CO_2 LASER CUTTING OF CERAMIC TILES

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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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DECLARATION

I hereby, declared this reported entitled "CO_2 Laser Cutting of Ceramic Tiles" is the results of my own research expect as cited in references.

Signature	:	……………………………………………..
Author's Name	:	MUHAMMAD QUSYAIRI BIN ABDUL RAHMAN
Date	:	11 MAY 2009

APPROVAL

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

……………………………………

ABSTRACT

This project will cover the cutting of commercially-available ceramic tiles by using a CO_2 laser cutting machine, with the object of producing a laser beam machining (LBM) database that contains the essential parameter information for their successful processing. Various laser cutting parameters were investigated that would generate a cut in ceramic tile which required minimal post-treatment. There are three main objectives during the accomplishment of this project. The first is to determine the capability of CO_2 laser cutting machine in cutting the ceramic tiles. The parameters that have controlled are power input of the CO_2 laser cutting, pressure and the cutting speed. Besides that, the second objective is to know whether or not the CO_2 laser cutting machine make the engraving process. Then the last objective is to identify the suitable setting of parameters in cutting and engraving the ceramic tiles. The literature review covered the principles of the characteristic of the high power fiber laser, CO_2 laser and Nd: YAG laser as well as the principle of laser cutting. To get the measurement of the result, a laboratory test will do to carry out the result of kerf width produced by laser cutting process practically.

ABSTRAK

Projek ini merangkumi pemotongan jubin seramik yang berada di pasaran sekarang menggunakan mesin pemotongan laser CO_2 dengan objek yang hasil dari data “Laser Beam Machining (LBM)” yang mengandungi beberapa informasi asas berkaitan parameter yang digunakan untuk menghasilkan proses yang berjaya. Pemotongan laser melalui pelarasan pelbagai parameter telah disiasat dan akan menjana satu pemotongan pada jubin seramik yang memerlukan rawatan susulan secara minimum. Terdapat tiga objektif utama sepanjang projek ini dijalankan. Objektif yang pertama ialah untuk menentukan kebolehan mesin pemotongan laser CO2 untuk memotong jubin seramik. Antara parameter yang dikawal ialah kuasa yang digunakan untuk pemotongan, tekanan dan kelajuan pemotongan. Selain itu, objektif kedua adalah untuk mengetahui kebolehan mesin pemotongan laser CO_2 dalam menghasilkan proses ukiran pada jubin seramik. Seterusnya, objektif ketiga adalah untuk mengenal pasti pelarasan yang sesuai untuk proses pemotongan dan ukiran pada jubin seramik. Untuk ulasan karya telah merangkumi prinsip dan ciri-ciri laser, laser CO_2 dan laser Nd: YAG termasuk beberapa prinsip pemotongan melalui kaedah laser. Untuk mendapatkan keputusan kelebaran kerf, ujian akan dilakukan di makmal yang dilakukan secara praktikal.

DEDICATION

For my beloved family & friends:

Abdul Rahman B. Yahya

Noraini Bt. Jaafar

Nurul Nadiah BT Abdul Rahman

Muhammad Siddiqi B. Abdul Rahman

Nurul Nasihah Bt Abdul Rahman

Muhammad Khalid Zaidan B. Abdul Rahman

Muhammad Arif Marzuqi B. Abdul Rahman

Nurul Nasyuha Bt. Abdul Rahman

Siti Haza Bt. Hasan

THANK YOU VERY MUCH BECAUSE NEVER GIVE UP IN SUPPORTING AND ENCOURAGING ME

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بسم الله الرحمن الرحيم

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CHAPTER 1

INTRODUCTION

1.1 Background

Industrial CO_2 laser cutting started at the beginning of the1970's as a method of cutting plywood to produce die-boards for the cartoon industry. Within decade, improvement in optics, power and the use of oxygen as a cutting gas meant that CO_2 laser cutting was taken seriously as a method of profiling metals. During the 80's and 90's the subject developed into a well accepted standard production method.

Presently, laser cutting is used by large variety of industries. From aerospace to sign manufacture. Materials cut include steels, plastic, ceramics, wood-based product and alloy of all types.

1.2 CO_2 laser cutting

Laser cutting is a technology that uses a laser in cutting different kinds of materials, mostly metals such as carbon steel, aluminum, stainless steel and copper alloys. It is widely used in the metal fabrication industry to increase cutting speed and cutting capacity, reduce production costs, increase productivity and improve cutting quality.

