

# OPTIMIZATION OF MATERIAL REMOVAL RATE AND SURFACE ROUGHNESS OF PLASMA ARC CUTTING BY USING TAGUCHI METHOD

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**Abstract**— In last forty years there is tremendous research in machining and development in technology. With increase in competition in market and to attain high accuracy now a days the nonconventional machining are become lifeline of any industry. One of the most important non conventional machining methods is Plasma Arc Machining. Its high accuracy, finishing, ability of machining any hard materials and to produce intricate shape increases its demand in market.

In thesis work literature has been studied in context to parametric optimization of Plasma Arc Cutting Machine. In order to attain target and optimum results, Taguchi method employed. The appropriate orthogonal array has been selected as per number of factors and there levels to perform minimum experimentation.

The work pieces of Stainless Steel (316 L) materials were used for experiment purpose. The optimum value has been determined with the help of main effect plot and ANOVA table. The Regression equation for MRR and Surface Roughness (Ra) has been developed with the help of Minitab 15 Software. Confirmation test have done to confirm the value estimated through the software.

The Confirmation for MRR run was done by using the setting of 5.0 bar (Gas pressure), 150 A (Current flow rate), 600 mm/min (cutting speed) and 4.0 mm (arc gap). The optimum parameter level for Surface Roughness are 6.0 Bar (Gas Pressure), 150 A (Current), 400 mm/min (Cutting Speed) and 2 mm (Arc Gap). Experimental results are provided to confirm the effectiveness of this approach. After the confirmation the MRR value was 0.8331g/sec and Ra2.635µm. Error within 10% was allowed.

**Index Terms**— MRR, Plasma Arc Cutting, ANOVA, Design of experiments.

## I. INTRODUCTION

A subject to proposition composing is the Analysis of Process Parameters of, Plasma Arc Cutting Using Design of, Experiment Techniques. On fundamental looking undertaking for get ideal technique for get most Material Removal Rate also least an surface unpleasantness (S R).

An individual shouldn't been doc, physicists for comprehend the (PAC) procedure and Gouging system. Their territory unit 4 positions during what physically issue could likewise will discovered: strong, fluid, Gas or Plasma. varies From first physically position to an alternate happen.

H<sub>2</sub>O is utilized for instance of those four conditions of issue. inside the strong express it's freeze at temp. of 0° or else cooler. By an expansion of warmth an ice dissolves and converted to H<sub>2</sub>O, the fluid. An option for extra warmth to temp. of 212° F or more sizzling, changes over this fluid to its vaporized state, steam.

The fourth condition of issue, plasma, appearance and carries on kind of a warmth gas, anyway with a significant distinction; it consumes power.

In the event that developed peruse daylight transmitted with light saw Plasma on real life. among shining container of light was plasma comprising of air mass Mercury, metallic component vapour.

For a long time, oxy acetylene cutting has normally an strategy to determination for rapidly slicing through plate. In the course of recent years plasma cutting has pretty much appropriated, for a couple of magnificent motivations to possibly generally fundamentally.

Plasma stream which will the cutting is more smoking And smaller then an oxy- acetylene fire, that kerfs expansiveness a littler, or might be cleanser cuts. which marks PAC altogether appropriate to Cutting level strong, an errand the oxy-acetylene cutting light isn't fundamentally appropriate for before it lefts stores of dross over sides. A Tight focal point of plasma circular segment will in general weaken heat twisting inside the cut segments.

## A. PROBLEM STATEMENT

A Gas circular segment removing is portrayed as far as 2 particular rates. At cutting velocities over, the plasma fly doesn't pass alloy portion. On paces underneath, a fluid substance by kerf branches for absolute base portion, shaping

of flawed impurity the best approach for appropriately pick a gas cutting framework. Gas will cuts during broad choice of cutting specs (flows, base thickened or spout portal distances across) for plasma circular segment cutting of perfect steel materials.

The plasma curve cutting philosophy utilizes a plasma burn with an incredibly thin bore to create a moved bend towards W.P. on middle existing thickness of among an drag of light. a vitality or force of quick gas stream produced through Plasma light melts, vaporizes or expels alloy by district of error of the spout. Remains are :

- Cutting of metal which type?
- Power input primary is which during cutting process?
- How much thickness to cut?

