International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 3, Vol. 3, Dec. 2016.
e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 57-61

Optimization for Process Parameter of MIG Welding For Stainless Steel (SS-304) and Mild Steel Using Taguchi and ANOVA Method

Shalaka A. Mahajan
mahajanshalakaa@gmail.com

Er. N. K. Patil

Department of Mechanical Engineering,
SSBT College of Engineering,
Jalgaon, Maharashtra, India

***Abstract*—Metal inert gas welding (MIG) is a gas welding process used in industries for various purposes. Apart from its application in industry it plays a very crucial role in the production of aerospace and aerodynamic structures. MIG welding is one of the modern and advanced methods used for joining two dissimilar materials. The aim of this research project is to determine the influence of various welding parameters. The two metals stainless steel SS304 and mild steel are join by MIG welding process. The parameters of MIG welding are optimized using Taguchi method. Nine experimental runs (L9) based on an orthogonal array Taguchi method were performed. This project presents the effect of welding parameters like welding speed, welding current and welding voltage. The ultimate tensile strength is calculated on UTM machine. The most significant factor and predicted optimal parameter setting is obtained by applying the ANOVA and signal to noise ratio (S/N ratio). Experiment with optimized parameter setting, is giving valid results. The confirmation test is conducted and found that results are closer to the optimized results. These results showed the successful correlation between experimental and statistical techniques.**

***Index Terms*—** MIG welding, optimization, orthogonal array, S/N ratio.

I. INTRODUCTION

The joining of dissimilar metals is generally more challenging than that of similar metals because of difference in the physical, mechanical and metallurgical properties of the metals to be joined. The main purpose of dissimilar metal joining are to gain good mechanical properties of one material and either low specific weight or good corrosion resistance or good electrical properties of second material. In recent years the joining processes for dissimilar materials have received considerable attention in many fields. Much of this activity has focused on the transportation industries such as aerospace, aviation, shipbuilding, railway transportation. In more specific manner, welding austenitic stainless steels to carbon and low alloy steels are widely practiced in the process and construction industries. Austenitic stainless steel is a high alloy steel. These alloying elements increase its thermal resistance, corrosion resistance and strength, therefore this type of steel is much recommended. Low carbon steels are those which contain carbon less than 0.15% and easily joined by welding. Some industries use these steels for lining process (low carbon steel with stainless steel) especially in pressure vassals industry and metal inert gas welding (MIG) is used extensively for these processes. Stainless Steel 304 is a nickel and chromium based alloy, which is widely used in valves, refrigeration equipment, evaporators, cryogenic vessels due to their exceptional corrosion resistant, high ductility, non-magnetic and it retains solid phase up to 1400 degree Celsius. Welding is a reliable and efficient metal joining process used in almost all industries. Welded joints are extensively used in the fabrication industry, including ships, offshore structures, steel bridges, aerospace and pressure vessels. Steel pipes have been in widespread use for the engineering applications such as nuclear power plants, underground pipelines, etc. Physical properties desired in any welded components are like tensile strength, Yield strength and, elongation. To achieve these physical properties, penetration is the key parameter to check. Weld penetration is the method of measuring the quality of a product and is an important parameter in welding process. It is one of the prime requirements of customers for welded parts.

II. LITERATURE REVIEW

S. D. Ambekar [1] The present study is to investigate the influence of welding parameters on the penetration. The optimization for Gas metal arc welding process parameters (GMAW) of Martensitic Stainless steel work piece AISI 410 using Taguchi method is done. Sixteen experimental runs (L16) based on an orthogonal array Taguchi method were performed. This paper presents the effect of welding parameters like welding speed, welding current and wire diameter on penetration. The ANOVA and signal to noise ratio (S/N ratio) is applied to identify the most significant factor and predicted optimal parameter setting. The confirmation test is conducted and found the results closer to the optimize results. The Process parameters such as, welding current, wire diameter and welding speed are studied and optimized. It is observed that the welding speed is most influencing factors and gas flow rate is least influencing factor. The optimal parameter setting for GMAW process was selected by using grey-based Taguchi method so as to improve a cost function of important welding quality parameters. An L16 orthogonal array was adopted to conduct the experiment suggested by MINITAB14 Statistical software. ANOVA was performed to find the impact of process parameters on the individual quality parameters. It is observed that by using Taguchi method analysis the optimum combination of the machine is found that A-4, B-4 and C-4 i.e. welding speed = 60 cm/min, welding current = 110 amp and wire diameter = 1.2 mm percentage contribution of various parameters for MIG welding found to be welding speed 46.61 %, welding current 21.24 % and wire diameter is 27.25 % and the error is found to be 4.90 %. This error is due to human ineffectiveness and machine vibration.