A laser or LASER (Light Amplification by Stimulated Emission of Radiation) is a device that generates a highly concentrated monochromatic and coherent beam of light. The light is produced through the process of stimulated emission.

Among the most commonly used laser in cutting is the carbon dioxide laser (CO_2 laser), a kind of gas laser that is also used in welding. It is capable of emitting a maximum of 100 kilowatts at 9.6 µm and 10.6 µm and of cutting 20-30 m of one millimeter-thick material in a minute.

Cutting is done by aiming the energy produced by the high-power laser at a small portion of the object to be cut. That small portion is pierced first before a cut is made.From the small hole, a cut is created either by moving the beam across the area of the material being cut, or by moving the object while the laser is kept still. One can employ both methods. As the intense beam of light strikes the part of the object or material, the letters temperature rises, causing it to melt burn and evaporate even without sufficient amount of heat.

Not all materials require the same amount of laser power (the rate at which energy is delivered by the light). Thicker materials need more laser power while thinner ones need lesser laser power. Usually, carbon dioxide laser cutting is done with 1,000 to 1,500 watts. Materials such as steel need more than 2 kW.

Compared to other metal cutting procedures, laser cutting is far more advantageous, although it has some disadvantages, too. Its primary advantages are precision, cutting quality, cutting speed and economy. Among its disadvantages is its high voltage requirement. There is also risk of getting serious burns from the laser beam.

1.3 Problem Statement

In practical applications of laser cutting, the quality of the cut surfaces is the critical factor. Recently methods for studying the influence on quality of the main process variables have been developed, which seek to improve quality rather than explain the cutting mechanism. In the present study, CO_2 laser cutting of ceramics tiles is carried out at different combinations of levels of cutting parameters which include cutting speed, assisting gas pressure, work piece thickness and laser pulsing frequency. Waviness (striations), flatness and metallurgical changes at the cut surface are considered as measurable variables in evaluating the overall cut quality. Factorial analysis is carried out to determine the parameters which affect cut quality while a neural network is introduced to classify the resulting striation patterns.

However manual techniques are limited to straight line cutting and relatively large radius cuts. Internal and undercut profiles are nearly impossible to produce with scoring alone (with the possible exception of internal circles); more sophisticated methods having to be applied to achieve this profiles. Traditionally diamond saw, hydrodynamic or ultra sonic machining are used to creat a complex geometries in ceramics tiles, but these process are very expensive and time consuming.

After used the CO_2 laser cutting to cut a ceramics tiles, the most problem that happen is a crack damage, which is essentially caused by a high temperature gradient within the ceramics tiles substrate during the cutting process. These cracks reduce the strength and sources for critical crack growth, which may result in partial or complete failure of the tiles substrate.

1.4 Objective

i. To determine the capability of CO_2 laser cutting machine in cutting the ceramic tiles
ii. To know whether or not the CO_2 laser cutting machine make the engraving process
iii. To identify the suitable setting of parameters in cutting and engraving the ceramic tiles

1.5 Scope of Project

This research project will focus primarily on application of CO_2 laser cutting on ceramic tiles, the capability of CO_2 laser cutting machine to cut the ceramic tiles, and also to determine whether this machine can be used to cut the ceramic tiles. Besides, this project also to investigate suitable value of parameters that should be setting in order to get the smallest value of kerf width. The analysis will be done by observing the surface of ceramic tiles that will be cut by using the microscopic tool. Besides, the analysis also will be made by using Minitab v14 software to get the relationship between all parameters.

CHAPTER 2

LITERATURE REVIEWS

2.1 Background

The engineering ceramics are being increasingly used in industry due to their outstanding physical and chemical properties. But these materials are difficult to machine by traditional machining processes, as they are hard and brittle.

The reports that had been related to the project title are sorted according the best criteria on the help to understand well the project title needs. The literally reviews can be shown in the consistence of the meanings of the title of the project until the methods that had been done by other researchers in previous studies. Basically, laser cutting is a thermal process. The materials' thermo-physical properties rather than mechanical properties decide whether they can be machined easily or not. Moreover, it is possible to cut complex contours because of its high flexibility. However, during the laser cutting process the formation of a heat affected region is unavoidable and this has a tendency to induce cracks. So laser cutting engineering ceramics efficiently and without damage is an attractive subject to solve. From the other study showed that cutting sintered Si3N4 with a continuous wave laser or a normal pulsed laser would induce cracks which decrease the work piece strength to one third as compared with the original. (Yamomoto JC, 1987.)

