UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SURFACE MODIFICATION OF LOW CARBON STEEL IN LASER CUTTING

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

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

……..

ABSTRACT

Laser cutting is an advanced machining which becoming important for the industrial application. The machine can do its jobs faster, more accurate and more complex shape than other conventional machine and can machine a lot of materials available. The demand of the modern material with high hardness leads to more difficult for machining, laser cutting hereby solve the problems of this. In the research, surface modification of the low carbon steel will be identify and observed after machining. By using sets of parameters with different cutting speed and laser output power, the impact of this parameter on the surface of cut will be investigate. Firstly is to do surface roughness test on the machine surface of each samples. Then the sample will be mounted on epoxy to be grind and polish, before observation under microscope, the sample undergoes etching. Finally the cut surface grain structure is observed for microstructure changes of size. Machine which in used for the experiment will be all located in the laboratory. In the experiment, roughness test shows that the surface cut with the higher speed will have higher value of roughness but when the speed is lower it will affect more heat to be transfer on the material and causing heat affected zone to be increase in the size on the surface. In other explanation will be the spreading of heat during laser decrease as the laser beam does not stay longer a location.

ABSTRAK

Pemotong laser merupakan mesin termaju dan semakin menjadi penggunaan yang penting dalam aplikasi industri. Mesin laser mampu melakukan kerja-kerja pemotongan dengan lebih cepat, tepat dan boleh memotong bentuk-bentuk yang kompleks berbanding dengan mesin tradisional. Mesin laser juga dapat memotong pelbagai jenis bahan yang terdapat di dunia ini. Dengan permintaan bahan yang berkekerasan yang tinggi akan menyukarkan lagu pemotongan dengan menggunakan mesin tradisional, dengan kewujudan mesin pemotong laser lalu menyelesaikan masalah ini. Dalam penyelidikan ini, perubahan dalam permukaan yang dipotong oleh laser pada besi berkandungan karbon rendah akan dikenalpasti dan diperhatikan selepas pemesinan. Dengan menggunakan beberapa set parameter berlainan dalam mesin seperti perubahan kelajuan memotong dan kuasa output laser. Impak pada permukaan dipotong akan dikaji. Kajian pertama selepas pemesinan ialah ujian kekasaran pada setiap sempel. Kemudiannya sempel akan disediakan dalam epoxy dan dikilatkan. Sebelum dilihat melalui mikroskop, sempel akan dicelup dalam larutan nital untuk beberapa saat sehingga seminit dan dibersih dan dikeringkan. Ujian kekasaran menunjukkan sekiranya kelajuan laser meningkat akan menyebabkan bacaan kekasaran meningkat. Akan tetapi melalui gambar dibesarkan dalam mikroskop semakin lambat kelajuan laser akan menyebabkan HAZ tersebar lebih jauh. Dengan kata lain, sekiranya pancaran laser tidak berada dalam kawasan dengan lama akan mengurangkan haba mengalir.

DEDICATION

This work is dedicated to my beloved parents, Luei Heng Bee and Chan Soo Mooi, without their caring support and the respect for education it would not have been possible.

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AC	-	Alternative current
CNC	-	Computer numerical control
CW	-	Continuous Wave
DC	-	Direct current
EDM	-	Electrical discharge machining
HAZ	-	Heat affected zone
LBM	-	Laser beam machining
LGAC	-	Laser generated air contaminant
OEM	-	Original Equipment Manufacturer
SEM	-	Scanning electron microscope
TEM	-	Transmission Electron Microscope
UV	-	Ultra-Violet
YAG	-	Yttrium Aluminium Garnet

CHAPTER 1
INTRODUCTION

This chapter will briefly explain about the research and what is the current motivation that brings out the idea to study on the laser beam machining and machining effect on the workpiece.

