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Process Parameters Optimization for Improving th Mechanical Properties of IS2062 MildsteelWeldments by GMAW

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Abstract**—*****Mildsteel is the largely material for industrial and commercial applications. Gas Metal Arc Welding (GMAW) and Gas Tungstan Arc Welding (GTAW) process is the largely used metal joining process for thin gauge milsteel and stainless. This research focus on the on the effect of process welding parameters for acquring greater mechanical properties of weld plates. the Taguchi parametric optimization methodology and regression analysis is identified and used for Acquring the greater welding effectiveness and efficiency. The shielding gas, weld volrage& current is choosen as a process parameters for this research to Acquring the greater welding effectiveness and efficiency. At end of process, the mechanical properties like ultimate tensile strength, toughness and hardness of the weldment. After completion of the experimental work, the S/N ratio and mean S/N ratio were evaluated and the optimum values of each parameters was evaluated through the Taguchi method. Subsequently the significant co-efficient for each input factor of the mechanical properties was evaluated of by using the analysis of variance and prediction on the mechanical properties is evaluated by using regression analysis. In this research, 15 mm IS2062 Mild Steel is welded by GMAW with the shielding gas mixtures of pure(100%) CO2 , Ar+20% CO2, and Ar+10% O2. The tensile strength optimum value was provided by the shielding gas mixture Ar+20% CO2 and also it gives the optimum value for toughness. The superior hardness value is obtained by Pure(100%) CO2 with respect to other shielding gas mixtures. The evaluated values tells that the welding current & shielding gas and have impressive effect on the IS2062 weldment mechanical properties.***

Keywords:GMAW, IS2062, Optimization, Welding process Parameters

I. INTRODUCTION

GMAW is the very common welding process due to it speed,ease of use,ease of automation and speed of welding. GMAW is a less popular for under water welding process [1-4].High weld deposition rate, less distortion and less distortion are the other important advantages of welding process [4-9]. The GMAW weldments mechanical properties are depends on the process parameters like welding current, arc gap, speed, gas flow rate and voltage.

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The proper shielding gas mixture is used to achieve better mechanical properties [10].

The pure carbon di oxide produces the maximum hardness values and the carbon di oxide mixes with the argon produces more tensile strength properties [10, 12, 16]. The welding current raises the deeperweld penetration. And also the arc speed and welding voltage affects the deeper weld penetration. S.R.Patil et.al investigated to improve the strength of welded joints by optimization of various welding parameters [11]. The taguchi method is a analytic technique is mainly incorporated for optimization of welding process parameters. Quality of weld, experiment performing and wastage of resources are reduced by using process Parameter optimization [13, 15].

II. MATERIALS AND METHODS

Mild steel is the easily available, most versatile and less cost form of steel and it provides every application which needs a bulk amount of steel. It is softer and more easily shaped. The IS2062 mild steel is taken as the base weld material for this research. The composition of chemical of IS2062 mild steel is mentioned in the table-1.

Table-1 The composition of Chemical in IS 2062 Mild steel

GRADE	PERCENTAGE	C	Mn	Si	S	P
IS 2062	Minimum	0.23	1.5	0.045	0.40	0.045
	Maximum	0.25	1.55	0.050	0.43	0.050

From the manuscript review and the previous research work done by researchers concluded that the below mentioned parameters are the most important process welding parameters which have the greater influence than other process weld parameters. The most important process parameters considered are, Welding Current (Amps), Gas Flow Rate (LPM), Shielding Gas and Welding Voltage (Volts). Selection of level for the parameters depends upon the number of weld experiments were carried out and the range of MIG weld parameters. Range of MIG welding parameter selection and different levels of parameters for the present study are mentioned in the Table-2 and table-3.