M. Durairaj [2] This paper summarizes the Grey relational theory and Taguchi optimization technique, in order to optimize the cutting parameters in Wire EDM for SS304. The objective of optimization is to attain the minimum kerf width and the best surface quality simultaneously and separately. In this present study stainless steel 304 is used as a work piece, brass wire of 0.25mm diameter used as a tool and 16, orthogonal array has been used. The input parameters selected for optimization are gap voltage, wire feed, pulse on time, and pulse off time. Dielectric fluid pressure, wire speed, wire tension, resistance and cutting length are taken as fixed parameters. For each experiment surface roughness and kerf width was determined by using contact type surf coder and video measuring system respectively. By using multi objective optimization technique grey relational theory, the optimal value is obtained for surface roughness and kerf width and by using Taguchi optimization technique, optimized value is obtained separately. Experimental investigation on wire electrical discharge machining of Stainless Steel (SS304) has been done using brass wire of 0.25mm. The following conclusions are made. The optimized input parameter combinations to get the minimum surface roughness are 40V gap voltage, 2mm/min wire feed, 6 µs pulse on time, 10 µs pulse off time and similarly optimized conditions to get the minimum kerf width are 50V gap voltage, 2mm/min Wire Feed, 4 µs pulse on time, 6 µs pulse off time. Based on the Grey relational analysis, the optimized input parameter combinations to get both the minimum surface roughness and the nominal kerf width are 50V gap voltage, 2mm/min wire feed, 4 µs pulse on time and 4 µs pulse off time. The Analysis of Variance resulted that the pulse on time has major influence on the surface roughness (µm) and kerf width (mm) in both the Taguchi optimization method and Grey relational analysis. The objectives such as surface roughness and kerf width are optimized using a single objective taguchi method and multi objective grey relational analysis and the same has been validated with the experimental results.

V.M Varma Prasad [3] this paper deals with the effects of weld parameters on residual stress developed during TIG welding of pipes. The 3D numerical simulation ANSYS code is used to predict the residual stress distribution developed during circumferential TIG welding. The simulated results are validated using experimental results available in the literature. The effects of welding current and pipe thickness on residual stress and temperature fields at different locations were assessed The FE model for circumferential welding of pipe is developed and the temperature histories for outer and inner surfaces are plotted. The high temperature gradients in the surfaces lead to a plastic deformation in and around the weld zone. During the cooling phase due to the shrinkage and deformation in the weld zone a high compressive stress is developed on the outer surface and a tensile residual stress is developed on the inner surface. That is, from outer surface to inner surface the nature of residual stress changes from compressive to tensile. From the simulated results the following points can be concluded:

- From the simulated finite element model, the temperature distribution and residual stress distribution can be plotted.
- The temperature distributions after the weld source passes are steady in nature.
- Axial residual stress variation along the thickness has much importance in designing the pressure vessels and piping. Residual stress changes from compressive to tensile from outer to inner surface after the welding, and at a particular point it diminishes completely.
- The range of residual stress distribution became wider when welding current increases.

S. V. Sapakal [4] This paper presents the influence of welding parameters like welding current, welding voltage, welding speed on penetration depth of MS C20 material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of MS C20 material & optimize the welding parameters. Finally the conformations tests have been carried out to compare the predicated values with the experimental values confirm its effectiveness in the analysis of penetration. A conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method. The improvement of S/N ratio is 2.13. The experiment value that is observed from optimal welding parameters, the penetration is 5.25mm. & S/N ratio is 14.40.

