Experimental Investigation for Parametric Optimization of Gas Metal Arc Welding Process for Welding Of AISI 1018

Shubham Gothi[1], Sagar Ramavat[2]

[1] Research scholar, Mechanical Engg. Dept., Aadishwar College of Technology-Gandhinagar, Gujarat, India

[2]Prof. Sagar Ramavat, HOD Mechanical Engg. Dept., Aadishwar College of Technology-Gandhinagar, Gujarat, India

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 parameter on the penetration. The effect of welding current, welding voltage and gas flow rate on the depth of the penetration in gas metal arc welding of AISI 1018 mild steel having 8mm thickness has been going to study through experiments and analysis, and investigate the optimization process parameter. The optimization for gas metal arc welding process parameters of Mild Steel work piece using Taguchi method will done. Twenty seven experimental runs (L27) based on an orthogonal array Taguchi method will performed and investigate the effect of welding parameters like welding current, welding voltage and gas flow rate on depth of penetration. The depths of penetration were measured for each specimen after the welding operations and the effects of these parameters on penetration were researched.

Keyword: - *Gas Metal Arc Welding, AISI 1018 Mild Steel, Process Parameter, Depth of Penetration, S/N ratio, ANOVA analysis*

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1. INTRODUCTION

A Gas Metal arc welding (GMAW) is the process that included of heating, melting and solidification of parents metals and a filler (wire electrode) material in restricted fusion zone by transient heat source to form a joint between the parent metals. The continuous wire electrode from an automatic wire feeder and fed through the contact tip inside the welding torch is melted by the internal resistive power and heat transferred from the welding arc. Pressure regulator and flow meters are used to regulate the gas flow and pressure from the gas cylinder. Shielding of the arc and the molten weld pool is done by using inert gases such as argon, carbon dioxide and helium. The GMAW welding parameters influence the quality, productivity and cost of welding joint. The perfect arc will be achieved if all the welding parameters in conformation. These parameters consists of arc welding current, arc voltage, welding speed, torch angle, free wire length, nozzle distance, welding position and gas flow rate. The enough penetration, high heating rate and right welding profile occur the quality of welding joint. These are affected from welding current, arc voltage, welding speed and protective gas parameters All commercially important metals such as carbon steel, stainless steel, aluminum and copper can be welded with this process in all positions by choosing the appropriate shielding gas, electrode and welding condition The equipment involve in the welding are power source, wire fed unit, welding gun, shielding gas. This method is different from TIG welding because in TIG welding a non-consumable wire is used but in MIG welding consumable wire is used.[2][3][5]

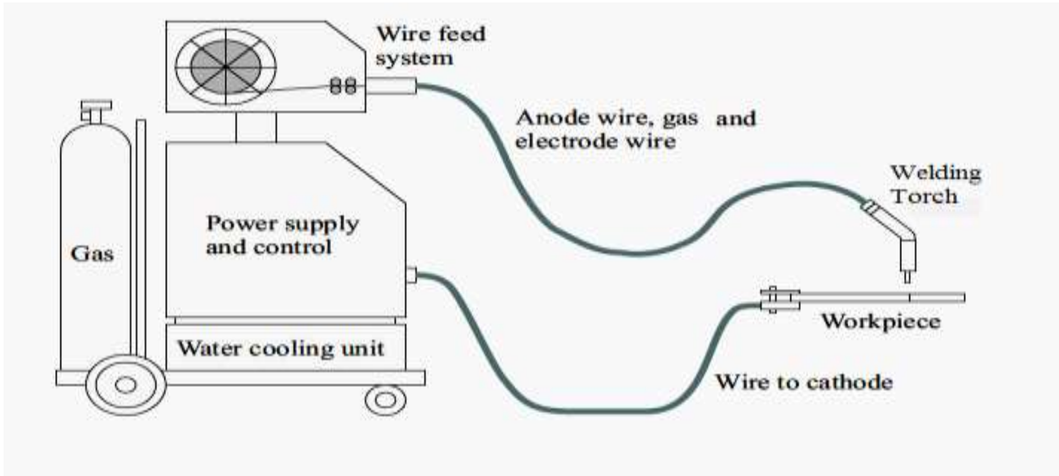

Fig.1 Schematic Diagram of GMAW process [12]

