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Experimental Investigation on Process Parameters of E250 Mild Steel in Plasma Arc Cutting

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ABSTRACT

Now days industrialization and a fabrication shop play vital role for any manufacturing industry. The initial step involved in any fabrication shop are based on the cutting plate and to obtain a high surface finish to attain high accuracy now a day non-conventional machining are become life line of many industry. Plasma is essentially for an ionized gas that has been heated to high temperature. Due to the demand of increasing micro-scale material processing, the use of plasma is common. The Mild Steel E250 plate of 6 mm thickness using unconventional Plasma Arc Cutting process by varying the parameters like current, cutting speed, arc height and pressure, thereby analyzing the roughness and hardness properties and machining time of the work piece cut to optimize the parameters. In this work of Plasma Arc Cutting (PAC) show the effect Speed (mm/Sec.), Current (A), Arc Height (mm),Pressure (bar) on E250 Mild Steel Material. We have done Experiment by using Taguchi design methods and ANOVA analysis for Machining time, Hardness and Surface roughness by performing cuts of different run sets of L16 orthogonal Array.

KEYWORDS: *Plasma arc Cutting, Taguchi Method, Orthogonal array*

I. INTRODUCTION

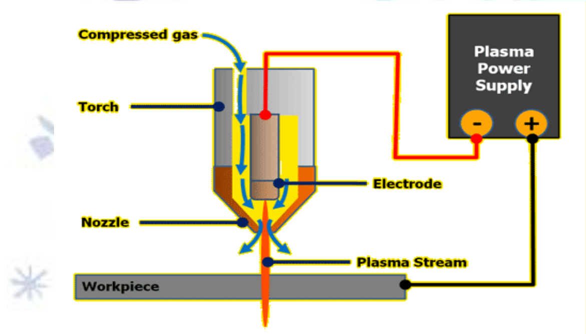
A plasma is a hot ionized gas. It consisting of approximately equal numbers of positively(+ve) charged ions and negatively(-ve) charged electrons. The plasmas characteristics are significantly different from the ordinary neutral gases so that plasmas are considered a distinct "fourth state of matter." For example, because plasmas are made up of electrically charged particles, they are strongly influenced by magnetic and electric fields (see figure) while neutral gases are not. An example of such influence is the trapping of energetic charged particles along geomagnetic field lines to form the Van Allen radiation belts.

In addition to that externally imposed fields, such as the Earth's magnetic field or the interplanetary magnetic field, the plasma is acted upon by electric and magnetic fields created within the plasma itself through electric currents and localized charge concentrations that result from the differential motion of the ions and electrons. The forces exerted by these fields on the charged particles that to make up the plasma act over long distances and impart to the particles' behavior a coherent, collective quality that neutral gases do not display. (Despite of the existence electric potentials and localized charge concentrations, a plasma is electrically "quasi-neutral," because, in aggregate, there are approximately equal numbers of positively and negatively charged particles distributed so that their charges cancel.)

1.1 PLASMA ARC CUTTING MACHINE

Plasma Arc Cutting is one of the thermal removing process which operates on the principal of passing an electric arc gas through a restricted outlet. In this cutting process, constricted arc is used. Polyatomic gases dissociate in the arc and partially ionize; gases partially ionize. The plasma beam thus generated has a high temperature and kinetic energy. It melts or partially vaporizes the material and blows it away. Thereby the kerfs is produced. The sheet thickness which can be cut is limited since for plasma cutting the whole heat required to liquefy the material has to be made available by the plasma cutting. With plasma cutting a difference is made between transferred and non-transferred arc. For the plasma cutting process, the material to be cut shall be electrically conducting since it forms part if the electrical circuit. This part is suitable for low and high cutting performance, i.e. cutting of thin and thick metal sheets.

