Angular Distortion Analysis on the Basis of Current, Gas Flow Rate and Welding Speed in Austenitic Stainless Steel Welding Using GTAW With and Without Flux Powder

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Abstract - This study aims at the investigation of the effect of flux powder on angular distortion in 304- austenitic stainless steel welding using Gas Tungsten Arc Welding (GTAW). Trial runs have been conducted to find the most effective levels of the factor to be used for the experimentation. Three input machine parameters namely current, welding speed and gas flow rate have been considered in order to find out the influence of parameter on weld bead geometry, i.e. angular distortion. The range of input parameter has been selected on the basis of the size of the specimen.

Keywords – Angular distortion, Gas flow rate, Flux powder, Gas tungsten arc welding

I. INTRODUCTION

In order for gas tungsten arc welding to be a feasible process for welding of thick material the shallow penetration and subsequent low productivity must be improved. Surface active fluxes have shown success in increasing the penetration of GTAW process, allowing thicker material to be welded in fewer passes and in less time. Improvement in weld penetration has long been sought in Gas Tungsten Arc Welding because this welding process has a single pass welding process. The technique of using active fluxes in- crease penetration makes it possible to join thick material by single-pass welds with no edge preparation.

II. SYSTEM MODEL

Objective of study is experimental analysis of the effects of flux powder with different process parameter i.e. current, gas flow rate and arc travel speed on the bead angular distortion and generating the optimum values of different responses in TIG Welding process.

Gas Tungsten Arc Welding process was employed in the following steps:

1. Specimen size of 100 mm x 100 mm x 5 mm were cut from the plate which were roughly polished with 400 grit abrasive paper to remove surface impurities and then washed with acetone.

2. Flux powder was mixed with acetone, acetone and flux powder typically mixed in a ratio 1:1 to produce like paint.

3. Flux powder paste is applied manually with paintbrush to the surface where welding to be performed. Acetone evaporates leaving behind a thin layer of active flux. The coating density of flux is about 10 mg/cm2 and thickness of flux layer is about 0.2mm.

4. Welding is done in a single pass on the work piece without clamping the work- piece.

III. PREVIOUS WORK

This literature review begins with some general information about the surface active flux. It is followed by a discussion on how the surface-active element in the flux influences Marangoni flow penetration in Gas Tungsten Arc Welding. Ravi *et al*. [7] studied the effect of different fluxes on hardness and micro- structure of Stainless steel 304 in GTAW welding. They used Fe_2O_3, $MgCl_2$, MnO_2, and ZnO as activating flux to investigate the effect of activated tungsten inert gas (activated TIG) process on microstructure and hardness of grade 304 stainless steels. Since the activated TIG welding showed non uniformly cooled unidirectional grains with size varying from fine to coarse in the weld zone in their microstructure characteristics. The results showed that MnO_2 flux can only led to increase in the hardness (306Hv) in weld zone except the other flux used. The fissure bend test originally developed and evaluated for determining the cracking resistance of SMA deposited austenitic weld metals had been extended to evaluate GTA and GMA deposited filler metals. The effect of nitrogen additions to the shielding gas, in the GTA process, on the ferrite content of the deposited weld metal had been defined. The nitrogen addition technique showed that it is an effective way of reducing and/or controlling ferrite content. Her-Yueh Huang [4] investigated the effects of shielding gas composition and activating flux on weld morphology, angular distortion, retained delta-ferrite content, mechanical properties and hot cracking susceptibility. An autogenously gas tungsten arc welding process was used on austenitic stainless steel to produce a bead on plate weld. The nitrogen content in the argon-based shielding gas was in the range of 2.5–10 vol. %. Activating flux materials consisted of a manganese oxide powder and zinc oxide powder mixture. The results showed that the penetration and cross-sectional area of the weld increased with the increase of nitrogen added to the argon-base shielding gas. The hot cracking susceptibility of the austenitic stainless steel welds increased as the nitrogen content increased. Activating flux plays a major role than nitrogen added in argon shielding gas, which influenced the various properties of austenitic stainless steel TIG welds. The flux effect on TIG weld shape variations was investigated by application of the heat transfer and fluid flow model[9]. The simulation made use of Ni- monic 263 alloy, TiO, TiO_2 and Ti_2O_3 as the flux. The arc constriction and the reversed Marangoni convection were considered to be the two main factors for increasing penetration of A-TIG weld pool and the simulated results showed that the latter was the main factor for changing weld shapes. The surface tension temperature coefficient was sensitive to the active elements and affects the pattern of the fluid flow. By controlling the category and quantity of the active elements, different kinds of the weld shapes were obtained. The performance of activated TIG process in mild steel welds studied by Balvinder *et al*.[3]. Different kind of oxide Cr2O3 ,MgCO3, 1:1 mixture of both these powder, MgO, CaO, Al2O3 oxide powder were used on mild steel. The experimental results showed that activating flux aided TIG welding had increased the weld penetration, tending to reduce the width of the weld bead .Also on increasing penetration by applying the flux on mild steel its hardness get reduced and there subsequently increased in depth to width ratio. The Cr2O3 flux produced most noticeable effect.

