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

Mohan B. Raut, R. S. Shelke

Abstract: This paper presents the study to find the optimization for special purpose rotational 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 wire feed rate, welding voltage and tip to plate distance on MIG welding strength and quality of weld. Experiments are conducted based on design of experiments (DOE) of Taguchi Technique to achieve the required data. An Orthogonal Array, Signal to Noise (S/N) 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, optimization, Design of Experiments (DOE), Analysis of Variance (ANOVA), Signal to Noise (S/R) ratio

I. INTRODUCTION

Metal Inert Gas (MIG) welding is a process in which the source of heat is an arc formed between consumable metal electrode and the work piece, and the arc & 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. MIG welding, also called as Gas Metal Arc Welding (GMAW) is basically a semi automatic process, in which the arc lengths of electrode and the feeding of the wire are automatically controlled. The 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.GMAW welding process overcomes the restriction of using small lengths of electrodes and overcome the inability of the submerged-arc process to weld in various positions.

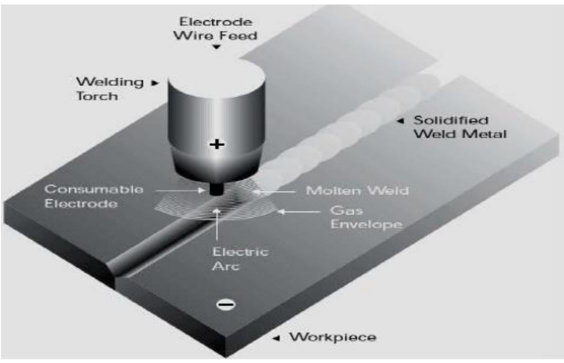

Fig. 1 Principle of MIG welding

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1.1. Factors Affecting Mig Welding

a) Welding Voltage: The arc length is one of the most important variables in MIG that must be held under control. When all the variables such as the electrode composition and sizes, the type of shielding gas and the welding technique are held constant, the arc length is directly related to the arc voltage. High and low voltages cause an unstable arc. Excessive voltage causes the formation of excessive spatter and porosity, in fillet welds it increases undercut and produces narrower beads with greater convexity, but an excessive low voltage may cause porosity and overlapping at the edges of the weld bead. And with constant voltage power source, the welding current increase when the electrode feeding rate is increased and decreased as the electrode speed is decreased, other factors remaining constant.

b) Welding Current: In MIG welding, metals are generally welded with direct current polarity electrode positive (DCEP, opposite to TIG welding), because it provides the maximum heat input to the work and therefore a relatively deep penetration can be obtained. When all the other welding parameters are held constant, increasing the current will increase the depth and the width of the weld penetration and the size of the weld bead.

c) Welding Speed : It is the rate at which the arc travels along the work- piece. It is controlled by the welder in semiautomatic welding and by the machine in automatic welding. The effects of the travel speed are just about similar to the effects of the arc voltage. The penetration is maximum at a certain value and decreases as the arc increased welding current, welding speed and arc voltage The grain size of microstructure also different from one point to another point.

d) Wire Feed Rate: MIG welding requires a wire feed system which feeds the electrode or filler wire to the weld joint. The wire feed is regulated in mm per minute.

e) Tip to Plate distance: The tip to plate distance is the gap between wire tip and work piece. It grealy ffects the quality of MIG welding.

f) Shielding Gas & Flow Rate: The primary function of shielding gas is to protect the arc and molten weld, pool from atmosphere oxygen and nitrogen. If not properly protected it forms oxides and nitrites and result in weld deficiencies such as porosity, slag inclusion and weld embrittlement. Thus the shielding gas and its flow rate have a substantial effect on arc characteristics, Mode of metal transfer, penetration and weld bead profile, speed of welding, cleaning of action, weld metal mechanical properties. Argon, helium and argon-helium mixtures are used in many applications for welding non-ferrous metals and alloys. Argon and Carbon dioxide are used in Carbon steel.

f) Electrode Size: To get the maximum deposition rate at a given current, one should have the smallest wire possible that provides the necessary penetration of the weld. The larger electrode diameters create weld with less penetration but welder in width. The choice of the wire electrode diameter depends on the thickness of the work piece to be welded, the required weld penetration, the desired weld profile and deposition rate, the position of welding and the cost of electrode wire.