1.2 PROCESS OF PLASMA ARC CUTTING



1.1 Process of Plasma Arc Cutting

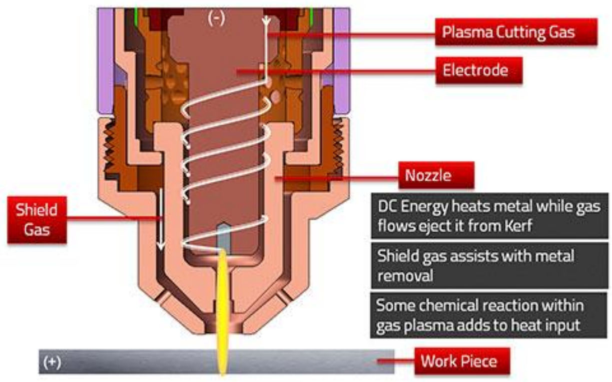
The basic principle is that the arc formed between the electrode and the work piece is constricted by a fine bore, copper nozzle. This increases the temperature and velocity of the plasma emanating from the nozzle. The temperature of the plasma is in excess of 20 000°C and the velocity can approach the speed of sound. When used for cutting, the plasma gas flow is increased so that the deeply penetrating plasma jet cuts through the material and molten material is removed in the efflux plasma.

The process differs from the oxy-fuel process in that the plasma process operates by using the arc to melt the metal whereas in the oxy-fuel process, the oxygen oxidizes the metal and the heat from the exothermic reaction melts the metal. Thus, unlike the oxy-fuel process, the plasma process can be applied to cutting metals which form refractory oxides such as stainless steel, aluminum, cast iron and non-ferrous alloys.

1.3 WORKING OF PLASMA ARC CUTTING

Inside a precision plasma torch, the electrode and nozzle do not touch, but are isolated from one another by a swirl ring which has small vent holes that transform the pre-flow/plasma gas into a swirling vortex. When a start command is issued to the power supply, it generates up to 400VDC of open circuit voltage and initiates the pre-flow gas through a hose lead set to the torch. The nozzle is temporarily connected to the positive potential of the power supply through a pilot arc circuit, and the electrode is at a negative. Higher quality of plasma arc cutting can be achieved by manipulating the cutting current and speed. Gases are used to create the plasma arc namely primary gases such as nitrogen, argon, hydrogen or mixture of them and secondary gas is a

Next, a high frequency spark is generated from the Arc Starting Console which causes the plasma gas to become ionized and electrically conductive, resulting in a current path from electrode to nozzle, and a pilot arc of plasma is created.



1.2 Cutting of the work piece

1.4 PROBLEM DISCUSSION

Plasma arc cutting can be characterized in terms of two different speeds.

- At higher cutting speeds, the plasma jet does not cut through metal plate.
- At lower speeds, the molten metal from the kerfs sticks to the bottom of the plate. So , we have to optimize proper parameters (Air pressure, current flow rate, cutting speed, arc gap) for plasma arc cutting.

1.5 OBJECTIVE

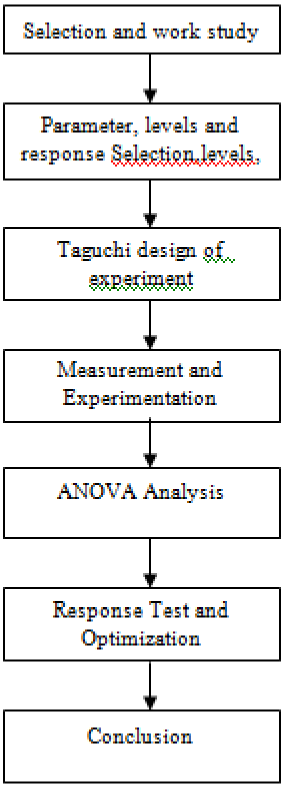
This project was developed to study about the plasma arc cutting parameter in order to get smooth cutting. The main purposes of this project are listed below:

- To study about the influence of Plasma Arc Cutting Parameters on Mild Steel E250.
- To design a series of experiment using the help of Design of Experiments (DOE) layout in order to study about Plasma Arc Cutting (PAC).
- To study about the best combination of solution for minimizing the Machining time, for

minimizing the Surface Roughness (µm) and to measure Hardness by using Taguchi Method.
- Analyze process performance at a for various parameters using ANOVA table.

1.6 SPECIFICATIONS
- Machine used in this project – Pro Arc Welding and Cutting machine.
- Current – 50A to 130A
- Speed range - 1500 to 3500 mm/min
- Arc gap – 2.1 to 2.5mm
- Gas pressure – 6 to 8.5 bar

II. METHODOLOGY



III. MATERIAL DESCRIPTION

3.1 MILD STEEL
Mild steel, also known as low **carbon steel**, is made from iron, sulfur, phosphorus, manganese and **carbon**. This type of steel is widely used for machined parts, non-critical components in tool and die sets and for parts that require tight radius bending.

