Optimization of Special Purpose Rotational MIG Welding by Experimental and Taguchi Technique

[1]Sumit Dubey, [2]Dr. Manish Gangil

M.Tech.Scholar[1], Professor[2]

Department of Mechanical Engineering, RKDF, University Bhopal, (M.P.) India.
[1]dubeysumit03@yahoo.in, [2]rkdfbhojpal@gmail.com,

* Corresponding Author: Sumit Dubey

Abstract: *This paper presents the case study to find the design optimization for special purpose MIG welding operation. The MIG Welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the effect of welding parameters like welding current, welding voltage, welding speed, gas flow rate, rotational speed of work piece, filler wire feed rate on MIG welding. Experiments are conducted based on Tagnchi Technique to achieve the required data. An Orthogonal Array, Signal to Noise (SIN) ratio and analysis of varience (ANOVA) are used to find out the welding characteristics and optimization parameters. Finally the confirmations tests have been carried out to compare the predicted values with the experimental values.*

Keywords: *MIG welding, optimization, Design of Experiments (DUE), Analysis of Variance (ANUVA), Signal to Noise (SNR) ratio*

1. INTRODUCTION

Metal Inert Gas (MIG) Welding is a process in which the source of heat is an arc format between consumable metal electrode and the work piece, and the arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of gas either inert such as argon, helium or an argon-helium mixture or active such as carbon dioxide, argon-carbon dioxide mixture, which is chemically active or not inert (Karadeniz et al. 2007). Initially GMAW was called as MIG Welding because only inert gasses were used to protect the molten puddle. The application of this process was restricted to aluminum, deoxidized copper and silicon bronze. Later it was used to weld ferrite and austenitic steels, and mild steel successfully by using active gasses in place of inert gasses and hence was term MAG (Metal Active Gas) welding (Suban and Tusek, 2003, Quinn et al.1999). The American Welding Society refers to the process Gas Metal Arc Welding process to cover inert as well as active shield gasses. GMAW is basically a semi-automatic process, in which the arc lengths of electrode and the feeding of the wire are automatically controlled. The welding operator's job is reduced to positioning the gun at a correct angle and moving it along the seam at a controlled travel speed. Hence less operator skill is required with this process as compare to TIG and manual metal arc process. Yet basic training is required in the setting up of the equipment and manipulation of the gun must be provided to the operator to ensure quality GMAW welding (Jang et al. 2005, Praveen and Yarlagadda, 2005). GMAW welding process overcome the restriction of using small lengths of electrodes and overcome the inability of the submerged-arc process to weld in various positions. By suitable adjusting the process parameters, it is possible to weld joints in the thickness range of 1-13 mm in all welding position (Kuk et al. 2004, Murugan and Parmar, 1994)

2. LITERATURE REYIEW

1. **Satyaduttsinh P. Chavda, Jayesh V.Desai, Tushar M. Patel** presented in the paper the influence of welding parameters like welding current, welding voltage, Gas flow rate, wire feed rate, etc. on weld strength, weld pool geometry of Medium Carbon Steel material during welding. By using DOE method, the parameters can be optimized and having the best parameters combination for target quality. The analysis from DOE method can give the significance of the parameters as it give effect to change of the quality and strength of product or does not. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array and analysis of variance (ANOYA) are employed to investigate the welding characteristics of Medium Carbon Steel material and optimize the welding parameters.

2. Nirmalendhu Choudhury, Ramesh Rudrapati and Asish Bandyopadhyay have presented study pertains to the improvement of ultimate load of stainless steel - mild steel weld specimen made of tungsten inert gas (TIG) welding. L_{16} orthogonal array (OA) of Taguchi method has been used to conduct the experiments using several levels of current, gas flow rate and filler rod diameter. Statistical techniques analysis of variance (ANOVA), signal-to-noise (S/N) ratio and graphical main effect plots have been used to study the effects of welding parameters on ultimate load of weld specimen. Optimum parametric condition obtained by Taguchi method. Confirmatory test has been conducted to validate the predicted setting.

3. S R. Patil, C. A. Waghmare studied the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (DTS) of AlSI 1030 mild steel material during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (SIN) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for maximum tensile strength. From this study, it is observed that welding current and welding speed are major parameters which influence on the tensile strength of welded joint.