2. LITERATURE REVIEW

Erdal Karadeniz et al.[1] presented 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. Erdemir 6842 steel plate was used as base metal in MIG welding process.The welding currents were chosen as 95, 105, 115 A, arc voltages were chosen as 22, 24, and 26 V and the welding speeds were chosen as 40, 60 and 80 cm/min for all experiments. it was obvious that increasing welding current increased the depth of penetration. In addition, arc voltage is another parameter in incrimination of penetration. However, its effect is not as much as currents. The highest penetration was observed in 60 cm/min welding current.

Izzatul Aini Ibrahim et al.[2] present Gas Metal Arc Welding (GMAW) process is leading in the development in arc welding process which is higher productivity and good in quality. The arc voltage and welding current were chosen as 22, 26 and 30 V and 90, 150 and 210 A respectively. The welding speed was chosen as 20, 40 and 60 cm/min. The penetration, microstructure and hardness were measured for each specimen after the welding process and the effect of it was studied. As a result, increasing the parameters value of welding current increased the value of depth of penetration. Other than that, arc voltage and welding speed is another factor that influenced the value of depth of penetration. The microstructure showed the different grain boundaries of each parameter that affected of the welding parameters.

Behcet Gulenca et al.[3] presented 304L stainless steel was bonded by MIG welding and mechanical and microstructural properties of the welded samples were investigated. Welding was carried out under different shielding media, which are argon and different additions of hydrogen in Ar. As current values, 140, 180 and 240A were chosen for the welding current parameters. The sample that was welded under 1.5% H2–Ar shielding media and with a welding current of 240A was found to be the best in terms of means of tensile strength. For all the welding parameters, hardness test results showed that base metal gave a higher hardness value than HAZ and weld metal. As results the highest tensile strength was obtained from the welding that was carried out under 1.5% H2–Ar shielding with a welding current of 240A and The best toughness value was obtained from the samples that were welded under 5% H2–Ar shielding with a welding current of 240A.

Nabendu Ghosh et al. [4] presented, visual inspection and X-ray radiographic test has been conducted in order to detect surface and sub-surface defects of weld specimens made of AISI 316L austenitic stainless steels. The welding currents were chosen as 100, 112, 124 A, Gas flow rate 10, 15, 20 l/min and the nozzle to plate distance 9, 12, 15 mm for all experiments. The quality of the weld has been evaluated in terms of yield strength, ultimate tensile strength and percentage of elongation of the welded specimens. Results of visual inspection indicate that undercut, blow holes and spatter have been found in few samples, uneven deposition, and excessive penetration have also been found in some samples and in X-ray radiography test indicate lack of penetration, low – level porosity and lack of fusion in some of the samples.

S. D. Ambekar et al.[5] presented, the optimization for GMAW process of Martensitic Stainless steel work piece AISI 410. The welding currents were chosen as 80, 90, 100, 110 A, welding speed were chosen as 30, 40, 50 and 60 V and the wire diameter were chosen as 0.8, 0.9, 1.0 and 1.2 mm for all experiments. it was obvious that increasing welding current increased the depth of penetration. It is observed that by using Taguchi method analysis the optimum combination of the machine is found that 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 %.

Tarun Patel et al.[6] presented the effect of Current (A), Voltage (V), Gas Flow rate (Ltr/min) and on weld depth of ST-37 low carbon alloy steel material. Experiment by using L9 orthogonal Array to find out weld depth and also perform confirmatory Experiment to find out optimal run set of current, voltage speed and gas flow rate. The welding currents were chosen as 270, 300, 330 A, arc voltages were chosen as 35, 42, and 49 V and the welding speeds were chosen as 11, 14 and 18 Lir/min for all experiments. The results of the Taguchi experiment identify that 42 voltage, 330 current, flow rate 14 Ltr/min are optimum parameter setting for weld depth.

