Parametric Optimization of Gas metal arc welding process by using Taguchi method on stainless steel AISI 410

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Abstract:
Gas metal arc welding is a fusion welding process having wide applications in industries. Gas metal arc welding is one of the conventional and traditional methods to join materials. The present study is to investigate the influence of welding parameters on the penetration. The optimization for Gas metal arc welding process parameters (GMAW) of Martensitic Stainless steel work piece AISI 410 using Taguchi method is done. Sixteen experimental runs (L16) based on an orthogonal array Taguchi method were performed. This paper presents the effect of welding parameters like welding speed, welding current and wire diameter on penetration. The ANOVA and signal to noise ratio (S/N ratio) is applied to identify the most significant factor and predicted optimal parameter setting. Experiment with the optimized parameter setting, which have been obtained from the analysis, are giving valid the results. The confirmation test is conducted and found the results closer to the optimize results. These results showed the successful implementation of methodology.

Keywords: *GMAW, Penetration, Process parameters, Signal to noise ratio, Wire diameter*

1. Introduction

Gas Metal Arc Welding (GMAW) is welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. GAS Metal Arc welding process is an important component in many industrial operations. The GMAW welding parameters are the most important factors affecting the quality, productivity and cost of welding. This work presents effect of the welding parameters on the response penetration. In which input parameters for MIG welding are welding speed, welding current and wire diameter and the output parameter is penetration. We are going to use Martensitic stainless steel AISI 410 material for welding it has a very large scale application in the process industry. Sample of 100mm×80mm×5mm size has been used as a work piece material and bead on welding is done for present experiments. It is a high carbon steel. Selection of process parameters is on bases of literature review and economical suitability of industrial application. Design of experiment is most suitable method for find out best process parameters for MIG Welding. According to literature review, preliminary experiments and economical consideration process parameters and levels are selected For Experimental design Taguchi method is applied to find out number of readings. To find out percentage contribution of each input parameter for obtaining optimal conditions, we used analysis of variance (ANOVA) method. A S/N Ratio is obtained from the Taguchi analysis by analyzing S/N Ratio we have find the optimum parameters.

Note : Gas metal arc welding (GMAW) is also known as Metal inert gas welding (MIG).

