International Journal For Technological Research In Engineering (IJTRE)
Volume 2, Issue 7, March-2015
ISSN: 2347-4718

To Study The Effect Of SiO_2 In A-GTAW Welded Joint Made On Stainless Steel (AISI SS304)

Amit Kumar[1], Mohd Majid[2]
[1]*Department of Mechanical Engineering, Doon valley group of institutions*
Karnal, India
[2]*Department of Mechanical Engineering , Sant Longowal Institute of Engg. And Technology*
Sangrur, India

Abstract — **Gas Tungsten Arc Welding (GTAW) is the most important joining technique used in almost all types of manufacturing sector. GTAW is suitable for welding thin work materials where good quality and surface finish are required. The presence of certain impurities in steel such as sulphur, oxygen etc in the weld pool can significantly reduce the weld penetration depth and limits it for welding upto 4 mm thick sheets only. Several mechanisms have been proposed for producing a relatively deep and narrow weld. A novel variant of GTAW process called the A-GTAW process involves application of thin coating (10-15µm thick) of activated flux on the joint area prior to welding. Literature identifies that the penetration capability of the arc in GTAW can be significantly increased by the application of a flux coating containing active ingredients, onto the joint surface prior to welding.**

The present study investigated the performance of stainless steel (AISI SS304) using A-GTAW process using Design of Experiments (DOE) methodology. L18 orthogonal array design matrix was followed. Mechanical testing- Tensile testing, micro hardness testing and microstructures was carried out to check the performance of the welded joints. Taguchi`s method was used to analyze the results. The results indicated that the performance of weldments was improved by welding with A-GTAW. Tensile strength and micro hardness was improved by A-GTAW.

Key words: GTAW, A-GTAW, stainless Steel (AISI SS304), Design of Experiments, Taguchi Methodology, Performance, Measures, Optimization.

1. INTRODUCTION

Welding is commonly defined as a joining process that uses heat, pressure, and chemicals to fuse two materials together permanently. Depending upon the combination of temperature and pressure, from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding processes has been developed. 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.

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 permits 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 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 is often automated. Manual gas tungsten arc welding is often considered the most difficult of all the welding processes commonly used in industry. Because the welder must maintain a short arc length, great care and skill are required to prevent contact between the electrode and the work piece. [2]

A novel variant of GTAW process called the A-GTAW process involves application of thin coating of activated flux such as Cr_2O_3, TiO_2 and SiO_2 etc.on the joint area prior to welding. Activated flux is prepared by making a paste of metal oxide in acetone and is applied to the joint area with a paint brush.It has been observed that the A-GTAW improves the overall quality of GTAW welds. Penetration is increased by 300% in a single pass weld. In A-GTAW, activated flux changes the surface tension in the weld pool so that the fluid flow is changed, and tends to increase the penetration. [4] Activated flux does not cause any change in chemical properties of the weld metals as compared to the base metal. Further, it has been found that there is no degradation in microstructure or mechanical properties. The procedure and apparatus or machine used in A-GTAW is same as used in GTAW, only difference being application of activated flux prior to welding.

2. LITERATURE REVIEW

Chang-Pin Chou et al. (2011) studied the Effect of Activated TIG flux on performance of dissimilar weld between mild steel and stainless steel and found the effect of CaO, Fe_2O_3, Cr_2O_3, and SiO_2 fluxes on surface appearance,

weld morphology, angular distortion, and weld defect when using TIG process to weld 6 mm thick dissimilar metals between G3131 mild steel and 316L stainless steel. The SiO_2 powder can give the greatest improvement in joint penetration and also a satisfactory surface appearance of G3131 mild steel to 316L stainless steel dissimilar welds.**Chou Chang-Pin** et al. (2005) studied the Evaluation of TIG flux welding on the characteristics of stainless steel and found that TIG flux welding can significantly reduce the angular distortion of stainless steel weldments and the 80% MnO_2, 20% ZnO mixture can give full weld penetration and also a satisfactory surface appearance with type 304 stainless steel TIG flux welds. TIG flux welding can increase the arc voltage, the amount of heat input per unit length in a weld is also increased, and therefore the retained δ ferrite content in austenitic stainless steel welds will be increased. As a result, the hot cracking susceptibility in as welded structures is reduced**.**
Marya et al. (2007) Optimized the design of silica coating for productivity gains during the TIG welding of 304L stainless steel and found that Optimized thickness in A-TIG is observed to vary between 40-70 micro meter depend upon welding current. Further increase in coating thickness overall performance in terms of weld penetration is reduced. The silica application generates higher inclusion density in weld metal with resulting decrease in the tensile strength. However, this reduction is comparatively weak when improvement in weld penetrations are considered in overall process analysis.Modenesi et al. (2000) studied the TIG welding with single-component Fluxes and found simple Fluxes of only one component present an adequate performance for A-TIG welding, resulting in a great increase of penetration in comparison to TIG welding, without any important deterioration of the welding conditions or of the microstructure of the welds.
Review of the literature identifies that there exists scantly published work on the welding of Steels using GTAW and Activated-GTAW welding, where comparative study has been performed. Technological improvements in the welding of Steels are necessary for industrial benefits. Activated-GTAW welding improves the overall quality of the welding, leading to the better productivity. It has also been observed that the penetration is increased to a greater extent, with Activated-GTAW welding. The overall bead geometry is also improved.