4. S.R. Meshram, N.S. Pohokar worked on a grey-based Taguchi method is adopted to optimize the Gas Metal Arc Welding Process parameters. Many quality characteristic parameters are combined into one integrated quality parameter by using grey relational grade or rank. The welding process parameters considered in this analysis are voltage, wire feed rate, Welding Speed, Nozzle to Plate Distance and Gas Flow. The quality parameters consider are Penetration, Reinforcement, and Bead Width.

5. Meenu Sharma and Dr. M. Khan have given the details of application of Taguchi technique to determine the optimal process parameters for submerged arc welding (SAW). A planned experimental work has been carried out on semiautomatic submerged arc welding machine and signal to noise ratios are computed. Contribution of each factor is validated by analysis of variance (ANOVA). The results of the present investigation indicate that the welding voltage in the most significant parameter that controls the bead penetration as compared to other controlling parameters. The contribution of voltage, current trolley speed and nozzle-to-plate distance are respectively: 60.8%, 9.86%, 3.54% and 13.8%. Optimum results have been obtained by using 26V, 475A at a trolley speed of 0.25 and NPDOF 16mm.

6. Sonu Prakash Sharma and Amit Bhudhiraja have discussed an investigation into the use of Taguchi's Parameter Design methodology for Parametric Study of MIG Welding of Austenitic Stainless Steel & Low Carbon Steel. This paper represent bead on plate welds were carried out on AlSI 304 & Low Carbon Steel plates using MIG welding process. Taguchi method is used to formulate the experimental design. Design of experiments using orthogonal array is employed to develop the weld ments. Ideal combination of controllable factor levels was determined for the hardness to calculate the signal-to-noise ratio.

7. M. Aghakhani, E. Mehrdad, and E. Hayati has studied that gas metal arc welding is a fusion welding process having wide applications in industry. In this process proper selection of input welding parameters is necessary in order to obtain a good quality weld and subsequently increase the productivity of the process. In order to obtain a good quality weld, it is therefore, necessary to control the input welding parameters.

8. Dinesh Mohan Arya, Vedansh Chaturvedi and Jyoti Vimal studied to investigate the optimization process parameters for Metal inert gas welding (MIG). The optimization of MIG welding operating parameters are for alloy steel work piece using grey relational analysis method. Sixteen experimental runs based on an orthogonal array Taguchi method were performed. This paper presents the influence of welding parameters like wire diameter, welding current, arc voltage, welding speed, and gas flow rate optimization based on bead geometry of welding joint. The objective function have been chosen in relation to parameters of MIG welding bead geometry Tensile strength, Bead width, Bead height, Penetration and Heat affected zone (HAZ) for quality target. Optimal parameters contribution of the MIG operation was obtained via grey relational analysis.

9. Chandresh N. Patel has studied about welding as a manufacturing process, which is carried out for joining of metals by metal inert gas (mig) welding and tungsten inert gas (tig) welding. All welds will be prepared by MIG and TIG welding technique. I have studied Design of Experiment method (Full factorial method) for this work and by use of the experimental data have optimized by grey relational analysis (GRA) optimization technique. In which input parameters for MIG welding are welding current, wire diameter and wire feed rate and the output parameter is hardness.

10. Lenin N., Sivakumar M. and Vigneshkumar D has studied welding as a basic manufacturing process for making components or assemblies. Recent welding economics research has focused on developing the reliable machinery database to ensure optimum production. In this paper, the optimization of welding input process parameters for obtaining greater weld strength in the manual metal arc (MMA) welding of dissimilar metals like stainless steel and carbon steel is presented.

11. MOHD. SHOEB, Prof. Mohd. Parvez, prof. Pratibha Kumari studied the various welding parameters such as welding speed, voltage and gas flow rate were varied on HSLA steel and the the effects of these parameters on weld bead geometry such as penetration, width & height have been studied. Mathematical equations have been developed using factorial technique. And the result of various effects are shown in tables. (Numerical Values).

12. Biswajit Das, B. Debbarma, R. N. Rai, S. C. Saha studied the effect of various welding process parameters on the weldability of Mild Steel specimens of grade EN-3A having dimensions 150mm, 100mm, 6 mm, welded by metal inert gas welding were investigated. The welding current, arc voltage, welding speed are chosen as welding parameters. The depth of penetrations were measured for each specimen after the welding operation is done on closed butt joint and the effects of welding speed, current, voltage parameters on depth of penetration were investigated an experimental study has been done for finding the depth of penetration of welded joint in MIG welding process for welding a mild steel specimen of grade EN-3A.

