PRELIMINARY INVESTIGATION OF LASER JOINING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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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 (Process Manufacturing) (Hons.)

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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 (Process Manufacturing) with honor. The member of the supervisory is as follow:

………………………………

(PM IR. DR. SIVARAO SUBRAMONIAN)

ABSTRAK

Kini, kimpalan laser adalah satu proses yang digunakan dalam industri. Proses ini adalah salah satu teknologi yang canggih yang sangat diperlukan dalam industri kerana pemprosesan masa yang singkat dan mata alat yang tidak bersentuhan dengan bahan kerja. Tetapi, kelemahan proses ini memerlukan kos yang tinggi untuk penyediaan mesin kimpalan laser yang baru. *Hybridizing* adalah jalan penyelesaian yang mana laser mesin pemotong digunakan untuk melakukan proses kimpalan. *Hybridization* adalah di mana dua set proses yang berbeza dilaksanakan di dalam satu mesin yang sama. Kajian ini adalah untuk menyiasat potensi *hybridizing* kimpalan laser CO2 ke mesin pemotong laser. Dari proses hybridizing, ia menyediakan penyelesaian ekonomi dalam pemprosesan bahan. Siasatan dibuat untuk mencari parameter proses yang optimum seperti kuasa laser, kelajuan perjalanan, kekerapan. Kemudian, Rekabentuk Eksperimen (D.O.E) analisis adalah berstruktur dan daripada proses eksperimen, keputusan diperoleh. Keputusan menunjukkani kebolehkimpalan yang cemerlang dalam menyambungkan keluli lembut ss400 dengan ketebalan 2.6mm.

ABSTRACT

Nowadays, laser welding is a process that been used in the industry. This process is one of the advance technologies that really need in the industry because of the short time processing and non-contact tool with the workpiece. But, the disadvantage of this process is required high cost in order to setup a new laser welding machine. Hybridizing is a solution whereby laser cutting machine is used in order to do the laser welding process. Hybridization is the process by which two different sets of process are bred together in one machine. This study is to investigate the potential of hybridizing laser welding onto CO_2 laser cutting machine. From the hybridizing process, it provides the economical solution in material processing. Investigation is made in order to find the optimized process parameters that are laser power, travel speed, frequency. Then, Design of Experiment (D.O.E) analysis is structured and result is obtained from the experimental process. The results give an excellent weldability in joining mild steel ss400 with the thickness of 2.6mm

DEDICATION

To my beloved family.

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%	-	percent
&	-	and
”	-	inch
<	-	less than
>	-	more than
±	-	plus minus
≈	-	almost equal to
®	-	Right
3D	-	three dimensional
A	-	Absorption
angstroms	-	measure of length, 1 angstrom= $10E^{-10}m$
ANOVA	-	Analysis Of Variance
ANSI	-	American National Standard Institute
cm	-	centimetre
CO_2	-	Carbon Dioxide Gas
CVL	-	Copper Vapour
Cw	-	clock wise
CW	-	Continuous Wave
D	-	Diameter
D.O.E	-	Design of Experiment
DC	-	Duty Cycle
DIN	-	Deutsche Industry Norm
E	-	Energy per Pulse
e.g.	-	example
EB	-	Electron Beam
EDM	-	Electro Discharge Machining

etc.	-	Exedra/ and others
F	-	Frequency
F.D.	-	Focal Distance
FKP	-	Faculty of Manufacturing Engineering *(Fakulti Kejuruteraan Pembuatan)*
GP	-	Gated Pulse
H_2	-	Hydrogen Gas
HAZ	-	Heat Affected Zone
He	-	Helium Gas
Hz	-	Hertz
in.	-	inch
IPTA	-	The Public Institution of Higher Learning *(Institut Pengajian Tinggi Awam)*
ISO	-	International Organization for Standardization
J	-	Joule
K	-	Kelvin
k	-	kilo
kg	-	Kilogram
L	-	Length
LASER	-	Light Amplification by Stimulated Emission of Radiation
m	-	meter
mA	-	mili Ampere
MB	-	Mega Byte
Mil	-	1 mil = 0.254 mm
mJ	-	mili Joule
mm	-	millimetre
MPa		Mega Pascal
N		Nominal value
N_2	-	Nitrogen Gas
NC	-	Numerical Control
Nd:YAG	-	Neodymium Yttrium Aluminium Garnet

Nm	-	Nanometer
No/Num	-	Number
^{o}	-	Degree
ø	-	Diameter
O_2	-	Oxygen Gas
p	-	Pressure
P	-	Power
Pa	-	average power
P_p	-	peak power
ps	-	Pico second
PSM	-	Bachelors Degree Project *(Projek Sarjana Muda)*
R	-	Radius
R	-	Reflectivity
RF	-	radio-frequency
s	-	Seconds
SOD	-	Stand Off Distance
STD.		Standard
T	-	Transmissivity
t	-	Thickness
TEA	-	Transversely Excited Atmosphere Pressure
UTeM	-	Malaysia Melaka Technical University *(Universiti Teknikal Malaysia Melaka)*
UV	-	Ultraviolet
V	-	Volt
W	-	Watt
WJ	-	Water jet
λ	-	Wave length symbol
µm	-	micrometer
Σ	-	Total
τ	-	Pulse width symbol