3. ADOPTED METHODOLOGY

Stainless steel (AISI SS304) plate was selected as the test specimen. Table 2.1 lists the chemical compositions of this steel. Plates measuring 6 mm thick were cut into 100*150 mm strips. V-groove with1.2 mm root face, 1 mm root gap and included groove angle is 60° were made. Polished with 400 grit silicon carbide paper to remove surface contamination, then cleaned with acetone and welded by GTAW and A-GTAW using 1.6 mm diameter matching filler wire.

Table.3.1: Composition of stainless steel (AISI SS304) (wt %)

Alloy Elements	c	Si	Mn	Ni	Cr	P	S	Fe
Contents	.037	0.36	1.33	8.73	18.83	.035	.009	70.36

GTAW was performed on an advanced square wave GTAW machine. Straight polarity and mounted torch with a standard 2%thoriated tungsten electrode were used in this welding process and 99.99% argon was used as shielding gas. The remaining welding parameters listed below in Table.2.2

Table3.2: show the specification of various parameters in GTAW

S.No.	Parameters	Specifications
1	Travel speed	50 mm/min
2	Diameter of electrode	3.2 mm
3	Tip angle of electrode	45 degree
4	Shielding gas	Pure argon
5	Gas flow rate	6, 8 10 (L/min)
6	Welding current	120A, 140A, 160A

Activated GTAW is same as GTAW process; only difference is activated flux layer applied prior to welding. Machine and apparatus for A-GTAW is same as GTAW and welding process followed is also same. Activating flux composed of SiO_2 powder mixtures in acetone was applied to the surface of the joint to be welded by means of a brush before GTAW.

Taguchi analysis

The experimental design is very important aspect for the efficient and in depth analysis of any process [7-9]. The basic parameters selected for the current experimental study are type of welding (GTAW and A-GTAW), welding current (A), shielding gas flow rate (L/min).

1. Noise factors: Type of welding (GTAW and A-GTAW).
2. Control factors: welding current (A), shielding gas flow rate (L/min).

In the present experimental study each control factor is given three levels as shown in Table 2.3. In the current study, L_{18} (2^1x3^2) orthogonal array has been used in the present study. Accordingly 18 runs were performed on the basis of orthogonal array. The noise factor (type of welding) has been assigned outer array, where as the control factors have been assigned inner arrays. The interaction between noise factor and control factor will also be studied.

Table3.3: Experimental Parameters and Their Levels

Factors	Units	Level 1	Level 2	Level 3
Type of Welding	-----	A-GTAW (Designated as`1`)	GTAW (Designated as `2)	---
Current	A	120	140	160
Shielding Gas Flow Rate	L/min	6	8	10

Performance Measures

In the present study, depth to width ratio, tensile strength, micro-hardness (VHN) and microstructural studies has been selected as response parameters or performance measures. Tensile test is done to determine tensile strength and micro hardness test is used to find micro hardness of the specimens.

4. RESULT AND DISSCUSSION

The results of the experimentation and mechanical testing of different welded specimens are given in Table 4.1.

Welding Type*	Welding Current (A)	SGFR (L/min)	Depth to Width ratio	Tensile strength (KN/mm^2)	Mean Microha rdness (VHN)
1	120	6	0.58	110.0	225
1	120	8	0.62	118.5	209
1	120	10	0.59	112.6	220
1	140	6	0.62	119.1	201
1	140	8	0.64	121.0	190
1	140	10	0.60	116.0	206
1	160	6	0.45	92.2	248
1	160	8	0.60	101.1	228
1	160	10	0.46	94.0	260
2	120	6	0.47	98.2	237
2	120	8	0.55	100.4	233
2	120	10	0.44	91.4	250
2	140	6	0.33	82.3	270
2	140	8	0.35	85.5	261
2	140	10	0.48	84.2	264
2	160	6	0.29	87.2	266
2	160	8	0.39	91.2	252
2	160	10	0.43	90.4	260

*1= A-GTAW, 2=GTAW

4.1 Microhardness Measurement

Micro hardness analysis done here is dependable variable on three factors:

1. Type of welding (GTAW & A-GTAW)
2. Current (A)

3. Shielding Gas Flow Rate (L/min)

Various graphs and tests have been constructed to determine which factors have a statistically significant effect on the micro hardness. Analysis of variance for S/N ratios for micro hardness is given in Table 4.2.

