ISSN: 2250-3676
Volume-4, Issue-3, 257-262

EXPERIMENTAL INVESTIGATION OF DEPOSITION RATE OF TIG WELDING OF GRADE 316 STAINLESS STEEL

Er. Parvinder Singh
Assistant Professor, ME Department, DAV University, Jalandhar, India, er.parvinder87@gmail.com

Abstract

Tungsten Inert Gas Arc Welding is a commonly used welding technique due to its versatility and ease that can be maintained in almost all type of working conditions. Stainless Steel (SS316) possessing high strength and toughness is usually known to offer major challenges during its welding. In this work, Taguchi's DOE approach is used to plan and design the experiments to study the effect of welding process parameters on metal deposition rate and hardness of the weld bead. Three input parameters—current, gas flow rate and no. of passes—were selected to ascertain their effect on the metal deposition rate and hardness. The results show that during the welding of Stainless Steel (SS316) no. of passes is the most significant factor followed by current and gas flow rate, for deposition rate and gas flow rate is significant factor followed by no of passes and current, for hardness as the response. The experimentation has been carried out by using L-9 OA as standardized by Taguchi and the analysis has been accomplished by following standard procedure of data analysis on raw data as well as S/N data. It is revealed that all the three selected parameters—current, no. of passes and gas flow rate—affect both the mean value and variation around the mean value of the selected response i.e. metal deposition rate and hardness of weld bead. The results have further been validated by confirmation experiments.

Index Terms: *SS316, S/N ratio, DOE, Gas flow rate.*

-- *** --

1. INTRODUCTION

1.1 WELDING

The earliest known from of welding called forge welding, date back to the year 2000 B.C forge welding is primitive process of joining metal by heating and hammering until the metal are fused (mixed) together. Although forge welding still exist, it is mainly limited to the blacksmith trade. Today, there are many welding process available. The primary differences between the various welding are the method by which heat is generated to melt the metal.

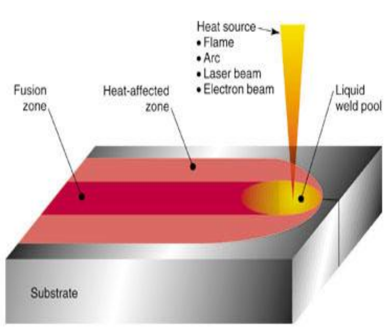


Fig1.1: Welding

1.2 Gas tungsten arc welding (GTAW)

Also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as aplasma.GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

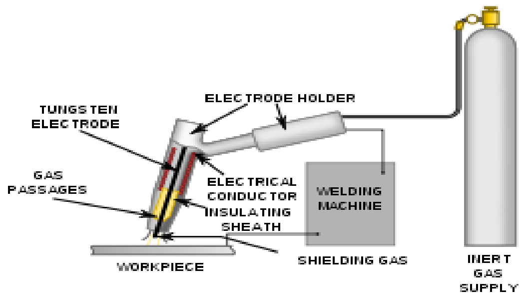


Fig: 1.2 TIG Welding Shielding Gas

1.3 WELDING PARAMETERS

Regardless of the technology, efficiency or variability, these are the list of parameters that affect the quality and outcome of the weld. When these parameters are improperly configured or out of range for the equipment or materials, this can lead to a variety of problems.

1.3.1 Current

Too much current can lead to splatter and workpiece damage. In thin materials, it can lead to a widening of the material gap. Too little current can lead to sticking of the filler wire. This can also lead to heat damage and a much larger weld affected area, as high temperatures must be applied for much longer periods of time in order to deposit the same amount of filling materials. Current limiting helps to prevent splatter when the tungsten tip accidentally comes too close or in contact with the workpiece. Fixed current mode will vary the voltage in order to maintain a constant arc current.

1.3.2 Welding Voltage

This can be fixed or adjustable depending on the equipment. Some metals require a specific voltage range to be able to work. A high initial voltage allows for easy arc initiation and allows for a greater range of working tip distance. Too large a voltage, however, can lead to greater variability in workpiece quality (depending on the work piece distance and a greater variation in power and heat delivered to the work area.