## B. OBJECTIVES

This venture is created for survey concerning an gas circular segment cutting specs at wash removing abuse extremity strategy. A most elements of this venture zone unit listed below:

- a) For examine concerning an impact of PAC Specs. at chrome steel.
- b) For style an progression about examination misuse advice about style of Observations .DOE design for survey concerning ( P A C ).
- c) For examine concerning top mix goals to augmenting an texture Removal Rate to limiting an  $Ra(\mu m)$  by Taguchi method.

Normally these comes are evolving inside the area here:

- a) Project targets at optimization of cutting specs. Of ( P A C ).
- b) An fabric accustomed chip is chrome material of specs A S T MA240TP316 L.
- c) Style of Experiments layout is recycled for experiment and analyzing with Taguchi technique.

## II. LITERATURE-REVIEW

P A C can be strategy which is acclimated remove metal or different alloys (and for the most part different materials) utilizing a plasma burn. all through this procedure, a section ( Ar ) had carried at rapid away a spout also indistinguishable period of electrical circular segment was made by vapor through spout for exterior to remove, turned assortment of this gas to plasma. It adequately warm liquefy alloy should sliced also shifts adequately quick flow fluid alloy faraway beside a cut. Gas will even utilized to Gas curve connection also different uses [24].

Gas is normally a ionizing gas. This Gas taken as an unmistakable condition on issue, beside gase, due to particular

factors. ionizing alludes for nearness of 1 and a ton of free Electrons, that aren't ensured to A particle or atom. [27].

Arc kind purpose an couple of duration way for deal with creating gas. Initial, an higher voltages and lower current c.k.t was utilized for instate an amazingly next to no high force flash inside the light body, consequently creating a tiny low pocket of plasma gas. this will be referenced because of the pilot circular segment. The pilot curve incorporates an arrival electrical way structured to light. A pilots curve would keep up till it's taken onto vicinity of W.P. however this touches off an premier P A C bend. A gas circular segments unit of estimation hot and unit of estimation at interims the fluctuate of fifteen,000 degrees Celsius.

Alloys similar nuclear number 13 or chrome material type a concoction aggravate that restrains more response, making standard oxy fuel cutting impractical. Plasma cutting, be that as it may, doesn't have confidence in response to figure, thus it will cut nuclear number 13, perfect and the diff. Material. During entirely unexpected gaseous will be utilized to P A C, the overall population nowadays utilize packed gas for the plasma gas. In many outlets, packed gas is rapidly out there, thus plasma needn't bother with fuel gas and compacted O for operation.

Plasma cutting is at times simpler to tenderfoot for ace, also specialist metals, P A C is a lot quicker then oxy fuel cutting. In any case, to noteworthy areas of metal (1in. or more prominent), oxy fuel keeps on being most prevalent since oxy fuel is by and large speedier and, for heavier plate applications, frightfully high ability power gives are expected to P A C uses [28].

## TAGUCHI DESIGN OVERVIEW

Dr Genichi Taguchi is viewed how preeminent advocator solid factors style, that Associate in Nursing building strategy for item or technique style that spotlights on limiting variety and additionally affectability to clamor. when utilized appropriately, Taguchi styles give a solid and efficient method for arranging item that work methodically and ideally over a spread of conditions.

In solid parameter style, the primary objective is to look out issue settings that limit reaction variety, while altering (or keeping) the technique not off kilter. when we tend to affirm that variables affect variety, we can attempt to see settings for manageable elements that may either downsize the variety, assemble the product unfeeling toward changes in wild (clamor) factors, or both. a route planned with this objective will produce additional steady yield. An item structured with this objective will convey additional reliable execution despite nature all through that it is used.

Building learning got the opportunity to direct the choice of things and reactions.

At the point when associations among the board factors region unit most likely or not surely knew, we should dependably pick a style that is equipped for assessing those communications. Minitab will encourage U.S. to pick a

Taguchi style that doesn't frustrate co operations of enthusiasm with each other or with main effects.

Clamor factors for the external cluster got the opportunity to try and be meticulously chosen and can might want fundamental experimentation. The commotion levels chose got the chance to reflect the shift of conditions underneath that the reaction variable got the opportunity to keep tough. solid parameter style utilizes Taguchi styles (symmetrical clusters), which grant U.S. to explore a few variables with few runs. Taguchi styles region unit adjusted, that is, no issue is weighted extra or less in Associate in Nursing test, hence allowing components to be investigated severally of each other.