II. LITERATURE REVIEW

K Satyaduttsinh P. Chavda studied and investigated 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 (ANOVA) are employed to investigate the welding characteristics of Medium Carbon Steel material and 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 weld strength and Depth of penetration. [1]

Nirmalendhu Choudhury et al. have studied and investigated the improvement of ultimate load of stainless steel – mild steel weld specimen made of tungsten inert gas (TIG) welding. L16 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. [2]

Mr.L.Suresh Kumar et al. Studied and investigated in Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Process of TIG & MIG Welding that about the mechanical properties of austenitic stainless steel for the process of TIG and MIG welding. [3]

S R. Patil et al. studied and found the the problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality Various optimization methods can be useful to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. Design of experiment (DoE) techniques has been applied to carry out such optimization. Taguchi method have been adapted for many applications in different areas. [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. 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. I. Khan have gievn 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. [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 AISI 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. [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. [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. [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. In which input parameters for MIG welding are welding current, wire diameter and wire feed rate and the output parameter is hardness. Also the input parameters for TIG welding are welding current, wire diameter. [10]

Lenin N., Sivakumar M. and Vigneshkumar D has studied welding as a basic manufacturing process for making components . The Taguchi method is adopted to analyze the effect of each welding process parameter on the weld strength, and the optimal process parameters are obtained to achieve greater weld strength. [11]

Abbas Al-Refaie, Tai-Hsi Wu, Ming-Hsien Li state in "An Effective Approach for Solving The Multi-Response Problem in Taguchi Method" that a simple, yet very effective, approach for solving the multi-response problem in the Taguchi method. S/N ratio is calculated for each factor level, and then weighted with respect to the level of the largest average. [12]

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.

[13] Biswajit Das, B. Debbarma, R. N. Rai, S. C. Saha, national institute of technology, agartala state in "Influence of Process Parameters on Depth of Penetration of welded joint in MIG welding process" that 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. [14] 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 joint were varied. [15]

Omar Bataineh, Anas Al-Shoubaki, Omar Barqawi 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 design experiments. [16] Pawan Kumar, Dr.B.K.Roy, Nishant has studied an investigation into the use of Taguchi's Parameter Design methodology for Parametric Study of Gas Metal Arc Welding of Stainless Steel & Low Carbon Steel. In this research work, bead on plate welds were carried out on AISI 304 & Low Carbon Steel plates using gas metal arc welding (GMAW) process. Taguchi method is used to formulate the experimental design. [17]

S.Naveenkumar, Dr. K. SooryaPrakash, G. Gokilakrishnan, N. V. Kamalesh studied that generally, there is a lack of comparative study regarding the performance of the optimization methods, in other words for a given optimization problem which method would suit better. Literature survey reveals that Taguchi approach is the best suited to improve mechanical properties of weldment, therefore Taguchi approach is selected to optimize the welding parameters for MIG and TIG welding of low carbon steel (AISI 1019). The main aim of the project work is to obtain an optimal value of MIG and TIG welding process parameters (such as voltage, current, and welding speed for MIG welding and Peak current, base current, pulse frequency for TIG welding) resulting in an optimal value of notch tensile strength, impact toughness and hardness when welding low carbon steel (AISI 1019) sheet of 3.15 mm and less than 3 mm thickness. [18]