1.1 Background

In the world of today, metal working operation is a common process to human being, but the requirements for high accuracy and precision going higher and higher each day to enable new possible product is being produce with various kind of geometrical shape. As the manufacturing tends to become more and more complex, more technology will be invented and implemented. If there is possibility human tends to produce machining operation which will not need additional machining process in order to give a better finishing. The reason behind is to have lower cost in the production, fewer machining operation or finishing operation will reduce the cost of product being manufactured. Sometimes there are some circumstances which cause the manufacturing process to be increase, such as the complexity where one machining process cannot do all the profile or maybe there is needed to have tools change whenever removing material of different profile. There are also additional of time when there is a need of changing tool or even changing of machining processes which also means change of workstation. When this happens, lead time to the next process will be increases. Non-traditional machining process created is not only to fulfilled the reason on increasing performance of certain manufacturing process but there is a need to taken in account on how the effect of machining processes affect on

the workpiece especially when heat generated which there is a high possibility altering the properties of the material which it used to be. On the second though material nowadays required on better quality with high hardness, toughness and impact resistance leads to an increasing of difficulty in cutting this type of material. But still there is a need on new material being created, which is to suits the current manufacturing work. Conventional machined unable to cut any material which is harder than its cutting tool but with existents of modern machining is used such as electrolytic grinding, supersonic machining, electrical discharging machining (EDM) and laser cutting have been discover. Laser cutting can produce a very precise and fine surface but laser cutting do have some differences where laser cutting need to deburring after the cutting process depends on the surface at the bottom surface will have melted material cools at the bottom edge. Laser cutting is effective for single piece, one-of-a-kind operation but also in mass production.

As for this project, the need is to determine any modification occur on a low carbon steel plate is after going through laser cutting process. As we know that laser cutting process can be very high precision and accuracy but how far will laser cutting can bring a machining process to serve its main purpose. The reason for this research is to determine the change on the cut surface after machining. The equipment which will be used one will be CO_2 Laser Beam Cutting machine (LVD HELIUS 2513) for plate cutting, Surface roughness tester (Mitutoyo SJ-301) for measuring the surface roughness, optical microscope (ZEISS Axioskop 2) and others supporting equipment to assist in the research. Laser cutting machine will be run in optimum preloaded parameters for the 6mm thick low carbon steel plate material where the parameter is given by the manufacturer of the machine which ensures that the laser beam can penetrate the plate to cut. Cut surface of the plate will be examined for its roughness and then the microstructure changes.

1.2 Problems Statement

Laser cutting is non contact machining process, but there is still heat generated out during the process of cutting material. This mean during machining process, heat generated will affect structure on the cut surface. Heat generated is very high thus it must leads to melting of material in order to cut. Cutting gas and assists gas which is introduced during the cutting process changes in the structure of the material and there might cause stress in the material as it also do some cooling work. Heat generated during machining will be cool by gas assist where it directly blown on the molten material to enable cutting process to be run smoothly. But when there is some situation where rapid cooling occurs therefore surface of the material being cut might change, in this experiment the surface modification generated during the machining process of laser cutting will be study. The changes or the formation of the layer of different microstructure from the parents' material will be observed. The reasons on formation of different structure and the effects on the material is examined and discussed.

1.3 Objectives

The main objectives of this study are as below:

(a) To study the cut surface of low carbon steel after laser cut.
(b) To identify any microstructure changes after machining process.
(c) To study the effect of cutting parameter on surface modification.

1.4 Scope

This research will be carried out within the limitation;

(a) Laser cutting machining used is the CO_2 gas assist laser machine at FASA B to cut the sample of material low carbon steel plate.
(b) Parameters used will be the parameters given from the machine manufacturer for material 6mm low carbon steel plate.
(c) Numbers of samples which will be prepared will be 4 samples for laser cutting process. Each sample will be cut using 4 different types of settings for 6mm low carbon steel plate which are the rapid, medium, slow and general settings.
(d) Microstructure observation will be at the cross-section of the machining surface. Where revealing the general structure of low carbon steel.

1.5 Significant of Study

The significant of study in this research are:

(a) Performance of the CO_2 laser cutting will be tested by how the surface produced by observing on how parameters affect the possibility of the surface produced.