Mild steel is a carbon steel typically with a maximum of 0.25% Carbon and 0.4%-0.7% manganese, 0.1%-0.5% Silicon and some + traces of other elements such as phosphorous, it may also contain lead. Mild steel is not an alloy steel and therefore does not contain large amounts of other elements besides iron; you will not find vast amounts of chromium, molybdenum, or other alloying elements in mild steel. Since its carbon and alloying element content are relatively low, there are several properties it has that differentiate it from higher carbon and alloy steels.

Less carbon means that mild steel is typically more ductile, machine able and weld able than high carbon and other steels, however, it also means it is nearly impossible to harden and strengthen through heating and quenching. The low carbon content also means it has very little carbon and other alloying elements to block dislocations in its crystal structure, generally resulting in less tensile strength than high carbon and alloy steels. Mild steel also has a high amount iron and ferrite, making it magnetic.

3.2 HOW MILD STEEL IS MADE
Mild steel is made similar to how other carbon steels are made. A common way this is done involves a combination of iron ore and coal. Once the coal and iron ore are extracted from the earth, they are melted together in a blast furnace. Once melted, the mixture is moved to another furnace to burn off any impurities that they may have, as well as to make any other adjustments to the mild steel's chemical composition. Following that, the steel is allowed to solidify into a rectangular shape. This slab of mild steel is then usually brought down to the desired size using processes called hot rolling or cold drawing, although there are other methods that can also be used.

3.1 Photos of Mild Steel

3.3 E250 MILD STEEL
E250 is the specification of Steel for general Structural Purposes. It is the Indian standard specification code for Mild Steel. Mild Steel Plates which have been manufactured using a high quality of raw materials which have been procured from well known vendors in the market and they have been made using state of art technology and these plates are alable in various sizes and thicknesses which can be got customized. These

products have been priced at very affordable rates in the market. There are 3 grades of structural steel in the E250 standard (A, B, C).

3.4 CHEMICAL COMPOSITION OF E250

E250 Mild Steel contains

- Carbon - 0.23%
- Manganese - 1.5%
- Sulphur - 0.05%
- Phosphorus -0.05%
- Silicon -0.4%
- Carbon Equivalent -0.42%

3.5 MECHANICAL PROPERTIES OF E250

Tensile Strength(N/mm^2)	Yield Stress (N/mm^2)			Percentage Elongation
	20	0 - 40	40	
410	50	40	30	23

IV. TAGUCHI DESIGN

4.1 Taguchi design overview

- *Dr. Gnocchi Taguchi is father of the “Taguchi Method” and “Robust Engineering*
- *He is an electrical engineer.*

Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product design that focuses on minimizing variation and or sensitivity to noise. When used properly, Taguchi design provides a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. In robust parameter design the primary goal is to find factors setting that minimize the response variation, while adjusting (or keeping) the process on target. After you determine which factors affect about variation, you can try to fine settings for controllable factors that will either reduce the variation, make the product insensitive to changes in uncontrollable (noise) factors, or both, a process designed with goal will produce more consistent output, a product designed with this goal will deliver more consistent performance regardless of the environment in which it is used. Engineering knowledge should guide the selection of factors and responses. Robust parameter design is particularly suited for energy transfer processes: for example, a car's steering wheel is designed to transfer energy from the steering wheels to the wheels to the car. You should also scale control factors ad responses so that interactions are unlikely. When interactions among control factors are likely or not well understood, you should choose a design that is capable of estimating those interactions. Minitab can help you select a Taguchi design that does not confound interactions of interest with each other or may require preliminary experimentation. The noise levels selected should reflect the parameter design uses Taguchi designs (orthogonal arrays), which allow you to analyze many factors with few runs. Taguchi designs are balanced, that is no factor is weighted more or less in the experiment, thus allowing factors to be analyzed independently of each other

4.2 ANALYSIS OF VARIENCE (ANOVA)

Analysis of variance (ANOVA) is a statistical model which can be used for find out effect of independent parameter on single dependent parameter and also it can be useful to find out the significant machining parameters and the percentage contribution of each parameter.