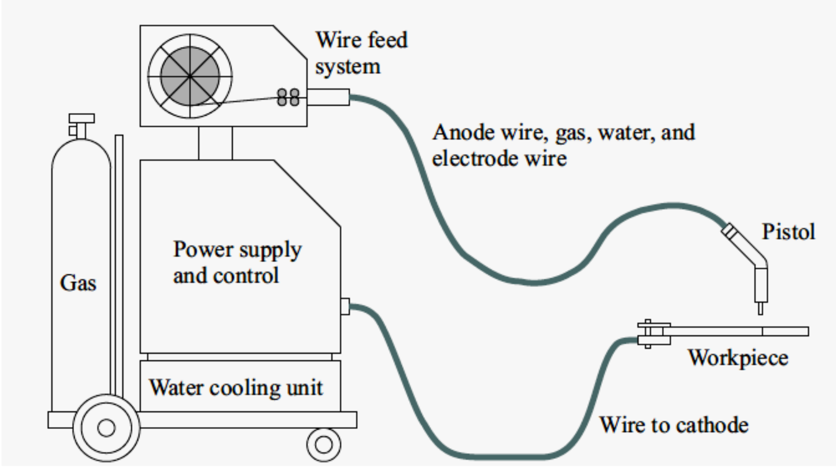


Fig. 1. Typical Gas Metel Arc Welding Machine

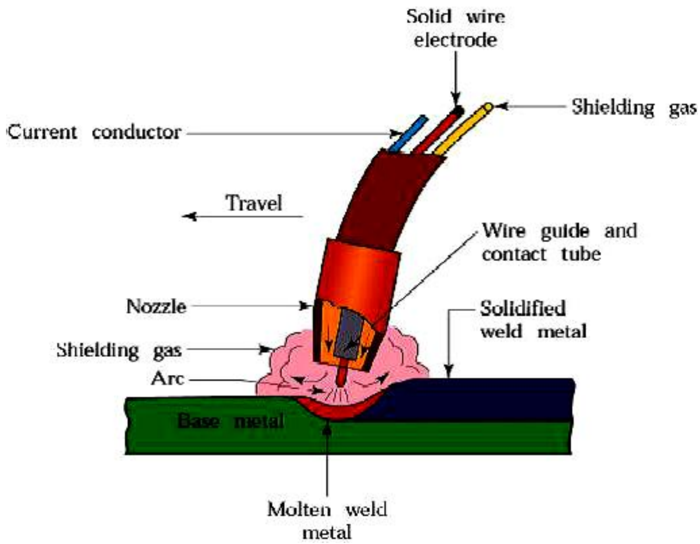


Fig. 1.2 welding gun

2. Literature Review

Erdal Karadeniz, Ugur Ozsarac, Ceyhan Yildiz study the effects of various welding parameters on welding penetration in Erdemir 6842 steel having 2.5 mm thickness welded by robotic gas metal arc welding were investigated. The welding current, arc voltage and welding speed were chosen as variable parameters. The depths of penetration were measured for each specimen after the welding operations and the effects of these parameters on
penetration were researched. [1]

Izzatul Aini Ibrahim, Syarul ashraf mohamat, Amalina.amir performed experiments in the effects of different parameters on welding penetration, micro structural and hardness measurement was measured in mild steel that having the 6mm thickness of the base metal by using the robotic gas metal arc welding. The variable parameters are arc voltage, welding current and welding speed. The penetration, microstructure and hardness were measured for each specimen after the welding process and the effect it was studied. [2]

Ugur Esme, Melih Bayramoglu, Yugut Kazancoglu, Sueda Ozgun studied Application of Taguchi method for the optimization of resistance spot welding Low carbon steel is extensively used for deep drawing of motor car bodies, motor cycle parts, and other domestic applications. Therefore, the present work was planned to optimize the resistance spot welding parameters of SAE 1010 steel sheets with different thicknesses. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. [3]

K. Abbasi, S. Alam and Dr. M.I. Khan study the effect of MIG welding parameters on the weld bead and shape factor characteristic .In this study the specimen used for welding is of mild steel. The welding parameters chosen as current, arc voltage, welding speed & heat input rate. The depth of penetration and weld width were measured for each specimen after the welding operation and effect of welding speed and heat input rate parameters on depth of penetration and weld width were investigated. [4]

3. Scheme of Investigation

In order to maximize the quality characteristics, the present investigation has been made in the following sequence.

- Selection of base material.
- Identify the importance GMAW welding process parameters.
- Perform preliminary tests.
- Find the upper and lower limits (i.e. range) of the identified process parameters.
- Select the orthogonal array (design of matrix).
- Conduct the experiments as per the selected orthogonal array.
- Record the quality characteristics.
- Find the optimum condition for MIG welding.
- Conduct the confirmation test.
- Identify the significant factors.

4. Experimental Procudere

To study the effect of Welding Process parameter on weld Penetration in Gas Metal Arc Welding a heat source is required. Heat source produce an electric arc to generate heat to melt the metal and form a weld for this purpose continuous supply of either direct or alternating electric current. The experiments were carried out on ZUPAR ARC – 300 Inverter based arc welding power source with soft switching technology GMAW Welding machine of SURAJ STEEL WORKS INDUSITRIES, W76, MIDC, Waluj , Aurangabad.

AISI 410 Steel material plate is used, as it has a very large scale application in the process industry. Sample of 100mm×80mm×5mm size has been used as a work piece material and bead on welding is done for present experiments. The specimen were confirmed for AISI 410 from Mattest Laboratory, C-150, M.I.D.C Waluj and the chemical examination results are shown in Table 4.1.The SS 410 sheet is converted in the desired work pieces size by using cutting operation. After cutting operation the work pieces are straighten by holding them in a press. The burr from the cut edges of the work pieces is removed by manual filing.

Table 4.1: Chemical Composition of Test specimens

AISI 410	composition	Mn	Si	P	C	Ni	Cr	S
	percentage	1.00	1.00	0.04	0.15	0.75	11.5-13.5	0.03

4.1 Control Parameters Selection

The objective of this study as discussed earlier is to optimize the welding process parameters for enhancing weld penetration. A total of the three welding process parameters were chosen as the controlling factors. Each parameter was designed to have the four levels denoted by 1, 2 ,3 and 4 respectively. Three parameters and four levels are shown in Table 4.1. The levels of these parameters were selected by doing literature survey. Preliminary Test results are considered while selecting Parameter and level. The parameter gas flow rate is neglected because it doesn't seems to show much effect on weld penetration. very small variations occurs during OVAT analysis so this parameter is neglected for further experimentation.