(b) To find out the formation of the heat affected zone on laser cutting surface and how it was form by different parameter settings during machining. How far the heat spread from the cutting surface controlled by the parameter used in the machining process.

(c) To find out the surface modification by laser cutting process by observing the microstructure changes between the surface of cut and its parents' material.

CHAPTER 2
LITERATURE REVIEW

This chapter will discuss about the machine which will be going to be used and also the experiment which have been done before related to the machine which will be going to be used. The experiment which will be closely giving hints on how the experiment will be carried out and what is the precautions will be undertaken.

1.6 Introduction to Laser Beam Machining

Laser-beam machining (LBM) or laser cutting is a machining process using laser (light amplification by stimulated emission of radiation) as its source. This optical energy highly focuses on the surface of the workpiece, where this high-density energy source melts and evaporates portions of the workpiece in a controlled manner. Laser-beam machining does not require vacuum condition in order to operate and it is able to machine variety of metallic and non-metallic materials. In laser beam machining the physical parameters which is very important are the reflectivity and thermal conductivity of the workpiece surface and its specific heat and latent heats of melting and evaporation. The general types of laser are that has been used on metal, plastic and ceramics is shown in Table 3.1 below.

Table 2.1: Type of laser used on metal, plastic and ceramics (Kalpakjian and Schmid, 2006).

Cutting Application	Laser Type
Metals	PCO_2, $CWCO_2$, Nd: YAG, ruby
Plastics	$CWCO_2$
Ceramics	PCO_2

Laser Beam Machining is a non-traditional machining process where the way it removes material is by melting or known as thermally modifies a material by focusing a coherent beam of monochromatic light on the workpiece. The process carry out does not involve mass material removal but in a very rapid material removal in an easily controlled, non-contact, non-wearing tool. LBM can used in variety of metal processing function such as drilling, welding, marking and heat treating. How effective of the laser machining is depends on the reflectivity, absorption coefficient, thermal conductivity, specific heat and heat of vaporization of the workpiece. (ASM Volume 16 Machining)

2.1.1 CO_2 Laser Cutting

CO_2 laser cutting is a cutting process using light 10.6 um (far infrared range) wavelength, where this source of energy beam is transmitted and focused on the surface of the material being cut by a lens. The focused laser beam heats the surface and melting of a capillary is form throughout the depth of the material. The size of the capillary is usually larger than the focused laser beam diameter. Gas assisting CO_2 laser cutting will enable molten material is ejected from the base of the capillary by a jet of gas coaxial with the laser beam. Depending on what type of material being cut, some can be cut easily with CO_2 gas assisting. The cut is generated by the movement of the focused laser beam across the surface of the material which is place stationary or vice versa. There are also some laser cutting machine will have both laser beam and workpiece move together to have a better complex linear cut or two dimensional parts can be produced. CO_2 laser beam energy is transmitted guided by mirrors. The cut material will be expelled using gas jet. The distance between nozzle and material surface will be approximately 0.2" $\pm$ 0.004". The laser source usually located inside the machine and the workpiece table sizes will be in the range of 8ft x 4ft to 20ft x 6.5ft. The laser machine output power will be in the range of 1500 to 2600 Watts.

The CO_2 laser will available in 2 designs, one is the axial-flow laser and another one is the transverse-flow or gas transport laser. The axial-flow type will have fast and

slow flow where the fast axial-flow will achieve 600 W/m (180 W/ft) of tube length and have an average power up to 5000 W. Whereas the slow axial-flow laser will be limited to 100 W/m (30 W/ft) of tube length and have less than 1500 W of output power. Axial-flow CO_2 laser can operate in either CW or pulsed mode. Pulse frequencies in the range of 1 to 10 000 pulses per second. The transverse-flow laser on have CW mode even its beam can be modulated with a beam chopper. Transverse-flow laser is used when compact medium-power lasers are needed or high powers are required where the average output power range around 2500 to 15 000 W.

