AdvancedMaterials
Manufacturing &Characterization

journalhomepage: www.ijammc-griet.com

Experimental Studies On Distortion Of Tig Welded Ss304 L Sheets And Its Influencing Parameters Using Anova

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A B S T R A C T

Gas Tungsten Arc Welding is one of the widely used welding processes which deploy a non-consumable tungsten electrode. Selection of certain welding process parameters becomes vital to achieve mechanically sound weld joints. Due to the non-uniform heat distribution, the welded components predominantly show bending distortions. This work emphasizes on minimizing the distortions, which are undesirable in strength and integrity perspective of the weld joints. Using the Analysis of Variance, the distortion in the welded joint was minimized by studying the most influential parameter attributing to it. 1.55 mm thick 304L stainless steel sheets were welded autogenously using an automatic GTAW machine. A full factorial experiment was designed with two factors as current (I) and welding speed. Two levels were selected for each factor based on the trials conducted. Distortions were measured by ink impression method and experimental data was analyzed in Minitab 17 for sorting out the influence of each parameter. Results obtained from this study signify that welding current is the critical parameter, which influences distortion to a relatively greater extent than the weld traverse speed of the electrode. Samples with relatively lesser traverse weld speeds portray more pronounced distortions due to the lack of uniform mobilization of localized heat input.

Keywords: GTAW, Distortion, SS304L, Design of Experiment.

1. INTRODUCTION

Stainless steels are the most widely used in manufacturing and construction industries. Stainless steels are categorized into five group viz. Austenitic, Ferritic, Martensitic, Duplex and Precipitation hardened. Austenitic stainless steels are the most popular and most commonly used stainless steel grade due to its properties like high strength, toughness, weldability and corrosion resistance. These austenitic stainless steels consist of 15-27% chromium which makes it highly corrosion resistant and 4-37% nickel helps to stabilize the austenitic phase [1]. A low carbon variant of austenitic stainless steel is preferred where working temperature is high and acidic. Austenitic steels generally resist intergranular corrosion [2]. Type 304L is used as a constructional component in architectural panels, food processing equipment, and chemical storage tanks. [3] As shown in figure 1, in GTAW welding process, metals are joined together by means of heat produced between non-consumable tungsten electrode and work piece. The heat produced will be attributed to melting of the faying surfaces and creating weld pool in inert atmosphere.

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• Doi: http://dx.doi.org/10.11127/ijammc2018.03.06

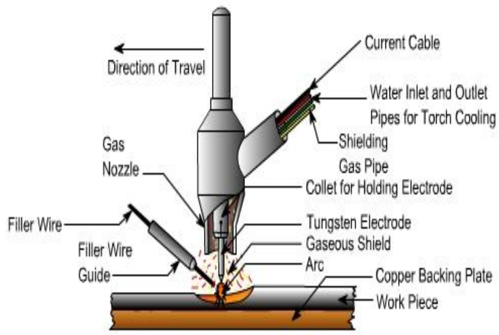

Figure 1. GTAW Welding Process[4]

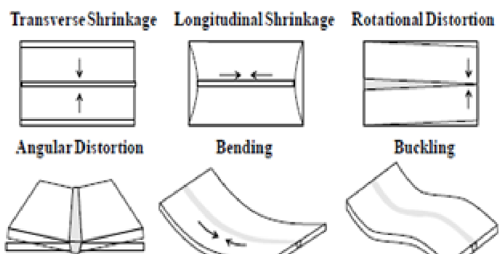

Figure 2. Types of Welding Distortions [5]

