OPTIMIZATION PARAMETERS OF PLASMA ARC CUTTING FOR 1100 ALUMINUM ALLOY BY USING TAGUCHI METHOD

by

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LIST OF EQUATION

(1) MRR=WRW/T [g/min]

(2) MRR=WRV/T [mm^3/min]

(3) MSD= $\frac{\left(\frac{1}{y1}\right)^2+\left(\frac{1}{y2}\right)^2+\cdots+\left(\frac{1}{yn}\right)^2}{n}$ MSD for QB = higher is better)

(4) MSD = $\frac{(y1)^2+(y2)^2+\cdots+(yn)^2}{n}$ MSD for QC = (smaller is better)

(5) MSD = $\frac{(y1-y0)^2+(y2-y0)^2+\cdots+(yn-y0)^2}{n}$ MSD for QN = (Normal is better)

(6) S/N = -10 $\log_{10}$ MSD

LIST OF SYMBOL

PAC	Plasma Arc Cutting
DOE	Design of Experiment
WRW	Work Piece Removal Weight
WRV	Work Piece Removal Volume
T	Cutting Time
AC	Alternative Current
DC	Direct Current
ρ	Work Piece Density
R_a	Surface Roughness
MRR	Material Removal Rate
ANOVA	Analysis of Variance
MSD	Mean Standard Deviation
CF	Correction Factor
S/N	Signal to Noise Ratio
S_A	Sum of Square of Factor A

P_A	Percentage Deviation of Factor A
S_B	Sum of Square of Factor B
P_B	Percentage Deviation of Factor B
S_C	Sum of Square of Factor C
P_C	Percentage Deviation of Factor C
S_T	Sum of all Observation
ΣY_i^2	Sum of Square Deviation
QC	Quality Characteristic
OA	Orthogonal Array

PengoptimumanParameter PemotonganArka PlasmaUntuk1100Aloi Aluminium Dengan MenggunakanKaedahTaguchi

ABSTRAK (BM)

Syarikat pembuatan menentukan improvment proses mengeluarkan haba berdasarkan dimensi dan penampilan fizikal permukaan bahan pemotongan. Kekasaran permukaan kawasan pemotongan bagi bahan dan kadar pembuangan bahan yang dikeluarkan semasa manual plasma arka proses pemotongan yang telah dianggap penting. Plasma mesin pemotong arka model PS-100 telah digunakan untuk memotong aloi aluminium 1100 secara manual berdasarkan penetapan parameter yang dipilih. Dua ketebalan yang berbeza spesimen dengan 3 mm dan 6 mm telah digunakan. Kadar pembuangan bahan (MRR) diukur dengan menentukan berat spesimen sebelum dan selepas proses pemotongan. Analisis kekasaran permukaan (R_a) yang diukur oleh MITUTOYO peranti CS-3100. Kaedah Taguchi telah digunakan sebagai susun atur percubaan untuk mendapatkan MRR dan Ra nilai. Dengan lager keadaan yang lebih baik Signal kepada Nisbah Bunyi nisbah (S/N), sumbangan peratusan kadar pembuangan bahan di 3 mm maksimum 69,55% dan nilai minimum 4.08%. Walaupun, sumbangan Pembuangan Kadar Bahan di 6 mm adalah maksimum 80.2% untuk mendapatkan dan minimum 11.8%. Walau bagaimanapun, dengan keadaan yang lebih kecil lebih baik daripada nisbah S / N, peratus sumbangannya kekasaran permukaan untuk 3 mm adalah maksimum 23.4%, dan minimum 11.0%, manakala, sumbangan peratusan kekasaran permukaan selama 6 mm adalah maksimum 56.6%, dan minimum 7.6%. Keputusan menunjukkan bahawa kelajuan semasa dan pemotongan adalah parameter yang paling penting, diikuti dengan jurang arka untuk kedua-dua kadar pembuangan bahan dan kekasaran permukaan.