Vikas Chauhan [5] the quality of a weld joint is greatly defined by the input parameters used in the welding process. All the properties such as tensile strength, hardness, weld-bead geometry and HAZ etc. are depends on the input parameters and defined the quality of weld-joint quality. So selecting the right input parameters at optimum level which satisfies the desired output is very important. As considering the effect of input parameters on the output parameters several mathematical methods are developed. Taguchi design of experiment is one of those methods which are used to optimize the input parameters as per the desired outputs by using its orthogonal array technique. A literature review of application of Taguchi method in the field of welding is given herein. By analyzing the literature on Taguchi approach used for design of experiment in welding process, it is concluded that Taguchi approach can widely be used for reducing the no. of experiments to obtain the desired output of any quality characteristics of welding process. Further, this approach can be used for optimization of process parameters in order to get better results, for which the process could be considered safe, environment friendly and economical.

III. TAGUCHI DESIGN METHOD

The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Taguchi 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 varies. An L-9 orthogonal array is shown below:

TABLE I
L-9 ORTHOGONAL ARRAY

	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

IV. SCOPE OF THE WORK

Metal inert gas welding is one of the widely used techniques for joining ferrous and non ferrous metals. MIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, there is no slag to clean off after welding because no flux used.MIG weld quality is strongly characterized by weld bead geometry. In MIG Welding method, we will optimize other parameters which are not used in this experiment and This experiment will be done for same method or work piece by other DOE method or other optimization techniques and also if you can be compared Experimental result with prediction result by using Finite Element Analysis. Taguchi's DOE or ANOVA, Orthogonal Array shall be used to conduct the experiments. The parameters selected for controlling the process are welding voltage, current and gas flow rate, wire feed rate, wire diameter. Strength of welded joints shall be tested by a UTM. From the results of the experiments, DOE- FEA models shall be developed to study the effect of process parameters on tensile strength and weld pool geometry. Optimization shall be done to find optimum welding conditions to maximize tensile strength and weld pool geometry, depth of penetration etc. of welded specimen. Confirmation tests shall also be conducted to validate the optimum parameter settings.

V. DESIGN OF EXPERIMENT

Type of work piece Joint: Stainless steel 304 & low carbon steel

TABLE II
PROCESS PARAMETERS AND THEIR VALUES AT DIFFERENT LEVELS

Process Parameters	Symbol	Level 1	Level 2	Level 3
Variable Parameters				
Current (A)	A	80	100	120
Voltage (V)	B	16	19	22
Speed (cm/min.)	C	30	40	50

Constant parameters are,
Thickness of work piece: 5 mm
Gas flow rate: 9.5 l/min.

Table III
Conducting the Matrix Experiment

No. of Experiments	Current	Voltage	Speed
1	80	16	30
2	80	19	40
3	80	22	50
4	100	16	40
5	100	19	50
6	100	22	30
7	120	16	50
8	120	19	30
9	120	22	40

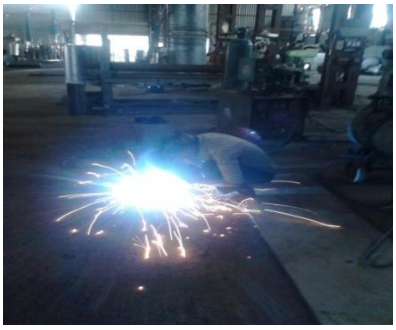

Fig 1. Dissimilar metals welded before breaking

TABLE IV
EXPERIMENTAL RESULTS FOR THE ULTIMATE TENSILE STRENGTH

Trial No.	Ultimate Tensile Strength	S/N Ratio
1	501.24	54.0009
2	530.335	54.4910
3	531.37	54.5079
4	468.80	53.4198
5	510.23	54.1553
6	579.83	55.2660
7	512.43	54.1927
8	539.99	54.6477
9	524.00	54.3866

