International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2015 Vol. 5 (3) July-September, pp.1-7/Pasha and Saritha
Review Article

OPTIMIZATION OF PROCESS PARAMETERS OF ARC WELDED JOINT BY TAGUCHI

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ABSTRACT
Arc welding is a type of welding, in which the power supplies to create an electric arc between an electrode and the base material to melt the metals at the welding zone. The present Investigation has been carried out on the welding parameters to achieve good quality of Arc welding. It has been explained that, important of different welding parameters such as Weld Current, Weld Voltage, Welding Speed, Electrode Angle and Electrode Size on Mechanical properties of welded joint. Process parameters were optimized by Taguchi design of experiments. Optimized process parameters for tensile strength were weld current 200Amps, penetration 1 mm, width of weld 30^0, and size of electrode 3.15mm. Optimized process parameters for impact strength were, weld current 150Amps, penetration 0 mm, width of weld 45^0, and size of electrode 4.0mm. Regression equation has been stated by regression analysis for tensile strength & impact strength to predict the tensile & impact strength for various process parameters. Interaction between various process parameters were explained by interaction plots which were drawn by Minitab software. The ranks of process parameters which were effects the Mechanical properties were given according to delta values. Range of process parameters were explained by contour plots which were drawn by Minitab software.

Keywords: *Arc Welding, Mechanical Properties, Welding Parameters, Taguchi Design of Experiments, Minitab Software*

INTRODUCTION
Manual metal arc welding was first invented in Russia in 1888. It involved a bare metal rod with no flux coating to give a protective gas shield (Shahnwaz *et al.,* 2012). The development of coated electrodes did not occur until the early 1900s when the Kjellberg process was invented in Sweden and the Quasi-arc method was introduced (Saurav *et al.,* 2008). It is worth noting that coated electrodes were slow to be adopted because of their high cost. However, it was inevitable that as the demand for sound welds grew, manual metal arc became synonymous with coated electrodes (Saurav *et al.,* 2008). When an arc is struck between the metal rod (electrode) and the work piece, both the rod and work piece surface melt to form a weld pool. Simultaneous melting of the flux coating on the rod will form gas and slag which protects the weld pool from the surrounding atmosphere. The slag will solidify and cool and must be chipped off the weld bead once the weld run is complete (or before the next weld pass is deposited) (Ankita *et al.,* 2011).Welding is an efficient and economical method for joining of metals. Welding has made significant impact on the large number of industry by raising their operational efficiency, productivity & service life the plant and relevant equipment. Welding is one of the most common fabrication techniques which is extensively used to obtained good quality weld joints for various structural components (Kumanan *et al.,* 2007). The present trend in the fabrication industries is to automate welding processes to obtained high production rate. Arc welding, which is heat-type welding, is one of the most important manufacturing operations for the joining of structural elements for a wide range of applications, including guide way for trains, ships, bridges, building structures, automobiles, and nuclear reactors, to name a few. It requires a continuous supply of either direct or alternating electric current, which create an electric arc to generate enough heat to melt the metal and form a weld (Abhay *et al.,* 2008).

Experimental Procedure
The test material is comprised 150mmx60mmx5mm thick material of Mild steel according to Taguchi design, the 18 mild steel specimens of were prepared and failing operation on grinding machine. After

that numbers were written on the work pieces for the identification. Entered the pre determined values of 4 factors (welding current, penetration, width of angle, size of electrode) according to Taguchi orthogonal matrix in to the system which is coupled to the arc welding machine.

Arc welding is a type of welding, in which the power supplies to create an electric arc between an electrode and the base material to melt the metals at the welding zone. It can be used either Direct Current. These weld joints of Mild steel are taken for Tensile Testing and to study the Micro structure.

To determine the behavior of the objective function DOE (Design of experiment) was used. In this TAGUCHI design of experiment is used. Here L_9 Orthogonal array is selected, (As shown in table). The First row indicates the number of factors which will be tested which are 4 in this case. The First column shows the number of Experiments that must be completed for the Experiment, in this case being 9. The other columns underneath show the levels of each factor, in this case 3 i.e. (High-3, medium-2 and Low-1).

