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Optimization of Welding Process Parameters for Welding of Pipes using Taguchi's Tools

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Abstract: *The aim of work is to weld carbon steel pipes with GTAW process thereby deciding levels and contribution of significant process parameters in welding quality. In this study an attempt is made to investigate the effect of welding process parameters on tensile strength of the welded joint. The analysis of the selected process parameters such as welding current, gap between the pipes, shielding gas flow rate and diameter of electrode has been conducted as an influential factor on tensile strength based on Taguchi's experimental design methods. Taguchi's tools such as orthogonal array, ANOVA, signal -to-noise ratio, parameter design have been used for this purpose and an optimal condition has been found out .The estimation of optimum performance characteristics at the optimum levels of parameters is done. Also the optimal variable combination was selected and confirmatory experiment was performed to find improvement in present performance.*

Keywords*:* *GTAW process*

I. INTRODUCTION

Welding is the process of permanent joining two materials through localized coalescence due to suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combination of temperature and pressure from a high temp with no pressure to a high pressure with low temperature, a wide range of welding process has been developed. Gas Tungsten Arc Welding (GTAW), also known as Tungsten Inert Gas (TIG) welding is a process that produces an electric arc maintained between a non-consumable tungsten electrode and the part to be welded. The heat-affected zone, the molten chemical properties. The shielding gas serves to blanket the weld and exclude active properties in the surrounding air. Inert gases such as Argon and Helium do not chemically react or combine with other gases. They pose no odor and are transparent, permitting the welder maximum visibility of the arc metal and the tungsten electrode are all shielded from atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Inert gas (usually Argon) is inactive or deficient in active

II. LITERATURE SURVEY

Joseph [1] presented the Taguchi method to investigate the inadequacies of existing GMAW welding process parameters utilized by the investigated industrial firm in its signature welding protocol, by suggesting alternative, uniquely crafted and improved process parameters to replace its existing signature welding protocols. UgurEsme [2] reported on an investigation of the effect and optimization of welding parameters on the tensile shear strength in the resistance spot welding (RSW) process. The level of importance of welding parameters is determined by using analysis of Variance. (ANOVA) and the optimum welding parameter combination were obtained by using the analysis of signal-to-noise ratio (S/N) ratio. N.B. Mostafa M.N. Khaijavi [3] used central composite rotable design matrix to develop a mathematical model for predicting weld penetration as a function of welding process parameter. By using the constrained optimization method, the process parameters for maximizing weld penetration are obtained. The optimization result is predicted that weld penetration attains its maximum value when welding current, arc voltage, nozzle- to-plate distance and electrode –to – work angle are maximum &welding speed is minimum.

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II. MATERIAL USED

A333 GR.8, O.D.= 60mm, ID=50mm, L=200mm

Carbon Steel Chemical Composition

The chemical composition of carbon steel pipes is A333 Grade8 is given in the tableTable.1.Composition of material

Element	C	Mn	Si	S	P	Ni
%	0.13	0.90	0.20	0.04	0.04	9.2

Properties of materials

Table.2. Properties of material

Standard	Grade	Tensile Strength(MPa)	Yield Point	Elongat ion (%)
ASTM	A333	≥ 690	≥ 515	≥22

Component drawing

OD =60 mm, ID = 48mm, Thickness = 6mm, L= 200mm

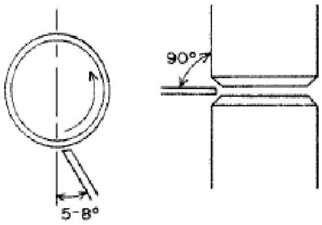

Fig.1 Pipes to be welded

Edge preparation

The edges of the specimen are prepared using a portable grinding machine. The edge preparations are arranged to make the weld joint. A gap is maintained between the pieces to ensure proper penetration of the weld.