1.3.3 Gas Flow and Composition

Various welding or shielding gasses are available including mixtures of argon, carbon dioxide, oxygen, nitrogen, helium, hydrogen, nitric oxide, sulfur hexafluoride and dichlorodifluoromethane. The choice of gas is specific to the working metals and affects the production costs, electrode life, weld temperature, arc stability, welder control complexity, and molten weld fluidity, weld speed, splatter. Most importantly it also affects the finished weld penetration depth and subsurface profile, surface profile, composition, porosity, corrosion resistance, strength, ductility, hardness and brittleness

1.4 STANDARD L9 ORTHOGONAL ARRAY

To study the effect of input parameters such as current, gas flow rate and number of passes on various response variables like hardness of weld bead.

Input (Control) Parameters

- Current (A)
- Gas flow rate(B)
- Number of passes (C)

The standard format of L9 array used for this experimental study is shown below:-

Table: 1.1 - Standard L9 Orthogonal Array

Exp. No.	Factors		
	A	**B**	**C**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

1.5 WORK MATERIAL

Stainless steel is actually a generic referring to a family of over two dozen grade of commonly used alloys. Essentially it is an alloy having of 10.5 percent chromium. In this experimental work, 316 Stainless Steel is used as a work piece. Stainless steel, grade 316 is a versatile "low carbon (0.08%)-Chromium-Nickel steel suitable for a wide variety of welding application. Photographic view of welded sample is shown below.

Fig. 1.3 Welded Samples 316 Stainless Steel

1.6 EXPERIMENTAL SETUP

The experiment was conducted at National Institute of Technology Kurukshetra, Haryana (India) in the Welding and SOM lab of Mechanical Engineering Department, with the following set up:-

1.6.1 Welding equipment

MILLER 160 semiautomatic TIG equipment with direct current, power source with a 160 A capacity was used to join the stainless steel plates (type 304) of size 100 mm (length)$\times$96 mm (width) $\times$5 mm (height).

Fig. 1.4 TIG Welding Machine

AWS ER304 of 1.6 mm electroad is used for a square butt joint with a 2 mm root opening was selected to join the plates in the flat position, straight polarity is used to weld the plate .

1.7 DEPOSITION RATE

The deposition rate of a welding consumable (electrode, wire or rod) is the rate at which weld metal is deposited (melted) onto a metal surface. Deposition rate is expressed in kilograms per hour (kg/hr).Deposition rate is based on continuous operation, not allowing for stops and starts such as, electrode change over, chipping slag, cleaning spatter, machine adjustments or other reason.When welding current is increased so does the deposition rate. When electrical stick out is increased in the case the deposition rate will also increased.

1.7.1 Deposition Rate Calculation: Deposition rates are calculated by doing actual welding tests, and the following shows the formula for measuring deposition rates.

$$\textbf{Deposition rate} = \frac{\textbf{Weight of plate after welding} - \textbf{Weight of plate before welding}}{\textbf{Measured period of time}}$$

Example:-

Weight of plate before welding = 2.00kg

Weight of plate after welding = 2.95kg

Welded in 60 seconds

$= 2.95\text{-}2.00 \div 60$ sec

$= .950\times60\times60 \div 60$

$= 57$ kg/hr

Deposition rate calculation for experiment No.1

Weight of test plate before welding- .231 kg

Weight of test plate after welding- .233 kg

Measured period of time – 28 sec

So as per above example:

$$\text{Deposition rate} = \frac{(0.233\text{kg} - 0.231\text{kg}) = 0.002\text{kg}}{28\text{sec}}$$

$$= \frac{.002\times60\times60}{28} = 0.257 \text{ kg /hr}$$

Similarly the calculation of deposition rate (Kg/hr) for rest of the experiments (each experiments has two run) is calculated, given below:-

Table 1.2 Deposition Rate (Kg/hr)

Experiment no. 1	Experiment no.2	Experiment no.3
1. .257 2. .249	1. .140 2. .149	1. .093 2. .098
Experiment no.4	**Experiment no.5**	**Experiment no.6**
1. .140 2. .151	1. .092 2. .080	1. .276 2. .269
Experiment no.7	**Experiment no.8**	**Experiment no.9**
1. .189 2. .196	1. .553 2. .547	1. .141 2. .152