Optimization Parameters of Plasma Arc Cutting for 1100 Aluminum Alloy By Using Taguchi Method

ABSTRACT

Manufacturing companies define the qualities of thermal removing process based on the dimension and physical appearance of the cutting material surface. The surface roughness of the cutting area for the material and the material removal rate being removed during the manual plasma arc cutting process were importantly considered. Plasma arc cutter machine model PS-100 was used to cut aluminum alloy 1100 manually based on the selected parameters setting. Two different thicknesses of specimens with 3 mm and 6 mm were used. The material removal rate (MRR) was measured by determining the weight of the specimens before and after the cutting process. The surface roughness (R_a) measured by MITUTOYO CS-3100 device. Taguchi method was utilized as an experimental layout to obtain MRR and R_a values. With lager the better condition of Signal to Noise Ratio (S/N) ratio, the percentage contribution of Material Removal Rate at 3 mm maximum 69.55% and minimum 4.08% value. While, contribution of Material Removal Rate at 6 mm is maximum 80.2 % for obtaining and minimum 11.8%. However, with smaller the better condition of S/N ratio, the percentage contribution of surface roughness for 3 mm is maximum 23.4%, and minimum 11.0%, while, the percentage contribution of surface roughness for 6 mm is maximum 56.6%, and minimum 7.6%. The results indicate that the current and cutting speed is the most significant parameters, followed by the arc gap for both rate of material removal and surface roughness.

CHAPTER 1

INTRODUCTION

1.1 Overview

The thesis explains the efficiency related to plasma arc cutting with various operating parameters. The purpose of this theses to achieving the combination of those parameters.

Today, a huge number of industries are advanced in the field of plasma cutting and the usage of this technology are being permitted in these industries. The function related to plasma cutting is being considered arc cutting procedure the process of which consists of melting the metal with the heat of constricted arc at an area which is localized. The different shapes and structures that of electric arc are being considered the emergent properties related to non-linear pattern of both current and electric field. The arc which results in the area which is gas-filled among two electrodes which are being considered conductive and it causes a very high amount of temperature which can cause melting or converting anything into vapors. The plasma arc which is being considered of high temperature cuts with the help of various metals at high speed. Malaysia is said to emergently advancing in the field of advanced machining like plasma arc cutting which is currently in use of industries.

The plasma cutters have replaced with traditional cutting which is done through sawing, punching, drilling, and cutting. The plasma arc which is being considered of high temperature cuts with the help of various metals at high speed. Though, with the help of plasma arc cutting can cut materials up to 38 mm.

The use of plasma arc is wide in industry but it is still limited for its basic use. The efficiency and feasibility of plasma arc cutting usage needs approval with the help of using fractional factorial from DOE (Design of experiment)

1.2 Problem Statement

For the purpose of producing a product the cutting mechanism and process is of utmost importance. The material cutting takes a lot of time. Therefore, this study is conducted for the purpose of finding solution related to the cutting mechanism which in turn will improve the procedure. The problems statement of this theses are:

- It takes a lot of time if the cutting is done with traditional way of cutting like saw.
- What factors have impact on cutting process?
- What are the optimum conditions for the purpose of achieving optimum performance?
- The efficient way for conducting the cutting process for aluminum 1100 alloy with thickness 3 mm and 6 mm.

1.3 Motivation

This research concentrates on operating and examining the efficiency related to the process of plasma arc cutting based on various parameters. The machine used in the study is Goldcut PS-100.This machine is being considered perfect for the purpose of maintenance, fabrication or other application which require cutting of thicker aluminum of i.e. of 3 mm and 6 mm that are used in almost industry. The weight of machine PS 100 is 162.8 kg, and the "Valet style" of machine's undercarriage helps in carrying machine at job site.

The PS 100 machine can help cutting metal up to 35mm. The Goldcut PS 100 machine have Dual winding technology for fast arc transfers, excellent gouging performance and unparalleled ease of use.

Figure 1.1 shows the Goldcut PS 100 machine. Further information about this machine is discussed in part 3.3.1.

Figure 1.1: Goldcut PS 100 machine

Optimization related to process parameter is being considered the major step in Taguchi method for the purpose of achieving high quality with no rising cost of both time and money. The reason is that optimization of process parameter can help enhancing the features of quality and the optimum process parameters which are gained from Taguchi method are being considered insensitive to the changes occurring in environmental conditions and other factors creating noise. The classical process parameter design is being considered complex and difficult to use particularly when various experiments have to be done with the increase in the number related to process parameter. A special design is used by Taguchi method which is of orthogonal arrays for the purpose of studying the whole space of process parameter with a few experiments (Roy, 2001).

