terms related to the cutting process are illustrated in Figure 2.3.

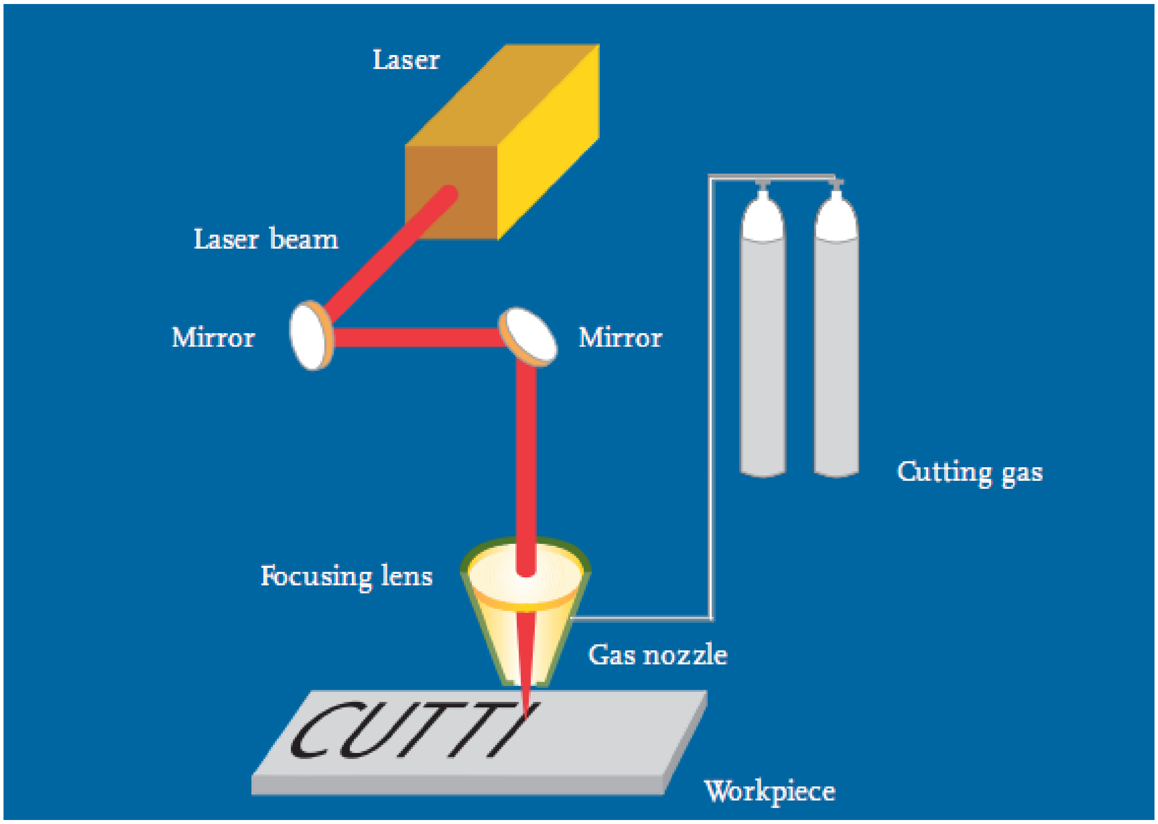

Figure 2.1: Principle of laser cutting (Berkmanns and Mark, n.d)