ANOVA is used to check the sufficiency of the second order model which includes test for significance of regression model, model coefficients and test for lack of fit. The ANOVA analysis for MRR and Rare illustrated in the tables where columns describe the degree of freedom (DF), the sequential sum of squares (SEQSS), adjusted sum of squares (ADJSS), adjusted mean squares (ADJMS), F-values (F) and probability of certainty (P). The sequential sum of squares (SEQSS) is the added sum of squares given that the prior terms are in the model, which depends on the model order. Allow **P-value (≤0.05)** indicates statistical significance for the source on the corresponding response (α=0.05) or 95% confidence level. We take ANOVA analysis with regression analysis.

4.3 PARAMETERS AND LEVEL SELECTION

Parameter	Level1	Level2	Level3	Level4
Pressure P1	6.3	7.0	8.2	-
Current P2	50	90	130	-
Gap P3	2.5	2.4	2.1	-
Speed P4	1600	2400	2800	3200

4.1 Parameters table

4.4 ORTHOGONAL ARRAY

S.NO	Current	Gas Pressure	Speed	Arc gap
1	50	6.3	1600	2.5
2	50	6.3	2000	2.4
3	50	6.3	2400	2.1
4	50	7.0	2800	2.5
5	50	7.0	3200	2.4
6	90	7.0	2000	2.1
7	90	7.0	2400	2.5
8	90	8.2	2800	2.5
9	90	8.2	3200	2.4
10	90	8.2	2000	2.1
11	130	6.3	2400	2.1
12	130	6.3	2800	2.4
13	130	7.0	2000	2.4
14	130	7.0	3200	2.1
15	130	8.2	2000	2.5
16	130	8.2	2400	2.1

4.2 Orthogonal Array table

4.5 INPUT PARAMETERS

- Current flow rate
- Arc gap
- Cutting speed
- Pressure

4.5.1 Current flow rate

It can also be carried by ions in an electrolyte, or by both ions and electrons such as in an ionized gas (plasma). The SI unit for measuring an electric current is the ampere, which is the flow of electric charge across a surface at the rate of one coulomb per second.

4.5.2 Arc gap

A spark gap consists of an arrangement of two conducting electrodes separated by a gap usually filled with a gas such as air, designed to allow an electric spark to pass between the conductors.

Pressure	Current	Speed	Nozzle distance
1	1	1	1
1	1	2	2
1	1	3	3
2	1	4	3
2	1	4	2
2	2	3	1
3	2	2	1
3	2	1	2
3	2	4	3
1	2	2	2
1	3	3	1
2	3	4	3
2	3	1	1
3	3	4	2
3	3	3	3
3	3	2	1

4.3 Table of Input parameters

4.5.3 Cutting Speed

Cutting speed (also called surface speed or simply speed) may be defined as the rate (or speed) at the work piece surface, irrespective of the machining operation used.

4.5.4 Pressure

Pressure is the force applied perpendicular to the surface of an object per unit area over which that force is distributed.

4.6 RESPONSE PARAMETERS

- Surface roughness
- Hardness
- Machining time

4.6.1 Hardness Tester

Hardness is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material.

Scale	Indentor	Load gf.	Dial	Applications
	Diamond	150	Black	Hard Cast Irons, Pearlitic Malleable Iron Steel, Titanium.

4.6.1a EXPERIMENTAL DATA FOR HARDNESS

Specimen no.	Hardness Value (HRC)
1	53
2	95
3	69
4	80
5	88
6	93
7	90
8	91
9.	81
10	86
11	85
12	78
13	72
14	80
15	89
16	76

4.6.2 Surface Roughness

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface.

4.6.2a EXPERIMENTAL DATA FOR HARDNESS

Specimen no.	Roughness Value (μm)
1	1.12
2	0.94
3	0.54
4	0.68
5	0.76
6	0.81
7	0.45
8	0.77
9	0.81
10	0.40
11	0.56
12	0.60
13	0.58
14	0.55
15	0.57
16	0.77

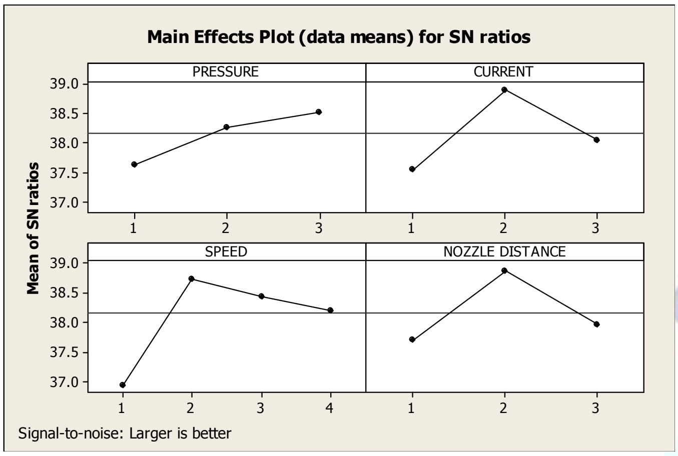
4.6.3 Machining Time

The time required for a job to complete the process of cutting is known as machining time.