On the other hand, experiments on drilling and scanning Si3N4 ceramics with an Acoustic-optic Q-switched YAG laser showed that the lengths of the cracks could be limited below the grain size, resulting in crack-free machining. (Morita, 1991.)

2.2 Laser Cutting

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 on the order of 10^4 W mm^{-2} in combination with the melt shearing action of a stream of inert or active assist gas, this view has been supported in the work of John C. Ion (1995).The focused laser beam melts the material throughout the material thickness and a pressurized gas jet, acting coaxially with the laser beam, blows away the molten material from the cut kerf. The basic principle of laser cutting is shown in Figure 2.1 and the terms related to the cutting process are illustrated in Figure 2.2. (D Petring, 2001).

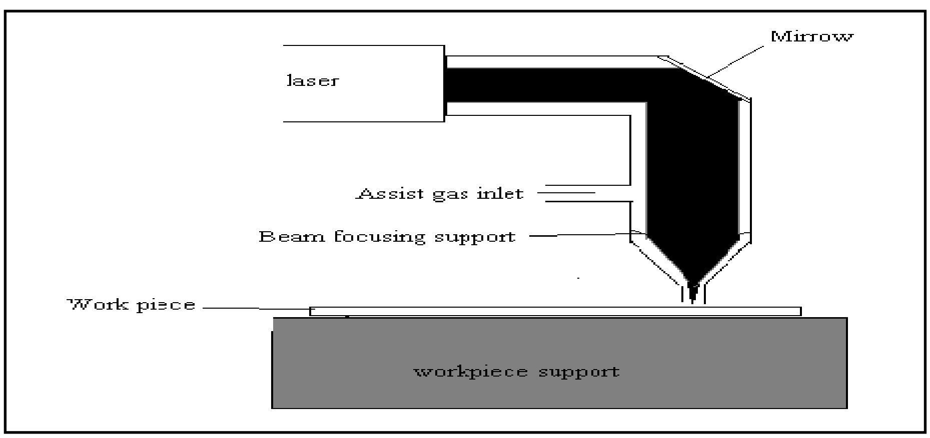
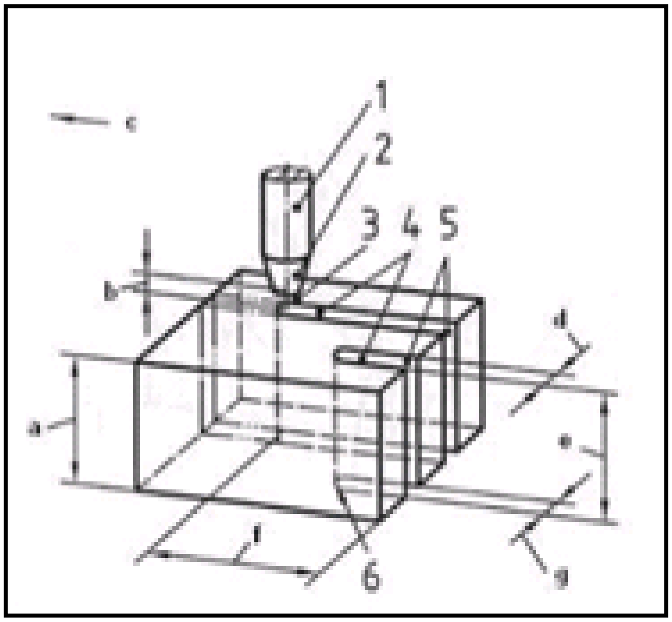


Figure 2.1: Basic principle of laser cutting



1. Torch
2. Nozzle
3. Beam
4. Kerf
5. Start of cut
6. End of cut

a. Work piece thickness
b. Nozzle distance
c. Cutting direction
d. Top kerf width
e. Cut thickness
f. Length of cut
g. Bottom kerf width

Figure 2.2: Terms related to the cutting process of the work piece [European Committee for Standardization, n.d.]