CO_2 laser is used in several types of application not just in cutting but also used in drilling, engraving, ablation, structuring and welding. Nearly everything can be cut by laser cutting process which includes all types of metal except for high reflective index metal, all plastics, glass and wood. Material thickness in which laser cutting will be optimized will be around 0.12" to 0.4" depends of what type of material. Laser cutting is commonly used in cutting flat sheet steel of medium thickness for sheet metal processing. Minimum slit size will be around 0.006" depending on the cutting speed. In every laser cutting the surface finish will show a striated structure. Burring will occur on the cut surface and there will be structural changing, deformation and tempering after laser cutting. There is also a weakness when laser cutting thin workpiece where the gas pressure will cause the distance between the workpiece and the nozzle hard to maintain. (ASM Volume 16 Machining)

In every machining operation there is safety consideration while handling it. In laser cutting, safety glasses are not necessary required as there will guard shield install in the machine as well. CO_2 laser are class 4 laser therefore during the machining process the machine is built to prevent human access to the laser beams during machining. The laser might cause serious burns to human tissue and permanent damage to the eyes. Air pollution might happens when machining involve with plastics and some alloys material which produce toxic gases. Therefore proper air ventilation is required where it could be air suction ducting install at the top of the machine. In terms of noise pollution in laser cutting will be in the safe level as there the noise level produce is very low. After machining process cleaning of laser

machine sometimes will not be necessary as the waste produce mainly in the form of dust therefore vacuum or filtering will be use to clean up the machine.

Laser technology is still a very young technology and it has not reached the age of 40 years. Laser is regarded as a device for producing finely controllable energy beam which in contact with the material or the workpiece, generates considerable heat. The laser beam enables tool-free machining where this light absorbed by the workpiece and transform into thermal energy. Laser beam has a lot of usage and becoming one of the important tools for cutting, welding or heat treatment. Laser cutting is normally used in thin sheet cutting especially to use on mild steel sheet metal. Laser cutting is very well known in cutting steel sheet material and have been apply widely in the industrial lasers. Laser cutting is being described as thermal, noncontact, mechanized process capable of cutting most materials with a high degree of precision and accuracy. In laser cutting, the area where to be melted or vaporized is very small and very well defined therefore only the surface of the material is affected by the heating, melting and evaporation.

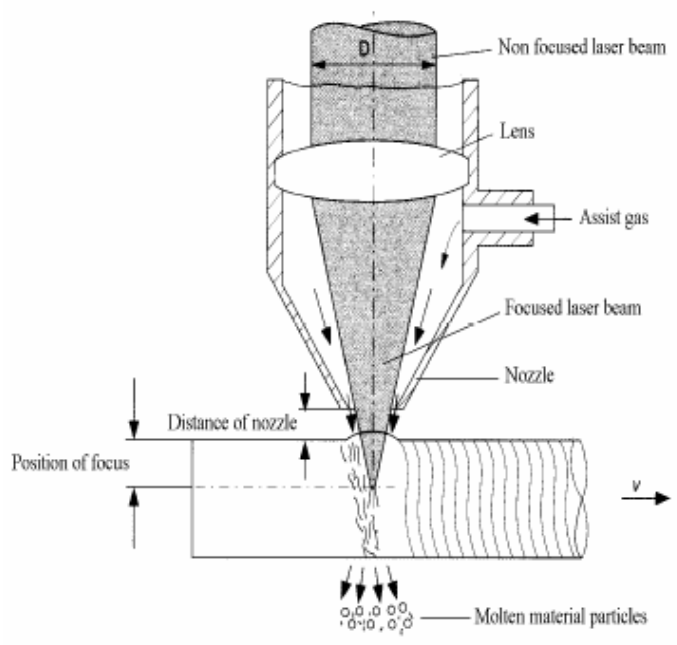

Figure 2.1: Gas assists in laser cutting (Radovanic and Dasic, 2006)

The important physical parameters in LBM are the reflectivity and thermal conductivity of the workpiece surface and its specific heat and latent heats of melting and evaporation. The lower value of the physical parameters, contributes more