J.Pasupathy, V.Ravisankar studied Tungsten Inert Gas welding (TIG) process is an important component in many industrial operations. The TIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the influence of welding parameters like welding current, welding speed on strength of low carbon steel on AA1050 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 dissimilar joint and optimize the welding parameters. [19] Lakshman Singh, Davinder Singh, Pragat Singh have studied and investigated in "A Review: Parametric effect on mechanical properties and weld bead geometry of Aluminium alloy in GTAW " that Gas tungsten arc welding (GTAW) is high quality and high precision welding process which are suitable for welding thin metals. Inert gas as helium and argon are used as a shielding gas to prevent the weld bead from air, dust and other contaminations in welding. [20]

Vidal, V. Infante, P. Peças, P. Vilaça studied the Friction Stir Welding (FSW) process is still an innovative solid state mechanical processing technology enabling high quality joints in materials previously considered with low weldability such as most of the aeronautic aluminium alloys. The Taguchi method was used to find the optimal FSW parameters for improvement mechanical behaviour of AA2024-T351. The Taguchi design is an efficient and effective experimental method in which a response variable can be optimized. The parameters considered were vertical downward forging force, travel speed and pin length. [21]

M.St. Weglowski, Y. Huang, Y.M. Zhang state in "Effect of welding current on metal transfer in GMAW" that Purpose: The paper presents findings related to the influence of welding current on metal transfer in GMAW. The main goal was to understand how droplet diameter, droplet velocity and droplet transfer rate change with the wire feed speed which determines the welding current. Design/methodology/approach. [22]

Pradeep Deshmukh, M. B. Sorte suggested that welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld-bead geometry, mechanical properties, and distortion. Performance outputs such as deposition rate, dilution and hardness, which subsequently affect weld quality. An exhaustive literature survey indicates that five control factors, viz., arc current, arc voltage, welding speed, electrode stick-out and preheat temperature, predominantly influence weld quality. In relation to this, an attempt has been made in this study to analyse the effect of process parameters on outputs of welding using the Taguchi method. [23] Satyabrata Podder, Uttam Roy state in "ANFIS based weld metal deposition prediction system in MAG welding using Hybrid Learning Algorithm" that this work proposes a soft computing based artificial intelligent technique adaptive neuro fuzzy interference system (ANFIS), to predict the weld metal deposition in the metal active gas (mag) welding process for a given set of welding parameters using hybrid learning algorithm to have a correct amount of weld metal deposition to meet the correct welding requirement. [24]

P. Dhanapal, Dr.S.S.Mohamed Nazirudeen state in "Parameter Optimization Austempered Ductile Iron using Taguchi Method" that Carbidic Austempered Ductile Iron [CADI] is the family of ductile iron containing wear resistance alloy carbides in the ausferrite matrix. This CADI is manufactured by selecting proper material composition through the melting route.In an effort to obtain the optimal production parameters, Taguchi method is applied. To analyse the effect of production parameters on the machanical properties, signal-to-noise (S/N) ratio is calculated based on the design of experiments and the linear graph.

The analysis of varience is calculated to find the amount of contribution of factors [25]

III. PARAMETERS SELECTION

By literature review and past experience the following input control parameters are selected for optimization.
a. Wire feed rate in mm/min
b. Welding voltage in volts
c. Tip to plate distance in mm. Their levels are defines as per below table.

Table-1 Welding parameters and their Levels

Welding Parameters	Unit	Symbol	Level		
			Level 1	Level 2	Level 3
Wire Feed Rate	mm/min	A	2310	2355	2400
Welding Voltage	volts	B	16	18	20
Tip to Plate Distance	mm	C	5	6	7

IV. DESIGN OF EXPERIMENTS AND EXPERIMENTAL SET-UP

4.1. Design of Experiment (DOE)

It is scientifically setup of the different involved parameters in various combination to do particular operation but generally as the factors increases the No of combinations also increase. It becomes difficult to try all possible combination as it consumes money time and effort .Therefore Taguchi based DOE design of experiment is designed using the OA orthogonal array. Taguchi optimization procedure begins with selection of orthogonal array (OA) with distinct number of levels(L) defined for factor (F) such as wire feed rate (mm/min), welding voltage (volts) and tip to plate distance (mm)
Minimum number of trials in the array is given by-

Na = (L-1)F + 1 ,
= (3-1)3+1
= 7 ≈ 9

where F = Number of factors = 3
L = Number of levels = 3

therefore we take Orthogonal array of $L9$, experiment set up is designed for three levels of wire feed rate (mm/min), welding voltage (volts) and tip to plate distance (mm).