INPUT Variables

Table 1: Input variables for 9Runs, 3 Levels and 4 Factors

Runs	**Current (Amps)**	**Penetration (mm)**	**Width of weld (Degree)**	**Size of electrode (mm)**
1	100	0	30	3.15
2	100	1	45	4.0
3	100	2	60	5.0
4	150	0	45	5.0
5	150	1	60	3.15
6	150	2	30	4.0
7	200	0	60	4.0
8	200	1	30	5.0
9	200	2	45	3.15

Prepared Specimens before and after Welding

Figure 1: Specimens before & after Welding

Figure 2: Specimens before &after Tensile Strength Test

Table 2: Tensile Test Results

RUNS	**Breaking or MAX. Load (KN)**	**Ultimate Tensile Strength (MPa)**	**Fractured At**
1	18	180	WELD
2	10	100	WELD
3	2	20	WELD
4	4	40	WELD
5	23	230	WELD
6	14	140	WELD
7	16	160	WELD
8	15	150	WELD
9	16	160	WELD
Base metal	24	240	

S/N Ratio

(Larger is the best)

$S/N = -10 \log [(1/N) \Sigma (1/Y_i^2)]$

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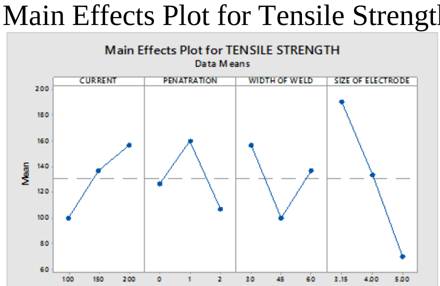
Table 3: Over View of Tensile Strength and S/N Ratio

Run	**Current (amps)**	**Penetration (mm)**	**Width of Weld (angle)**	**Size of Electrode (mm)**	**Tensile strength (MPa)**	**S/N ratio (R_i)**
1	1	1	1	1	180	45.105 $=R_1$
2	1	2	2	2	100	40.000 $=R_2$
3	1	3	3	3	20	26.020 $=R_3$
4	2	1	2	3	40	32.041 $=R_4$
5	2	2	3	1	230	47.234 $=R_5$
6	2	3	1	2	140	42.922 $=R_6$
7	3	1	3	2	160	44.082 $=R_7$
8	3	2	1	3	150	43.521 $=R_8$
9	3	3	2	1	160	44.082 $=R_9$

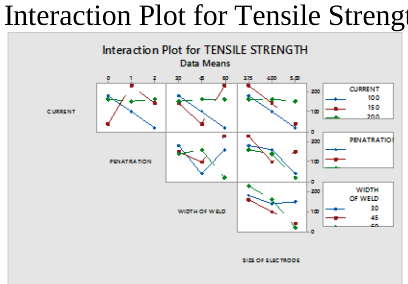
Table 4: Taguchi Analysis by Minitab software for Means of Tensile strength

Factors/levels	**1**	**2**	**3**	**Maximum value**	**Delta**	**Ranking**
Current (amps)	37.041	40.732	43.895	43.895	6.854	2
Penetration (mm)	40.409	43.585	37.674	43.585	5.911	3
Width of Weld (angle)	43.849	38.707	39.112	43.849	5.142	4
Size of Electrode (mm)	45.473	42.334	33.860	45.473	11.613	1

Main Effects Plot for Tensile Strength



Interaction Plot for Tensile Strength



The Regression Equation for Tensile Strength

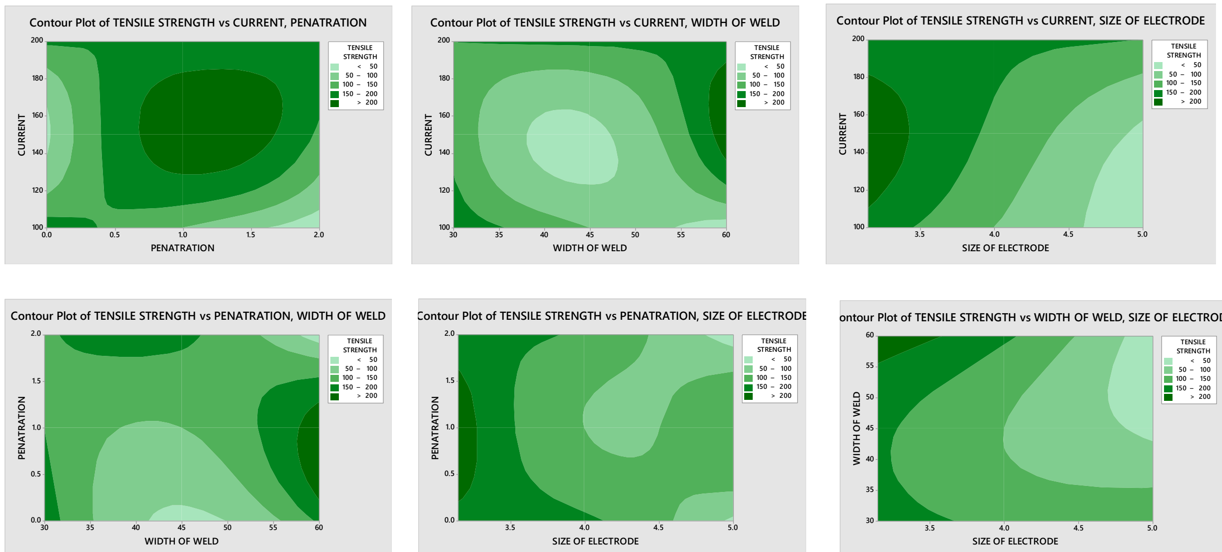
Tensile Strength = 349 + 0.567 Current - 10.0 Penetration - 0.67 Width of Weld - 64.8 Size of Electrode