Rajkumar Duhan et al.[7] studied of MIG (GMAW) welding process for study of micro structure and effect of heat on hardness of base metal, weld bead and HAZ by welding of EN 31. In this present research paper an electrode of 308 having diameter 1.2 mm was used with direct current electrode positive polarity. CO2 was employed for shielding purposes. Double – V butt joint was applied with 90°, two variables are decided current and voltage. In heat affected zone (HAZ) the value of hardness was found highest but the harness at weld-ment was found minimum. In order to understand the micro structural changes occurring in the weld zone is investigated through the optical microscopy. The hardness measurements were taken across the weld zone and HAZ.

Rakesh Sharma et al[8] presented to investigate the optimization process parameters for MIG welding. In the present work, bead-on -plate welds were carried out on MS 5986 Fe 410 carbon steel sheets using GMAW process. The welding voltages were chosen as 32, 42, 45 A, travel speed were chosen as 1, 2, and 3mm/s and the gas flow rate 8, 10, 11 Lir/min and current 280, 300, 320 A were chosen for all experiments. A mixture of argon-carbon dioxide was employed for shielding purposes. The minimum depth of penetration obtained from the experimental studies was 0.2mm when the process parameters such as voltage, travel speed, gas flow rate and welding current were maintained at 32V, 1mm/sec, 8 lit/min and 280 amp respectively. And maximum depth of penetration obtained from the experimental studies was 2.4mm when the process parameters such as voltage, travel speed, gas flow rate and welding current were maintained at 42V, 1mm/sec, 10 lit/min and 320 amp respectively.

P.Sathiya et al[9] presented bead-on -plate welds were carried out on AISI 904 L super austenitic stainless steel sheets using GMAW process. In this present investigation AISI 904 L solid wire having 1.2 mm diameter was used as an electrode with direct current electrode positive polarity. Argon was employed for shielding purposes. The shape of the fusion zone depends upon a number of parameters such as gas flow rate, voltage, travel speed and wire feed rate. The bead profile parameters such as bead width, bead height and depth of penetration are measured. From the experimental results, the gray relational analysis is applied to optimize the input parameters simultaneously considering multiple output variables. In order to understand the microstructural changes occurring in the weld zone is investigated through the optical microscopy. The hardness measurements were taken across the fusion zone.

H.R. Ghazvinloo[10] presented impact energy and bead penetration of AA6061 joints produced by robotic MIG welding. Different samples were obtained by employing arc voltages of 20, 23 and 26 V, welding currents of 110, 130 and 150 A, welding speeds of 50, 60 and 70 cm/min. Results were clearly illustrated that when heat input increases, fatigue life of weld metal decreases whereas impact energy of weld metal increases in first and then drops significantly. A linear increase in depth of penetration with increasing welding current and arc voltage was also observed. The biggest penetration in this investigation was observed for 60 cm/min welding speed.

C.W. Dong[11] presented additional shielding gas for compensation to overcome welding defects, which often occur when high temperature solid and liquid phase welds are exposed to air. This method properly modifies the current pulsed MIG welding device by adding an airflow control branch of shielding gas for compensation. The study of microstructure and physical properties of the weld indicates that after introducing a certain amount of shielding gas for compensation, not only is weld formation significantly improved, but there is also timely track and protection of the weld surface. This largely inhibits the occurrence of welding defects during high-speed pulsed MIG single-wire welding and helps improve welding efficiency.

3 EXPERIMENTAL PROCEDURES

The experiment was carried on AISI 1018 mild steel plates of size 100x100x8mm.

