International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 8, Issue 4 (JULY-AUGUST 2020), PP. 94-101

OPTIMIZATION OF GTA WELDING PROCESS PARAMETERS FOR AISI304 STAINLESS STEEL PLATE USING TAGUCHI METHOD

Irfan Ahmad[1], Atul Kumar Tiwari[2],
[1]M.Tech (ME) Scholar, Sagar Institute of Technology & Management, Barabanki
[2]Assistant Professor, School of Management Sciences, Lucknow
Uttar Pradesh, India

***Abstract*— The effects of process parameters of GTA welding on weld distortion, depth of penetration, micros hardness, tensile strength and microstructure of welded joints of stainless steel plate of AISIs 304s stainless steel has been studied. The optimum combinations of process parameters has been suggested to achieve minimum weld distortion, maximum depth of penetration (DOP) of welds bead and micros hardness. Design of experiment (DOE) was used to plans and design the experiment to study the effects of TIG welding parameter on both mechanical and metallurgical properties of AISIs 304 stainless steel. The input parameters considered in present investigation were welding current, gas flow rate, root face and welding speed. L9 Orthogonal Array (OA) techniques was used to formulate the experimental layout. It was concluded that the minimum weld distortions were founds at optimal setting of parameters of welding current (90 A), gas flow rate (10 LPM), root face (1 mm) and welding speed (31.578 mm/min) and the optimum response value is 2.3996 mm. Welding speeds (WS) is the most significant parameter for distortions during GTA welding. Welding current (A) is the most significant parameter for depth of bead penetration (DOP) during GTA welding. The recommended parametric combinations for optimum depth of bead penetrations is welding current (110 A), gas flow rate (10 LPM), root face (1.5 mm) and welding speed (31.578 mm/min.) and the optimum response value is 5.6961 mm. The micro hardness is maximum at I=90A, GFR=1.5lpm, RF=1.5mm, WS=21.428 mm/min. for both heat affected zone (HAZ) and welds zone (WZ). The highest and lowest values of tensile strengths were founds in sample no.4 and sample no.7. The experimental and predicted value were found in goods agreement. In addition to this the microstructure of base metal (BM) consisting of equiaxed austenite grains with annealing twins with in austenite grains. The welds were found free from porosity, internal cracks and lacks of fusion. Microstructure shows precipitation of carbides particles at grains boundaries. The specimens from the weld metal founds dendritically cored structure containing some deltas ferrite and precipitated small carbide particles.**

***Index Terms*— DOE, OA, S/N ratio, Taguchi method, Weld Distortion, Micro Hardness, Tensile Strength, Microstructure etc.**

I. INTRODUCTION

Tungsten inert gas welding is an arc welding process wherein coalescence is produced by heating the job with an electric arc established between a tungsten electrode and the base metal. No flux is used but the arc and the molten metal are shielded by an inert gas, which may be argon, helium, hydrogen, nitrogen or mixtures of some of these gases. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld [1].

Welding parameter acts pivotal role in determining the quality of weld joint. The quality of joint is related to weld bead geometry, mechanical properties and distortion. In addition to this the quality of weld joint is directly affected by welding input parameters during welding.

A. Stainless Steel

Stainless steels are a crucial category of engineering materials that are used widely in a very type of industries and environment. Welding is an important fabrication technique for stainless steels. In general, the stainless steels are considered weld able material however there are several rules that must be followed to make sure that they readily be fabricated to be freed from defects and can perform as expected in their intended service. “Stainless steels constitute a group of high-alloy steels based on Fe-Cr, Fe-Cr-C, and Fe- Cr-Ni systems. To be stainless, these steels must contains a minimum of 10.5wt% Cr this level of Cr allows formation of a passive surface oxide that prevents oxidation and corrosion of the underline ambient, non-corrosive conditions”.

B. Characteristics of Stainless steel

Stainless steels have sensible resistance to chemical reaction, even at high temperature, and that they are usually referred on heat-resisting alloys. Resistance to elevated temperature oxidation is primarily a perform of chromium content, some high chromium alloys (25-30wt %) will be used at temperature as high as 1000º C (1830ºF) another kind of heat resistance is resistance to carburization, that stainless-steel alloys of modest chromium content (about 16wt %) but nickel content (about 35wt %) are developed.

