Optimization of Process Parameters for Machining Stainless Steel using Plasma Arc Machining

Sheikh Junaid Nabi
Department of Mechanical Engineering
GRD IMT Dehradun, India

Abstract— Every product we use in day-to-day life has undergone the machining process either directly or indirectly. The importance of machining process can be judged from the fact that more than $100 billion is spent annually on machining related operations. Conventional machining processes stress the material beyond the yield point to start the material removal process. To achieve this purpose the cutting tool material should be harder than the workpiece material. With the discovery of new class of materials like nimonic alloys, alloys with alloying elements like Tungsten, Molybdenum and Columbium the conventional machining process are not suitable to put in use as machining these materials pose difficulty. Machining these materials with conventional methods is time consuming as well as difficult as the material removal rate decreases with increase in hardness. This led to development of non-conventional machining processes. Non-conventional machining processes do not replace the conventional machining process but supplement them. Some of the non-conventional machining processes are Electric Discharge Machining, Electro Chemical Machining, Electro Chemical Grinding, Ultrasonic Machining, Laser Beam Machining, Plasma Arc Machining, Water Jet Machining, Abrasive Water Jet Machining etc. With the development of non-conventional machining processes the production rate has been enhanced with increase in the product quality. Non-conventional machining processes had up to greater extent lowered the degree of further surface finishing requirement. In this paperwork literature has been studied in context to “Optimization of Process Parameters using Plasma Arc Machining”. The work pieces of Stainless Steel were used for experiment purpose. The Taguchi Experimental Design was used for process optimization. The optimization values have been developed with the aid of Minitab-18 Software. Confirmation tests were done to check the genuineness of the values obtained through the software.

Keywords: Plasma Arc Machining, Machining Stainless Steel

I. INTRODUCTION

The main aim of the work was optimization of parameters to enhance the machining process. Plasma is one among the four states of matter other being Solid, Liquid and Gas. This fourth state of matter is like a high temperature gas, with an important difference that it conducts electricity. When gas is heated to very high temperature of the order of 30,000 ℃, the atoms get ionized into positive and negative ions enabling it to conduct electricity. This phase of the ionized gas is termed as plasma. The major difference between a neutral gas and plasma is that particles of plasma exert electromagnetic forces on each other. In view of high temperature available in plasma arc, it has been put into use in machining process like sheet and plate cutting operations.

Plasma arc machining is best suited for machining hard-to-cut metals like supper and nimonic alloys. In plasma arc machining, arc is generated between the hot cathode and the workpiece which is made as anode. The molecules of the gas get dissociated due to collision with the electrons generated by the arc which results in ionization of the gas. The heat for machining process is produced by convection from high temperature plasma. Primary gas such as H_2 or N_2 gas is introduced around the cathode and is subjected to pass through a narrow path of the nozzle towards the workpiece. The temperature of the gas rises to 28,000℃ within the narrow path. The swirler is provided to prevent the gas turbulence and to stabilize the gas flow. The secondary gases are inert gases which are used for shielding purpose and are termed as shielding gases. The type of shielding gas depends upon the material being machined. [1]

Before the discovery of Plasma Arc Machining process Oxy-Acetylene cutting was widely preferred machining process for quick cutting. Nowadays, Plasma Arc Machining process has taken over reasonably because of its excellent machining characteristics. Any material that is electrically conductive can be machined using Plasma Arc Machining. Plasma jet gives cleaner cuts moreover the width of kerf is smaller.

II. RESEARCH WORK

Since lot of work has been done in MRR and Surface finish but very little work has been done on optimization of these characteristics in Plasma Arc Cutting process. During the work attention was focused upon to find out optimal value of MRR and SURFACE ROUGHNESS (Ra).

Taguchi method using design of experiments approach can be used to optimize a process. D.O.E approach for modeling of MRR in PAC process was applied and the various input parameters were taken under experimental investigation and then model was prepared. The results obtained were analyzed and the models were produced by using MINITAB software. This will help in improving the effective and efficient working of the PAC process. [2]

A. *Various Input parameters*

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

After literature review four main input parameters selected are Gas Pressure, Current, Cutting Speed, and Arc Gap. The other two parameters kerf (5mm) and Material Thickness (12mm) were kept fixed for the whole experiment. The material used in the experiment is Stainless Steel.

B. Design of Experiment

The objective of this research work is to study MRR and Surface roughness, the design variables can be summarized as follows:

1) Two levels of the Gas Pressure (6Bar and 7Bar).
2) Two levels of Current Flow Rate (150A and 200A).
3) Two levels of Cutting Speed (400mm/min and 600mm/min).
4) Two levels of Arc Gap (2mm and 4mm)

For conducting the experiments, it has been decided to follow the Taguchi method of experimental design and an appropriate orthogonal array is to be selected after taking into consideration the above design variables. Out of the above listed design variables, the orthogonal array was to be selected for four design variables Gas Pressure, Current, Cutting Speed and Arc gap which would constitute the L16 orthogonal array. [3]

The two most important output responses are Material Removal Rate and Surface Roughness the same have been selected as response parameters for this research work also. The effect of the variation in input process parameter was studied on these two response parameters and the experimental data was analyzed as per Taguchi method to find out the optimum machining condition and percentage contribution of each factor. The following machining parameters were kept fixed.