Table.1 Base Material Chemical Composition

ASTM	C%	Si%	Mn%	S%	P%	Ni%	Cr%	Fe
1018 Mild Steel	0.15	0.13	0.9	0.05	0.018	0.005	0.008	98.81 - 99.26

Table.2 Selection of parameter level

Machining process Parameter	Level 1	Level 2	Level 3
Welding Current (Amp)	180	200	220
Voltage	28	30	32
Gas Flow Rate (L/Min)	14	18	22

The base material chemical compositions and parameter level are resented in Table 1 and 2. The filler (ER70S-6) wire having 1.20 mm diameter was used in this study. Using a carbon dioxide as shielding gas at three different flow rates i.e. 14 lit/min, 18 lit/min & 22 lit/min. The bead on plate welding was performed with a GMAW process. In this study, an L27 orthogonal array design was used.

After done with the welding process for all those of arc welding process, the specimens will cut perpendicular to the welding direction by using a cut-off machine to cut the specimens and polished with different grades of emery sheets. Then, the specimens will etched using 2% nital to clearly the metal zone of welding. The depth of penetration will measure and microstructural will observed on the etched specimens by stereo zoom microscopes.

4. RESULT AND DISCUSSION

The welding was performed MIG Super Arc 400 series welding machine with different set of parameters. The macrograph of the welded sample is presented in Figure 2.

Fig.2 Macrograph of the welded sample (Experiment No.26)

After performing analysis of different part of welding joint with various parameters such as welding current, arc voltage and Gas flow rate in taguchi method and finding out best way to improve penetration of welding joint.

Table.3 experimental tested data

Sr. No	Welding current (Amp)	Arc Voltage (Volt)	Gas Flow Rate (L/Min)	Penetration	SNRA1	MEAN1
1	180	28	14	6.411	16.13852	6.411
2	180	28	18	6.464	16.21003	6.464
3	180	28	22	6.31	16.00059	6.31
4	180	30	14	6.571	16.35263	6.571
5	180	30	18	6.612	16.40666	6.612
6	180	30	22	6.511	16.27295	6.511
7	180	32	14	6.599	16.38956	6.599
8	180	32	18	6.634	16.43551	6.634
9	180	32	22	6.541	16.31288	6.541
10	200	28	14	6.781	16.62587	6.781
11	200	28	18	6.872	16.74166	6.872
12	200	28	22	6.741	16.57449	6.741
13	200	30	14	6.86	16.72648	6.86
14	200	30	18	6.932	16.81717	6.932
15	200	30	22	6.802	16.65273	6.802
16	200	32	14	6.941	16.82844	6.941
17	200	32	18	6.97	16.86466	6.97
18	200	32	22	6.872	16.74166	6.872
19	220	28	14	6.983	16.88084	6.983
20	220	28	18	7.02	16.92674	7.02
21	220	28	22	6.911	16.79082	6.911
22	220	30	14	7.078	16.99821	7.078
23	220	30	18	7.101	17.02639	7.101
24	220	30	22	7.001	16.9032	7.001
25	220	32	14	7.15	17.08612	7.15
26	220	32	18	7.202	17.14906	7.202
27	220	32	22	7.312	17.28072	7.312

Taguchi technique is used to increases the output and reduced the cost of the products. The Taguchi Design is based on orthogonal array. Taguchi design recognizes the control factors to minimize the effect of Noise factor. Orthogonal array helps to reduce the time and cost of the experiment. The Signal-to-Noise (S/N) Ratio which are log function of required output which is the objective function to be optimized[6].