13. Vinod Kumar has studied the paper to investigate the effects of process parameters on weld bead width of austenitic stainless steel SS-310 in tungsten inert gas welding. The four parameters namely welding current, type of gas, gas flow rate and included angle of weld plates during butt j oint were varied at three levels. The DOE approach was used to design experimental conditions. Orthogonal array L_9 was used for carrying out experimentation. The optimization of weld bead width in tungsten inert gas welding of austenitic stainless steel alloy was done using ANOVA.

14. Omar Bataineh, Anas Al-Shoubaki; Omar Barqa Wi MIG studied that welding is among the most important processes in assembly operations for aluminum alloys. The success of this process in terms of providing weld joints of good quality and high strength depends on the process conditions used in the setup. This study aims at identifying and optimising the main factors that have significant effect on weld joint strength through factorial

3. EXPERIMENTAL SET-UP AND METHODOLOGY

Test set up, interaction, and techniques utilized for welding, material handling, strategies utilized for improving cycle boundaries are shrouded in this section.

3.1 MATERIALS AND METHODS

Butt weld joints are arranged utilizing GTAW under changed interaction boundaries of welding as given by L_9 symmetrical exhibit of Taguchi strategy under argon gas protecting. The exploratory set up showing the gas tungsten circular segment welding machine and dormant gas chamber has been displayed in fig.1 and fig.2. The welding machine is Lincoln Electric Italia make with 3 stages, 400V. Treated steel welded test got together with the extremity of direct current terminal negative using diverse cycle boundaries have been portrayed in Table1. The particular of GTAW machine has been uncovered in Table 2.

Table-1: Input parameters and their levels

Process parameters	**Levels**		
	1	**2**	**3**
Welding current, A (A)	90	100	110
Gas flow rate, LPM (B)	1.0	1.5	2.0
Root face, mm (C)	1.0	1.5	2.0
Welding speed ,mm/min (D)	15.384	21.428	31.578

The base metal sheets of dimensions 100mm x 50mm x 6mm were cut on power hacksaw machine. As the thickness of the plates is 6mm, a V groove butt joint of 450 groove angle is made (Fig. 4). Weld beads of 50 mm length were deposited along the width using 2.4 mm filler wires of ER SS304L. The experimental flow chart is shown in fig. 5.Table 5 shows chemical, physical and mechanical properties of AISI 304 stainless Steel used for the study.

Table-2 Specification of TIG welding machine

Manufacturer, Model No.	Lincoln Electric Italia, V260-T
Main Supply Voltage, Frequency & Max. Primary Current	400V3phase, 50/60 Hz., 21 A
Max Observed Power and No-load voltage	14.6 KVA, 80V
Current with duty cycle 35%	260 A
Current with duty cycle 60%	200 A
Current with duty cycle 100%	160 A
Dimension, Wt., Production Class	144×19×25.5 cm, 14/16 kg, IP 21

Fig.1 Shielding Gas (Argon: 99.9% Pure) Fig. 3 Welding Power Source

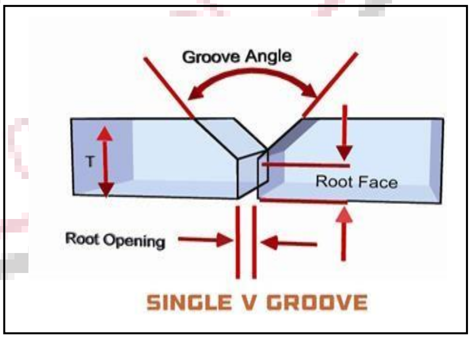

Fig.2 Welded specimen Fig. 4 Configuration diagram of work-piece

Table 3: Chemical Properties of AISI 304 Stainless Steel

(Base Metal: AISI 304 SS)								
Element	**C**	**Cr**	**Mn**	**Ni**	**P**	**S**	**Si**	**Fe**
Wt. (%)	0.02	18.90	2.00	10.0	0.043	0.02	0.87	Balance
(Filler Metal: ER SS304L)								
Element	**C**	**Cr**	**Mn**	**Ni**	**P**	**S**	**Si**	**Fe**
Wt. (%)	0.03	18-19	2	8-12	0.045	0.03	0.75	Balance