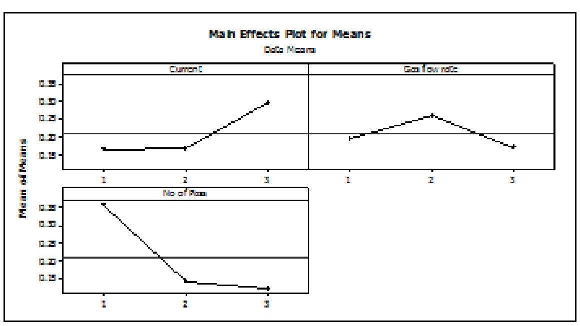
1.7.2 Analysis of Variance (ANOVA)

Analysis of variance is a statistical method used to interpret experimental data and make the necessary decision. ANOVA is statically based decision tool for detected any deference in the average performance of group of items tested.The ANOVA (general linear model) for mean have been performed to identify the significant parameters to quantify their effect on performance characteristics. The ANOVA test for raw data is given in table no.1.3.

Table: 1.3 Test Data for Deposition Rate (Kg/hr)

Experiment No.	Deposition Rate		Deposition Mean Value	Deposition S/N Ratio
	1st Run	2nd Run		
1	0.257	0.249	0.253	-11.941
2	0.140	0.149	0.145	-16.815
3	0.093	0.098	0.096	-20.409
4	0.140	0.151	0.146	-16.761
5	0.092	0.080	0.086	-21.374
6	0.276	0.269	0.273	-11.295
7	0.189	0.196	0.193	-14.316
8	0.553	0.547	0.550	-5.193
9	0.141	0.152	0.147	-16.702
Average			0.210	-14.978
Maximum	0.553	0.547	0.550	-5.193
Minimum	0.092	0.080	0.086	-21.374

Optimal Combination of Plot $A_3B_2C_1$



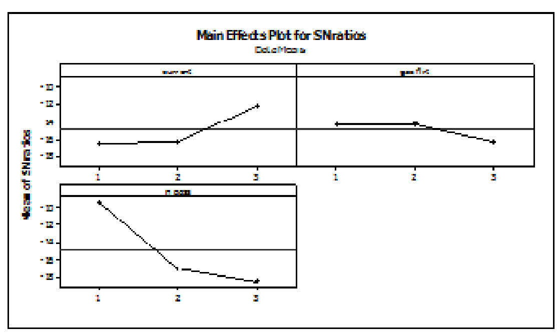


Fig 1.5: Effect of process parameter on Deposition Rate

Table: 1.4- ANOVA A Test Summery For Deposition Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contribution
Current	2	0.0678	0.0678	0.0339	11.72	0.002	20.82
Gas flow rate	2	0.0250	0.0250	0.0125	4.32	0.041	7.67
No of Passes	2	0.2009	0.2009	0.1004	34.73	0.000	61.72
Error	11	0.0318	0.0318	0.0028			
Total	17	0.3256					
S = 0.0537861 R-Sq = 90.23% R-Sq(adj) = 84.90%							

1.8 DISCUSSION

After performing experiment and analyzing the results, the discussion for the effect different input parameters on response variables is described below

1.8.1 Effect on Deposition Rate: It can be seen for the fig 1.5 that the current and no. of passes affects the deposition rate very significantly. The different input parameters used in the experimentation can be ranked in order of increasing effect as current, gas flow rate and number of passes. It is clear from the fig 1.5 that current and no. of passes affects deposition rate significantly. The slop of graph of current and no. of passes indicates that increase in current results in increase of deposition rate while increase of no. of passes results in decrease of deposition rate and it is also practical that in a given time more heat is needed to melt a given amount of metal. According to joule's effect, heat is directly proportional to current and time, given $H = I^2 Rt$ where (H = heat, I = current, R = resistant, t = time). The analyses of variance test results showed that the $\mathbf{A_3B_2C_1}$ is the optimal parameters setting for the deposition rate. In this study we conclude that the optimal input parameter setting for current is 140 amp, 10 liter/min, 1 number of passes, while welding the stainless steel 304 on TIG welding as far the deposition rate is concerned.

1.8.2 ANOVA Results

Form table 1.4, we can observe that the following parameters are statistically significant at 5% level of significance for their effects on deposition rate; No. of passes, current and gas flow rate. The percent contribution of these parameters in the variation of deposition rate is 61.72, 20.82 and 8.81 respectively. The order of significance is- No. of passes, current gas flow rate, on the basis of the observed p value, which is less than the significance level (0.05) for all these parameters.