IV. PROPOSED METHODOLOGY

This part presents the various steps involved in material selection, preparation of work piece, the experimental setup used, the process of making sample, selection of process parameters, steps involved in welding, sectioning, polishing & etching has been described. Last step is preparing of work piece for identifying the shape of the weld bead profile.

4.1 SELECTION OF MATERIAL

Stainless steel 304 is the most versatile and most widely used of all stainless steels. Its chemical composition, mechanical properties, weldability, and corrosion resistance provides the best all-round performance stainless steel at relatively low cost. It also has excellent low temperature properties and responds well to hardening by cold working. Because of its lower carbon content stainless steel is not so prone to give car- bide precipitation and resultant corrosion after the welding. It is also termed as a chromium-nickel austenitic alloy. Chemical composition of stainless steel shown in Table 4.1

Table 4.1 Chemical Composition of Stainless Steel-304

Chemical composition							
Constituent	C	Mn	P	S	Cr	Ni	Si
%	.036	1.08	.038	.005	18.52	8.051	.23

4.2 PREPARATION OF SPECIMEN

Preparation of specimen is a key step for performing welding. First of all specimens are cut into size of 100 mm x 80 mm x 5 mm in abrasive cutting machine which is shown in Fig. 4.1 and then grinding is performed for removing burr and sharp edges from the specimen edge. Grinding machines as shown in Fig. 4.1

Fig. 4.1 Grinding Machine and Abrasive Cutting Machine

After removing burrs from the specimen parts, then specimen were roughly polished with abrasive paper to remove surface impurities and then cleaned with acetone. GTAW process was employed on 304 stainless steel material with butt joint. The flux was mixed with acetone and make like paste then paste is manually applied at the area where welding to be done. Now specimens are ready for performing welding operation.

The experimental result sho

4.3 EXPERIMENT PROCEDURE

Trail runs have been conducted to find out suitable factors and their levels for welding the specimen. The process parameter at different levels are listed in Table the most important parameter which have greater influence on the weld bead geometry were found as welding current, travel speed and gas flow rate. Similarly factor levels were evaluated the trail runs and subsequently inspecting the weld bead geometry.

Table 4.2 Process Parameter and Level

Factor	Level		
	1	2	3
Current (A)	130	140	150
Gas flow rate (L/min)	12	13	14
Travel speed (mm/min)	150	175	200

For the welding of specimens TIG machine is used from the welding lab of central workshop. Maximum current capacity of TIG machine is 160 ampere. TIG welding machine is shown in Fig 4.2. The main components of the machine are power and earth cables, argon cylinder welding torch cable and welding torch, face shield etc.

Fig. 4.2 TIG Welding Equipment

Other equipment is used for the dedicated travel speed Table which is fabricated for providing automatic travel speed to specimen so that one of the factor i.e. arc travel speed can be regulated.