The laser cutting process types, defined according to their dominant transformation process, include: laser fusion cutting (inert gas cutting), laser oxygen cutting and laser vaporization cutting. These cutting methods - discussed in detail in the following sections - are applicable for the cutting of metals commonly used in industry. (Natarajan, 1990)

2.2.1 Laser fusion cutting

Powell (1993) has written 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 2.3 is a schematic of laser fusion cutting. (Petring, 2001)

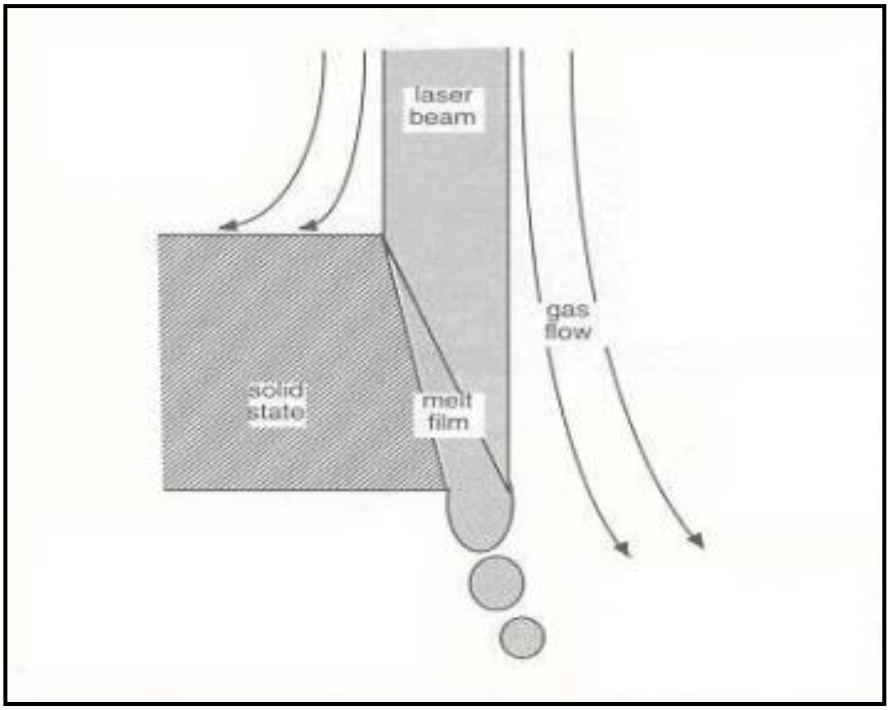


Figure 2.3: A sketch of laser fusion cutting [Petring, 2001]

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 bar) 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 compared to laser cutting with inert gases. The laser beam is responsible for igniting and stabilizing a burning process within the kerf, and the assist gas blows out the molten material from the cut zone and protects the laser optics. Figure 2.4 is a schematic of laser oxygen cutting. (Petring, 2001)

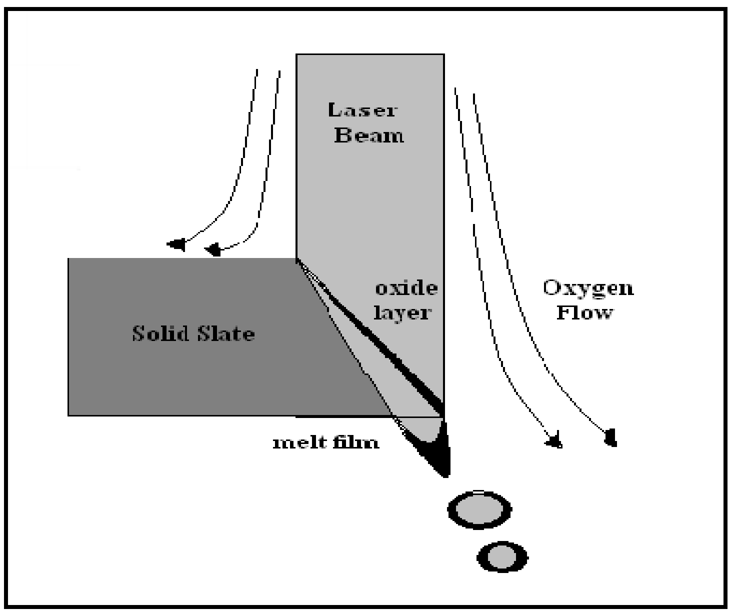


Figure 2.4: A sketch of laser oxygen cutting

Laser oxygen cutting is applicable to mild steel and low-alloyed steel. The formation of the oxide layer on the cutting front increases the absorption of the laser radiation compared to absorption of a pure metallic melt. The oxides reduce the viscosity and surface tension of the melt and thereby simplify melt ejection. However, the resulting cut edges are oxidized. (Petring, 2001)