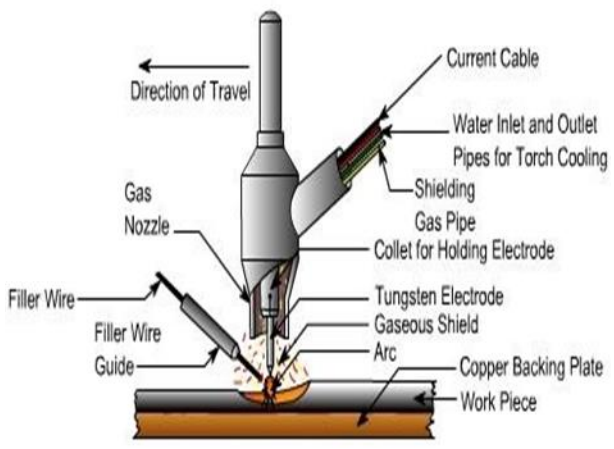

Figure 1.1 Process diagrams- TIG Welding [30].

C. Weldability of stainless steel

The state of mind in which someone try to ensure relative freedom from hazards, risks, accidents, illness and harmful effects etc. in any environment can be termed as Safety. The heat-treatment condition before welding should be chosen to minimize defects and optimise properties, and depends on post weld treatment which will be applied to the welded assembly. The martensitic varieties are generally welded in annealed condition for thin sections and therefore the over aged condition for thick section that inherently have high strength. Welding material within the averaged condition can scale back the stresses generated due to material slightly weekend state. Semi-austenitic varieties are typically welded within the solution-treated or annealed condition. The austenitic types are the foremost tough types to weld attributable to solidification, liquation and ductility-deep cracking problem. They're usually welded in a solution- annealed condition, to minimize intrinsic strength.

II. LITERATURE REVIEW

In this chapter different research papers published in the journals of international repute were studied and the end results of different experiments carried out by the researchers around the world is written.

Gas tungsten arc welding is the most widely used welding technique employed for fabrication of product out of stainless steel due to its ability to produce cleaner weld joint wherein heat is produced between a non-consumable electrode and the work metal under the shielding of inert gas, B. P. Agarwal et al, and Ravindra Kumar. In contrast, the manual metal arc welding suffers from the drawback of slag entrapment B.

P. Agarwal et al and B.P. Agarwal. The heat of the arcs melts thes bottom metal and produces as weld pool. This inert shielding gas prevents oxidation of the tungsten electrode, the molten welds puddle, and he heat-affected zone adjacent to the weld because of air aspiration, D.L. Olsons et al. As the electrode is non-consumable, a weld can be produced by the fusion of the base metal as well as filler material added separately. The productivity of the welding process iss governed by rate at which molten metal is deposited. Another distinct advantages of gas tungsten arc welding (GTAW) is itss effective utilizations in position and is especially well adapted to the welding of thin metalss also due to itss ability to use relatively lower heats input. The process cans be applied by the manual, semiautomatic and automatic methods. The wholes process of GTAW has been depicted in Fig.1.1. In order to obtain better quality of the weld joint of high strength application of optimized process parameter plays an important role and also helps to reduce the number of trials, B. P. Agarwal et al and Agarwal Bansi Prashad. G.R .Mir Shekari et al., investigated the microstructure and corrosion behavior of multi-pass gas tungsten arc welded 304Ls stainless steel. Effect of single pass and multi-pass gas tungsten arc welding on microstructure, hardness and corrosions behavior of 304Ls stainless steel has been studied.

He observed that the microstructure of fusion zones exhibited dendritic structure contained lathy and skeletal ferrite. Wichan Chuaiphan et al. investigated the effect of welding speed on microstructures, mechanical properties and corrosions behavior of GTA welded AISI 201 stainless steel sheets. The joints created victimization the high fastenings speed exhibiteds smaller weld bead size, higher tensile strength and elongation, higher hardness and higher pitting corrosion potentials than those welded with mediums and low weldings speeds.