Table-2 GMAW welding process parameters and the different levels

S.No	welding Parameter	Unit	Level-1	Level-2	Level-3
1	Shielding Gas	-	Ar +20% CO_2 (1)	Pure(100%) CO_2 (2)	Ar+10%O_2 (3)
2	Welding Current	Amps	120	150	180
3	Welding Voltage	Volts	20	22	24

Table-3 Constant MIG welding parameters

S.No	MIG welding Parameter	Value
1	Electrode type	ER70S6
2	Wire diameter (mm)	1.
3	speed of welding (mm/sec)	2.2
4	feed rate of wire (m/min)	1.5
5	Metal thickness (mm)	10
6	Gas flow rate (LPM)	10

Selection of process weld parameters for the current study is three and the levels for each MIG weld parameter is three. To calculate Degrees Of Freedom (DOF) by using this formula,

DOF = N*(n-1)

Where,N = Number of process parameters

n = Number of levels

DOF = 3*(3-1) = 6.

Hence, here orthogonal L9 array was selected. The L9 array is mentioned in Table-4.

Table-4 Orthogonal array

S. No	Shielding Gas	Welding current (A)	Welding voltage (V)
1	1	120	20
2	1	150	22
3	1	180	24
4	2	120	22
5	2	150	24
6	2	180	20
7	3	120	24
8	3	150	20
9	3	180	22

The dimensions of weld material are 200mm x 200mm x 15mm (breathxlengthxthick) & 50° groove angle have been prepared and the experiments are done based on orthogonal L9 array layout as tabulated in the table-4. Using acetone, the surface oxides or scales were thoroughly removed for all the samples.

III. RESULTS AND DISCUSSIONS

Tensile properties

Tensile test was performed to evaluate the plasticity, tensile characteristics and strength and of weldments and to evaluate the involvement of defects on weldmentjoint. The UTM (universal testing machine) is used for examine the tensile properties. The tensile characteristics of all joints has been performed in transverse direction. The ASTM E8M-04 standard is used for the tensile test specimen dimension and shape. The Tensile strength of MIG weldments is given in Table-5.

Table-5 Tensile characteristics of MIG weldments

Welding current (A)	Welding voltage (V)	Shielding Gas	Tensile strength (N/mm^2)
120	20	Ar+20%CO2	392
150	22	Ar+20%CO2	386
180	24	Ar+20%CO2	388
120	22	Pure(100%) CO2	387
150	24	Pure(100%) CO2	384
180	20	Pure(100%) CO2	379
120	24	Ar+10%O2	381
150	20	Ar+10%O2	378
180	22	Ar+10%O2	375

The results are clearly noted that the supply shielding gas of argon+18 % carbon dioxide, which provides the best tensile properties than other, protecting gas supply in GMAW process.

Hardness properties

The hardness test was performed to evaluate the weld metal hardness value. The hardness test was evaluated on the transverse direction of the MIG Welding region using the applied load 187.5 kgf, for the time span of 20 s. The hardness test was performed on the Brinell hardness testing machine. The hardness value of welded specimen is mentioned in the Table 6.

Table-6 Hardness value of the weldements

Welding current (A)	Welding voltage (V)	Shielding Gas	Weld metal hardness
120	20	Ar+20%CO2	178
150	22	Ar+20%CO2	176
180	24	Ar+20%CO2	174
120	22	Pure(100%) CO2	180
150	24	Pure(100%) CO2	177
180	20	Pure(100%) CO2	172
120	24	Ar+10%O2	175
150	20	Ar+10%O2	172
180	22	Ar+10%O2	170

The results are clearly noted that the supply shielding gas of pure carbon dioxide will provides the good hardness properties provides than other, protecting gas supply in GMAW process.

Impact properties

The test is evaluated to calculate the impact energy of weld metal and also check the values of output results. The impact test was done on the transverse cross-section on MIG Welding region. The Impact test was done on Charpy testing machine. Toughness value from impact test of MIG weldments was mentioned in the Table-7.

Table-7 Toughness value of the welded specimen

Welding current (A)	Welding voltage (V)	Shielding Gas	Toughness Joules
120	20	Ar+20%CO2	78
150	22	Ar+20%CO2	80
180	24	Ar+20%CO2	84
120	22	Pure CO2	76
150	24	Pure CO2	79
180	20	Pure CO2	77
120	24	Ar+10%O2	73
150	20	Ar+10%O2	71
180	22	Ar+10%O2	76

The results are clearly noted that the supply shielding gas of argon+20% carbon dioxide provides the best toughness properties than other, protecting gas supply in GMAW process.