Table 4: Physical Properties of AISI 304 stainless Steel

Grade	**Density(g/cc)**	**Mean Coefficient of Thermal Expansion(µm/m/°C)**	**Thermal conductivity (W/m^{0}c) at 25^{0}c**	**Resistivity(Ω.cm)at 20^{0}c**
AISI 304	8	16.9	16.2	7.2e-005

Table 5: Mechanical Properties of AISI 304 stainless Steel

Grade	**Yield strength (MPa)**	**Tensile Strength (MPa)**	**Elongation (%)**
AISI 304	290	621	55

4. RESULTS AND DISCUSSION

The welding operation was carried outs on stainless steel test-pieces as per the parameters incurred by the Taguchi's orthogonal array ass givens in the Table 3. The distortion was measured using Vernier caliper and the results of distortion and depth of Penetration (DOP) have been shown in Table 4.

A larger value of S/N ratios corresponds to better quality characteristics.

Tables 6: Response Table for S/N ratios for distortions (smaller-the-better)

Level	**I (A)**	**GFR (LPM)**	**RF(mm)**	**WS (mm/min)**
1	8.5253	3.2099	6.9717	-2.5347
2	1.4790	12.4644	4.4370	7.2236
3	6.1679	0.5048	4.7705	11.4903
Delta	7.0533	11.9596	2.5347	14.0250
Rank	3	2	4	1

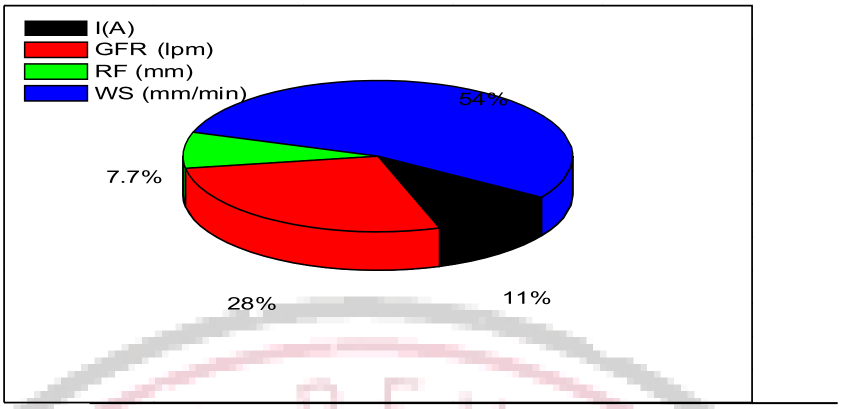

Fig. 3 Percentage Contribution of factors affecting welds distortion

Table 7: Response Table for mean for weld distortion

Level	I(A)	GFRs (LPM)	RF(mm)	WS (mm/min)
1	0.5000	0.7167	0.6967	1.4667
2	0.8667	0.4133	1.0500	0.5667
3	1.0133	1.2500	0.6333	0.3467
Delta	0.5133	0.8367	0.4167	0.3467
Rank	3	2	4	1

Table 8: ANOVA table for weld distortion

Sources	DOF	SS	MS	%P
I(A)	2	0.41947	0.209735	10.720
GFRs (lpm)	2	1.07647	0.538235	27.520
RF (mm)	2	0.30247	0.151235	7.730
WS (mm/min)	2	2.1128	1.0564	54.030
Error	0			
Total	8	3.91121		100.000

Therefore optimized level is the level with largest values of S/N ratio. Response table for S/N ratio of weld distortion is shown in Tables 5. The means of weld distortions has been shown in Table 6. From Tables 7, it is founds that welding speeds and gas flow rate have maximums effects on welds distortion of GTA welded AISI 304 stainless steel plate. The above table gives the values of control factors at each level. Fig.5 gives the relative percentage contribution of parameters of welding speed, welding current, and gas flow rate and root face. It is understood further that there is comparatively higher effects of welding speed and gas flow rate on weld distortion of welds joints. Fig. 4 and Fig.5 shows the S/N ratios and mean plot demonstrating effects of each parameter on weld distortions of GTA welded AISIs 304 stainless steel plate. The ANOVA table for distortion has been depicted in Table 8. It is observed that currents and root faces have relatively less effects on welds distortion.