III. EXPERIMENTAL SET-UP AND METHODOLOGY

A. Materials and Methods

Butt weld joints are prepared using GTAW under varied process parameters of welding as given by L9 orthogonal array of Taguchi method under argon gas shielding. As the metal deposition rate in case of gas tungsten arc welding is mainly governed by welding current, gas flow rate, welding speed (welding time) and to some extent root face. Therefore, these input parameters have been taken into consideration for the study and analysis. The three levels of each of the input parameters have been taken for present study based on trial experiment producing sound weld with no defects of porosity and lack of fusion. The selected process parameters and their levels are given in Table 3.1. The experimental set up showing the gas tungsten arc welding machine and inert gas cylinder has been shown in fig.3.1 and fig.3.2. The welding machine is Lincoln Electric Italia make with 3 phases, 400V. Stainless steel welded sample joined with the polarity of direct current electrode negative using different process parameters have been depicted in Table.3.1. The specification of GTAW machine has been revealed in Table 3.2.

Table-3.1: Input parameters and their levels

Process parameters	Levels		
	1	2	3
Welding current, A (A)	90	100	110
Gas flow rate, LPM (B)	1.0	1.5	2.0
Root face, mm (C)	1.0	1.5	2.0
Welding speed ,mm/min (D)	15.384	21.428	31.578

The base metal sheets of dimensions 100mm x 50mm x 6mm were cut on power hacksaw machine. As the thickness of the plates is 6mm, a V groove butt joint of 450 groove angle is made (Fig. 3.4). Weld beads of 50 mm length were deposited along the width using 2.4 mm filler wires of ER SS304L. The experimental flow chart is shown in fig.3.5.Table 3.3 shows chemical, physical and mechanical properties of AISI 304 stainless Steel used for the study.

Table-3.2 Specification of TIG welding machine

Manufacturer, Model No.	Lincoln Electric Italia, V260-T
Main Supply Voltage, Frequency & Max. Primary Current	400V3phase, 50/60 Hz., 21 A
Max Observed Power and No-load voltage	14.6 KVA, 80V
Current with duty cycle 35%	260 A
Current with duty cycle 60%	200 A
Current with duty cycle 100%	160 A
Dimension, Wt., Production Class	144×19×25.5 cm, 14/16 kg, IP 21

Fig.3.2 Shielding Gas (Argon: 99.9% Pure)

Fig.3.1 Welding Power Source

Fig.3.3 Welded specimen

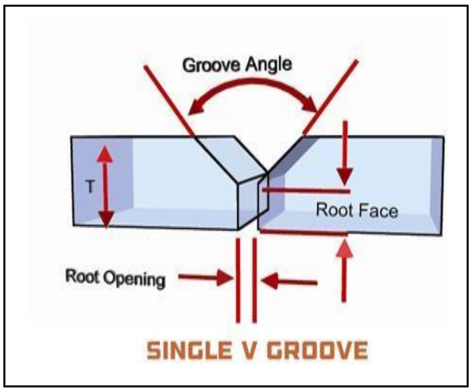

Fig.3.4 Configuration diagram of work-piece

Table 3.3: Chemical Properties of AISI 304 Stainless Steel

(Base Metal: AISI 304 SS)							
Element C	Cr	Mn	Ni	P	S	Si	Fe
Wt. (%)0.02	18.90	2.00	10.0	0.043	0.02	0.87	Balance
(Filler Metal: ER SS304L)							
Element C	Cr	Mn	Ni	P	S	Si	Fe
Wt. (%)0.03	18-19	2	8-12	0.045	0.03	0.75	Balance

Table 3.4: Physical Properties of AISI 304 stainless Steel

Grade	Density (g/cc)	Mean Coefficient of Thermal Expansion (µm/m/°C)	Thermal conductivity (W/m^{0}c) at 25^{0}c	Resistivity (Ω.cm)at 20^{0}c
AISI 304	8	16.9	16.2	7.2e-005

Table 3.5: Mechanical Properties of AISI 304 stainless Steel

Grade	Yield strength (MPa)	Tensile Strength (MPa)	Elongation (%)
AISI 304	290	621	55

Table 3.6. Working range of the process parameters

Symbol Element	Units	Lower level	Medium level	Higher Level
Welding current	A	90	100	110
Gas flow rate	Lpm	1	1.5	2.0
Root face	Mm	1	1.5	2.0
Welding speed	mm/min	15.384	21.428	31.578