The Regression Analysis Chart for Tensile Strength by Minitab Software

Table 5: Analysis Of Variance for Tensile Strength

Predictor	**Coefficients**	**P-value**
Constant	349	0.039
Current	0.567	0.201
Penetration	-10.0	0.618
Width of weld	-0.67	0.618
Electrode size	-64.8	0.032

Contour Plots For Tensile Strength Vs Factors by Minitab Software



Impact Test Results

Table 6: Impact Load Readings

Runs	Impact load (J)
Base metal	124
1	122
2	152
3	88
4	148
5	148
6	160
7	158
8	72
9	152

Table 7: Shows That Impact Test Results

RUNS	Breaking or MAX. Load (J)	Impact Strength (J/mm^2)	Remarks
1	122	2.44	Breaked into two parts
2	152	3.04	Breaked into two parts
3	88	1.76	Breaked into two parts
4	148	2.96	Breaked into two parts
5	148	2.96	Breaked into two parts
6	160	3.2	Breaked into two parts
7	158	3.16	Breaked into two parts
8	72	1.44	Not Breaked into two parts
9	152	3.04	Breaked into two parts
Base metal	124	2.48	Not Breaked into two parts

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Specimens before and after Impact Strength Test (Failed At Weld)

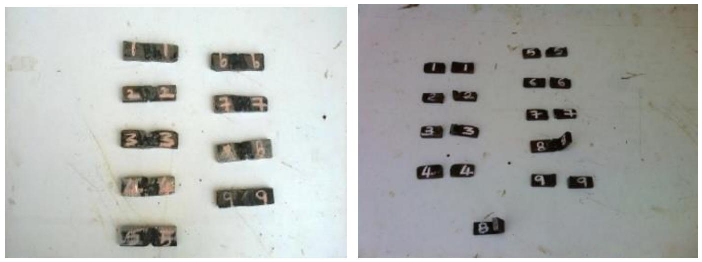


Figure 5: Specimens before and after Impact Strength Test

Table 8: Over View of Impact Strength and S/N Ratio

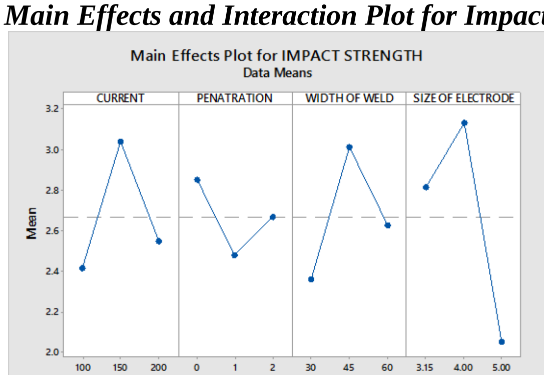
Run	Current (amps)	Penetration (mm)	Width of Weld (degrees)	Size of Electrode (mm)	Impact strength(J/mm^2)	S/N ratio (R_i)
1	1	1	1	1	2.44	7.4477=R_1
2	1	2	2	2	3.04	9.657=R_2
3	1	3	3	3	1.76	4.910 =R_3
4	2	1	2	3	2.96	9.425 =R_4
5	2	2	3	1	2.96	9.425=R_5
6	2	3	1	2	3.2	10.102=R_6
7	3	1	3	2	3.16	9.9937=R_7
8	3	2	1	3	1.44	3.1672=R_8
9	3	3	2	1	3.04	9.6574=R_9

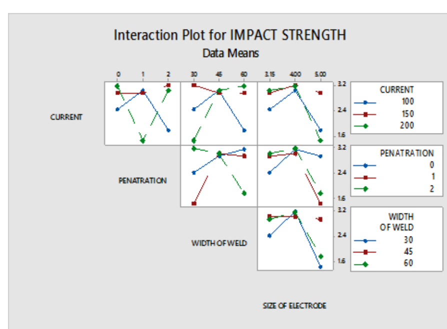
Taguchi Analysis by Minitab Software for Means of Impact Strength

Table 9: Response Table for Means of Impact Strength

Factors/levels	1	2	3	Maximum value	Delta	Ranking
C1	7.438	9.650	7.605	9.650	2.212	3
C2	9.055	7.416	8.223	9.055	1.631	4
C3	7.005	9.579	8.109	9.579	2.574	2
C4	8.943	9.9173	5.834	9.9173	4.083	1

Main Effects and Interaction Plot for Impact Strength





The Regression Equation for Impact Strength

Impact Strength = 3.90 + 0.00133 Current - 0.093 Penetration + 0.0089 Width of Weld - 0.430 Size Of Electrode