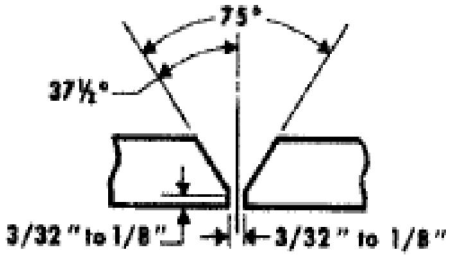

Fig. 2 Welding joint

IV. FORMATION OF ORTHOGONAL ARRAY BY TAGUCHI METHOD

In this study, three level process parameters welding current, gap between the pipes, gas flow rate and diameter of electrode are considered. Factors with its levels are given in Table 3

Table 3- Process parameters and their levels

Factors	**Symbol**	**Level1**	**Level2**	**Level3**
Welding current (A)	A	95	105	115
Gap Bet. Pipes(mm)	B	2.4	3	3.15
Gas flow rate(LPM)	C	5	8	10
Diameter of electrode(mm)	D	2	2.4	3

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Table4- Orthogonal array after assignment of parameters

S. N o.	Current (Amps)	Gap between the	Gas flow rate (LPM)	Dia. Of electrode (mm)
T1	95	2.4	5	2
T2	95	3	8	2.4
T3	95	3.15	10	3
T4	105	2.4	3	3
T5	105	3	3.15	2
T6	105	3.15	2.4	2.4
T7	115	2.4	10	2.4
T8	115	3	5	3
T9	115	3.15	8	2

Experimental observations

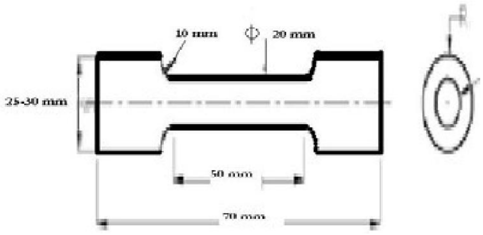

Fig. 3welding specimen used for the tensile test

The work piece is being cut in a single cross-section. The suitable purposed for the shape of work piece is as illustrated in fig. The simplification of steps to prepare the work piece specimen is as on figure below.

Table5Parameters with its levels

Factors	**Symbol**	**Unit**	**Level 1**	**Level 2**	**Level 3**
Welding current	A	Am p.	95	105	115
Gap Bet. Pipes	B	mm	2.4	3	3.15
Gas flow rate	C	Litte rs/m in	5	8	10
Diameter of electrode	D	mm	2	2.4	3

Presentation of Results

Three pieces from each welded pipe for each trial are taken for measuring tensile strength in Universal Testing Machine (UTM) after machining and the results are shown in Table7

Table 6 Observations of Runs

Sr. No.	Tensile Strength (MPa)			Mean	S/N ratio
	Y1	Y2	Y3		(ηi)
T1	664	661	664	663	56.443

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T2	670	675	665	670	56.521
T3	629	624	633	628.6	55.967
T4	648	640	650	646	56.204
T5	645	646	649	646.6	56.186
T6	665	670	664	666.3	56.473

5.1.2 S/N Ratio

The UTS of the welded structure is the category of the larger-the-better quality features.

For **Larger is the better category**, the S/n Ratio can be calculated by using following formula

$$SN_L = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

For first Run, S/N ratio is= -10 $\log_{10}$ [1/ $(663.000)^2$] =56.443 dB.

Similarly, S/N ratio for all runs are calculated and are shown in Table.8

5.3.2 S/N ratios for each factor at each level

m_{A1}=1/3 * ($\eta_1+\eta_2+\eta_3$) =1/3 (56.443 +56.521+55.967)

Similarly mean S/N ratios are calculated for each factor at each level & shown in Table8

Table 7 S/N ratios for each factor at each level

Level	Welding Current	Gap Bet. Pipes	Gas flow	Dia. of electrode
1	56.310	56.117	56.276	56.281
2	56.287	56.206	56.312	56.233
3	55.944	56.218	55.953	56.028

VI. ANNOVA

Analysis of variances (ANOVA) technique is successfully used for statistically analyzing the outcomes of experiments. ANOVA is a computational technique to estimate quantitatively the relative contribution which each controlled parameter makes on the overall measured response and is expressed as a percentage. Thus information about how significant the effect of each controlled parameter is on the experimental results can be obtained. The total variation in response is decomposed into variation due to various controlled factors and their interactions and due to the error involved in the experimentation

Table 8 ANOVA

Fact	DO F	Sum of square	Vari.	F-ratio	Contribution
A	2	0.255	0.127	-	41.802
B	2	0.021	0.01	-	3.452
C	2	0.22	0.11	-	35.991
D	2	0.114	0.057	-	18.736

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The same ANNOVA table can be obtained by giving the data of L9 orthogonal array to by QUALITEK– 4 Software. The output after feeding the data is as shown in the following table, where we can easily come to know the scope of pulling for non-significant factors by observing contribution in quality output characteristics.