Three categories are being considered related to characteristics of quality while doing the analysis related to S/N ratio i.e. the smaller is better, bigger is better, and nominal is the best. The computation of S/N ratio related every level of process parameter is done with the help of S/N analysis. Without having any concern with categories or the characteristics of quality, a huge number of S/N ratios correspond to quality characteristics which are being considered better.

Moreover, ANOVA a statistical analysis of variance is used to see which process parameters are statistically significant and to find the optimum levels of factors. The combination which will be in optimal combination related to process parameters can be predicted. At last, a confirmation experiment is practiced for the purpose of verification of optimal process parameters which is obtained from design of process parameters (Juang, 2000).

1.4 Objectives

The purpose of this project is to conduct a study related to parameters of plasma arc cutting with the help of advanced materials. The project related key objectives are:

1- To design and perform experiments based on level 9 Taguchi orthogonal array combination on Arc gap, cutting speed and current.

2- To examine and evaluate influence of each parameter on aluminum alloy using plasma arc cutting.

3- To identify significant level for each parameter for the purpose of achieving optimum performance measure.

1.5 Scope

The project is to be developed within the scopes mentioned below:

- This study was conducted at welding laboratory in ILP (Institute Latihan Perindustrain Kangar).
- Taguchi method DOE (design of experiment) layout are used for the purpose of testing and analysis.
- The Goldcut PS 100 machine are used with straight polarity for the purpose of machining operation.
- This study focuses on aluminum 1100 alloy with two thicknesses i.e. 3 mm and 6 mm. For the purpose of this study the scope in the plasma arc cutting operation is the

parameters named as current, Cutting Speed, arc distance, material removal rate and surface roughness.

1.6 Thesis Outlines

Chapter 1: Introduction

This chapter explains about problem introduction, objectives of the study, scopes, methodology of the study, and findings.

Chapter 2: Literature Review

Literature review on plasma arc cutting fundamental, system, material used (Aluminum 1100 alloy), and DOE (design of experiment).

Chapter 3: Methodology of Study

The project methodology consists of the flow chart for how the experiment is conducted. Also, the material and machine used in the study is briefly elaborated.

Chapter 4: Results and Discussions

This chapter explains the results of the study obtained from experiments with the help of Taguchi method DOE (design of experiments).

Chapter 5: Conclusion

In this chapter the project's value and further recommendation for the same projects which are to be developed in future are determined. Finally the conclusion related to the whole field of study in experiments is made which is based on the study's objective.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

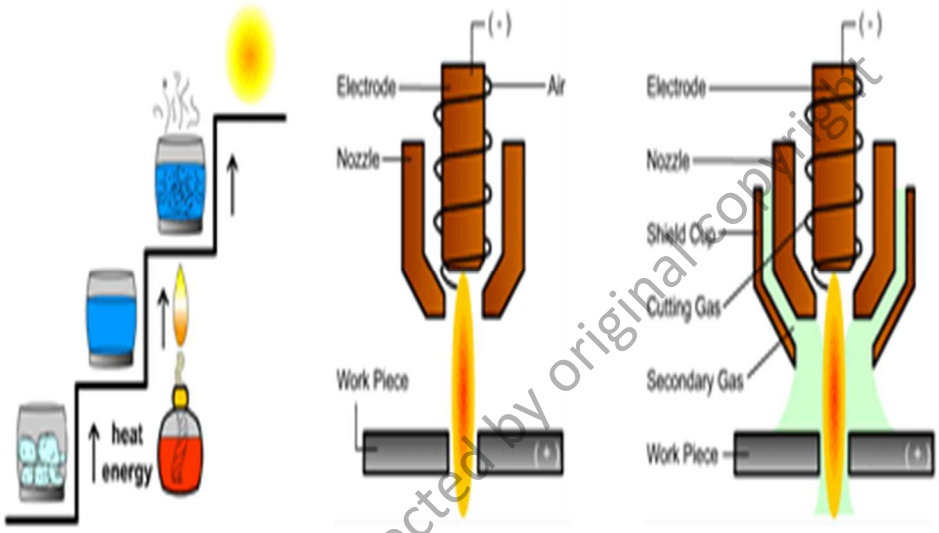
The plasma for arc cutting is being considered the method adopted for cutting aluminum or metals or sometime other materials. The process of plasma arc system, inert gas i.e. inert gas such as argon is blown with tremendous acceleration through the nozzle and simultaneously an electric arc is made with the help of that argon from the nozzle to cut surface which convert some part of the gas into plasma. At high temperature for the purpose of melting the cut metal, and fast movement of plasma helps the blowing metal away from the cut. Plasma is useful in plasma arc welding.