Table 3.7 Experimental Layout L9 (3^4) orthogonal array

L9(3^4)	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Conducting Experiments as per the design matrix given below:

Table 3.9: Design matrix with actual values of parameters

Exp. Run	Welding Current (A)	Gas Flow Rate (B)	Root Face (C)	Welding speed (mm/min.)
1	1 (90)	1 (1.0)	1 (1.0)	1(15.384)
2	1 (90)	2 (1.5)	2 (1.5)	1(15.384)
3	1 (90)	3 (2.0)	3 (2.0)	3 (31.578)
4	2 (100)	1 (1.0)	2 (1.5)	1 (15.384)
5	2 (100)	2 (1.5)	3 (2.0)	1 (15.384)
6	2 (100)	3 (2.0)	2 (1.0)	2 (21.428)
7	3 (110)	1 (1.0)	3 (2.0)	2 (21.428)
8	110	2 (1.5)	1 (1.0)	3 (31.578)
9	110	3 (2.0)	2 (1.5)	1 (15.384)

IV. RESULTS AND DISCUSSION

This chapter presents the results and discussion of the investigation done. This welding operation was carried outs ons stainless steel test-pieces as per the parameters incurred by the Taguchi's orthogonal array as given in the Table 3.1. The distortion was measured using Vernier caliper and the results of distortion and depth of Penetration (DOP) have been shown in Table 4.1.

Table 4.1: Distortion and depth of penetration (DOP) in weld joints at different combination of GTAWParameters.

S. No.	Welding Current (A)	Gas Flow Rate (LPM)	Root Face (mm)	Welding Speed (mm/min)	Weld Distortion (mm)	Depth of bead Penetration (DOP) (mm)
1	90	8	1	15.384	1.0	241.25
2	90	10	1.5	21.428	0.15	36.187
3	90	12	2	31.578	0.35	84.437
4	100	8	1.5	31.578	0.6	144.75
5	100	10	2	15.384	1	241.25
6	100	12	1	21.428	1	241.25
7	110	8	2	21.428	0.55	132.687
8	110	10	1	31.578	0.09	21.712
9	110	12	1.5	15.384	2.4	579

A. Effects ofs weldings parameters on weld distortion of GTA welded AISIs 304 stainless steel plate

There are nine experiments that were designed as per Taguchi's design of experiment. It is expected to get an optimized level for each factor. The signal-to noise ratio (S/N ratio) should be kept high to get minimum value of distortion. The S/N ratios is obtained using negative of logarithmic value of distortion calculated experimentally, which is continuously decreasing function. So the signal-to-noise ratio is always kept at maximums value. The calculation of S/N ratio is based on smaller-the-better model. An additive model of Taguchi methods was taken into considerations to obtain the optimized values for each response factor.

A larger value of S/N ratios corresponds to better quality characteristics.

Table 4.2: Response Table for S/N ratio for distortion (smaller-the-better)

Level	I(A)	GFR (LPM)	RF(mm)	WS (mm/min)
1	8.5253	3.2099	6.9717	-2.5347
2	1.4790	12.4644	4.4370	7.2236
3	6.1679	0.5048	4.7705	11.4903
Delta	7.0533	11.9596	2.5347	14.0250
Rank	3	2	4	1