V. SIMULATION/EXPERIMENTAL RESULTS

5.1 ANGULAR DISTORTION

Distortion or deformation can occur during welding as a result of the non-uniform expansion and contraction of the weld and base metal during the heating and cooling cycle. Stresses form in the weld as a result of the changes in volume, particularly if the weld is restrained by the fixed components or other materials surrounding it. If the restraints are partly removed, these stresses can cause the base material to distort and may even result in tears or fractures. Some of the factors that should be considered include the degree of restraint; the thermal and other properties of the parent material; inherent stresses induced from previous metal working processes such as rolling, forming and bending, design of weldment, accuracy of manufacture and the nature of the welding process itself the type of process, symmetry of the joint, preheat and the number and sequence of welds required.

5.2 S/N RATIO

In Taguchi's design method the design parameters (factors that can be controlled by designers) and noise factors (factors that cannot be controlled by designers, such as environmental factors) are considered influential on the product quality. The Signal to Noise (S/N) ratio is used in this analysis which takes both the mean and the variability of the experimental result into account. The S/N ratio depends on the quality characteristics of the product/process to be optimized. Usually, there are three categories of the performance characteristics in the analysis of the S/N ratio; that is, the lower-the-better, the higher-the-better, and the nominal-the-better. The S/N ratio for each response is computed differently based on the category of the performance characteristics and hence regard- less of the category the larger S/N ratio corresponds to a better performance characteristic. In the present study the dome height and thinning factor are the-higher-the-better performance characteristics. Once all of the S/N ratios have been computed for each run of an experiment, Taguchi advocates a graphical approach to analyze the data. In the graphical approach, the S/N ratios and average responses are plotted for each factor against each of its levels.

After the successful experiment, result has been discussed on Angular distortion (θ).

5.3 ANALYSIS OF ANGULAR DISTORTION WITHOUT FLUX

Three trail tests without flux have been done in order to get three angular distortion results which are listed in Table 5.1.

Table 5.1 Analysis of Angular Distortion (Without Flux)

S No.	θ1	θ2	θ3	Sum Square	S/N Ratio	Average
1	4.42	4.56	4.74	20.93	-13.21	4.57
2	4.63	4.52	4.32	20.18	-13.05	4.49
3	4.72	4.96	4.89	23.60	-13.73	4.86
4	3.59	3.64	3.74	13.38	-11.26	3.66
5	3.84	3.93	3.85	15.00	-11.76	3.87
6	3.31	3.41	3.41	11.40	-10.57	3.38
7	3.45	3.56	3.48	12.23	-10.87	3.50
8	3.22	3.35	3.27	10.76	-10.32	3.28
9	3.25	3.33	3.37	11.00	-10.42	3.32

The values of S/N ratio and angular distortion w.r.t. to current are given in Table 5.2 and the variation of the S/N ratio and Angular Distortion w.r.t. current is shown graphically in Fig. 5.1.

Table 5.2 Variation of S/N Ratio and Angular Distortion w.r.t. Current

S No.	Raw Data	S/N Data	Current(A)
1	4.64	-13.33	130
2	3.64	-11.20	140
3	3.36	-10.54	150

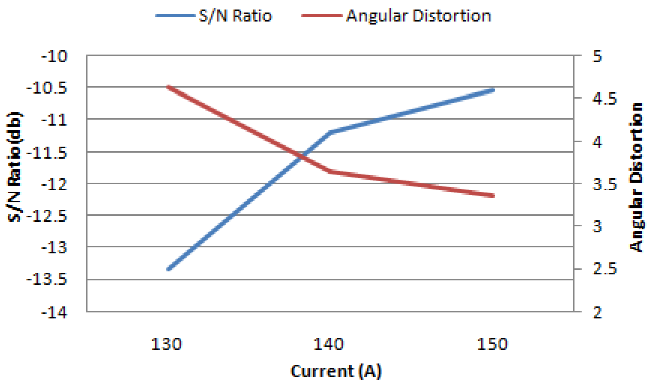

Fig. 5.1 S/N Ratio and Angular Distortion w.r.t. Current

The values of S/N ratio and angular distortion w.r.t. to gas flow rate are given in Table 5.3 and the variation of the S/N ratio and angular distortion w.r.t. gas flow rate is shown graphically in Fig. 5.2.