GTAW welding process is used for wide variety of materials like steels, some grades of aluminum and magnesium. This welding process is highly sophisticated and hence used in nuclear power plants, aerospace, automotive and petrochemical industries [6]. GTAW process is also called as precision welding because heat input provided to work piece can be controlled by controlling the input variables and hence this method can be employed to weld a wide range of dimensions varying from thick plates to thin sheets [7]. Though the heat input can be controlled, the distribution of heat cannot be effectively controlled. This results in distortion of the welded parts, after the completion of welding process. There are six types of distortion viz. longitudinal shrinkage, transverse shrinkage, angular distortion, bending, buckling, and rotational as illustrated in figure 2. [8]. Distortion can be controlled by either controlling design variables such as plate thickness, weld geometry, stiffeners etc. It can also be altered by controlling the welding variables such as current, groove angle, welding speed etc. [9]. Researchers have studied both numerical and experimental methods to control the distortions. Naik et al attempted to optimize the input welding parameters for GTAW welding of SS301 and found a linear agreement between current and angular distortion [10]. Shaikh et al worked on AA6061 to control the distortion during GTAW welding they have used Taguchi's approach to find percentage contribution of each parameter responsible for distortion [11]. P. Vasantharaja et al studied effect of two welding techniques namely TIG and A-TIG on distortion of SS316LN plates and observed that Activated TIG (A-TIG) exhibits lower angular distortion due to utilization of more intense heat source, lower weld metal pool, and single pass operation [12]. Mandavia et al have performed Taguchi's method to analyze influence of different input variables on distortion of SS304 plates, in this research work they have concluded that current, Groove angle and Welding speed are the three most responsible factors [13]. S. Akella et al used MS sheets of 3mm thick to study distortions by GTAW welding, from results obtained it is found that root gap has major contribution of 43% and current contributes 36% in influencing the distortion [14]. Vedprakash et al compared ANOVA and Artificial Neural Network developed to study welding distortion in SS304 and found that current and groove angles are directly proportional to degree of distortion while welding speed shows inverse relation, also the % contribution of current is highest among these input variables to influence the distortion [15]. This research work attempts to study the various parameters responsible for distortion in SS304L sheets during GTAW welding by ANOVA method.

2. EXPERIMENTATION

In this research work 1.55 mm thick type 304L stainless steel sheets have been used in as received condition. The chemical composition is shown in Table 1 below. Six pairs of specimens with different dimensions namely 100x200mm, 90x200mm, 80x200mm, 70x200mm, 60x200mm, 50x200mm. As thickness of sheet is very less square butt joint design were considered without any gap between the sheets. Two factor factorial experiments were designed with two levels of each as shown in Table 2 below. Two factors and levels were selected based on literature and trials. For Full factorial design, if levels are equal to number of factors, then maximum possible design is N=Lm. Where, L is max number of levels and m is maximum number of factors. An Ador Fontech automatic TIG welding machine (Model: TZ3BS4BY4) is used to fabricate the welds.

Table 1. Chemical Composition of SS304L

Elements	Amount (wt %)
Cr	17.74
Ni	8.39
C	0.04
Mn	1.67
Si	0.59
Cu	0.15
S	0.03
Mo	0.069
Fe	Bal

Table 2. Welding Parameters

Sl. no	Parameter	Current (A)	Speed (mm/min)	Voltage (v)	Purging (SLPM)
1	Level 1	58	100	10.1	12
2	Level 2	70	170	10.5	12

3. RESULTS AND DISCUSSION

3.1. MICROSTRUCTURE ANALYSIS

Figure 3 shows the 1.55mm thick type 304L Stainless steel weld joint fabricated by GTAW welding. Visual inspection gives a good impression about welding practice followed; it shows the thorough weld penetration throughout the weld length and also uniformly along the weld pool.