M I N I T A B gives both Static and Dynamic reaction tests.

A case of a dynamic reaction trial is Associate in Nursing car quickening test where the sign is that the quantity of weight on the throttle and conjointly the yield reaction is vehicle speed. we will in general square measure prepared to turn out a dynamic reaction analyze thru joining an proof issue for style – seems making motion reaction try. An objective to strong analysis search out Associate in Nursing ideal mix of the executives issue settings that come through quality against (obtuseness toward) commotion factors.

- Signal-to-commotion proportions (S/N proportions, which give a proportion of vigor) versus the control factors.
- Means (static plan) or slants (dynamic structure) versus the control factors.
- Standard deviations versus the control factors.

Utilize a outcomes also plots for perceive which components also co operations square measure indispensable

and measure anyway that reactions. For an total comprehension impacts that is prudent for assess S/ N proportions, implies, inclines (dynamic structure).

### III. MATERIAL AND METHODS

#### A. SPECIMEN PREPARATION

16 analysis examples taking measurement 30x30x12 was set up to trial effort. A substance to analyze example was hardness SS ASTMA240TP316L. Where L represents less contents of Carbon.



Fig. 3.1 Test Sample

#### B. MATERIAL

Treated Steel is fundamentally intermittent steel that contains metallic component at 100% or extra through mass. This one expansion of metallic component which provides its particular flawless, consumption opposing properties. The chromium substance permits the development of an intense, follower, undetectable, erosion opposing chromium oxide film on the steel surface.

Table 3.1. Composition ranges for 316 grades of SS.

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
316	Min	-	-	-	0	-	16.0	2.00	10.0	-
	Max	0.08	2.0	0.75	0.045	0.03	18.0	3.00	14.0	0.10
316L	Min	-	-	-	-	-	16.0	2.00	10.0	-
	Max	0.03	2.0	0.75	0.045	0.03	18.0	3.00	14.0	0.10
316H	Min	0.04	0.04	0	-	-	16.0	2.00	10.0	-
	max	0.10	0.10	0.75	0.045	0.03	18.0	3.00	14.0	-

Table 3.2 Mechanical properties of 316 grade SS

Grade	Tensile Strength(MPa)	Yield Str 0.2% Proof(MPa)	Elongation in 50mm (%)	Rockwell B (HRB) max	Brinell (HB)max
316	515	205	40	95	217
316L	485	170	40	95	217
316H	515	205	40	95	217

Great response obstruction in irregular administration for 870°C and in persistent administration to 925°C. Ceaseless utilization of 316 inside the 425~860°C shift isn't embraced if coming about substance compound consumption obstruction is inconceivably vital. Evaluation 316L could be a huge amount of confirmation against concoction compound precipitation and might be used inside the more than temperature fluctuates.

Evaluation 316 H had better quality on raised temp. also it generally utilized for auxiliary , weight comprising uses at temp. Higher than with respect to 500°C.EQUIPMENTS

#### C. Plasma Arc Cutting System

P A C cutter utilized to cutting, specialist dependably realize gas circular segment cuts (Oxyfuel is normally restricted to metal), a procedure delivers a little warmth affected zone.

Table 3.3 Technical Features

Technical Features	Machine
Supply voltage	3x400V- 50Hz
Rated power	30 kW
Operating pressure	5 bar
Primary fuse	16 A
Open circuit voltage	260 V
Pilot arc current	50 A

## IV. DESIGN OF STUDY

### A. OUTLINE OF WORK

It is discovered effectively a few work has been depleted MRR and Surface end anyway next to zero effort is complete On advancement of P A C. In this proposal exertion we would probably attempt and build up best worth of M R R and ( Ra ).