1.9 CONCLUSION

Based on the experiment conducted the following conclusions have been drawn:Current and no. of passes affect the deposition rate significantly while welding the stainless steel 316 on TIG welding machine. Theoretically, for the deposition rate; current should have a higher value for higher heat content to melt the electrode at a faster pace. No of passes is the most significant parameter affecting deposition rate, followed by current and gas flow rate. The percent contributions of these parameters towards the variation in deposition rate have been found to be 61.72, 20.82 and 7.67 respectively. $\mathbf{A_3B_2C_1}$ has been identified asthe optimal input parametric setting for deposition rate. The values of various input parameters corresponding to the optimal setting are:-

$\mathbf{A_3}$**= 140 Amp**
$\mathbf{B_2}$**= 10 liter/min**
$\mathbf{C_1}$ **= 1**

A= Current, B = gas flow rate, C = no of passes.

REFERENCES

1. Tsai,Y.S., Yeh, H.L. and Yeh, S.S. (1999), "Modeling, optimization and classification of weld quality in tungsten inert gas welding", Journal of Machine Tools &Tarng, Manufacture, vol. 39, pp. 1427–1438.
2. Owen, R.A., Preston, R.V., Withers, P.J. and Shercliff, H.R. (2003), "Neutron and synchrotron measurements of residual strain in TIG welded aluminium alloy 2024", journal of Materials Science and Engineering, vol. A346, pp. 159-167.
3. Juang, S.C. and Tarng, Y.S. (2002), "Process parameter selection for optimizing the weld pool geometry in the tungsten inert

gas welding of stainless steel", Journal of Materials Processing Technology, vol. 122, pp. 33–37.

4. Senthil Kumar, T., Balasubramanian, V. and Sanavullah, M.Y. (2007), "Influences of pulsed current tungsten inert gas welding parameters on the tensile properties of AA 6061 aluminium alloy", journal of Materials & Design, vol. 28, pp. 2080–2092.
5. Dutta, P. and Pratihar, D. K., (2007), "Modeling of TIG welding process using conventional regression analysis and neural network-based approaches", Journal of Materials Processing Technology, vol. 184, pp. 56–68.
6. Balasubramanian, M., Jayabalan, V. and Balasubramanian, V. (2008), "Developing mathematical models to predict tensile properties of pulsed current gas tungsten arc welded Ti–6Al–4V alloy", journal of Materials and Design, vol. 29, pp. 92–97.
7. Ruckert, G., Huneau, B. and Marya, S. (2007), "Optimizing the design of silica coating for productivity gains during the TIG welding of 304L stainless steel", journal of Materials and Design, vol. 28, pp. 2387–2393.
8. Bayraktar, E., Moiron, J. and Kaplan, D. (2006), "Effect of welding conditions on the formability characteristics of thin sheet steels: Mechanical and metallurgical effects", Journal of Materials Processing Technology, vol. 175, pp. 20–26.
9. Benyounis, K.Y. and Olabi, A.G. (2008), "Optimization of different welding processes using statistical and numerical approaches – A reference guide", Journal of Advances in Engineering Software, vol. 39, pp. 483–496.
10. Balasubramanian, M., Jayabalan, V. and Balasubramanian, V. (2008), "Effect of pulsed gas tungsten arc welding on corrosion behaviour of Ti–6Al–4V titanium alloy", Journal of Materials and Design, vol. 29, pp. 1359–1363.
11. Lua,Shanping., Fujii, Hidetoshi. andNogi, Kiyoshi. (2009), "Arc ignitability, bead protection and weld shape variations for He–Ar–O2 shielded GTA welding on SS304 stainless steel" , Journal of materials processing technology, vol. 209, pp. 1231–1239.
12. Kumar, A. and Sundarrajan, S. (2009), "Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments", Journal of Materials and Design, vol. 30, pp. 1288–1297.

BIOGRAPHIES

Parvinder Singh received his bachelor's Degree in Mechanical Engineering from Punjab technical university, Jalandhar in 2009 and M.Tech in Mechanical Engineering (Production & Industrial Engineering) from National Institute of Technology, Kurukushetra in 2013. He is having three year teaching experience as a Assistant professor. At present he is working as assistant professor in department of Mechanical Engineering at DAV University, Jalandhar-Punjab.