PERFORMANCE EVALUATION OF NITROGEN GAS-ASSISTED LASER CUTTING ON 316L AUSTENITIC STAINLESS STEEL PLATE

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First of all, all the praises and thanks to Allah S.W.T for His Love,
This thesis is dedicated to my family

To my beloved wife and son Khariah Bt Othman and Muhammad Hasif Bin Shahrizal

To my beloved parent, Aishah Bt Abd Malek, Abd Halim Bin Abd Rahim and Shahliza Bt Abd Halim

Thank you very much for your support and encouragement May Allah bless all people that I love and it's my honour to share this happiness with my love ones.

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ABSTRACT

Austenitic stainless steel in particular 316L has played an important role in the history of medicine for centuries. It is the most widely used material for medical devices, implants and controlled drug delivery systems. Stainless steels are popular class of engineered material because of its strength, corrosion resistance and oxidation resistance at temperatures up to 550^{o}C. Austenitic stainless steels are typical difficult to machine by the traditional methods and also non-traditional method. Laser cutting which is very prominent amongst the non-conventional machining methods is expected to be used quite extensively in cutting austenitic stainless steel due to the favourable features and advantages that it can offer. This project was undertaken to evaluate the cutting performance of laser cutting on austenitic stainless steel. The effects of cutting parameters such as laser power, cutting speed and gas pressure on the machining responses such as kerf width (KeW), surface roughness (SR) and striation width (SW) were investigated. The experimental plans were conducted according to the design of experimental (DOE) and analysis of variance (ANOVA) was employed in evaluating the experimental data. Subsequently mathematical models for KeW, SR and SW were established. Results showed that laser power and cutting speed were significant in influencing the cutting responses during laser cutting of austenitic stainless steel 316L.

ABSTRAK

Keluli tahan karat austenite, lebih terperinci 316L telah memainkan peranan yang penting dalam sejarah perubatan berabad yang lalu. Ia adalah bahan yang digunakan secara meluas untuk alatan perubatan, implan dan sistem pemberian ubat terkawal. Keluli tahan karat adalah bahan kejuruteraan yang popular dalam klasnya kerana kekuatan, tahan karat dan tahan pengoksidaan pada suhu 550 ^{o}C. Keluli tahan karat austenit adalah sukar untuk dimesin dengan kaedah tradisional dan juga kaedah bukan tradisional. Pemotongan laser adalah di antara kaedah pemesinan bukan tradisional yang terkemuka dijangka akan digunakan dengan meluas untuk pemotongan keluli tahan karat austenit disebabkan oleh ciri-ciri terpilih dan kelebihan yang boleh ditawarkan. Projek ini telah dijalankan untuk menilai prestasi pemotongan laser ke atas keluli tahan karat austenit. Tindakbalas apabila parameter pemotongan seperti kuasa laser, halaju pemotongan dan tekanan gas ke atas hasil pemotongan seperti jarak kerf (KeW), kekasaran permukaan (SR) dan jarak jaluran (SW) telah disiasat. Plan experimen telah dijalankan secara statistic dan analisa variasi (ANOVA) telah digunakan untuk menilai data experiment. Seterusnya model matematik untuk KeW, SR dan SW telah diperolehi. Keputusan menunjukkan kuasa laser dan halaju pemotongan adalah parameter mempengaruhi tindakbalas pemotongan untuk pemotongan laser ke atas keluli tahan karat austenit 316L.

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LIST OF SYMBOLS

ANOVA	-	Analysis of variance
CI	-	Confidence Interval
CO_2	-	Carbon dioxide
DOE	-	Design Of Experiment
HAZ	-	Heat affective zone
He	-	Helium
KeW	-	Kerf Width
MRR	-	Material Removal Rate
N_2	-	Nitrogen
SR	-	Surface Roughness
SW	-	Striation Width

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CHAPTER 1

INTRODUCTION

1.1 Overview

For centuries metals have played an important role in the history of engineering and medicine. The first stainless implant in modern medicine was dated back in 1926 by E.W. Haey Groves that used 18-8 (austenitic 304) stainless screws in fixation of femoral neck fracture. Following this achievement, several advances have been made in the use of stainless steel devices and implant in the human body. Nowadays biomaterials are becoming important as they are used to replace a part or a function of the body in a safe, reliable, economic and physiologically acceptable manner. Concurrent with this progress the demand for improved materials are increasing rapidly.