Table 4.2: Input Parameters for Analysis

Factors/Parameters	Level 1	Level 2	Level 3	Level 4
A Welding Speed (cm/min)	30	40	50	60
B Current (Amp)	80	90	100	110
C wire diameter (mm)	0.8	0.9	1.0	1.2

4.2 Selection of orthogonal array

Taguchi 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 affects the process performance. 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. For the present experimental work, three factors with their three levels are used for which the corresponding orthogonal array is L16 which is shown in Table 4.2 .

Table 4.2 orthogonal array

Exp. No.	Process Parameters		
	Welding Speed A	Welding Current B	Wire diameter C
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

4.3 Conduction of experiments and results

By putting the values of three levels of three parameters in L16 Orthogonal array , the sixteen set of experiments with different values of parameters and results are obtained as fallows.

Table 4.3 : Experimental Results

Ex No.	**Welding Speed** cm/min	**Welding Current** Amp	**Wire diameter** mm	**Penetration** mm	**S/N ratio**
1	30	80	0.8	2.04 mm	6.1926
2	30	90	0.9	2.21 mm	6.8878
3	30	100	1.0	2.83 mm	9.0357
4	30	110	1.2	3.16 mm	9.9937
5	40	80	0.9	2.50 mm	7.9588
6	40	90	0.8	2.43 mm	7.7121
7	40	100	1.2	3.18 mm	10.0485
8	40	110	1.0	3.80 mm	11.5957
9	50	80	1.0	2.54 mm	8.0967
10	50	90	1.2	3.36 mm	10.5268
11	50	100	0.8	2.89 mm	9.2180
12	50	110	0.9	3.13 mm	9.9109
13	60	80	1.2	4.10 mm	12.2557
14	60	90	1.0	4.16 mm	12.3819
15	60	100	0.9	2.91 mm	9.2779
16	60	110	0.8	4.22 mm	12.5062