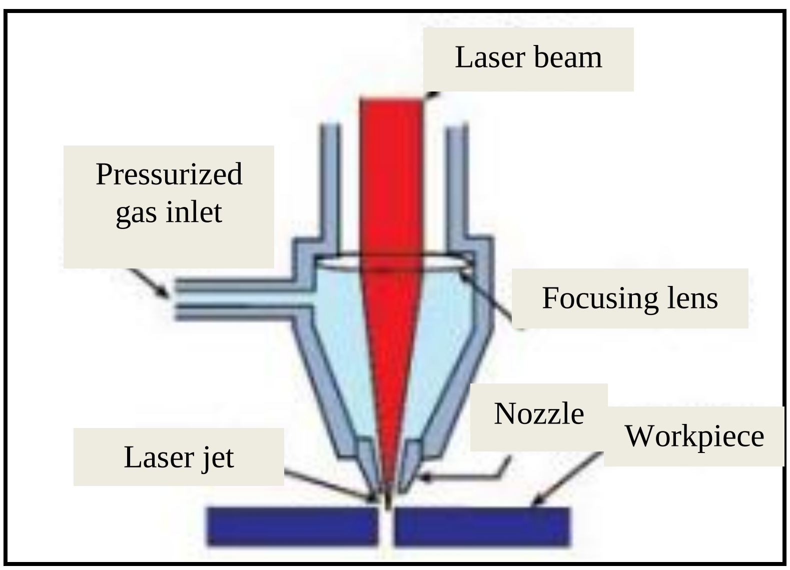

Figure 2.2: Basic principle of laser cutting

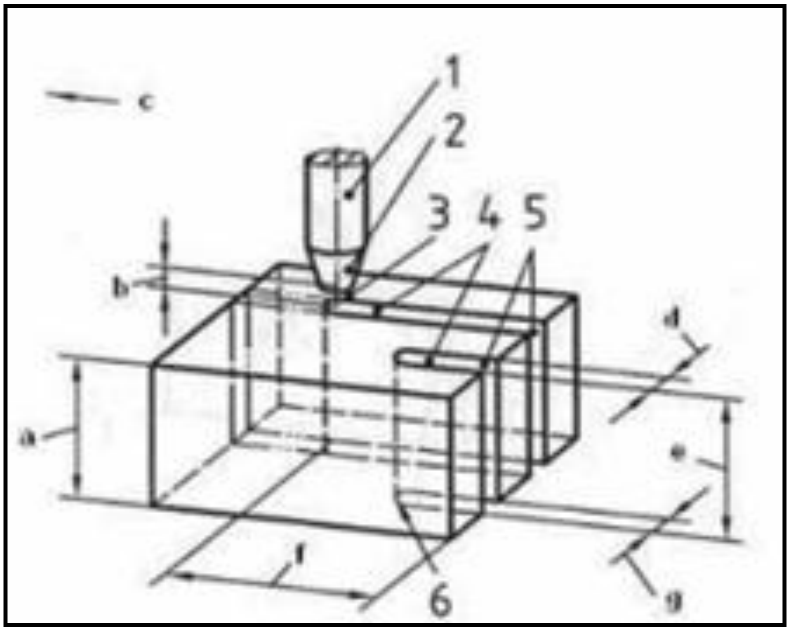

Figure 2.3: The term related to cutting process of workpiece (Lappeenranta, 2006)

The term related to cutting process:

1	Torch	a	Workpiece thickness
2	Nozzle	b	Nozzle distance
3	Beam	c	Cutting direction
4	Kerf	d	Top kerf width
5	Start of cut	e	Cut thickness
6	End of cut	f	Length of cut
		g	Bottom kerf width

Besides, Kalpakjian (2006) said that in laser- beam machining, the source of energy is a laser (an acronym for light amplification by stimulated emission of radiation), which focused optical energy on the source of the workpiece. The highly focused, high density energy source melts and evaporates portions of the workpiece in a controlled manner. This process (which does not require a vacuum) is used to machine a variety of metallic and nonmetallic materials.

Whether laser cutting with CO_2 or Nd: YAG lasers, the principles employed are basically the same. The beam from the laser is focused on to the surface of the material being cut by means of a lens. The focused laser beam heats the material surface and a very local melt capillary is quickly established throughout the depth of the material. The diameter of this capillary is usually just slightly greater than the diameter of the focused laser beam. The great majority of CO_2 laser cutting is performed using an assist gas. The significant feature of gas assisted laser cutting is that the molten material is ejected from the base of the capillary by a jet of gas coaxial with the laser beam. For some materials this gas can further assist the process by chemical (exothermic) reaction as well as physical work. The cut is generated by either moving the focused laser beam across the surface of the stationary material or by keeping the laser beam stationary or moving the workpiece. Hybrids of these two options are also possible. In this way simple and complex linear cuts or two dimensional parts can be produced. More complex systems are required for three dimensional processing. Most lasers cutting with CO_2 lasers are performed in the power range 1 - 1.5kW. However, over the last few years higher beam quality lasers with powers up to 6kW have become available and these lasers have been able to extend the thickness cut, on steel for example, to 20 - 25mm (Petring, 2001).