Find optimum point for mechanical properties

In Taguchi method, Signal/Noise ratio, signal shows the advisable output characteristics value and the noise shows the unadvisable output characteristics values. The S/N ratio takes into account on the differences in data responses and also the near values of the response averages to the target fixed value. Normally the ultimate tensile strength, toughnessandthehardness value of the welded specimen are in the category of larger the better quality features. All the three levels of three process parameters are equally represented in 9 experiments. Then evaluate the S/N ratio for all retaliation in experiments. The S/N ratio for the tensile strength values are tabulated in the Table-8.

Table-8 Signal/Noise ratio for tensile strength

S. No	S/N ratio	S. No	S/N ratio	S. No	S/N ratio
1	51.865	4	51.754	7	51.618
2	51.731	5	51.686	8	51.549
3	51.776	6	51.572	9	51.480

To determine the optimum point for each parameter, the mean of S/N ratio has been determined. The mean of S/N ratio of every factor in every level for tensile strength is mentioned in Table-9 and Figure-1.

Table-9 mean value of the S/N ratio for tensile strength

Process Parameter	Level 1	Level 2	Level 3
Welding Current	51.75	51.66	51.61
Welding Voltage	51.66	51.66	51.69
Shielding gas	51.59	51.67	51.55

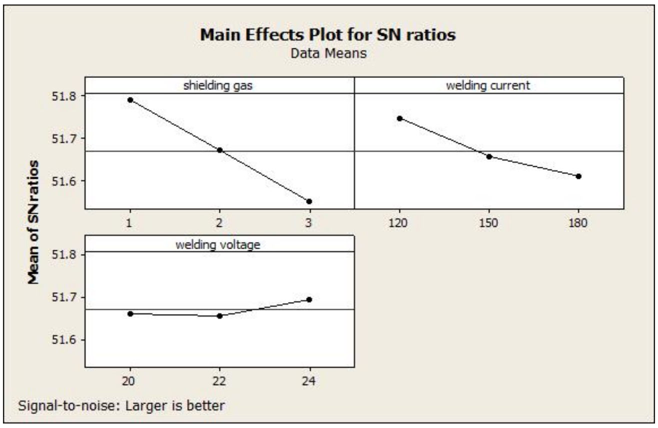

Figure-1 influence of weld parameters on Signal/Noiseratio for Tensile Strength

The Table-9 and Figure-1shows the results of the value of mean Signal/Noise ratio for tensile strength of welded specimen, and then the optimum value for tensile strength is found it. The optimum point is at a process parameter of welding current 120 Amps, welding voltage 24 Volts, shielding gas Ar+20% CO_2.

The Signal/Noise ratio for hardness and value of mean Signal/Noise ratio for Hardness is tabulated in Table - 10 and Table - 11.

Table - 10 S/N ratio for Hardness

S. No	S/N ratio	S.No	S/N ratio	S.No	S/N ratio
1	45.008	4	45.105	7	44.860
2	44.910	5	44.959	8	44.710
3	44.811	6	44.710	9	44.6090

Table-11mean value of Signal/Noise ratio for Hardness

Weld Parameter	Level-1	Level-2	Level-3
Welding Current	44.99	44.86	44.71
Welding Voltage	44.81	44.87	44.88
Shielding gas	44.91	44.93	44.73