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

Since during experimental work there were four factors and two levels for each, which are shown below;

1) Control Factors

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

Optimal condition has been calculated for MRR and surface roughness of

III. Experimental Result

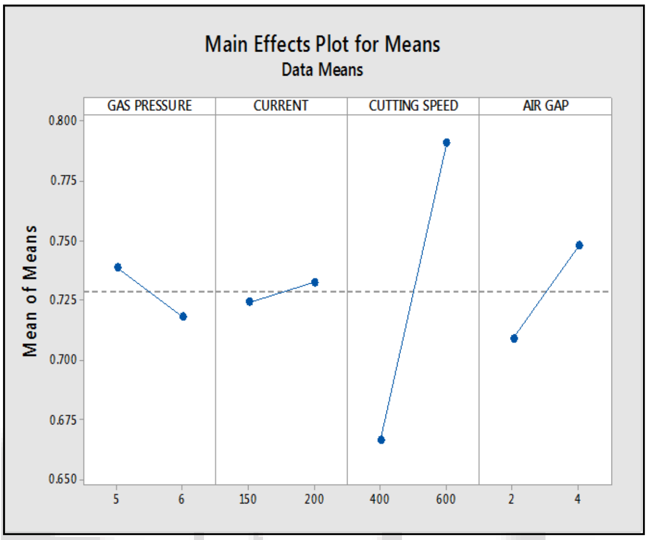
Orthogonal array of L 16 type was selected and the data was analyzed using Minitab 18 software and the results obtained were tabulated as;

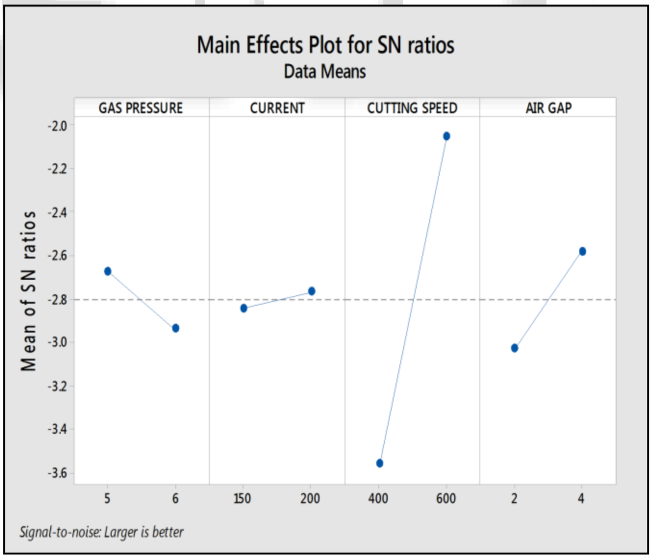
A. Experimental Values of MMR & SR

S No.	Initial Mass	Final Mass	Loss of Mass	Time taken	MMR (g/Sec)	SR
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	0.60000	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

IV. Experimental Results for MRR

"Larger is better" condition is preferred for MRR. The main effects plot for mean and SN ratio obtained using MINITAB 18 is below;

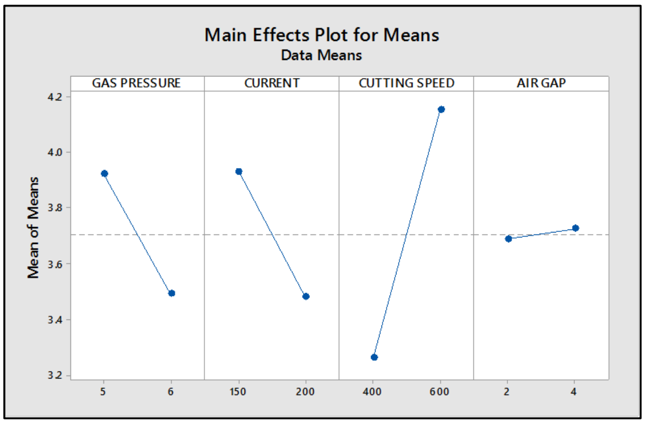


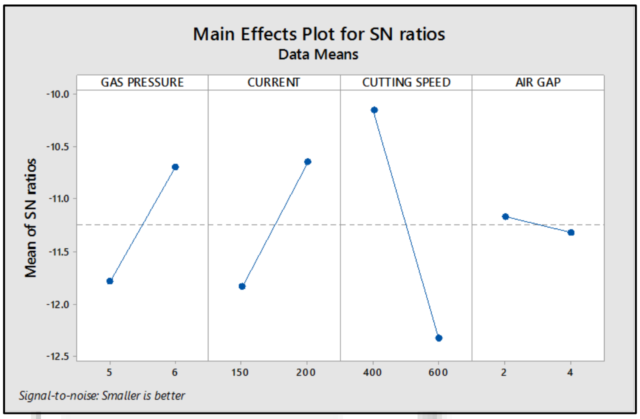


By using MINITAB it is evident that with increase in Gas Pressure MRR S/N ratio is decreasing. Material removal rate increases with increase in Current, Cutting Speed and Arc gap. Hence the optimal condition for material removal rate is A1B2C2D2.