We counsel to Construction Partition of B H E L, Bhopal, them prompted that chrome material( 316 L ) constituents zone unit efficiently out there and wide utilized in Plasma Cutting Machine .Taguchi philosophy exploitation style of examinations approach are frequently acclimated enhance a technique There we will for utilize D O E method for demonstrating of MRR at board of trustees strategy and furthermore the various information parameters are taken underneath exploratory examination thus model are prepared anyway experimentation work can be performed. The outcomes get are broke down and furthermore the models are made by exploitation MINITAB PC code. i/p specs are,:

- Current Flow Rate
- Arc Gap
- Kerf ( width of cut)
- Cutting Speed
- Material Type and Thickness
- Cutting gas Pressure
- Voltage

After broad conceptualizing by specialists of Fabrication Division of BHEL Bhopal.

### B. DESIGN OF EXPERIMENT

For study about Ra and material Removal Rate is the aim of this research, variable of design are as follows:

- Two levels of Gas press. ( 6.00 Bar and 7.0bar).
- Two levels of Current Flow Rate ( 0150 A and 0200 A).

- Two levels of Cutting Speed ( 0400 mm / min and 0600 mm / min ).
- Two levels of Arc Gap (002mm and 004mm)

To leading a tests, this is chosen for pursue an Taguchi technique for exploratory structure and a suitable symmetrical cluster is to be chosen subsequent to thinking about the above

plan factors. Out of the above recorded structure factors, the symmetrical cluster was to be chosen for four plan factors.

Mostly two significant yields were M R R and Ra a equivalent is chosen how reaction factors to that exploration effort moreover. An impact of variety at information procedure specs would examine on for that 2 specs also trial information would investigated according to Taguchi technique. The accompanying machining parameters were kept fixed.

Table 4.1 Fixed Machining Parameters

S. No.	Machining Parameters	Fixed Value
1	Material Type	Stainless Steel (316 L)
2	Material Thickness	12 mm
3	Kerf	5mm
4	Operating Voltage	200 V

### C. SELECTION OF ORTHOGONAL ARRAY AND PARAMETER ASSIGNMENT

On each of the 2 levels, 4 parameters are their in this experiment ( D o F ) for parameter of 2<sup>nd</sup> level is two (and level no. is -1). Also, D o F (total) for this experimental

analysis is 4. And D o F (total) should be higher than the orthogonal array Do F.

Table 4.2 Parametric Level Assignment

Parameter	Unit	Level 1	Level 2	DOF
Gas Pressure	bar	5	6	1
Current Flow Rate	ampere	150	200	1
Cutting Speed	mm/min	400	600	1
Arc Gap	mm	2	4	1

Standard L16 Array with (2\*4) :- Pillar no. 1 2 4 and 8 of L 16 ( 2\*\*15) Array is used for this experiment:-

Table 4.3 Experimental Layout in Coded Factor Levels

Runs	Gas Pressure	Current	Cutting Speed	Arc Gap
1	1	1	1	1
2	1	1	1	2
3	1	1	2	1
4	1	1	2	2
5	1	2	1	1
6	1	2	1	2
7	1	2	2	1
8	1	2	2	2
9	2	1	1	1
10	2	1	1	2
11	2	1	2	1
12	2	1	2	2
13	2	2	1	1
14	2	2	1	2
15	2	2	2	1
16	2	2	2	2

L 16 (2\*4) Taguchi design of orthogonal array represented by this table, where the L 16 indicates that 16 means runs, meaning of (2x4) defined as that there is 2 levels each with 4 factors.

#### D. A N O V A (Analysis of Variance)

A motivation behind an connected science examination of difference ( A N O V A ) for inquire about that style parameter significantly influences the texture expulsion rate and surface unpleasantness. upheld the multivariate examination, the overall significance of the m/c factors by pertinence substance evacuation amount , exterior harshness was researched for work out a ton of precisely the ideal mix of the m/c factors.2 kinds of varieties were available at trial information:

- In treatment variability
- Statement to observation variability

Then A N O V A encourages me for think about inconstancies inside exploratory information. our theory A N O V A list was done by assistance of M I N I T A B 15 programming. The normal misfortune is corresponding for mid formed blunder of Y regards its objective T . The underlying strategies of investigation of fluctuation was created via analyst, life researcher R . A . Fisher inside an Thirties, square measure for the most part alluded to as Fisher's multivariate examination or Fisher's investigation of change, on account of the work of Fisher ' s F - appropriation a s a piece of check connected arithmetic centrality.