4.2. L9 -3 Level Taguchi Orthogonal Array

Taguchi's orthogonal design uses a special set of predefined arrays called orthogonal arrays (OAs) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affect the process performance (process responses). The corresponding OA is selected from the set of predefined OAs according to the number of factors and their levels that will be used in the experiment.

Below Table-2 shows L9 Orthogonal array i.e experimental runs.

Table-2 Experimental Runs

Expt. No.	Process Parameters			
	Wire Feed Rate	Welding Voltage	Tip to Plate Dist.	Time
	mm/min	volts	mm	sec
1	2310	16	5	20
2	2310	16	6	20
3	2310	16	7	20
4	2310	18	5	20
5	2310	18	6	20
6	2310	18	7	20
7	2310	20	5	20
8	2310	20	6	20
9	2310	20	7	20
10	2355	16	5	20
11	2355	16	6	20
12	2355	16	7	20
13	2355	18	5	20
14	2355	18	6	20
15	2355	18	7	20
16	2355	20	5	20
17	2355	20	6	20
18	2355	20	7	20
19	2400	16	5	20
20	2400	16	6	20
21	2400	16	7	20
22	2400	18	5	20
23	2400	18	6	20
24	2400	18	7	20
25	2400	20	5	20
26	2400	20	6	20
27	2400	20	7	20

4.3. Experimental Set-up

The experimental set up consists of the special purpose rotational MIG welding machine. It consists of wire spool holding holding and feed mechanism, counter for revolution time setting, welding gun holding attachment, work holding fixture and welding transformer for power source.

Fig.1 shows the schematic arrangement of all the components together for the experimental run.

Fig.2 Experimental Set-up

4.4. Experimentation

Initially the flange and pipe both are held firmly in a fixture and manually welding spots (tacking) is done at three places at the periphery. Then the assembly is held on the fixture provided on the special purpose rotational MIG welding machine. The wire feed rate is ensured by manually feeding the wire per unit time. The tip to plate distance is set by using thickness gauge. The welding gun tip is touched at any point on the periphery and the run is started by counter. In one complete revolution, the rotational welding is finished. All the experiments are completed one by one by varying the parameters. The average bead width is measures and the specimen are tested on UTM for strength.

Fig. 3 Specimen

V. RESULTS AND DISCUSSION

The specimens are tested on Universal Testing Machine and all the results are recorded. Table 3 gives the results of experimental runs for total 27 runs.

Table 3 Experimental results

Expt .No.	Process Parameters					
	Wire Feed Rate	Welding Voltage	Tip to Plate Dist.	Time	Bead Wdt.	Load
	Mm/ min	volts	mm	sec	mm	kN
1	2310	16	5	20	3.12	36.48
2	2310	16	6	20	3.09	41.96
3	2310	16	7	20	3.11	45.92
4	2310	18	5	20	3.08	41.96
5	2310	18	6	20	3.12	43.24
6	2310	18	7	20	3.11	43.44
7	2310	20	5	20	3.12	45.16
8	2310	20	6	20	3.13	44.48
9	2310	20	7	20	3.11	44.16
10	2355	16	5	20	3.09	42.00
11	2355	16	6	20	3.1	32.20
12	2355	16	7	20	3.11	39.80
13	2355	18	5	20	3.12	45.12
14	2355	18	6	20	3.13	49.48
15	2355	18	7	20	3.09	41.02
16	2355	20	5	20	3.11	56.08
17	2355	20	6	20	3.13	49.16
18	2355	20	7	20	3.12	27.48
19	2400	16	5	20	3.11	45.56
20	2400	16	6	20	3.12	41.76
21	2400	16	7	20	3.09	46.96
22	2400	18	5	20	3.11	58.00
23	2400	18	6	20	3.12	48.52
24	2400	18	7	20	3.12	41.96
25	2400	20	5	20	3.13	46.00
26	2400	20	6	20	3.12	40.80
27	2400	20	7	20	3.11	48.40