Stainless steels are popular class of engineered materials known for their strength, corrosion resistance and oxidation resistance at temperatures up to 550^{o}C. Stainless steels are the most widely used material for medical devices, implants and controlled drug delivery systems. The most widely used stainless steel in medical applications today is austenitic stainless steels type 316 (Y.V. Murty 2003).

Austenitic stainless steels material are typical difficult to machine by the traditional methods (T. Akasaw *et al.* 2003). Poor surface finish and short tool life are common problem in machining of these materials that leads to high manufacturing cost. Since the cost of using conventional machining is generally prohibitive, non-conventional machining such as laser machining probably amongst the ideal technique in dealing with these materials because of its flexibility, rapid material removal and ability to produced intricate shape.

Laser cutting has proved its capability especially in cutting difficult to cut material such as austenitic stainless steels probably because of its high strength, low thermal conductivity, high ductility and high work hardening tendency (Ihsan Korkut *et al.* 2003). Although laser cutting technology is widely used in the manufacturing of mechanical components, its optimum cutting conditions in producing high quality product is still under investigation by many researchers.

1.2 Back ground of research

Laser cutting is a non-traditional process that is used in a two-dimensional machining process in which material removal is obtained by focusing a highly intense laser beam on the workpiece. The heat of the laser beam subsequently melts/vaporizes the workpiece throughout the thickness or depth of the material thus creating a metal cutting process. It is a noncontact process, whereby the workpiece doesn't need to be clamped or cantered on precise fixtures as in conventional machining. Accurate positioning of the workpiece on the X–Y table with defined direction of cut can be easily obtained during laser cutting thus facilitating machining of flimsy and flexible materials such as thin sheet metal. Demand for this process is increasing because of its ability to produce geometrical complex shapes as well as its ability to cut hard materials that are extremely difficult to machine when using conventional process.

Previous study (Shang-Liang Chen 1997) shows that oxygen cutting is still the best, although argon and nitrogen may be used instead for the cutting of 3 mm thick mild steel plate with high-pressure assistant-gas flow on high-power CO_2 laser . In the previous study, mild steel is the most used material being investigated for the optimum cutting conditions during laser cutting process. K. Abdel Ghany and M. Newishy (2005) reported that the laser cutting quality depends mainly on the laser power, pulse frequency, cutting speed and focus position when cutting 1.2 mm stainless steel sheet using pulsed and CW Nd:YAG laser.

It was found that research study on the effect of cutting conditions on a 3 mm austenitic stainless steels (316) sheet using CO_2 laser cutting was not reported so far. New machining data on laser cutting of austenitic stainless steels (316) sheet served a great significance and could be further exploited especially for continuous cutting condition. This project is undertaken to study the effect of cutting parameters such as laser power, cutting speed and gas pressure on surface roughness, striation and kerf width.

1.3 Research Statement

Laser cutting of austenitic stainless steel 316L with changes of significant cutting parameters will lead to improvement in cutting responses such as surface roughness, size of striation and kerf width.

1.4 Problem Statement

Some of the issues that are encountered by laser cutting users are as follows:

a) Challenging task in setting up the initial laser cutting parameters for material that are not listed in the default database/library of the laser cutting machine.
b) Extensive laser trial and error in order to obtain good cutting conditions and this can be very wasteful with respect to time and material, subsequently increasing production cost.
c) Laser cutting process parameter are interrelated, the right combination of optimum process parameters are desired to produce good quality characteristics.

1.5 Objective

The main objectives of this study are:

a) To investigate the effect of laser cutting parameters on the cutting responses such as kerf width (KeW), surface roughness (SR) and striation width (SW) when laser cutting 316L austenitic stainless steel.
b) To establish mathematical model for the cutting responses using DOE approach.

1.6 Scope of study

The scope of the study includes the following:

a) TC L2530 Plus TRUMPF CNC (CO_2) laser cutting center at Kolej Kemahiran Tinggi MARA (KKTM) Balik Pulau was used to conduct the experimental works.
b) The work piece was 316L austenitic stainless steel with 3 mm thickness.
c) Process parameters were cutting speed, laser power output, gas assisted pressure and focal length.
d) Cutting responses are surface roughness (SR), striation width (SW) and kerf width (KeW).
e) Two level full factorial experimental plan was employed to reduce the number of experiment.
f) ANOVA was used to identify the significant contribution of laser cutting parameters against the response variables.