## V. EXPERIMENTAL ANALYSIS

There are 4 factors and 2 levels for each, shown:

Table 5.1 Values of variables at different level

Control Factors	Unit	Level 1	Level 2	DOF
Gas Pressure	bar	5	6	1
Current Flow Rate	ampere	150	200	1
Cutting Speed	mm/min	400	600	1
Arc Gap	mm	2	4	1

As represent above orthogonal array after determined levels and parameters. Parameter data is collecting however it should be not any accident to user, Also according to literature review. Did the analysis as per according to orthogonal array (L 16 ) on P A C m/c no. b/0/2163,also results like M R R and Ra and provides as like table form. When o/p results gets, So as

analytically analysis of o/p results was find and graphically also. In which Mini-TAB is used for graphical analysis which indicates relation b/w all parameters. To find donation of every factor. For every response then A N O V A of the analyze data should be done.

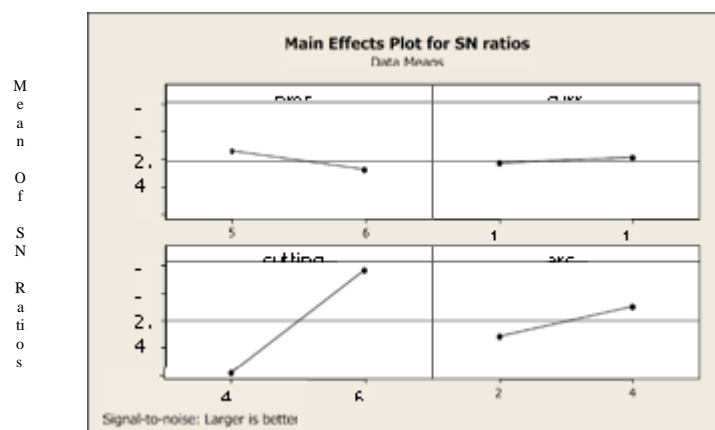
Table 5.2 Calculation Sheet for MRR and Surface Roughness

ExpNo.	Mass 1 (Before Cutting)	Mass 2 (After Cutting)	Mass Loss (g)	Time Taken (Sec)	MRR (g/Sec)	Surface roughness ( $\mu\text{m}$ )
1	90	61.2	28.8	45	0.640000	3.834
2	87	58.6	28.4	45	0.631111	3.688
3	85.4	56.4	29	40	0.725000	4.393
4	79.05	49.65	29.4	36	0.816667	4.679
5	98.54	69.74	28.8	40	0.720000	3.180
6	79.69	52.69	27	36	0.750000	3.458
7	102.77	73.87	28.9	36	0.802778	4.571
8	99.48	70.68	28.8	35	0.822857	3.568
9	82.63	56.23	26.4	40	0.660000	3.255
10	82.67	53.77	28.9	39	0.741026	3.688
11	72.4	43	29.4	38	0.773684	3.951
12	73	43.2	29.8	37	0.805405	3.958
13	93.45	64.65	28.8	49	0.587755	2.352
14	89.1	60.9	28.2	47	0.600000	2.636
15	86.75	58.55	28.2	37	0.762162	3.969
16	93.27	64.77	28.5	35	0.814286	4.123

Table 5.3 Experimental Layout and S/N ratios to MRR and Surface Roughness (Actual Factor Levels)

Exp No.	Pressure (Bar)	Current(A)	Speed (mm/min)	Arc Gap (mm)	MRR (g/Sec)	S/N ratio for MRR	SR Ra (μm)	S/N ratio for SR
1	5	150	400	2	0.640000	-3.87640	3.834	11.6730
2	5	150	400	4	0.631111	-3.99788	3.688	11.3358
3	5	150	600	2	0.725000	-2.79324	4.393	12.8552
4	5	150	600	4	0.816667	-1.75910	4.679	13.4031
5	5	200	400	2	0.720000	-2.85335	3.180	10.0485
6	5	200	400	4	0.750000	-2.49877	3.458	10.7765
7	5	200	600	2	0.802778	-1.90809	4.571	13.2002
8	5	200	600	4	0.822857	-1.69351	3.568	11.0485
9	6	150	400	2	0.660000	-3.60912	3.255	10.2510
10	6	150	400	4	0.741026	-2.60334	3.688	11.3358
11	6	150	600	2	0.773684	-2.22873	3.951	11.9341
12	6	150	600	4	0.805405	-1.87971	3.958	11.9495
13	6	200	400	2	0.587755	-4.61607	2.352	7.4287
14	6	200	400	4	0.600000	-4.43697	2.636	8.4189
15	6	200	600	2	0.762162	-2.35905	3.969	11.9736
16	6	200	600	4	0.814286	-1.78446	4.123	12.3043