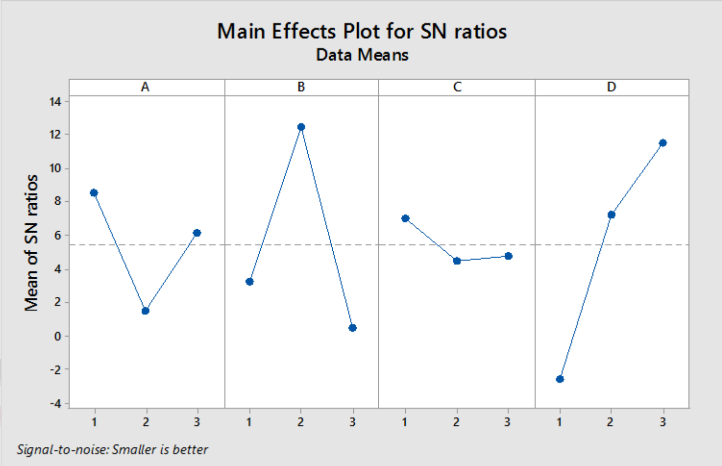

Fig. 4 Main effects plot of S/N ratio (weld distortion)

Fig. 5 Main effect plot of Mean (weld distortion)

5. CONCLUSION

This work presents improvement of the cycle boundaries of gas tungsten curve welding by taking weld twisting, profundity of weld dot entrance as a reaction variable. The accompanying end can be drawn for powerful welding of treated steel plate by gas tungsten circular segment welding measure as follows:

(1)Welding velocity (WS) is the main boundary for contortion during gas tungsten curve welding. The suggested parametric blend for ideal contortion is welding current (90 A), gas stream rate (10 LPM), root face (1 mm) and welding speed (31.578 mm/min) and the ideal reaction esteem is 2.3996 mm.

(2) A affirmation try was additionally performed and confirmed for the adequacy of the Taguchi technique. The test esteem acquired from setting of ideal welding boundaries was discovered 2.2587 mm. The % blunder between anticipated ideal and trial upsides of metal affidavit rate was found 5.871.

3) Welding current (A) is the main boundary for profundity of globule infiltration (DOP) during GTA welding. The suggested parametric blend for ideal profundity of globule entrance is welding current (110 A), gas stream rate (10 LPM), root face (1.5 mm) and welding speed (31.578 mm/min.) and the ideal reaction esteem is 5.6961 mm.

References

[1] Gangil, Manish, and M. K. Pradhan. "Modeling and optimization of electrical discharge machining process using RSM: a review." *Materials Today: Proceedings* 4.2 (2017): 1752-1761.

[2] Gangil, Manish, M. K. Pradhan, and Rajesh Purohit. "Review on modelling and optimization of electrical discharge machining process using modern techniques." *Materials Today: Proceedings* 4.2 (2017): 2048-2057.

[3] Gangil, Manish, and M. K. Pradhan. "Optimization the machining parameters by using VIKOR Method during EDM process of Titanium alloy." *Materials Today: Proceedings* 5.2 (2018): 7486-7495.

[4] Pradhan, M. K., Manish Gangil, and Prabhat Ranjan Kumar. "Application of MCDM for Optimization of EDM of LM6 Silicon Carbide Boron Carbide Hybrid Composite." *In6th International and 27th All India Manufacturing, Technology, Design and Research conference (AIMTDR 2016)*. 2016.

[5] Gangil, Manish, and M. K. Pradhan. "Electrical discharge machining of (Ti–6Al–4V) using RSM." *6th International and 27th All India Manufacturing, Technology, Design and Research conference (AIMTDR 2016)*. 2016..

[6] Gangil, Manish, and M. K. Pradhan. "Optimization of machining parameters of EDM for performance characteristics using RSM and GRA." *J. Mech. Eng. Biomech* 2.4 (2018): 27-33.

[7] Basak P.K and Gangil Manish "CNC Machine-A Boon For Engineering Industries For Performing Innovative Machining Of Cylindrical And Prismatic Parts" Industrial Engineering Journal (ISSN-0970-2555), 2021

[8] Basak P.K and Gangil Manish "FEA Designing of Propeller Shaft and Stress Analysis" Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 04, Issue 01, March-2021.

[9] Singh Ajit and Gangil Manish "Taguchi Optimization of Process Parameters on the Hardness and Impact Energy of Aluminum Alloy" Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 03, Issue 02, June 2020.