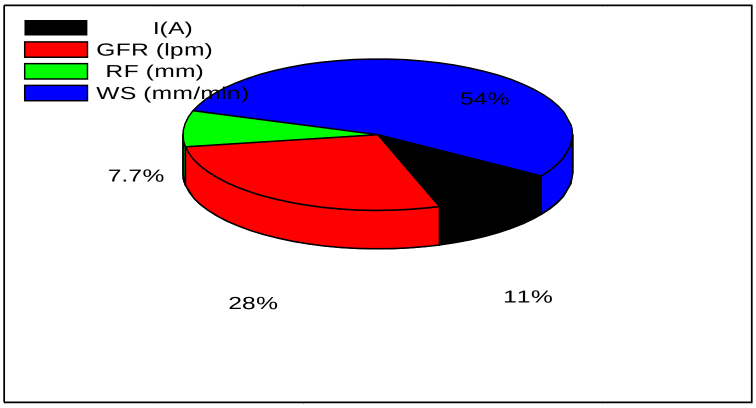

Fig.4.1 Percentage Contribution of factors affecting weld distortion

Table 4.3: Response Table for mean for weld distortion

Level	I(A)	GFR (LPM)	RF(mm)	WS (mm/min)
1	0.5000	0.7167	0.6967	1.4667
2	0.8667	0.4133	1.0500	0.5667
3	1.0133	1.2500	0.6333	0.3467
Delta	0.5133	0.8367	0.4167	0.3467
Rank	3	2	4	1

Table 4.4: ANOVA table for weld distortion

Sources	DOF	SS	MS	%P
I(A)	2	0.41947	0.209735	10.720
GFR (lpm)	2	1.07647	0.538235	27.520
RF (mm)	2	0.30247	0.151235	7.730
WS (mm/min)	2	2.1128	1.0564	54.030
Error	0			
Total	8	3.91121		100.000

Therefore optimized level is the level with largest values of S/N ratio. Response table for S/N ratio of weld distortion is shown in Tables 4.2. The means of weld distortion has been shown in Table 4.3. From Tables 4.3, it is found that welding speeds and gas flow rate have maximum effects on welds distortion of GTA welded AISI 304 stainless steel plate. The above table gives the values of control factors at each level. Fig.4.1 gives the relative percentage contribution of parameters of welding speed, welding current, gas flow rate and root face. It is understood further that there is comparatively higher effects of welding speed and gas flow rate ons weld distortion of welds joints. Fig.4.2 and Fig.4.3 shows the S/N ratios and mean plot demonstrating effects of each parameter on weld distortions of GTA welded AISIs 304 stainless steel plate. The ANOVA table for distortion has been depicted in Table 4.4. It is observed that currents and root faces has relatively less effects on welds distortion.

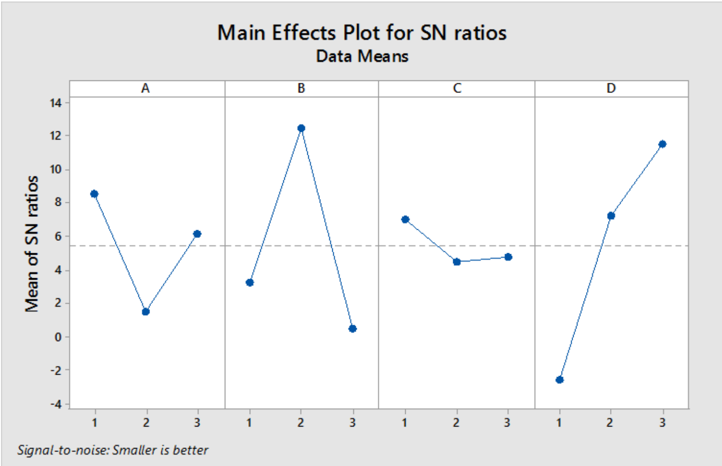

Fig 4.2. Main effects plot of S/N ratio (weld distortion)

Fig 4.3. Main effects plot of Mean (weld distortion)

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

This work presents optimization of the process parameters of gas tungsten arc welding by taking weld distortion, depth of weld bead penetration as a response variable. The following conclusion can be drawn for effective welding of stainless steel plate by gas tungsten arc welding process as follows:

- Welding speed (WS) is the most significant parameter for distortion during gas tungsten arc welding. The recommended parametric combination for optimum distortion is welding current (90 A), gas flow rate (10 LPM), root face (1 mm) and welding speed (31.578 mm/min) and the optimum response value is 2.3996 mm.
- A confirmation experiment was also performed and verified for the effectiveness of the Taguchi method. The experimental value obtained from setting of optimal welding parameters was found 2.2587 mm. The % error between predicted optimal and experimental values of metal deposition rate was found 5.871.
- Welding current (A) is the most significant parameter for depth of bead penetration (DOP) during GTA welding. The recommended parametric combination for optimum depth of bead penetration is welding current (110 A), gas

flow rate (10 LPM), root face (1.5 mm) and welding speed (31.578 mm/min.) and the optimum response value is 5.6961 mm.