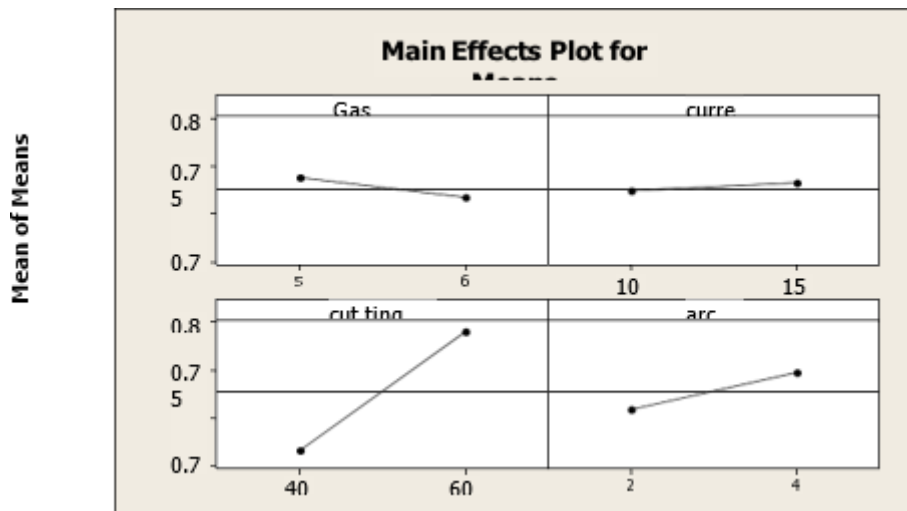
#### A. EXPERIMENTAL RESULTS FOR MRR



Graph 5.1 Effects of various factors on S / N Ratio of MRR



B. Main Effect Plot for Mean of MRR

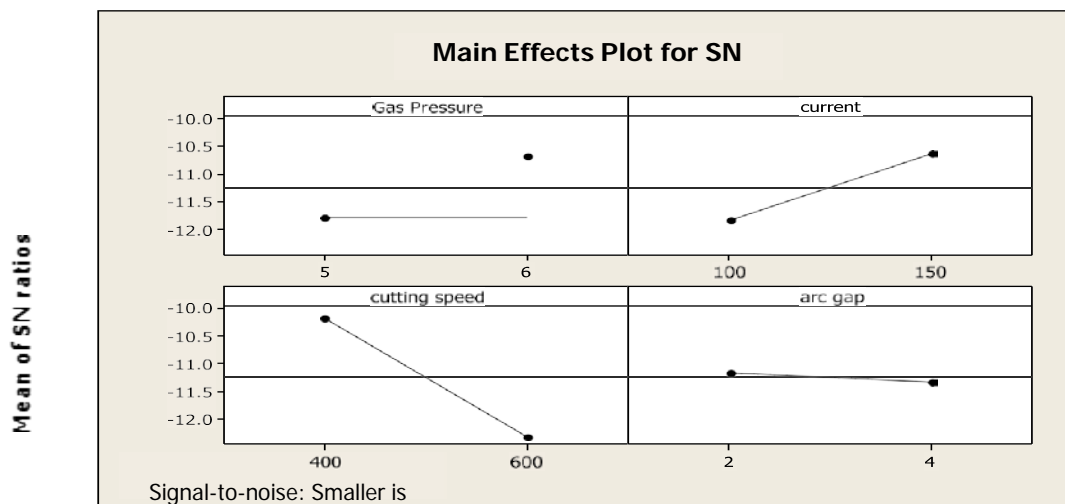


Graph 5.2 Effects of various factors on Mean of MRR

Observing the M R R decrement by decreasing of the gaseous press. On above graph at midpoint of M R R and other

factors. Also increment in Current, Cutting speed and Arc Gap with an increase in an M R R.