4.6.3a EXPERIMENTAL DATA FOR MACHINING TIME

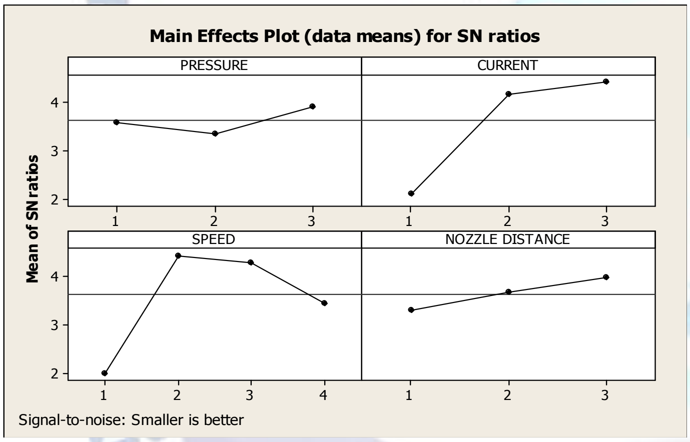
Specimen	Machining Time
1	16
2	13
3	10
4	8
5	8
6	10
7	13
8	16
9	8
10	13
11	10
12	8
13	16
14	8
15	10
16	13

V. RESULT AND DISCUSSION



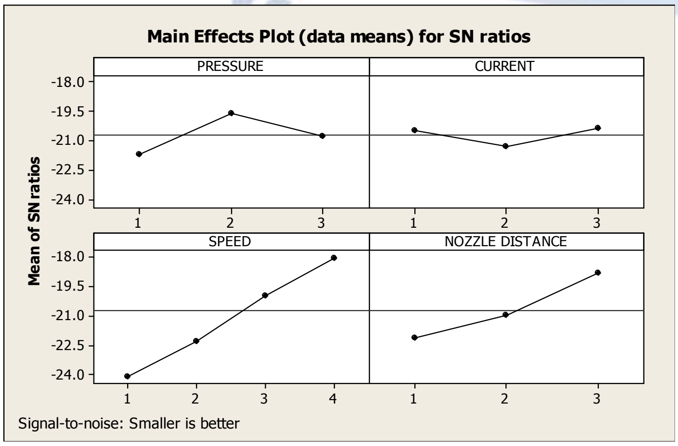
5.1 SN Ratio Graph for Hardness

From the above SN graph, it is absorbed that the optimum hardness obtained for the pressure 8.2 bar, current 90 A, arc height 2.5 mm and speed 2800 rpm.



5.2 *SN Ratio Graph for Roughness*

From the above SN graph, it is absorbed that the optimum hardness obtained for the pressure 8.2 bar, current 90 A, arc height 2.5 mm and speed 2800 rpm.



5.3 SN Ratio Graph for Machining Time

From the above SN graph, it is absorbed that the optimum hardness obtained for the pressure 8.2 bar, current 130 A, arc height 2.5 mm and speed 2400 rpm.

VI. CONCLUSION

In this experiment it is concluded that, In plasma arc cutting process there are various process parameters such as pressure, current, speed and arc height which affect cutting quality. By selecting the proper process parameters we can achieve proper cutting quality.

- Hardness will be better for maximum pressure and arc height, medium current and speed.
- Roughness will be better for maximum pressure and arc height, medium current and speed.
- Machining time will be better for maximum pressure, current and arc height, medium speed.

From SN Ratio Graph, the optimized parameter values are

Parameters	Pressure (bar)	Current (A)	Speed (rpm)	Arc height (mm)
Hardness	8.2	90	2.5	2800
Roughness	8.2	90	2.5	2800
Machining time	8.2	90	2.5	2800

6.1 Optimized parameters values table

Thus, In plasma arc cutting of E250 Mild Steel of 6 mm thickness the good cutting quality can be achieved by optimizing parameters as mentioned in table 6.1

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