Figure 3. GTAW Welded Sample

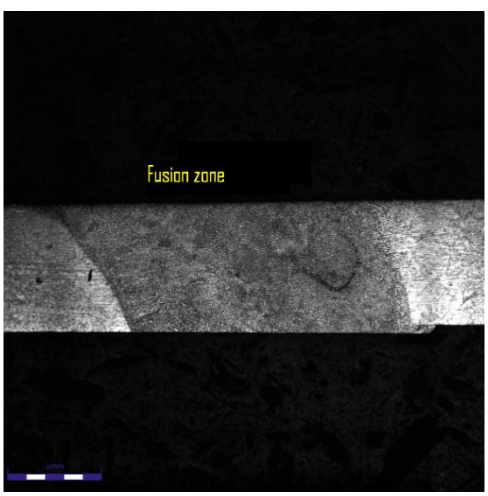

Figure 4. Microstructure weld cross-section

Figure 4 shows the overview of the weld cross-section, which confirms the full penetration of weld with absence of any defects or flaws. Figure 5 shows the interface zone, where we can observe the fine dendrite structure with presence of δ-ferrites in fusion zone, this fine dendrite structure indicates the good weld strength. For any welding process, HAZ is expected to be narrow as it shows the coarse grains, which are not desirable in strength perspective. Here, it is observed that HAZ is very narrow to fusion zone; it accounts for 250 µm, whereas fusion zone accounts for 4684 µm.

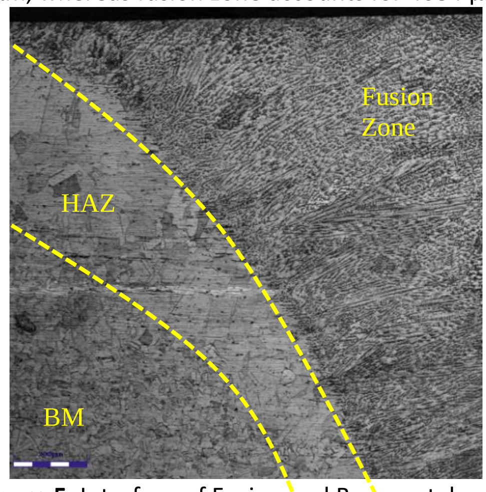

Figure 5. Interface of Fusion and Base metal zone

3.1. MODEL ADEQUACY CHECKING

In statistical model, it is assumed that residuals are normally distributed and this can be confirmed by plotting residual plot. Figure 6 shows the normal probability plot which elucidates the residuals fall in a straight line, since the errors are normally distributed. Also versus fits shows no unusual structure, implying that the designed model is correct.

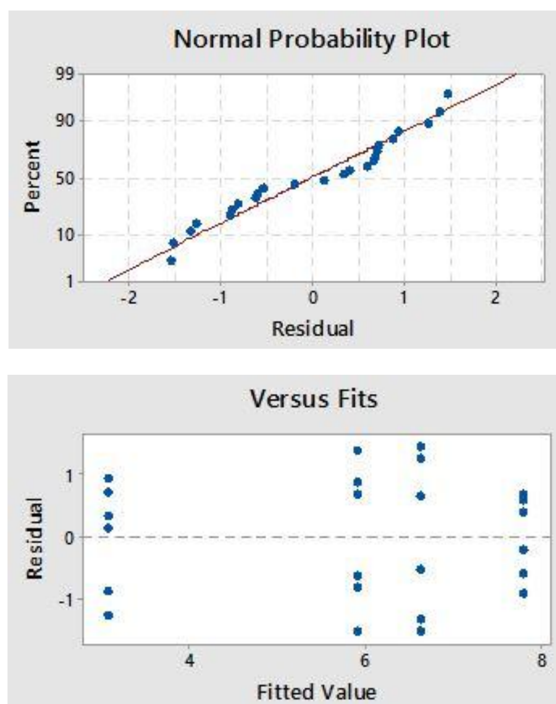

Figure 6. Residual Plots for Distortion angle

Table 3.Experimental Results

Parameter		Distortion Values			
	Welding Speed	**100mm/min**		**170mm/min**	
Current (A)	58A	8.1	7.9	3.2	3.8
		6.1	7.3	4.2	3.8
		5.1	5.3	3.4	4.0
	70A	7.6	7.2	6.8	4.4
		8.2	7.8	7.3	5.3
		8.4	8.5	6.6	5.1

3.2. ANOVA ANALYSIS

Statistical Model

$$\mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ij}$$

Hypothesis

Null Hypothesis=$\alpha_i = 0$, $\beta_j = 0$

Alternate Hypothesis = at least one, $\alpha_i \neq 0 \beta_j \neq 0$

As name suggests, the analysis of variance (ANOVA) is a statistical tool, which analyzes the variation among the group mean and helps to find out, whether the survey results are significant or not. It also helps in deciding, whether to reject null hypothesis or accept alternate hypothesis. Results of experiments are illustrated in Table 3. It shows the angular distortion values corresponding to the current and welding speed.