Table 9 .ANOVA without Pooling

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 welding current	2	.255	.127	-----	.255	41.802
2 Gap bet. pipes	2	.021	.01	-----	.021	3.452
3 Gas flow rate	2	.22	.11	-----	.22	35.991
4 Dia. of electrode	2	.114	.057	-----	.114	18.736
Other/Error	0					
Total:	8	.611				100.00%

Since contributions of Gap between pipes is very small they are pooled together to highlight the significant factors. After pooling, the sum of squares and variances are recalculated and final ANOVA table with pooling is shown in Table7.2

Table 10 ANOVA Table with Pooling

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 welding current	2	.255	.127	12.106	.234	38.371
2 Gap bet. pipes	(2)	(.021)		POOLED	(CL= *NC*)	
3 Gas flow rate	2	.22	.11	10.423	.198	32.557
4 Dia. of electrode	2	.114	.057	5.426	.093	15.292
Other/Error	2	.02	.01			13.78
Total:	8	.611				100.00%

Since contributions of Gap between pipes is very small they are pooled together to highlight the significant factors. After pooling, the sum of squares and variances are recalculated and final ANOVA table with pooling is shown in
Results of ANOVA shown by QUALITEK– 4 Software are as follows.

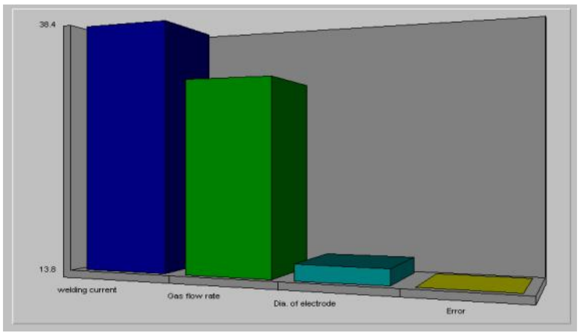

Fig.4 Significant factors and Interaction Influence

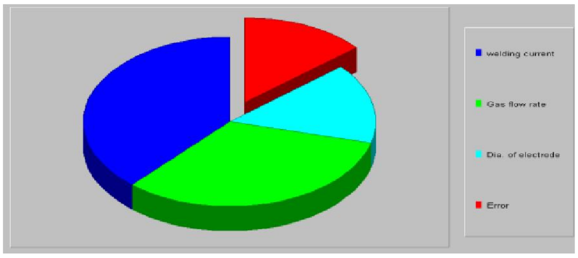

Fig. 5.Pie Chart for Significant Factors

Based on **Taguchi parameter design and Analysis of variance**, been found that three control factors i.e**. welding current, gas flow rate and diameter of electrode** are more significant factors.
For optimizing the welding process, we have to select that level of significant factors which gives maximum S/N ratio.

Table 11 Significant factors and their levels

Significant factor	**Level**
Welding Current	95 Amp
Gas flow rate	8 (Litt./min)
Dia. of electrode	2 mm

6.1 Confirmation run

The confirmation experiment validates the initial experimental results obtained and the conclusion thereof. In this case , the improvement of the performance characteristics of the welding process are predicted and verified. The predicted S/N ratio

Table12 . Observations of confirmation run

Trial no.	Tensile Strength (MPa)	S/N Ratio
1	650	56.276
2	652	
3	651	
4	653	
5	652	

Table 13.Final Results

Parameters	Predicted	Obtained
S/N Ratio	56.539	56.276

VII. CONCLUSION AND SCOPE FOR FUTURE WORK

From the analysis, it is proved that, by improving the quality by Taguchi method of parameter design at the lowest possible cost, it is possible to identify the optimum level of signal factors at which the noise factors effect on the response parameter is less. Thus by using by using Taguchi method it is possible to optimize welding process at the lowest possible cost. The outcome of this project is the optimized process parameters of welding which leads to minimum rejection. The optimized parameters levels are Welding current 95 Amp, Gas flow rate 8 (Litt./min), Dia. of electrode 2 mm. Also the project gives a clear picture of every factor‘s contribution to the variation in the tensile strength of weld joint and quality can be improved without additional cost. One can apply the same procedure to optimize other welding processes with different levels.

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