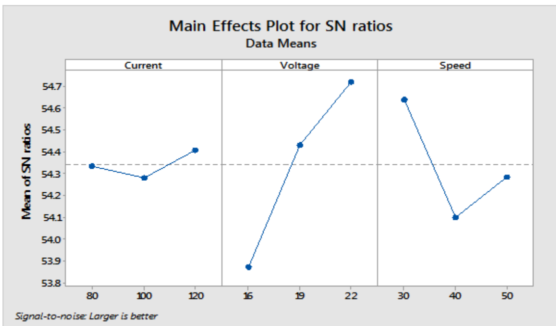

Fig 2: S/N RATIO PLOT

TABLE V
S/N RESPONSE FOR ULTIMATE TENSILE STRENGTH

Level	A	B	C
1	54.33	53.87	54.64
2	54.28	54.43	54.10
3	54.41	54.72	54.29
Delta	0.13	0.85	0.54
Rank	3	1	2

From table, the optimum levels are A3B3C1 which is based on larger-the-better criterion. The ANOVA is a statistical tool used to determine the level of contribution of each process parameter to the overall improvement of the tensile strength of the welded joint. From the above table, the welding voltage has maximum contribution. This has been found to have the most influence on tensile strength. Thus, a little variation in the welding voltage is expected to greatly affect the tensile strength of the weld. Hence, the more the welding voltage, higher the strength.

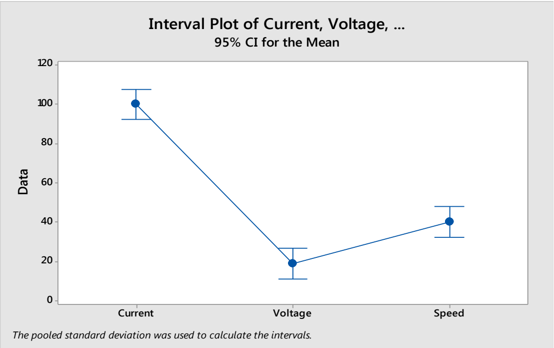

Fig 3: Analysis of variance for ultimate tensile strength

TABLE VI
ANALYSIS OF VARIANCE

Source	DF	Adj SS	Adj MS	F-Value	p-Value	% contribution
Current	2	56.29	28.15	0.02	0.977	0.77
Voltage	2	3993	1996.3	3.6	0.094	54.54
Speed	2	1671	835.4	0.89	0.46	22.82
Error	6	5650	941.6	-	-	21.87
Total	8	7321	-	-	-	100

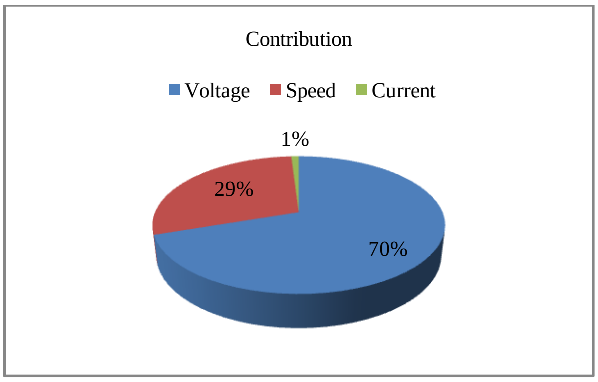

Fig 4: Level of contribution of process parameter

VI. RESULTS

Regression Equation is,
Ultimate Tensile Strength = 394.3+ 0.112 Current + 8.48 Voltage - 1.117 Speed

Table VII
COMPARISION BETWEEN EXPERIMENTAL AND THEORETICAL RESULT

Trial No.	Experimental Results for UTM	Theoretical Results for UTM	Error
1	501.24	505.43	4.19
2	530.335	519.7	9.16
3	531.37	533.97	3.4
4	468.80	496.5	2.7
5	510.23	510.77	0.54
6	579.83	558.55	6.4
7	512.43	487.57	8.48
8	539.99	535.35	4.64
9	524.00	549.62	5.62

As the optimum levels are A3B3C1 and it is not conducted in experiment one more experiment is conducted to find out optimum value. Following values are obtained:

Table VIII
OPTIMUM PARAMETER RESULT

Sr. No.	Current	Voltage	Speed	UTM	Predicted Value	Error
1	120	22	30	590.34	595.56	1.11

From the above results it can be clearly seen that the maximum ultimate tensile strength is obtained by this optimum level. So the optimum parameter from this result is obtained as current= 120A, voltage=22V and speed=30 cm/min.