Table 4.2: Analysis of Variance for S/N ratios for Micro Hardness

Source	Degree of Freedom (DF)	Sum of Squares (SS)	Adjusted Sum of Squares (SS)	Adjusted Mean Square (MS)	F-Value	P-Value
Welding type	1	7.296	7.296	7.2957	22.47	0.000
Welding Current(A)	2	2.748	2.748	1.3742	4.23	0.041
SGFR (L/min)	2	1.035	1.035	0.5175	1.59	0.243
Residual error	12	3.897	3.897	0.3247		
Total	17	14.976				

Since the P-value in the Table 4.2 is less than 0.05, there is a statistically significant relationship between the variables at the 95.0% confidence level. The dependable variable micro hardness (VHN) and three in dependable variables namely welding type, welding current (A) and shielding gas flow rate (L/min) are studied to test the significance and to develop the model.

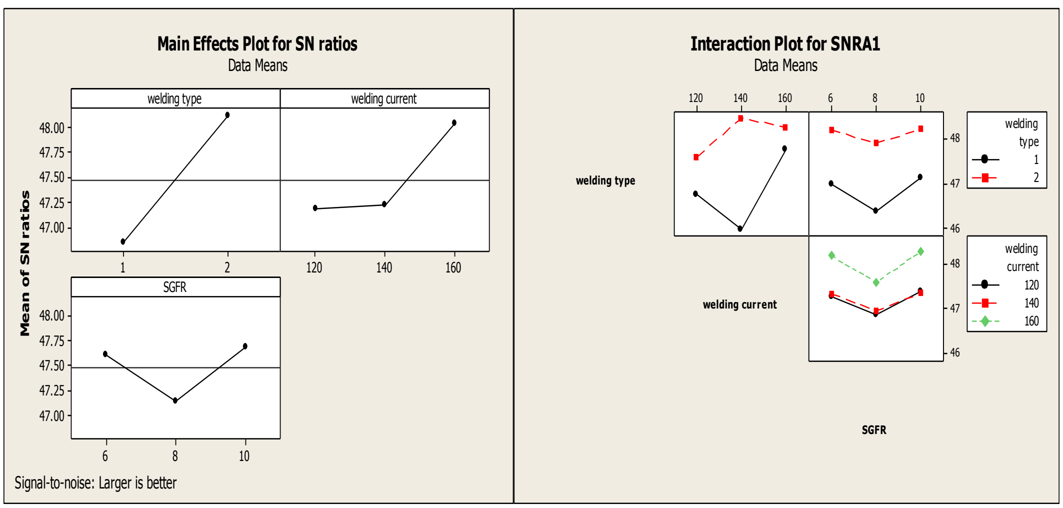

Figure 4.1: Main effects plot for S/N ratios for Micro Hardness and Interaction plots for S/N ratios

The optimum parameters found here are given in Table 4.3

Table 4.3: Optimum parameters for Micro Hardness

Welding type	Welding current(A)	Shielding gas flow rate (SGFR)(L/min)
2	160	10

4.2 Analysis of Depth to Width Ratio

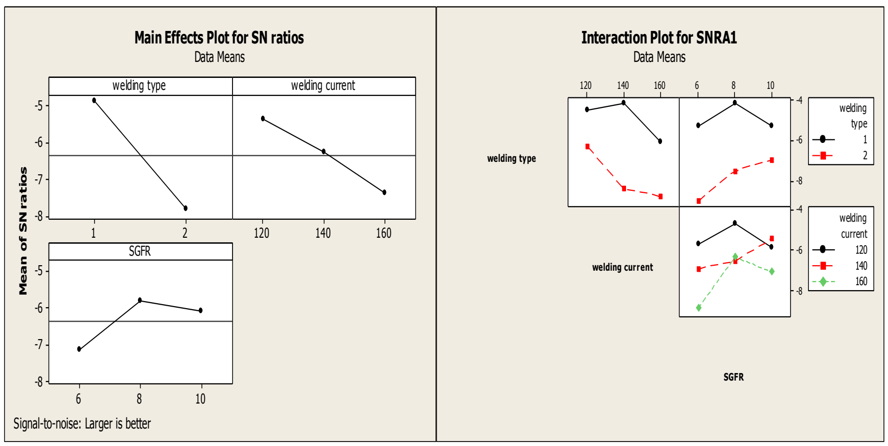

Figure 4.2: Main effects plot for S/N ratios for Depth to Width ratio and Interaction Plot for S/N ratios
The optimum parameters found here are given in Table 4.4.