Recently, industry has more attention towards the process of plasma arc cutting. The plasma devices do provide cutting of better quality as it uses finer nozzles and oxygen as cutting gas which meet the requirement of industry's cost and precision (Fernicola, 1994).

The process of plasma arc cutting is mostly like laser cutting and since plasma cutting is using other gasses and oxygen cutting; which makes it more cost effective. Moreover, the process of plasma arc cutting allows the cutting of many more inert metals (Fernicola, 1994; and Vignardet, 1994). If the processes of thermal cutting are discussed, the process of plasma arc cutting is being considered one of the most diffused procedures because of providing more productivity, high flexibility at reasonable costs.

With the emergence of plasma arc cutting, various refinement processes, developments, and improvement in equipment's was made. The process of plasma arc cutting can increase the efficiency and speed of both sheet and plate metal cutting operation.

The approval in both hand held and auto systems is gained by PAC (plasma arc cutting). The offer made to manufacturers by advancement in CNC (computer numerical controls), robots, and other automation techniques of higher cutting speed gained with the help of plasma arc cutting process. The enhanced torch design and more effective power supplies helped in popularity of plasma arc cutting.



(a) (b) (c)

Figure 2.1: Plasma State

One well known definition of plasma is considering it the fourth state of matter after solid, liquid, and gas. The difference related to these three states is based on the level of energy difference. When energy in the form of heat is added to ice it starts melting as shown in (Figure 2.1) (a). With the increasing energy the water is then changed into vapors, hydrogen, and oxygen, in the shape of steam. The gases then become ionized if more energy in the form of heat is added.

Plasma arc cutting is being considered the process of arc cutting which serves metal with the help of melting the specific parties taken for cutting using electric arc which helps in

removing the dissolve part of materials with high cutting capability of hot ionized gas blowing from the normal cutting process as shown in (Figure 2.1) (b).

Plasma arc cutting is being considered the process of cutting metal with high temperature, high speed stream which consist of ionized gases for the purpose of melting and blowing metal from the line of cut. PAC is being considered the process of melting where a jet consisting of ionized gas with a temperature of 30000 C^o is used for the purpose of melting and blowing out the material from the cut. In the process of PAC and electric arc is used between electrode and the work piece. The electrode is then recessed in gas which is cooled with water or air which constrict the arc and causes the formation of narrow, high velocity, and high temperature jet. When the jet hit the work piece and the gas reverts to its normal states which cause emission of heat. This heat emission helps in melting the metal and the blowing gas eject it from the cut as shown in (Figure 2.1) (c) (Ilii, S. M., 2010).

In the process of arc cutting other gases is used as the cutting gas, while in plasma cutting oxygen, argon, and air are used as protection and cutting gas. A chemical reaction occurs among these gases caused from supplied energy and the burning gases blow out through nozzle whole (Geough, 1998). While cutting a high temperature occurs and the material which melts is then removed from cutting area with the help of blowing gases. In accordance to surveys, manufacturing industries considers dimension and physical appearance of utmost importance after industrial application of this procedure. Therefore, the study aims to find out the micro structure changes in the parts cut with the help of plasma arc and the variation of original hardness of the part (Ilii, S. M., 2010).

The speed and effectiveness can be increased with the help of plasma arc cutting of both sheet and plate metal cutting operations. A two cycle approach is use by torch for the purpose of producing plasma. First, a high voltage low current is used for the purpose of initializing a

small pocket of plasma gas, the new conductive plasma struck the work piece i.e. anode. The circuit is completed by plasma between electrode and anode (work piece) and now the low voltage high current conducts. If the plasma uses high voltage starting circuit, is usually turned off for the purpose of avoiding excessive consumable wear. The plasma maintained between electrode and work-piece travels at a speed of 15,000km/h (over twelve times the speed of sound of the ambient air = 1225.044 km/h). Previously, plasma was only working on materials being considered conductive, however, the technological advancement allows the plasma ignition arc to be enclosed inside the nozzles, and the cutter is used for work-pieces which are non-conductive. A very hot and much localized "cone" is produced by plasma cutter for cutting. Due to this, they are extremely useful for cutting sheet metal in curved or angel shape. Figure 2.2 show the usages of plasma are cutting.