A. Experimental Results for Surface Roughness

"Smaller is better" is preferred for surface roughness. The main effects plot for mean and SN ratio obtained using MINITAB 18 is below;



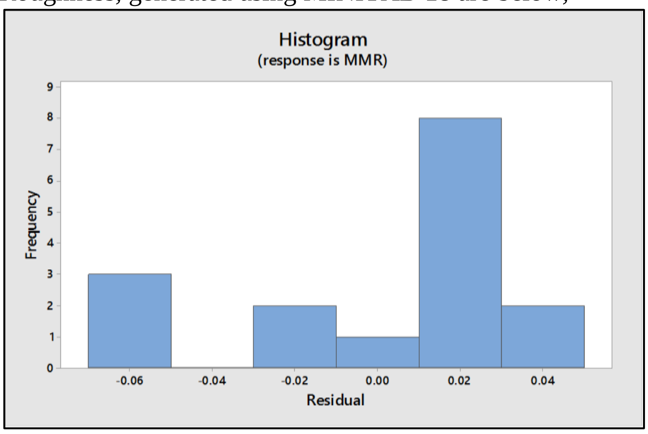


The graphs represent the effect of parameters on Surface Roughness. It can be seen that as value of Gas Pressure and Current increases, S/N ratio of Surface roughness also increases. However S/N ratio of Surface roughness decreases with increase in the Cutting Speed and Arc Gap. Hence the optimal condition for material removal rate is A2B2C1D1.

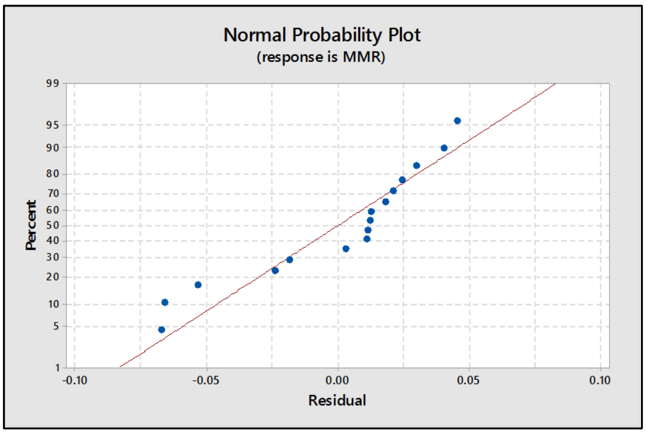
Once the optimal value of MRR and SR is predicted, the final step is to verify the improvement of the quality characteristic using the optimal level of the process parameters.

B. Analysis of Variance (ANOVA)

Since as already stated ANOVA help us to identify which parameter is important for us after literature review following ANOVA table is obtained for MRR and Surface roughness. Minitab 18 software is used for statistical calculation purpose. Normal probability plot and Histogram for MRR and Surface Roughness, generated using MINITAB 18 are below;



Residual Histogram for MMR



Normal plot of Residuals for MMR

V. CONCLUSION

During the work Taguchi method was used for optimization of process parameters for achieving the enhanced response parameters for the machining processes. The Taguchi method provides a systematic and efficient methodology for determining optimal parameters with far less work than would be required for most optimization techniques. The confirmation experiments were conducted to verify the optimal parameters. It has been shown that Material Removal Rate (MRR) and Surface Roughness (Ra) can be significantly improved in the Plasma Arc Cutting process using the optimum level of parameters.

The Plasma Arc Cutting (PAC) machining of Stainless Steel has been performed with the application of combination with design of experiment (DOE).The design factors were selected with two levels for each and same was analyzed for achieving the optimum condition. Some design factors were kept constant throughout the experiment work as same will involve higher order of orthogonal array. The PAC parameters studied were Gas Pressure, Current flow, Cutting Speed and Arc gap of machine. The software utilized during the thesis work was MINITAB 18. Using the Taguchi method the graph for response parameters was generated and studied. From the graph the effect of various parameters was studied depending upon the condition accepted i-e Either Larger is better or Smaller is better.

Analysis of Variation was studied using the MINITAB Software and it was observed that some parameters are not making any significant effect .This is because we must take large number of observations either by considering L27 0r L32 orthogonal array with 3 level designs.

ACKNOWLEDGEMENT

I would like to express my deep sense of respect and gratitude toward my supervisor Mr. ASHIF ALI, who not only guided the academic/industrial project work but also stood as a teacher and philosopher in realizing the imagination in pragmatic way, I want to thank him for introducing me for the field of Optimization and giving the opportunity to work under him. His optimism has provided an invaluable influence on my career and outlook for the future. I consider it my good fortune to have got an opportunity to work with such a wonderful person.

REFERENCES

[1] Tarng Y S, Yang , Application of the Taguchi Method to the Optimization of the Submerged Arc Welding Process.
[2] Hatala Michal Faculty of Manufacturing Technologies, Principle of Plasma Cutting Technology.
[3] Jeffus Larry (2003). Welding Principles and Applications: Sixth Edition.