- A confirmation experiment was also performed and verified for the effectiveness of the Taguchi method. The experimental value obtained from setting of optimal welding parameters was found 5.4962. The % error between predicted optimal and experimental values of metal deposition rate was found 3.5094.
- The microstructure of base metal (BM) consisting of equiaxed austenite grains with annealing twins with in austenite grains. The welds are free from porosity, internal cracks and lack of fusion. This is an annealed austenitic stain less steel. The location in the heat affected zone (HAZ) where the strip is exposed to temperature in the sensitizing range 600 to 800 C during welding.
- Microstructure shows precipitation of carbide particles at grain boundaries. The specimen from the weld metal showing dendritically cored structure containing some delta ferrite (white islands) and precipitated small carbide particles.
- The micro hardness is maximum at I=90A, GFR=1.5lpm, RF=1.5mm, WS=21.428 mm/min. for both HAZ and WZ.
- The highest and lowest values of tensile strength were found in sample no.4 and sample no.7.

B. Scope for future work

In this study, selected parameters were welding current, welding speed, arc gap and gas flow rate. Effects of selected parameters on microstructure and effect of magnetic field can be studied. Except selected parameters other welding parameters and other performance measures can be considered for further research. Effect of heat input on metallurgical and mechanical properties of the GTA welded other series of stainless steel can be considered for further study.

REFERENCES

[1] Suresh Kumar L., Verma S.M., Radhakrishna Prasad P.,s Kirankumar P.,s Siva Shanker T., “Experimental Investigation for weldin aspects of AISI 304s and 316 by Taguchi Techniques for the process of TIG and MIG welding”, International Journal of Engineering trends and technology, Vol. 2, issue 2, pp. 28-33, 2011.

[2] Balasubramanian M., Jayabalan V. & Balasubramanian V., Developing mathematical models to predicts the tensile properties of pulsed current gas tungsten arc welded Ti-6Al-4V alloy, Material and Design 29,pp. 92-97, 2008.

[3] Prasads Raos K. Fusion zone grains refinements ins GTAs welds using magnetic arc oscillation and current pulsing, RAMP, pp. 176-96, 2001.

[4] D. Dzelnitzki, Muendersbach, “Direct-Current welding with High frequency pulses, an interesting process variants © 2000 EWM HIGHTECH WELDING GmbH.

[5] Manual for Gass tungsten arc welding of Miller Electric Mfg. Co. USA

[6] Peter W.M., “Practical GTAW welding”, First edition , Abington Publishing, Abington Hall, Abington, Cambridge CB1 6AH, 1991, England.

[7] Pandey S., Wattal R., Gargs G.,s Agakhani M. “ Recent trendss in welding of Aluminium”, Workshops organizeds by the Aluminium Associations of India ands Indian Institute of Metals,

[8] Chandigarh, February 21, 2002, Paper No.4

[9] Olsons D.L., Siewert T.A., Liu S. &s Edwards G.R, “ASM Hand-Books Vol.6, Welding, Brazing and Soldering, Fourth Edition, (1997), The Materials Information Society, U.S.A.

[10] Weast R.C., Ed., Handbook of chemistry and physics, CRC press, (1973-1974), 54th Ed. pp.E-80 tos E-82 Osrams Sylvania, Inc. Literature.

[11] Campbell R.D. &Lacoursire E.J.,“A Guide to the Use of Tungsten Electrodes for GTA welding”, Welding Journal, (1995),s pp-39-45.

[12] Ushio, M., and Matsuda, F., “Study on GTAW arcs electrodes: Comparatives study on characteristics if tungstens oxide cathode”, IIW Document Number 212-(1986), pp. 648-86, International Institute of Welding.

[13] Parmar R.S., “Welding process and technology”, Second edition, Khanna Publishers, Delhi, India, 1995,s pp. 232-244.

[14] B. P. Agrawal, Ankit Kumar Chauhan, Ravindra Kumar, Ramkishor Anant, Sudhir Kumar, “GTA Pulsed Current Welding of Thin Sheets of SS304s Producing Superior Quality of Joint ats Highs Welding Speed”, Journal of Brazilians Society of Mechanical Engineers, Springer link, 2017.