Figure 2.2: Plasma Arcs Cutting in Industry

2.2 Aluminum

Aluminum is being considered soft, light weight, malleable and durable metal with many appearances ranging from silver to dull grey, which depend on the roughness of the surface. Aluminum is being considered non-magnetic and is insoluble in alcohol, though it can be soluble in water. The yield strength related to pure aluminum is said to be 7-11 MPa, while the

alloy of aluminum presses yield strength ranging from 200 MPa to 600 MPa and it is density is $2.70X10^{-3}$ g/mm^3, while milting point is 645C^o.

The appearance of aluminum is dulled while its reactivity is being considered passivity with the help of a film of aluminum oxide which is naturally made on metal's surface in normal conditions. The outcome of oxide film is resistance to corrosion. Thickening the film is done with the help of electrolysis or oxidizing agents and aluminum in this form which will resist the attack by dilute acids dilute alkalis and concentrated nitric acid.

Aluminum is spotted on the right side of the periodic table which is a clue of aluminum's non-metals behavior, reacting with hot alkalis for the purpose of making aluminates ions [A1 $(OH)_4$] and is the most typical reaction of metal with acid for the purpose of releasing hydrogen gas and make the positively charged metal ion,$A1^{3+}$. Pure aluminum is being considered quite soft which lack strength. Aluminum which is used in commercial application has a mixture of small amount of silicon and irons (less than 1%) added which results in enhanced strength and hardness.

2.3 Plasma Arc Cutting

When plasma is used for the purpose of cutting, the flow of plasma gas is increased for the purpose of deeply penetration of plasma jets cuts through the materials and removal of molten material as cutting dross. The process of plasma arc cutting runs with the help of the arc to melt the metal. The process of plasma arc cutting can be implied to metal cutting which will result in forming refractory oxides like stainless steel, aluminum, cast irons, and other ferrous alloys.

This study used plasma arc cutting for the purpose of performing 1100 aluminum alloy with two thickness; 3 mm and 6 mm. When the plasma arc cutting is used the system and

process is being considered elements of utmost importance. Knowing the research area of plasma arc cutting is important for the purpose of planning the direction of this work so this study can make a useful contribution in future.

2.3.1 System

Plasma arc cutter consists of 11 major parts as below in figure 2.3:

- Control Panel
- Access Panel
- Torch Heads
- Regulator /Filter
- Filter Assembly
- Torch Head Assembly
- Electrode
- Gas Distributor
- Constricting Nozzle
- Shielding Cup
- Ground Clamp

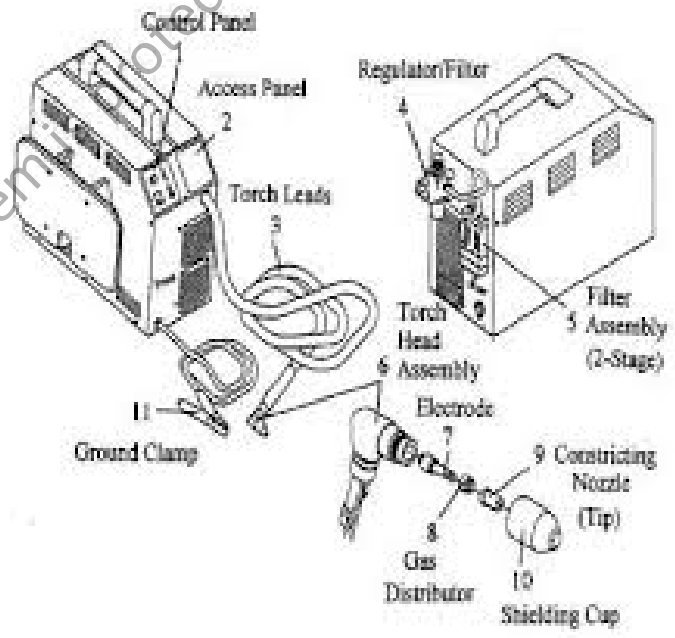


Figure 2.3: The plasma Arc systems

2.3.1.1 Plasma Torch