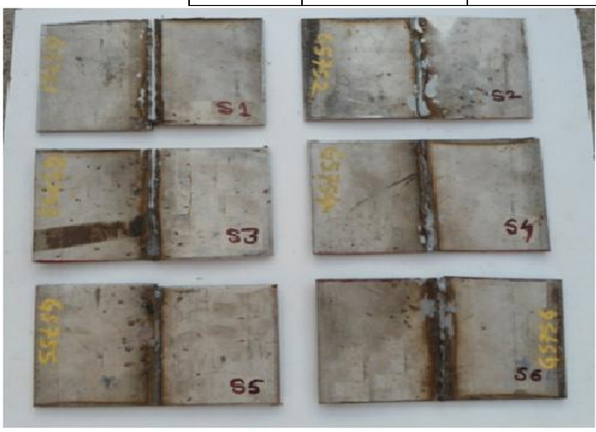


Figure 4.1 Welded Specimen Image 1

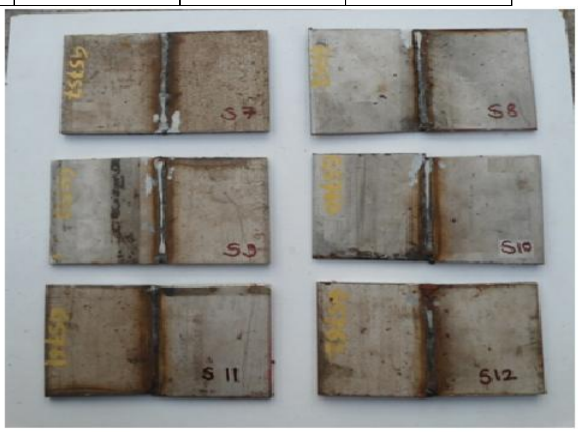


Figure 4.2 Welded Specimen Image 2

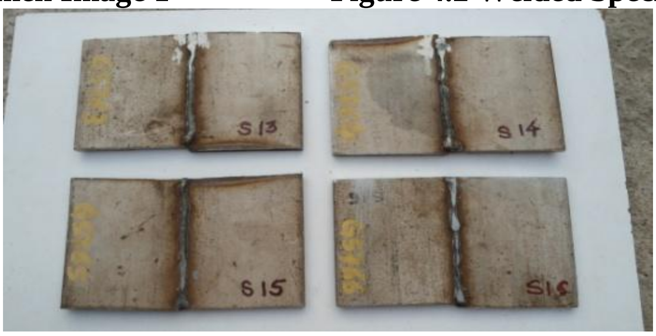


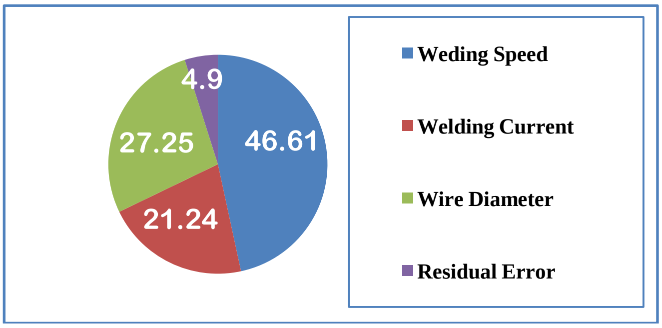
Figure 4.3 Welded Specimen Image 3

4.4 Analysis of S/N ratio, ANOVA and Main effect plots

Signal-to-Noise ratio (S/N ratio) was introduced by Sir Michael A Choma. The purpose of the Signal-to-Noise ratio (S/N ratio) is to investigate which design parameters significantly affect the quality characteristic In the Taguchi Method the term Signal represents the desirable value (mean) for the output characteristic and the term Noise represents the undesirable value (standard deviation) for the output characteristic. Therefore, the S/N ratio to the mean to S.D.S/N ratio used to measure the quality characteristic deviating from the desired value. The S/N ratio is defined as n=10log (M.S.D.) Where, M.S.D is the mean square deviation for the output characteristic. To obtain optimal welding performance, higher the better quality characteristic can be taken and S/N ratio is calculated for each experiment. Analysis of Variance (ANOVA) is a statistically based objective decision making tool for detecting any difference in average performance of groups of items tested. The decision rather than pure judgments, take variation in to account. The experimental design and subsequent analysis like ANOVA are intrinsically tied to each other. Analysis of Variance (ANOVA) breaks total variation down into accountable source and total variations is decomposed into its appropriate components.

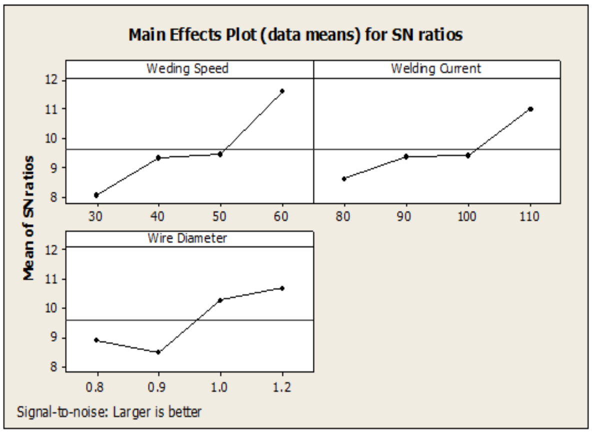
Table 4.4 Analysis of Variance table

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Welding speed	3	26.377	26.377	8.7924	11.05	0.0027
Welding current	3	12.020	12.020	4.0067	5.04	0.045
Wire diameter	3	15.419	13.413	4.4709	5.62	0.035
Error	6	2.774	4.774	0.7957		
Total	15	56.584				
S = 0.8920		R-Sq = 91.6%		R-Sq(adj) = 88.9%		



Graph 4.1 Pi Chart

Graph 4.2 Main effect plot for Means



Graph 4.3 Main effect plot for S/N ratio

4.5 Finding the optimal process parameters

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal levels are with the greatest S/N ratio. The optimal levels of process are Welding speed = 60 cm/min, welding current = 110 amp, Wire diameter =1.2 mm

4.6 Confirmation experiment

Once the optimal level of process parameters has been selected, the final step is to carry out the confirmation experiment by taking the optimal values of process parameter which are as fallows Welding speed = 60 cm/min, welding current = 110 amp, Wire diameter =1.2 mm. The above set of optimal process parameters are not found in orthogonal array so we have to carry out confirmation experiment. After carrying out confirmation experiment the actual penetration obtained is 4.53 mm. There is very less difference between actual and predicted values of penetration hence the results are valid

5. Microstructure Analysis

5.1 Microstructure Analysis of Parent Metal And Welded zone

Microstructure is one of the mechanical properties which are helpful for checking out the structure of the material. Microstructure of parent material before welding is shown in fig. 5.1 and microstructure of weld metal for sample-1 and sample-2 is shown in fig. 5.2 and 5.3 respectively. Parent metal is denoted as pm1 for the first sample, wm1 and wm2 designate the weld metal structure of first sample and second sample respectively after welding.