VII. CONCLUSION

The aim of present work was to optimize the process parameters of MIG welding machine for the dissimilar metal joint for stainless steel (SS- 304) and mild steel using Taguchi design method. MIG welding is one of the best welding technique by which we can join two similar and dissimilar materials. The experiment designed by Taguchi method fulfils the desired objective. Analysis of variance (ANOVA) helps to find out the significance level of the each parameter. The optimum value was predicted using MINITAB-13 software. Based on the investigations following conclusions are drawn.

- MIG welding process is very successful to join stainless steel (SS-304) and low carbon steel.
- Taguchi method can be used to discover the influence of process parameters (current, voltage and welding speed) on the ultimate tensile strength.
- Based on S/N ratio analysis and ANOVA, the process parameters which significantly affects the ultimate tensile strength was voltage and welding speed.
- Confirmation test carried out shows that results coming out at optimum level are under the interval range obtained at 95% confidence level.
- The percentage error between the predicted value and the value obtained from the confirmation testis found to be 1.97%.
- The effect of parameters on the ultimate tensile strength can be ranked in decreasing order as follows: voltage > speed > current.
- Argon as shielding gas has been found to work satisfactorily, very less spatter produce on the weld zone.

- The maximum ultimate tensile strength is obtained on an optimum level i.e. A3B3C1.

References

[1] Ambekar, S. D., and Sunil R. Wadhokar. "Parametric Optimization of Gas metal arc welding process by using Taguchi method on stainless steel AISI 410." International Journal of Research in Modern Engineering and Emerging Technology 3.1 (2015): 1-9.

[2] Durairaj, M., D. Sudharsun, and N. Swamynathan. "Analysis of process parameters in wire EDM with stainless steel using single objective Taguchi method and multi objective grey relational grade." Procedia Engineering 64 (2013): 868-877.

[3] Prasad, VM Varma, et al. "3D Simulation of Residual Stress Developed During TIG Welding of Stainless Steel Pipes" Procedia Technology 24 (2016): 364-371.

[4] Sapakal S. V., and M. T. Telsang. "Parametric optimization of MIG welding using Taguchi design method", International Journal of Advanced Engineering Research and Studies, Vol. I, Issue IV, July-Sept., 2012, pp 28-30.

[5] Chauhan, Vikas, and R. S. Jadoun. "Parametric optimization of MIG welding for stainless steel (SS-304) and low carbon steel using Taguchi design method" International Journal of Recent Scientific Research, Vol. 6, Issue, 2, February 2015, pp.2662-2666,

[6] Chavda, Satyaduttsinh P., Jayesh V. Desai, and Tushar M. Patel. "A Review on Optimization of MIG Welding Parameters using Taguchi's DOE Method." International Journal of Engineering and Management Research 4.1 (2014): 16-21.

[7] Javed Kazi, Syed Zaid, Syed Mohd. Talha, Mukri Yasir, Dakhwe Akib Kazi, "A Review on Various Welding Techniques", International Journal of Modern Engineering Research, Vol. 5, Issue 2, Feb. 2015, pp 22-28.

[8] Ravinder and S. K. Jarial." Parametric Optimization of TIG Welding on Stainless Steel (202) & Mild Steel by using Taguchi Method" International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463 Vol. 4 Issue 6, June-2015, pp: (484-494).

[9] Raut, Mohan B., and S. N. Shelke. "Optimization of Special Purpose Rotational MIG Welding by Experimental and Taguchi Technique." International Journal of Innovative Technology and Exploring Engineering (IJITEE) 4.6 (2014): 39-46.

[10] Gulwadea, Shekhar Rajendra, and R. R. Arakerimathb. "Parameter Optimization of TIG Welding Using Austenitic Stainless Steel" International Journal of Innovative and Emerging Research in Engineering, Volume 2, Special Issue 1, MEPCON 2015.