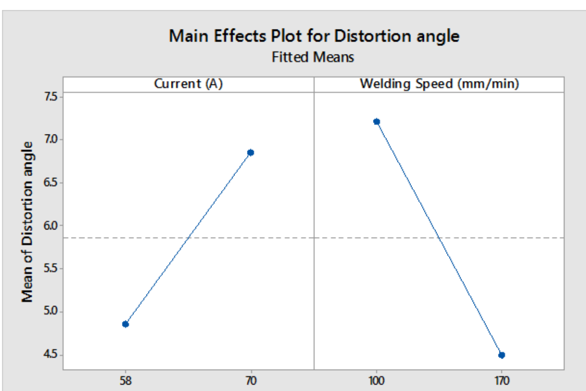

Figure 7. Main Effects Plot

The main effects plot studies the behavior of all the factors individually. According to the main effects plot shown in Figure 7, it is observed that current is directly proportional to the distortion angle. Since the current increases the heat input during welding, the arbitrary dissipation of heat originates the distortion. From the interaction plot, it was understood that for the 70 A current, distortion is maximum. In contrast, the welding speed showed the inverse relation; as welding speed increases the distortion is less pronounced. The optimum conditions for the weld distortion are current at level 1 and welding speed at level 2. From the Figure 8, it is observed that both lines are parallel to each other and hence it is further inferred, that there is no significant effect of interaction factor on weld distortion and this can be verified by ANOVA results shown in below Table 4.

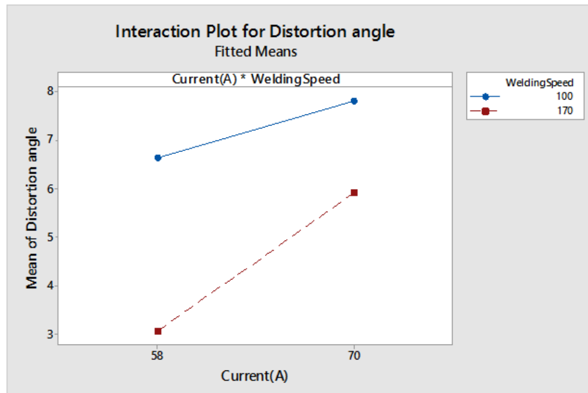

Figure 8. Interaction Plot

$$Heat\ input = \frac{V \times I \times 0.06}{S}$$

Where, V- voltage, I- current and S- welding speed. From Table 4, the contribution of each factor in distorting the samples can be found. Here welding current plays major role which contributes 60.15%, and welding speed contributes 32.67%. Hence it was concluded that current is the most significant input variable which needs to be controlled in order to control and mitigate the distortion.

Table 4. Result of ANOVA

Welding Parameters	DOF	Squared Sum	Mean Squares	F-Value	%P
Current	1	44.55	44.55	41.96	60.15
Welding Speed	1	24.20	24.20	22.79	32.67
Interaction	1	4.25	4.25	4.00	5.7
Error	20	21.235	1.062	1	1.4
Total	23	117.15	-	69.75	100

4. CONCLUSION

This study emphasizes the deployment of DOE in analyzing the effect of GTAW welding input variables (current and welding Speed) on welding distortion of SS304L sheets, from the full Factor Factorial design and thereby designing the optimal welding parameters with minimum distortion. From this experimental study, the following conclusions are drawn.

- The Microscopic analysis shows the fine dendrites and narrow HAZ, which indicates good strength and full penetration of the GTAW weld joint.
- In GTAW weldments with square butt joint design, the most influencing parameter was found to be welding current and welding traverse speed.
- In order to have a minimized welding distortion for 1.55 mm thick SS304L sheets, the optimal input variables are found to be 58 A of welding current and 170 mm/min of welding speed.
- The main effects plots illustrate, that current is the most significant parameter which contributes 60.15% in influencing the weld distortion, while speed contributes only 32.67%.

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