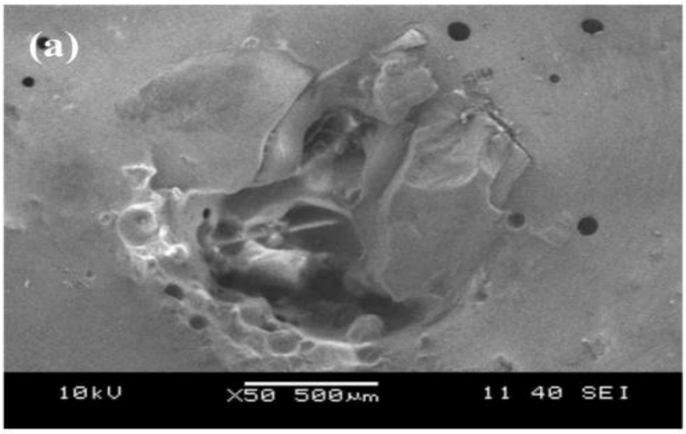


Fig-5.1 Microstructure of Parent Metal of Martensitic stainless steel AISI 410

The results of the structures of microstructure of weld metal of mild steel represents a fine grains of Ferrite and Martensite. No formation of takes Pearlite place. So according our results we can conclude that our weldments have grater hardness because both Martensite are hard constituents & there is no sign of formation of Pearlite.

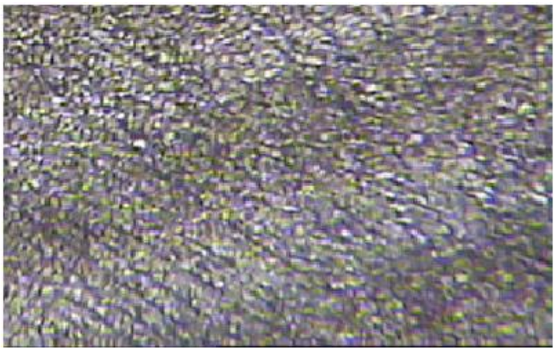


Fig-5.2: Microstructure of Weld Zone (wm1)

Fig-5.3: Microstructure of Weld Zone (wm2)

Figure 5.2 and 5.3 shows the microstructures of weld metal regionsand HAZ regions of the joint fabricated by GMAW process with two different heat input levels but same optimum conditions . Weld metal microstructures of heat inputs 0.96, and 1. 32 kJ/mm exhibits inputs 0.96 shows plain ferrite in a plain Martensite matrix, whereas heat input of 1. 32 kJ/mm shows a cicular ferrite in a plain Martensite matrix. At lower heat input level HAZ microstructure consists of coarse grained martensite wIth some carbides at the interior grains which lead to the higher hardness in that region across the weld centerline. Further increase in heat input leading to the formation of different microstructural constituents is like lower bainite plus martensite leading to the further decrease in hardness.

6. Conclusion

The Process parameters such as, welding current, wire diameter and welding speed are studied and optimized. The present study is carried to discuss an application of the Taguchi Method for investigating the effect of process parameter on Penetration. It is observed that the welding speed is most influencing factors and gas flow rate is least influencing factor.

The optimal parameter setting for GMAW process was selected by using grey-based Taguchi method so as to improve a cost function of important welding quality parameters. An L16 orthogonal array was adopted to conduct the experiment suggested by MINITAB14 Statistical software

ANOVA was performed to find the impact of process parameters on the individual quality parameters. It is observed that by using Taguchi method analysis the optimum combination of the machine is found that A-4 , B-4 and C-4 i.e Welding speed = 60 cm/min , welding current = 110 amp and wire diameter = 1.2 mm percentage contribution of various parameters for MIG welding found to be welding speed 46.61 %, welding current 21.24 % and wire diameter is 27.25 % and the error is found to be 4.90 %. This error is due to human ineffectiveness and machine vibration.

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