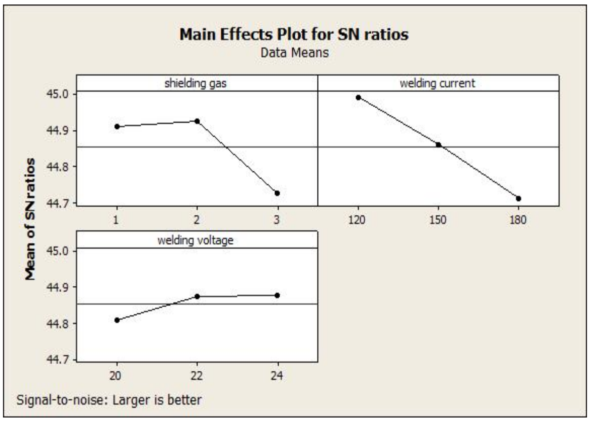

Figure-2 influence of weld parameters on Signal/Noise ratio for Hardness

The Table-11 and Figure-2 shows the results of the mean value of Signal/Noise ratio for hardness of welded specimen, and then the optimum value for hardness is found out. The optimum process weld parameters are welding process current 120 Amps, welding process voltage 24 Volts & shielding gas is pure carbon dioxide.

The Signal/Noise ratio for toughness and the value of mean S/N ratio for toughness of specimen is tabulated in the Table-12 & Table-13.

Table-12 Signal/Noise ratio values for toughness

S.No	S/N ratio	S.No	S/N ratio	S.No	S/N ratio
1	37.841	4	37.616	7	37.266
2	38.061	5	37.952	8	37.025
3	38.485	6	37.729	9	37.616

Table-13 value of mean S/N ratio for toughness

Weld Parameter	Level-1	Level-2	Level-3
Welding Current	37.57	37.68	37.94
Welding Voltage	37.53	37.76	37.90
Shielding gas	38.13	37.77	37.39

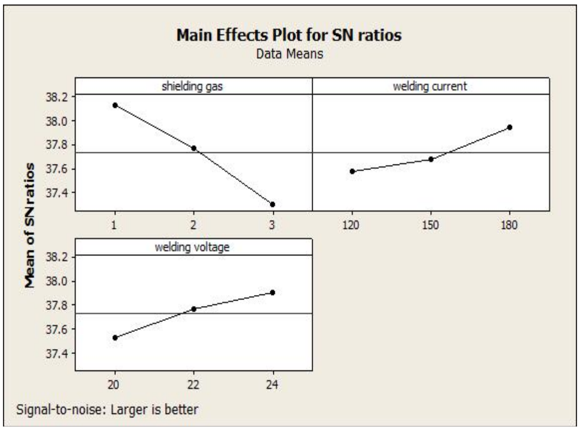

Figure 3 influence of weld parameters on Signal/Noise ratio for Toughness

The Table 13 and Figure 3 shows the output values of the average value of S/N ratio for toughness of welded specimen, and then the optimum value for toughness is found it. The optimum point is at a process parameter of welding current 180 Amps, welding voltage 24 Volts, shielding gas Ar+20% CO_2.

Regression analysis

A regression analysis is established for predict the values of Y dependent variable, with the given a set of explanatory variables p ($x_1,x_2\ldots..x_p$). The mathematical model developed to identify a set of process weld parameters for a desired output characteristics. The input process parameter for equations are welding process voltage, welding process current, shielding gas and output weldment characteristics are weldment toughness, tensile strength, and hardness of the welded specimen. Regression equation for the mechanical properties of the weldment is shown in below.

Tensile strength = 402 - 5.33 shielding gas - 0.100 welding current + 0.333 welding voltage

Weld metal hardness = 185 - 1.83 shielding gas - 0.0944 welding current + 0.333 welding voltage

Impact energy = Impact energy = 57.8 - 3.67 shielding gas + 0.0556 welding current + 0.833 welding voltage

Confirmation test

Optimum levels of design parameters is evaluated, then verify and predict the development of quality parameters. Validation of optimum result as shown in the Table-14.

