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OPTIMIZATION OF PROCESS PARAMETER USING TAGUCHI METHOD OF EN 8 GRADE MATERIAL MACHINED IN CNC 3-AXIS PLASMA CUTTING

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Abstract: Plasma cutting is a process that cut through electrically conductive materials by means of jet of hot plasma. EN 8 steel plays a vital role in manufacturing automotive and construction industry. In this experimental work EN 8 steel plates are machining by plasma cutting process with various process parameter. L_{16} orthogonal array is selected as design of experiment concept with input parameters are Gas pressure, Current flow and cutting speed and response parameters are surface roughness and Material removal rate. The experiment is conducted in 30mmX30mmX4mm size machining process by plasma cutting. The process parameters are designed by 4 levels and 3 factors for cutting process. The response parameters such as surface roughness are predicted by smaller the best concept and material removal rate is analyzed by larger the best concept, The best parameters of plasma cutting on EN 8 palates are optimized by signal to noise ratio and analyzed by ANOVA. Gas pressure is influencing process parameters of EN 8 steel plates cutting process of Plasma.

Keywords; Plasma cutting, EN 8, Taguchi, Surface roughness, MRR, ANOVA.

I. INTRODUCTION

Plasma Cutting

Nowadays a variety of non-conventional thermal processes are being used for the cutting of a variety of materials having a high strength and high melting point which cannot be satisfactorily cut by the conventional methods of cutting . These non-conventional methods include oxy fuel cutting, laser cutting, abrasive water jet cutting and plasma arc cutting.

1) Principle of plasma Cutting

This process uses a concentrated electrical arc which melts the material through a high-temperature plasma beam. All conductive materials can be cut. Plasma cutting units with cutting currents from 20 to 1000 amperes to cut plates with inert gas, 5 to 160 mm thicknesses. Plasma gases are compressed air, nitrogen, oxygen or argon/ hydrogen to cut mild and high alloy steels, aluminium, copper and other metals and alloys.

The plasma is additionally tied up by a water-cooled nozzle. With this energy densities up to $2x10^6$ W/cm^2 inside of the plasma beam can be achieved. Because of the high temperature the plasma expands and flows with supersonic velocity speed to the work piece (anode). Inside the plasma arc temperatures of 30000^oC can arise, that realize in connection with the high kinetic energy of the plasma beam and depending on the material thickness very high cutting speeds on all electrically conductive materials.

The term for advisable state of plasma arc is called stability of arc too. The stability of arc is keeping the plasma jet in desired form.

It is possible to be provided by:

a. Shape of Plasma Torch,

b. Streaming Jet,

c. Coolant.

We must monitor these parameters:
a. Temperature and electrical conducting,
b. Density of plasma jet,
c. Diameter of plasma beam,
d. Degree of the plasma beam focusing in output from nozzle.

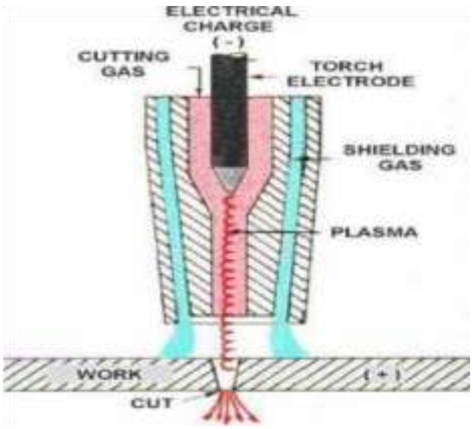

Fig 2 Plasma cutting process

2) ***Statement of problem***

- EN 8 steel is a hardened material and difficult to machine various shapes and does not provide surface finish and takes more cutting pressure for material cutting.
- The cutting tool should need more hardness than EN 8 plate for machining process.
- The material removing process takes more time for cutting process using conventional cutting tool.
- EN 8 steel plate's takes more time for cutting process and cutting tool gets more damage.

Objectives:

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

- To study about the influence of Plasma Arc Cutting Parameters on EN 8 Steel.
- To design a series of experiment using the help of Taguchi method in order to study about Plasma Arc Cutting (PAC).

- To design L16 orthogonal array with 4 levels and 3 Factors as an input parameters of plasma cutting process

- To study about the best combination of solution for maximizing the Material Removal Rate (MRR) and for minimizing the Surface Roughness (µm) with Taguchi Method.

Design of Experiments via Taguchi methods

Taguchi method involves reducing the variation in a process through robust design of experiments. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Therefore, poor quality in a process affects not only the manufacturer but also society.

He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning.

The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources.

ANOVA (Analysis of Variance)

In statistics, Analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation.