Table 10: The Regression Analysis Table for Impact Strength

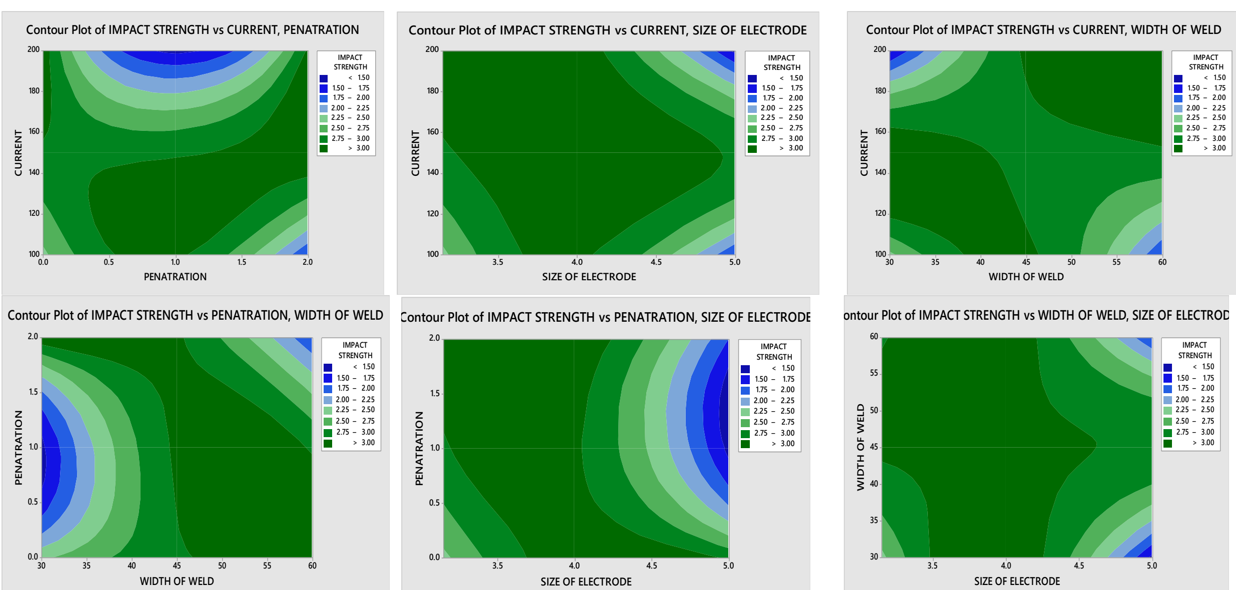
Runs	**Weld current (Amps)**	**Penetration (mm)**	**Width of weld /angle (degrees)**	**Size of electrode (mm)**	**Impact strength (j/mm^2)**
1	100	0	30	3.15	2.9455
2	100	1	45	4.0	2.620
3	100	2	60	5.0	2.231
4	150	0	45	5.0	2.35
5	150	1	60	3.15	3.186
6	150	2	30	4.0	2.4605
7	200	0	60	4.0	2.98
8	200	1	30	5.0	2.19
9	200	2	45	3.15	3.026

The Regression Analysis Chart for Impact Strength by Minitab Soft Ware

Table 11: Analysis Of Variance for Impact Strength

Predictor	**Coefficients**	**P-value**
Constant	3.90	0.108
Current	0.00133	0.837
Penetration	-0.093	0.774
Width of weld	0.0089	0.684
Size of electrode	-0.430	0.260

Contour Plots For Impact Strength Vs Factors by Minitab Software



Contour Plots for Impact Strength Vs Penetration and Width of the Weld

CONCLUSION

Mechanical behavior of the MMA welded joint for mild steel was studied by the Taguchi design of experiment and observed that the MMA weld joint exhibited comparable strength with the base material and the optimal value of process variables for a optimized tensile strength from the Taguchi design were weld current 200 Amps, penetration 1 mm, width of weld 30^0, and size of electrode 3.15 mm.

In this project high impact strength was occurred comparative the base metal strength. The optimal value of process variables for higher impact strength were weld current 150 Amps, penetration 0 mm, width of weld 45^0, and size of electrode 4.0 mm.
Regression equation was stated for Tensile and impact strength to predict the tensile and impact values at different process variables from regression analysis.
Studied the main affect, interaction and contour plots with the help of ANOVA for both tensile and impact and observed that at all levels of variables, There is an interaction between each other. And from the main affect plots it was observed that the level of factors that have more effect on the tensile strength and impact strength. From the Taguchi design of experiment it is observed that the factor that has more effect on the tensile strength was size of electrode (3.15 mm), and also the factor that has more effect on the impact strength was sire of electrode (4.0 mm).

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