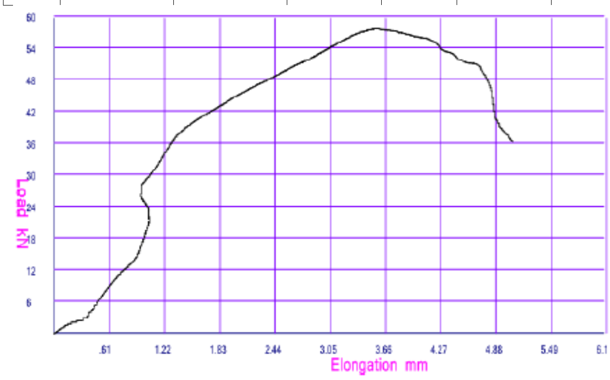

Fig.4 Graph between load vs elongation

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5.1. Taguchi Approach:

Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments. The experimental results are then transformed into signal-to-noise (S/N) ratio. Taguchi recommends the use of the S/N ratio to measure the quality characteristics deviating from the desired values. Usually there are three categories of quality characteristics deviating from the desired values i.e. the lower the better, the higher the better and the nominal is the better. The S/N ratio for each level of process parameter is computed based on S/N ratio analysis. A greater S/N ratio corresponds to the better quality characteristics.

5.2. Signal To Noise Ratio (S/N):

Parameter design study involves control and noise factors. The measure of interaction between these factors with regard to robustness is signal-to–noise (S/N) ratio. The signal to noise ratio (S/N ratio) was used to measure the sensitivity of the quality characteristic being investigated in a controlled manner. In Taguchi method, the term 'signal' represents the desirable effect (mean) for the output characteristic and the term 'noise' represents the undesirable effect (signal disturbance, S.D) for the output characteristic which influence the outcome due to external factors namely noise factors. The S/N ratio can be defined as

$$\text{S/N ratio, } \eta = -10 \log (\text{MSD}) \qquad (1)$$

Where, MSD: mean-square deviation for the output characteristic. The aim of any experiment is always to determine the highest possible S/N ratio for the result. A high value of S/N implies that the signal is much higher than the random effects of the noise factors or minimum variance. As mentioned earlier, there are three categories of quality characteristics, i.e. the-lower-the-better, the higher-the-better, and the-nominal-the-better. To obtain optimal blanking performance, the-lower-the-better quality characteristic for burr height must be taken. The mean-square deviation (M.S.D.) for the-higher -the-better quality characteristic can be expressed as ,

$$\text{MSD} = 1/n \times \Sigma y_i^2 \text{...............} i = 1 \text{ to } n \qquad (2)$$