2.2 Types of Laser Cutting

2.2.1 Laser fusion cutting

Powell (1993) in his research state that the laser fusion cutting process, also called inert gas melt shearing, is based on transformation of the material along the kerf into the molten state by heating with laser energy and the molten material blown out of the kerf by a high-pressure inert gas jet. The laser beam is the only heat source during this cutting process and the high-pressure inert gas jet is responsible for melt ejection. The inert gas jet (mainly nitrogen or argon) is also responsible for shielding the heated material from the surrounding air as well as protecting the laser optics. Figure 2.4 is a schematic of laser fusion cutting.

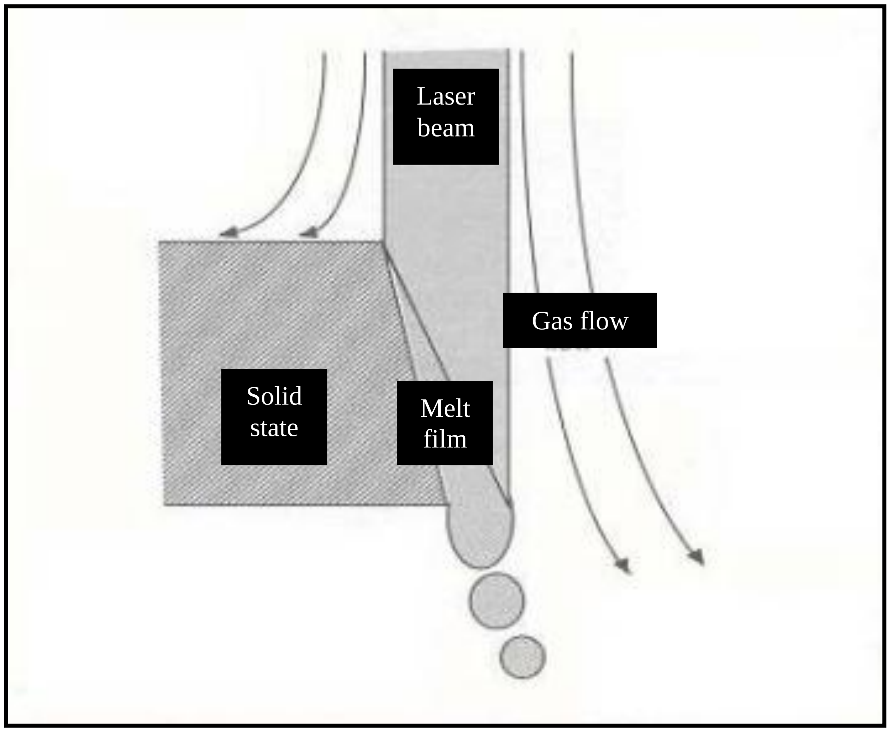

Figure 2.4: A sketch of laser fusion cutting

Laser fusion cutting is applicable to all metals especially stainless steels and other highly alloyed steels, aluminum and titanium alloys. A high quality cut edge is formed but the cutting speeds are relatively low in comparison with active gas cutting mechanisms. This view has been supported in the work of Ion (n.d). The advantage of this process is that the resulting cut edges are free of oxides and have the same corrosion resistance as the substrate. The cut edges may be welded without any post-cutting preparation. The main technical demand is to avoid adherent melt (dross attachment) at the bottom edges of the kerf. A high pressure (above 10 bars) is recommended to remove liquid that can adhere to the underside and solidify as dross. (Natarajan, 1990)

2.2.2 Laser oxygen cutting

The principle of laser oxygen cutting is that the focused laser beam heats the material in an oxidizing atmosphere and ignites an exothermic oxidation reaction of the oxygen with the material. The exothermic reaction supports the laser cutting process by providing additional heat input in the cutting zone resulting into higher cutting speeds