Doing multiple two-sample t-tests would result in an increased chance of committing a type I error. ANOVAs are useful in comparing two, three, or more means. The fundamental technique is a partitioning of the total sum of squares into components related to the effects used in the model.

$$SS_{total} = SS_{Error} + SS_{Treatment}$$

II EXPERIMENTAL DETAILS

The experiments are conducted as per L16 Taguchi design of experiment procedure and prepare 16 plates having dimensions of 30X30X 4 mm and work material is EN 8 steel. Specimen material – 1 (EN **8 steel / AISI 4340**)

Chemical Composition of EN 8

- Carbon 0.35 - 0.45%
- Silicon 0.05 - 0.35%
- Manganese 0.60 - 1.00%
- Chromium -
- Nickel -
- Molybdenum -
- Melting point of EN 8 steel: 1500

Mechanical Propertiesof EN 8

- Tensile strength = 550 MPa
- Yield strength =280 MPa
- Elongation =16%
- Impact Strength =54 J
- Hardness –Brinel =201 to 255

Equipment for the experiment use is:

- Plasma arc cutting system make with Thermal Tech.
- Digital weight balancer equipment.
- The surface roughness tester (FORM TALY SURF) Taylor Hobson Make (U.K.).

Factors of plasma cutting process

- Gas pressure
- Current Speed
- Current Flow

Table of technical features

Technical Features	**Machine**
Supply voltage	440V - 50Hz
Rated power	30 kW
Operating pressure	4 bar
Primary fuse	33 A
Open circuit voltage	440 V
Pilot arc current	30 - 39 A

Table of Levels and Factors of plasma cutting process

Levels	Gas pressure (Bar)	Current flow (ampere)	Cutting speed (mm/min)
1	3	30	1200
2	3.5	33	1300
3	4	36	1400
4	4.5	39	1500

II. RESULT AND DISCUSSION

Surface roughness

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations 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.

Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces.

Table Plasma cutting process parameters Vs surface roughness

Test no	Gas pressure (Bar)	Current flow (ampere)	Cutting speed (mm/min)	Roughness (µm)	SN RATIO
1	3	30	1200	12.7	-22.0761
2	3	33	1300	16.34	-24.2650
3	3	36	1400	19.21	-25.6705
4	3	39	1500	18.56	-25.3716
5	3.5	30	1300	16.6575	-24.4322
6	3.5	33	1200	16.568	-24.3854
7	3.5	36	1500	18.09	-25.1488
8	3.5	39	1400	15.768	-23.9555
9	4	30	1400	4.76	-13.5521
10	4	33	1500	5.666	-15.0655
11	4	36	1200	8.7689	-18.8589
12	4	39	1300	8.970	-19.0558

13	4.5	30	1500	7.5689	-17.5807
14	4.5	33	1400	4.9657	-13.9196
15	4.5	36	1300	6.2767	-15.9546
16	4.5	39	1200	7.68677	-17.7149

Figure Main effect plot for SN ratio of Plasma cutting of EN 8plates

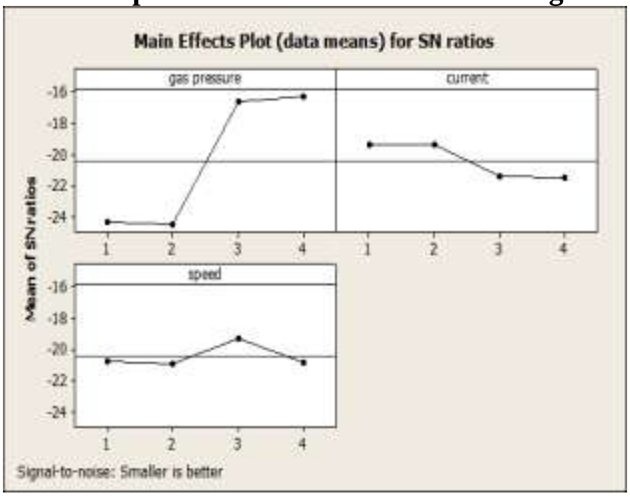

Table Response parameters for signal to noise ratio (Smaller the better)

Level	Gas pressure	current	speed
1	-24.35	-19.41	-20.76
2	-24.48	-19.41	-20.93
3	-16.63	-21.41	-19.27
4	-16.29	-21.52	-20.79
Delta	8.19	2.12	1.65
Rank	1	2	3