Where, n = number of repetitions or observations &
yi = the observed data

Table 4 S/N Ratios

S.N	Wire Feed Rate	Welding Voltage	Tip to Plate Dist.	Load	SNRA1	MEAN 1
	mm/min	volts	mm	kN		
1	2310	16	5	36.48	31.2411	36.48
2	2310	16	6	41.96	32.4567	41.96
3	2310	16	7	45.92	33.2438	45.94
4	2310	18	5	41.96	32.4567	41.96
5	2310	18	6	43.24	32.7177	43.24
6	2310	18	7	43.44	32.7578	43.44
7	2310	20	5	45.16	33.0951	45.16
8	2310	20	6	44.48	32.9633	44.48
9	2310	20	7	44.16	32.9006	44.16
10	2355	16	5	42.00	32.4650	42.00
11	2355	16	6	32.20	30.1571	32.20
12	2355	16	7	39.80	31.9977	39.80
13	2355	18	5	45.12	33.0874	45.12
14	2355	18	6	49.48	33.8886	49.48
15	2355	18	7	41.02	32.2599	41.02
16	2355	20	5	56.08	34.4986	53.08
17	2355	20	6	49.16	33.8322	49.16
18	2355	20	7	27.48	28.7803	27.48
19	2400	16	5	45.56	33.1717	45.56
20	2400	16	6	41.76	32.4152	41.76
21	2400	16	7	46.96	33.4346	46.96
22	**2400**	**18**	**5**	**58.00**	**35.2686**	**58.00**
23	2400	18	6	48.52	33.7184	48.52
24	2400	18	7	41.96	32.4567	41.96
25	2400	20	5	46.00	33.2552	46.00
26	2400	20	6	40.80	32.2132	40.80
27	2400	20	7	48.40	33.6969	48.40

Taguchi Design

Taguchi Orthogonal Array Design

L9 (3^3)

Factors: 3

Runs: 9

Columns of L9 (3^3) Array

Table 5 Response Table for Signal to Noise Ratios Larger is Better

Level	Wire Feed Rate	Welding Voltage	Tip to Plate Distance
1	32.65	32.29	33.17
2	32.33	33.18	32.71
3	33.29	32.8	32.39
Delta	0.96	0.89	0.78
Rank	1	2	3

Table 6 Response Table for Means

Level	Wire Feed Rate	Welding Voltage	Tip to Plate Distance
1	42.98	41.41	45.93
2	42.15	45.86	43.51
3	46.44	44.3	42.13
Delta	4.29	4.45	3.8
Rank	2	1	3

Fig. 3 gives the graph for main effects for means and Fig. 4 gives the graph fir main effects for SN ratios.

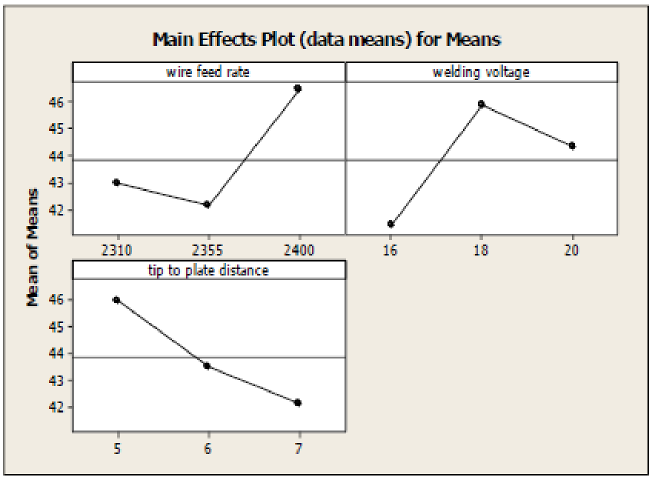

Fig.5. Graph for main effects plot for means

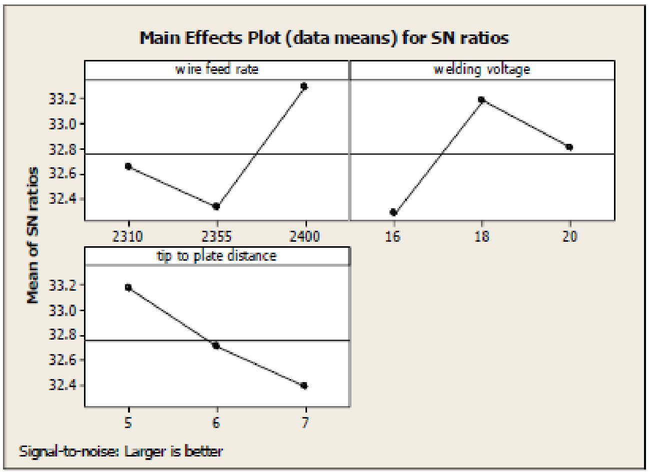

Fig.6 Graph for main effects plot for S/N ratios

Analysis of Variance (ANOVA):