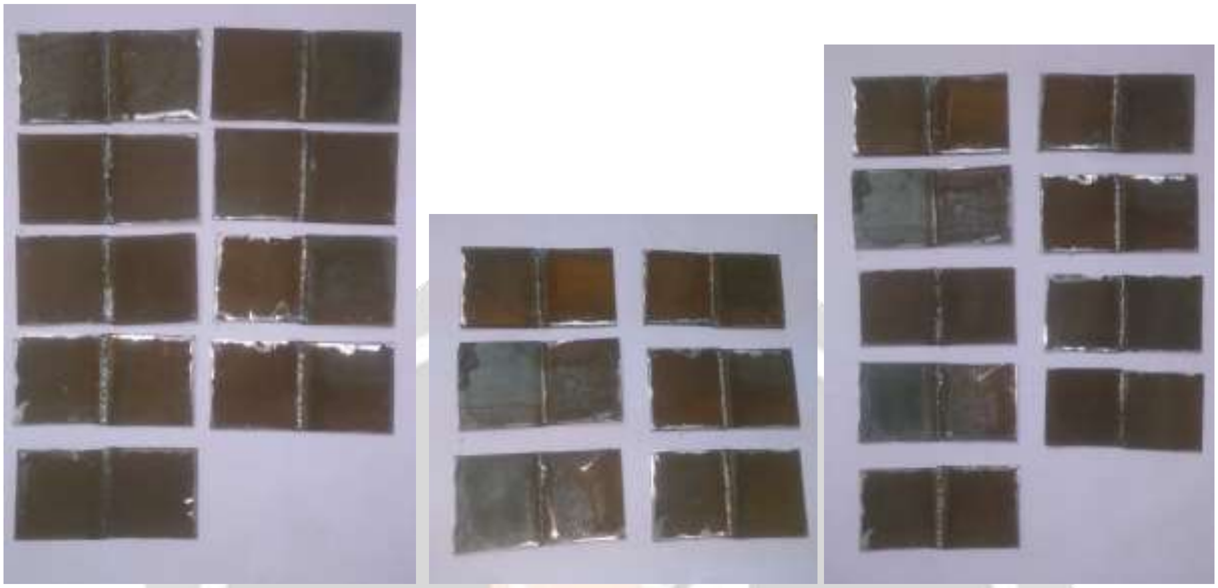

Fig.3 Workpiece

Taguchi method is a statistical method developed by Taguchi. Initially it was developed for improving the quality of goods manufactured (manufacturing process development), later its application was expanded to many other fields in Engineering, such as Biotechnology etc. Professional statisticians have acknowledged Taguchi's efforts especially in the development of designs for studying variation.[6]

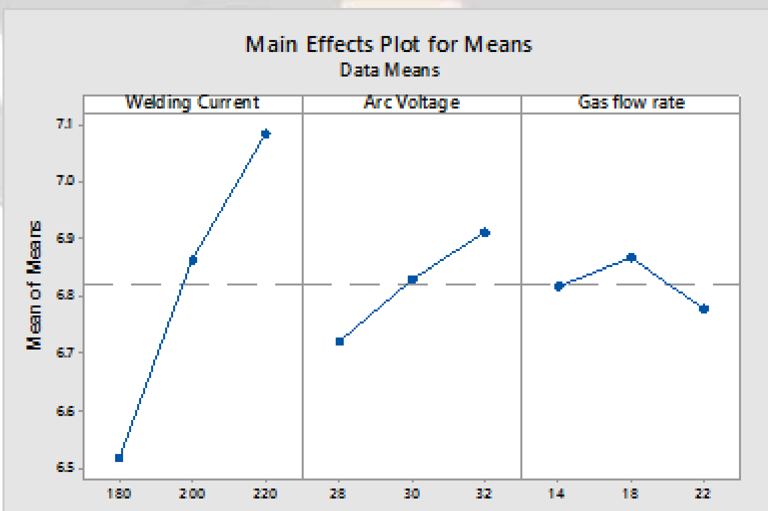

Fig.4 Mean effective plot for weld penetration

Fig.4 the first graph shows the effect of welding current on penetration. From Fig. 4, it is clearly shown that with increase in welding current, penetration increases. When welding current increases from 180 to 200 A, penetration increases from 6.517 to 6.863mm. When welding current again increases from 200 to 220 A, then penetration further increases from 6.863 to 7.084 mm. In fig. 4 the second graph indicated the effect of arc voltage on penetration. From Fig. 4, it is clearly shown that with increase in arc voltage, penetration increases. When arc voltage increases from 28 to 32 V, penetration increases from 6.721 to 6.913 mm. When gas flow rate increases from 14 to 20 L/min and 20 to 22 L/min, penetration further first increases 6.819 to 6.867 and then decreases from 6.867 to 6.778 mm.