Table-14 Validation of optimum result

Mechanical properties	Optimum point	Experimental value	Predicted value
Tensile strength (N/mm2)	A1 B1 C3	392	392.67
Hardness (BHN)	A2 B1 C3	178	178.4
Toughness (Joules)	A1 B3 C3	84	84.1

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Table 15 Comparison between experimental values to the predicted values

	Ultimate tensile strength			weld metal hardness			Impact energy		
S.No	**E.V**	**E.V**	**E.V**	**E.V**	**E.V**	**Error%**	**E.V**	**P.V**	**Error%**
1	392	178	78	78	78	0.6	178	178.5	0.6
2	386	176	80	80	80	0.2	176	176.3	0.2
3	388	174	84	84	84	0.0	174	174.2	0.1
4	387	180	76	76	76	0.6	180	177.3	1.5
5	384	177	79	79	79	0.3	177	175.2	1.0
6	379	172	77	77	77	0.0	172	171.0	0.6
7	381	175	73	73	73	0.6	175	176.2	0.7
8	378	172	71	71	71	0.2	172	172.0	0.0
9	375	170	76	76	76	1.1	170	169.8	0.1

From the above table 15 and table 16 show that the % of error between the experimental values to the predicted value is in the acceptable limit.

Identify the significant factor

The quality parameter characterises are significantly affected by design parameter, which is evaluated by ANOVA.Analysis of variance is done by using MINITAB software.

Table 16 The ANOVA table

	Source	**DF**	**Seq SS**	**Adi SS**	**Adj MS**	**F**	**P**
ultimate tensile strength	Shielding gas	2	170.67	170.67	85.33	19.69	0.048
	Welding current	2	56.00	56.00	28.00	6.46	0.134
	Welding voltage	2	4.67	4.67	2.33	0.54	0.650
	error	2	8.67	8.67	4.33		
	total	8	240				
		S = 2.08167		**R-Sq = 96.39%**		**R-Sq(adj) = 85.56%**	
weld metal hardness	Shielding gas	2	29.56	29.56	14.78	19	0.050
	Welding current	2	48.22	48.22	24.11	31.00	0.031
	Welding voltage	2	3.56	3.56	1.78	2.29	0.304
	error	2	1.56	1.56	0.778		
	total	8	82.89				
		S = 0.881917		**R-Sq = 98.12%**		**R-Sq(adj) = 92.49%**	
toughness	Shielding gas	2	80.889	80.889	40.444	52.00	0.019
	Welding current	2	17.556	17.556	8.778	11.29	0.081
	Welding voltage	2	16.889	16.889	8.444	10.86	0.084
	error	2	1.556	1.556	0.778		
	total	8	116.88				
		S = 0.881917		**R-Sq = 98.67%**		**R-Sq(adj) = 94.68%**	

Analysis of tensile strength through ANOVA shows that, the shielding gas andwelding current are the most significant process parameters on the tensile strength of the MIG weldment. The welding voltage has the minor effect on the tensile strength forMIGweldment when compared to other process parameters. Similarly the ANOVA is carried out to the other response which shows, shielding gas and welding current is highly significant process parameter that affects the hardness of the weldment.The toughness value of the MIG weldmentis highly influenced by Welding current. Shielding gas has equal influence on the toughness of weldment. Conformation of experiment showed that the experimental observations are within 95% confidence level.

IV. CONCLUSION

In this research, the Taguchi method and the multiple linear regression analysis are determined the optimum weld parameters in gas metal arc welding. The signal/noise ratio and ANOVA technique used to identify the weight of each parameter on the mechanical properties. The prediction of mechanical properties using numerical method is done by building a mathematical model.

The following decision were made depends on the experimental output results obtained.

- Using the Taguchi optimization method, the optimum process welding parameters for tensile strength are welding process current - 120 Amps, welding process voltage - 24 V, shielding gas - Ar+20% CO_2, gas flow rate - 10 LPM and corresponding tensile strength is 392 N/mm^2.
- For hardness, the optimum process welding parameters are welding process current -120 Amps, welding process voltage - 24 V, shielding gas – pure(100%) CO_2, gas flow rate - 10 LPM and the corresponding hardness value is 178 BHN.
- For toughness, the optimum welding process parameters are welding process current - 180 Amps, welding process voltage - 24 V, shielding gas - Ar+20% CO_2, gas flow rate - 10 LPM and the corresponding toughness value is 84 Joules.
- The maximum welding current and voltage increases the weldment impact strength and also reduces the weldments tensile strengthandweldment hardness.

Finally using the regression analysis, predicted and the experimental output values are compared and error percentage are within the acceptable limit.

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