CHAPTER 1
INTRODUCTION

1.1 Project Background

In this new era, in order to cut almost any material easily, laser machining is widely known and most suitable for this kind of job. In a controlled manner, the highly focused, high-density energy source and high-pressure gas are used to melt and evaporate portions of the work piece. One of the lasers machining process which is laser cutting could be referred as a material removal process accomplished by laser material interaction. Laser is also being used in processing such as welding besides machining that it being commonly used. Laser welding is a non-contact process and involves localized heat treating of materials to modify the surface mechanical and and tribological properties (Kalpakjian and Schmid, 2010).

The main goal of this study is to optimize the usage of the existing laser cutting machine due to high investment cost needed to setup a laser machine. Laser welding process will not be performed by laser welding machine in this study, but will be performed by using laser cutting machine. The controllable process parameters are quite same for any process in laser processing. The identifying process in order to find the most suitable parameters to be applied in laser welding process is the challenging part in conducting this study. The capability of laser cutting machine to do laser welding just by varying some of process parameters will be determined by this preliminary investigation. This experimentation work use a laser cutting machine with rated power 3kW and carbon dioxide, CO_2 laser beam.

Visual inspection and destructive tests are used to evaluate the weldment. The ability to weld the materials is expected to have from the laser cutting machine and at least pass the minimum quality produced by laser welding machine.

1.2 Problem Statement

Hybrid machine is a machine that might give human more advantage compared to traditional machine. For example may reduce time constraint and economical purpose. High capital cost is required in order to setup a new laser machine because any machine that involves laser is generally very expensive. There is a high possibility that a laser cutting machine can do welding without changing any part of the machine. However, several of the welding parameters may affect the laser cutting machine. In order to identify which controllable process parameters that have big impact in laser processing of metals, preliminary investigation is needed and the values are set within the range of experimental values in order to observe the weldability of laser cutting machine..

1.3 Objectives

The main objectives of this preliminary investigation are as followed:

i. To study the weldability of metal by using laser cutting machine.
ii. To analyse the quality and performance of the weldment.

1.4 Scope of Project

The main target of this project is to identify the best controllable process parameters that have big impact in laser processing. A set of process variables is developed and recommended in order to produce a high quality of weldment. There are three chosen parameters which are laser power, travel speed, and frequency that are varied within the range of experiment while other controllable parameters are fixed. Helius 2513 hybrid series is the model of laser cutting machine to perform welding process and was made in Belgium. Nitrogen that work as laser assisted gas and carbon dioxide (CO_2) laser beam with rated power of 3kW are equipped in the laser machine. The experimental on research work is conducted by butt welding on mild steel ss400 material. Non-destructive and destructive test are being used to examine the weldment.

1.5 Laser

Lasers are used as cutting tools due to high precision of operation and desirable end product quality. In laser cutting process, an assisting gas jet is used. In the case of inert gas assisted processing, assisting gas protects the surface from high temperature oxidation reactions while high temperature exothermic reactions takes place when oxygen is used as assisting gas. In laser gas assisted processing; proper selection of laser and work piece parameters (cutting parameters) increases the laser cutting efficiency and improves the end product quality. (Yilbas, 2004)

1.5.1 Laser History

According to Silfvast and William T. (2004), Charles Townes took the benefit of the stimulated emission process in order to create a microwave amplifier, known as maser. The device is use in the communication which is the device produced a coherent beam of microwaves. First production of maser was produced in ammonia vapour with the inversion between two energy levels that produced gain at a wavelength of 1.25 cm. The maser produced the wavelengths that were comparable to the dimensions of the device.

Townes and Schawlow published a paper on 1958 which concerning on the ideas about extending the maser concept to optical frequencies. The concept was an optical amplifier surrounded by an optical mirror resonant cavity to allow for growth of the beam. In 1960, Theodore Maiman of Hughes Research Laboratories used ruby crystal as the amplifier and a flashlamp in order to produce the first laser. A rod-shaped ruby crystal surrounded by the helical flash lamp and coated the flattened ends of the ruby rod with highly reflecting material to form the optical cavity. When the flashlamp was fired, an intense red beam was observed to emerge from the end of the rod.