C. EXPERIMENTAL RESULTS FOR SURFACE ROUGHNES



Graph 5.3 Effects of various factors on S / N Ratio of SR

This graph indicates the change in Ra parameters, Which represents as how the Ra S / N ratio increases with increasing current, gas press., where arc gap or Cutting speed increased, when S / N ratio of Ra decreased.

VI. ANALYSIS OF VARIANCE ( ANOVA )

However already defined A N O V A do benefits to determine imp. Factors for you. Table of A N O V A is required for Ra and M R R after literature review. Where M I N I T A B 15 software uses to do statistical calculation.

Table 5.4 ANOVA Table for M R R

Parameters	DOF	SS	MS	F	P	Contribution (%)
Gas Pressure	1	0.2854	0.2854	0.68	0.427	1.92
Current	1	0.0223	0.0223	0.05	0.822	1.5
Cutting Speed	1	9.1295	9.1295	21.75	0.001	61.44
Arc Gap	1	0.8056	0.8056	1.92	0.193	5.42
Residual Error	11	4.6172	0.41975			31.07
Total	15	14.8601				100

Table 5.4. represents ( A N O V A ) for M R R reply. An necessary knowledge have been required to % affect of every para over Responses. Here Cutting Speed was important

model values. Amount bigger then zero.1000 indicate the model terms don't seem to be vital.

Table 5.5 ANOVA Table for Surface Roughness (Ra)

Parameters	DOF	SS	MS	F	P	Contribution (%)
Gas Pressure	1	4.7795	4.7795	5.45	0.040	12.22
Current	1	5.6862	5.6862	6.48	0.027	14.53
Cutting Speed	1	18.9228	18.9228	21.58	0.001	48.36
Arc Gap	1	0.0912	0.0912	0.10	0.753	0.23
Residual Error	11	9.6452	0.8768			24.65
Total	15	39.1250				100

From table no.5.5, Because of them value of P, which are less than 0.0500, cutting speed, gas Press. And the (current i) are imp. Terms and if value of P larger than 0.0100 shows terms of models are n't imp..A value of P for the Arc gap term has been 0.753000 i.e. not an imp.

## VII. RESULTS

Optimal points of factors for maximizing M R R are A1B2C2D2 that is

- Gas press.: 05 Bar
- Current: 0150 A
- Cutting Speed: 0600 mm / min
- Arc Gap : 04 mm

Optimal points of factors for minimizing (Ra) are A2B2C1D1 that is :

- Gas Press. : 06Bar
- Current: 0150A
- Cutting Speed: 0400 mm/min
- Arc Gap: 002 mm

Afterward acting analysis according to given finest stages for M R R and S R subsequent marks gotten:

Table 6.1 Results Before and After Optimization

MRR (g/sec)	Predicted value of A1B2C2D2 =0.8264	Experimental result of A1B2C2D2=0.8331	Percentage = 0.81%
Surface Roughness ( $\mu\text{m}$ )	Predicted value of A2B2C1D1 = 2.8006	Experimental result of A2B2C1D1=2.635	Percentage = 5.91%

## VIII. CONCLUSION

- P A C theory have exhibited a utilization of Taguchi technique to an enhancement for m/c factors o f P A C m/c. The affirmation analyses were led to confirm the ideal factors. This is appeared (M R R ) and (Ra) could fundamentally better in the P A C procedure utilizing an ideal level of parameters.
- P A C m/c was broadly used in B H E L, for remove materials, for example, S. S. , Nickle-Based Alloy.
- By A N O V A analysis M R R we expect that a few factors were n't doing one of the critical impact. Analysis is on the grounds that we should take huge no. of perceptions or through consideration L 27 Or L 32 symmetrical cluster from three level designs.

## IX. SCOPE OF FUTURE WORK

A portion of recommendations for modify an outcome incorporate a duplication of an model that could decrease an varieties of information, increment the unwavering quality of records.

Recommendation for coming effort:

- 1) Use of P A C framework, include factor, for example Kerf, Voltage, point, solid measurement, also alter A.M., for example, metal and bronze at that pointlook at the result obtained.
- 2) Using other approach in a similar material of concentrate to think about the outcomes got, for example, R S M, Gray R a, and GA.
- 3) Analysis to physical computation to different technique at D O E for improviseinformation and skills.

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