Table 4.4: Optimum parameters for Depth to Width ratio

Welding type	Welding current(A)	Shielding gas flow rate (SGFR)(L/min)
1	120	6

4.3 Analysis of Tensile Strength

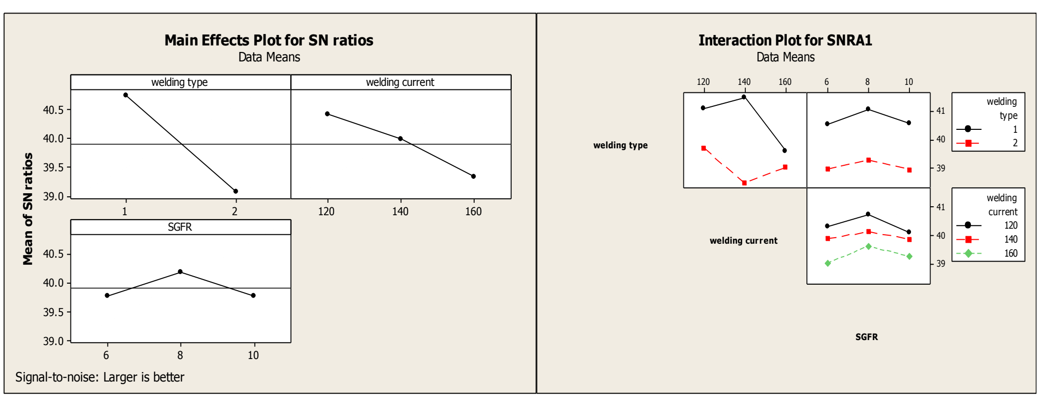

Figure 4.3: Main effects plot for S/N ratios for Tensile Strength and Interaction Plot for S/N ratios

The optimum parameters found here are given in Table 4.5.

Table 4.5: Optimum parameters for Tensile Strength

Welding type	Welding current(A)	Shielding gas flow rate (SGFR)(L/min)
1	120	8

4.4 Microstructual Analysis

Microstructural analysis of various specimens was done with an optical microscope of magnification up to 200 X to compare microstructure of GTAW and A-GTAW welds. Firstly the standard specimens are prepared. The standard sized sample is cut from the welded work piece. Firstly the sample polishing is done. Finishing of the specimen is done using the emery papers of size 100, 250, 400, 600, 1000, 1500, 2500 using polishing machine. Then the work pieces are polished using stainless steel powder and water mixture on velvet cloth using polishing machine. Then etchant is applied on the specimen. Etchant is a mixture of 12 ml HCL, 6 ml of HNo_3, 1 ml of HF, 1 ml H_2O.

5. CONCLUSIONS

Based on the present work a few important conclusions could be drawn. These conclusions are specific to the GTAW and A-GTAW used in the present work besides the different welding parametric combination used.

1. Using SiO_2 flux, not only significantly increased penetration capability, but also improved mechanical strength of the stainless steel (AISI SS304) welds as compared with conventional GTAW welds.
2. Changes in the welding current directly change the heat input and the pattern of the Marangoni convection, thus controlling the shape of the molten pool. For the GTAW process as the welding current increase there is formation of outward marangoni convection and thus decrease in depth to width ratio. In A- GTAW process as the welding current increase inward marangoni convection formed and thus increases in depth to width ratio.
3. For all the three combination of current viz 120A, 140A and 160A the depth to width is increasing for A-GTAW process as the width of the bead is decreasing resulting incremental in penetration
4. However in A-GTAW process the depth to width ratio is increasing as the current increases from 120A TO 140A, but on further increasing the current to 160A depth to width ratio decreases due to formation of outward marangoni convection resulting significant increment in width.
5. In A-GTAW process at 140A current the depth to width ratio is maximum but at the same time the hardness increases due to which ductility and toughness decrease it is due to the increase of Ferrite in austenite matrix and formation of coarse grain structure.
6. Welding parameters for best quality weld are :
    - Welding type: A-GTAW
    - Current: 120A
    - Shielding gas flow rate: 6 L/min

It can be concluded that A-GTAW at the above parameters has improved the overall quality of the stainless steel (AISI SS304) weldment, as tensile strength is improved with a decrease in micro hardness. So this study concludes that A-GTAW can be used to eliminate the drawbacks of GTAW process particularly for welding thicker plates having thicknesses more than 4 mm as its can reduces the number of passes for completing the weldment.

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