A. Javan, W. Bennett, and D. Harriott of Bell Laboratories developed the first gas laser by missing the helium and neon gases on 1961. Besides, L. F. Johnson and K. Nassau demonstrated the first neodymium laser in the same laboratories which it became one of the lasers available. Then, the first semiconductor laser was demonstrated in 1962 by R. Hall at the General Electric Research Laboratories while one of the most efficient and powerful lasers available today which is the infrared carbon dioxide laser is discovered by C. K. N. Patel of Bell Laboratories in 1963. In the same years, E. Bell of Spectra Physics found 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 ResearchLaboratories developed the first liquid laser by using an organic dye, which was dissolved in a solvent, thereby leading to the category of broadly tunable lasers.,W. Walter and co-workers at TRG reported the first copper vapor laser at 1966 too (Silfvast and William T. 2004).

In 1970, R. Hodgson of IBM reported that the first vacuum ultraviolet laser occured in independent molecular hydrogen by R. Waynant et al. of the Naval Research Laboratories . On the other hand, J. J. Ewing and C. Brau of the Avco–Everett Research Laboratory discovered the first of the well-known rare gas which was halide excimer lasers found in xenon fluoride in 1975.In that same year, J. van der Ziel and co-workers at Bell Laboratories, made the first quantum well laser gallium in aarsenide semiconductor.

In 1976, the first free-electron laser amplifier operating in the infrared at the CO2 laser wavelength demonstrated by J. M. J. Madey and co-workers at Stanford University. Then, Walling and co-workers at Allied Chemical Corporation obtained broadly tunable laser output, in 1979, from a solid-state laser material called alexandrite. Besides, D. Matthews and a large number of co-workers at the Lawrence Livermore Laboratories were successfully demonstrated the first soft–X-ray laser in a highly ionized selenium plasma in 1985. While in 1986, the titanium sapphire laser was discovered by P. Moulton. The first blue-green diode laser in ZnSe was developed by M. Hasse and co-workers in 1991. Then, In 1994, the quantum cascade laser was developed by F. Capasso and co-workers. S. Nakamura developed the first blue diode laser in GaN-based materials in the year of 1996.

1.5.2 Types of Laser

In the industrial of cutting, welding, and other material processing application, there are two types of laser that have been used. First, the 1.06 µm wavelength Nd:YAG laser, which uses the neodymium (Nd) ion as the active element. The second type of laser is the 10.6 µm wavelength CO2 laser, which uses the CO2 molecule as the active element. For the excitation, some equipment might be used, for example, electrically pumped, pulsed and continuous wave gas lasers which use alternating current (ac), direct current (dc), or radio frequency (rf). Carbon dioxide (CO2) lasers with beam power outputs of up to 12 kW also are in general use. Laser that have power till 45kW is still in used for the industrial material processing task even though it is no longer production. These lasers are capable to make single pass weld with complete joint steel with the thickness of 16mm maximum. Besides, it is also capable in cutting the material with the thickness 25mm. The laser beam is directed to the workpiece by flat optical elements, such as mirrors, and then focusedonto a small spot, which creates high power density at the weld joint or cut location using either reflective focusing elements or lenses. Although the bulk laser power is important, it is predominantly the beam power density, or the amount of power per unit area.

1.5.2.1 Carbon dioxide Laser

Nowadays, the most popular gas laser for material processing is the CO_2 laser. The C02 is mixed with the N_2 while the He is in the different amount for the lasing medium. However, it depends on the design of laser resonator, operating pressure, and the operating mode either it is pulsed or continuous. Electric discharge excites the CO_2 molecules through the gas mixture. The wavelength that IS emitted by the laser radiation is 10.6 µm. Normally, the range of conversion efficiencies is between 12 to 14%. For a long time, CO_2lasers have been the highest CW power sources available for laser materials processing (Olsen and FlemmingOve , 2009). For the current commercial systems, the maximum power output is 20 Kw. One of the disadvantages of CO_2 lasers is associated with the long wavelength of the emitted radiation. It causes most of the transparent material within the visible range of electromagnetic spectrum such as glass is opaque for CO_2 laser radiation. Thus, the laser resonator need the transmission elements and manufactured the beam guidance from special and expensive material such as Zink Selenide. Then, the beam deflection and focusing must be realised by means of reflective optics. For example, multilayer coated copper substrates. Another effect of the long wavelength is the high reflectivity of metals, which is normally used in materials processing and the radiation interaction with laser-induced plasma is increased.

1.5.2.2 Nd:YAG Laser

According to Olsen and Flemming Ove (2009), The Nd:YAG laser is still the most prevalent solid-state laser in used. A Nd-doped YAG crystal serves as lasing medium with an emitted wavelength of 1.06 µm. The excitation energy is optically provided by high intensity electric-discharge lamps or laser diodes. Compared to gas laser, the rod-shaped Nd:YAG laser crystal is optically active and decreased the output beam quality while the power output is increased. So, the Nd:Yag beam quality is lower than CO_2 laser beam quality. However, the laser may achieve similar focus spot sizes since it has shorter wavelength. 6 kW is the maximum CW output power of