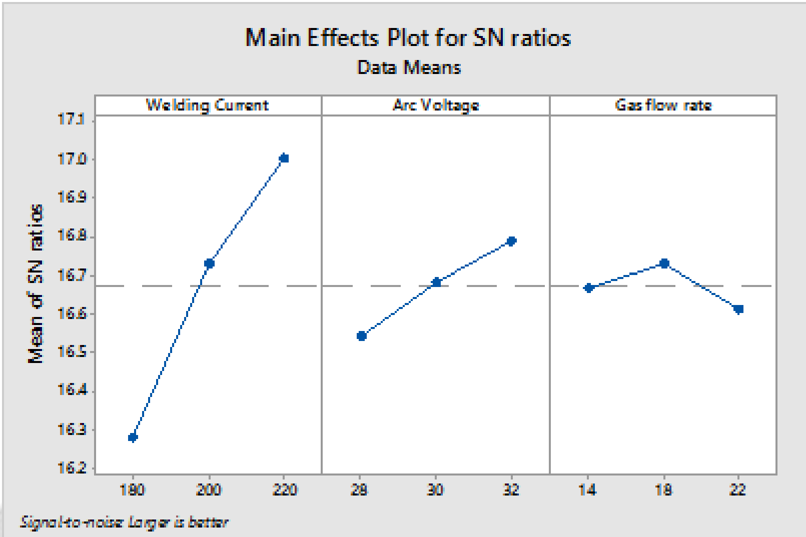

Fig.5 S/N ratio for weld penetration

Fig. 5 shows the response curve for S/N ratio, the largest S/N ratio was observed at current (220), voltage (32) and flow rate (18), which optimum parameter are setting for largest penetration. Parameter current is most significant parameter and gas flow rate is least significant for weld penetration.

4.3 ANOVA ANALYSIS

The analysis of variance is the statistical treatment applied to the results of to experiments to determine the percentage contribution of each factors. Study of ANOVA analysis helps to determine which of the factors need controls and which do not need control.

Table.4 ANOVA table for contribution

Parameters	Degree of Freedom	Sum of Squares	Mean Squares	F	P (%)
Current (Amp)	2	1.471	0.735	26.091	85.01
Voltage (V)	2	0.166	0.083	2.957	9.63
Gas Flow Rate (L/min)	2	0.036	0.018	0.6411	2.08
Error	20	0.056	0.028	1	3.25
Total	26				100

Analysis shows the percentage contribution of each process parameters on penetration. Percentage contribution of each parameters are welding current 85.01%, Arc Voltage 9.63%, Gas flow Rate 3.25%.Percentage contribution as shown in table 5.4

4.2 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 current = 220 A, Arc voltage = 32 V, gas flow rate =18 L/min. 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 7.350 mm. There is very less difference between actual and predicted values of penetration hence the results are valid.

4. CONCLUSIONS

The work presented in this thesis has focused on optimization of process parameter of a GMAW process with most emphasis on finding optimal welding parameter for the Penetration. One of the aims of this research was to find the effect of welding current, arc voltage and gas flow rate on penetration of the weld joint.

The experiment was carried out by three processing parameter that the Welding Current, Arc Voltage and Gas Flow Rate. The study presented that the Welding Current, Arc Voltage and Gas Flow Rate, this parameter are affecting the Penetration of the weld joint of Gas Metal arc welding process.

The ANOVA is conducted to know the percentage contribution of the input parameters on output parameters for plain penetration. ANOVA results that the percentage contribution of current is 85.01%, arc voltage is 9.63%, gas flow rate is 2.08% for penetration, which shows that the influence of welding current is very high compared to other parameters.

From Experiment Result And Analysis It Shows that, the value of penetration increased by increasing the welding current 180, 200 and 220 A. Welding current is factor that will determine the penetration of Welding process. Penetration is also influence by the factors from Arc Voltage and gas flow rate.

Using taguchi method analysis the optimum combination of machine is found that is Welding current 220A, Arc Voltage 32 V and gas flow rate 18 L/min where I found maximum penetration 7.350mm.

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