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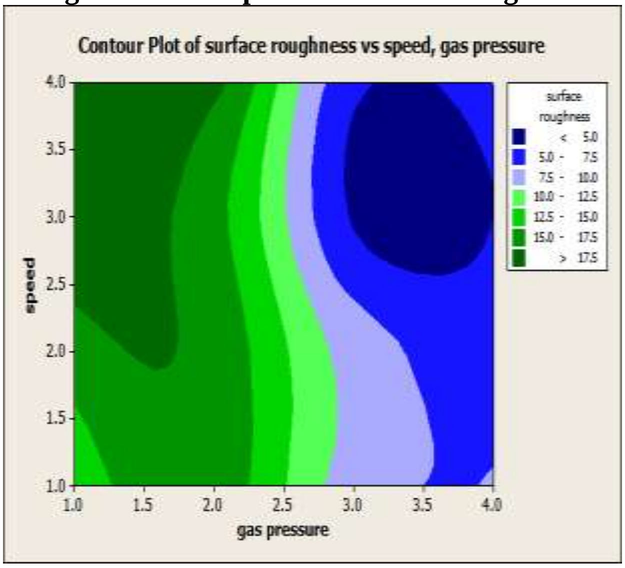
Figure Contour plot for Surfacee roughness



2 Material removal rate

In the physical orientation of PAM operations, such variables as torch standoff, angle to work, depth of cut, feed into the work, and speed of the work toward the torch are involved. Feed and depth of cut determine the volume of metal removed and illustrates the inter-relationship among some of the factors involved in plasma arc turning.

Level	Gas pressure	current	Speed
1	24.35	19.41	20.76
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Table response table for MRR

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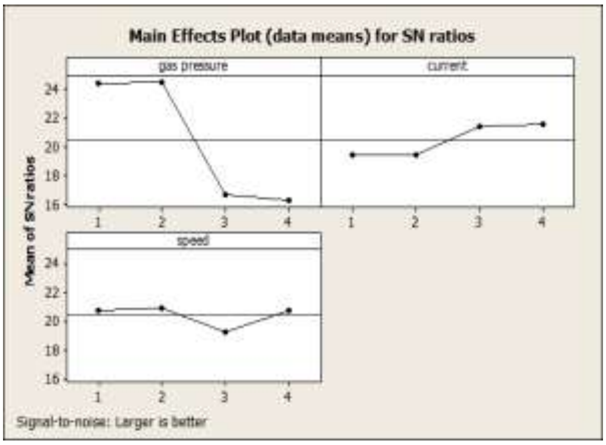

Figure main effect plot for SN ratios

Table Plasma cutting parameters vs. MRR

Test no	Gas pressure (Bar)	Current flow (ampere)	Cutting Speed (mm/min)	MRR g/sec	SN RATIO
1	3	30	1200	12.7	22.0761
2	3	33	1300	16.34	24.2650
3	3	36	1400	19.21	25.6705
4	3	39	1500	18.56	25.3716
5	3.5	30	1300	16.6575	24.4322
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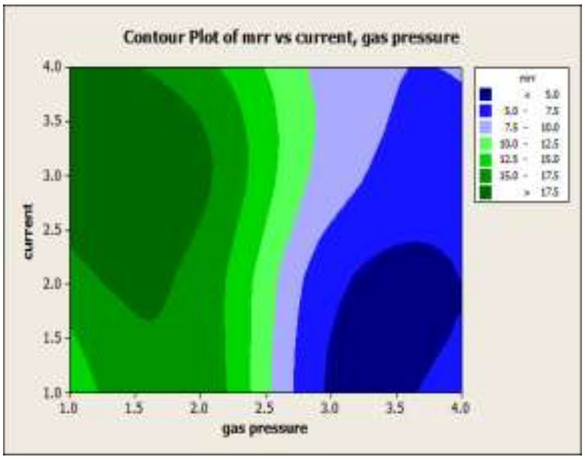

Figure Contour plots for material removal rate on Plasma process

III. CONCLUSION

In this experimental work plasma cutting on EN 8 steel plates with different machining process parameters has been conducted. L16 Orthogonal array is used design of experiment with 4 levels and 3 factors design. Gas pressure, current flow and cutting speed are the input parameters and surface roughness and material removal rate is response parameters. After conducting experiment the following the process parameters are the optimized in plasma cutting of EN 8 steel plates.

Surface roughness

The optimized process parameters of EN 8 plates are 4 bar of gas pressure, 30 ampere of current flow and 1400 rpm of plasma cutting
g is the best parameters while achieving lower surface roughness in small the better concept of signal to noise ratio.

The gas pressure is a dominating parameter of plasma cutting process while machining EN 8 plates. The EN 8 steel provided good machinability in plasma cutting process and provides good machining tolerance.

Material removal rate

The optimized process parameters of EN 8 plates are 4.5 bar of gas pressure, 39 ampere of current flow and 1200 rpm of plasma cutting is the best parameters while higher material removal rates in larger the better concept of signal to noise ratio. The gas pressure is a dominating parameter of higher material removal rate in plasma cutting process while machining EN 8 plates.

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