Prof. R.A.Fisher was the first man to use the term “variance” and, in fact, it was he who developed a very elaborate theory concerning ANOVA, explaining its usefulness in practical field. Thus through ANOVA technique one can, in general, investigates any number of factors which are hypothesized or said to influence the dependent variable .The basic principal of ANOVA is to test for differences among the means of the populations by examining the amount of variation within each of these sample. The main aim of ANOVA is to investigate the design parameters and to indicate which parameters are significantly affecting the output parameters. In the analysis, the sum of squares and variance are calculated. F-test value at 95% confidence level is used to decide the significant factors affecting the process and percentage contribution is calculated. Larger F – value indicates that the variation of the process parameter makes a big change on the performance. The analysis of variance (ANOVA) is applied in order to test the equality of several means, resulting in what process parameters (factors) are statistically significant.

Table 7 Analysis of Variance (ANOVA)

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
Wire Feed Rate	2	4.329	4.329	2.165	1.41	0.268
Welding Voltage	2	3.612	3.612	1.806	1.17	0.329
Tip to Plate Distance	2	2.764	2.764	1.382	0.90	0.423
Residual Error	20	30.749	30.749	1.537		
Total	26	41.453				

Note: DF- Degrees of Freedom,

Seq SS – Sequential Sum of Squares,

Adj SS – Adjusted Sum of Squares,

Adj MS – Adjusted Mean Square,

F test of hypothesis,

P value of hypothesis.

VI. CONFIRMATION TEST

Confirmation Test is conducted at optimal parameters combination (A3 B2 C1) i.e. Wire Feed Rate as 2400 mm/min, Welding Voltage as 18 Volts and Tip to plate distance as 5 mm to check the validity of the optimum welding condition. From the results of confirmatio test, it is found that optimum welding parametric condition has procuced maximum welding strength which shows the validation of the proposed optimization methodology.

Table 8 Confirmation Test Results

Obtained optimum parametric condition by Taguchi Technique		Obtained load by Confirmation Test
Wire Feed Rate, mm/min	2400	1. 58.02 kN
Welding Voltage, volts	18	2. 58.00 kN
Tip to Plate Distance, mm	5	3. 57.98 kN

The values of load obtained by testing on UTM in above table indicate the validity of the present optimization procedure by using Taguchi Technique.

VII. CONCLUSIONS

1) From literature review in initial stage of experiment, wire feed rate, welding voltage and Tip to plate distance are the comparatively important parameters which are taken for the experimentation.
2) The present work has successfully demonstrated the application of Taguchi Technique for multi objective optimization of process parameters in Special Purpose Rotational MIG Welding.
3) Design of Experiments (DOE) higher the welding strength of experiment says that the corresponding experimental combination is optimum condition for multi objective optimization and gives better product quality. Also the Taguchi Technique, the factor effect can be estimated and the optimal level for each controllable factor can also be determined.

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4) According to calculation experimental run 22 has the highest strength i.e. 58 kN and has the best multiple performance characteristic among 27 experiments. Optimum level for the experiment are- Wire Feed Rate= 2400 mm/min
Welding Voltage = 18 volts
Tip to Plate Distance = 5 mm
5) Analysis of Variance (ANOVA) for the combine objective indicates that minimum P-values is 0.176187, as shown in table these factors have a statistically significant effect 95.0% confidence level.
6) At the end of thesis, as per the objective mentioned, it is obtained at the end and optimum levels with the good welding quality within designed time.

FUTURE SCOPE

This investigation shows how to optimize the special purpose rotational MIG welding parameters using the Taguchi method. Further research work can add to the optimization of the control factors for heat affected zone, by considering other factors such as wire diameter, welding current, gas flow rate, etc. The research could be taken further by applying the same technique to other welding type which is used in the industry. This could help optimize the production cycle time and cost of production along with effective use of manpower and available resources.

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