Table 5.3 Variation of S/N Ratio and Angular Distortion w.r.t. Gas Flow

S No.	Raw Data	S/N Data	Gas Flow Rate (L/min)
1	3.91	-11.78	12
2	3.88	-11.71	13
3	3.85	-11.57	14

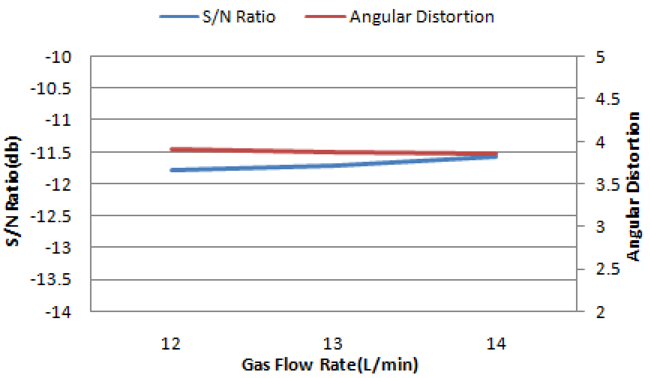

Fig. 5.2 S/N Ratio and Angular Distortion w.r.t. Gas Flow Rate

The values of S/N ratio and Angular Distortion w.r.t. to travel speed are given in Table 5.4 and the variation of the S/N ratio and Angular Distortion w.r.t. travel speed is shown graphically in Fig. 5.3.

Table 5.4 Variation of S/N Ratio and Angular Distortion w.r.t. Travel Speed

S No.	Raw Data	S/N Data	Travel Speed (mm/min)
1	3.74	-11.37	150
2	3.82	-11.58	175
3	4.08	-12.12	200

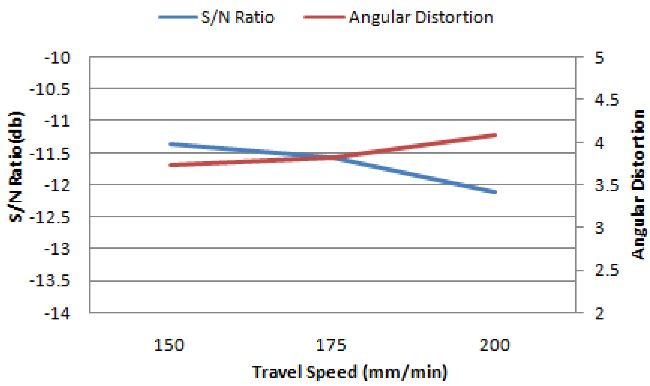

Fig. 5.3 S/N Ratio and Angular Distortion w.r.t. Travel Speed

5.3.1 Optimum Results for Each Parameter of Angular Distortion (Without Flux)

A smaller S/N value corresponds to a better performance when smaller the better method is used. Therefore, the optimal level of the angular distortion is the level with the smallest S/N value. Table show the main effect of the process parameter. Based on the analysis of the S/N ratio the optimal bead width is obtained for welding current of 140 (level 1), Gas Flow Rate of 12L/min (level 1) and travel speed of 150mm/min (level 3).

5.4 ANALYSIS OF ANGULAR DISTORTION WITH FLUX

Three trail tests with flux have been done in order to get three angular distortion results which are listed in Table 5.5.

Table 5.5 Analysis of Angular Distortion (With Flux)

S No.	θ1	θ2	θ3	Sum Square	S/N Ratio	Average
1	2.47	2.45	2.46	6.05	-7.82	2.46
2	2.36	2.19	2.28	5.18	-7.14	2.28
3	2.15	2.40	2.28	5.19	-7.15	2.28
4	2.54	2.65	2.60	6.74	-8.28	2.60

5	2.51	2.41	2.46	6.05	-7.82	2.46
6	2.57	2.59	2.46	6.45	-8.10	2.54
7	1.61	1.71	1.84	2.97	-4.72	1.72
8	1.93	1.89	1.95	3.70	-5.68	1.92
9	1.74	1.77	1.71	3.03	-4.81	1.74

The values of S/N ratio and Angular Distortion w.r.t. to current are given in Table 5.6 and the variation of the S/N ratio and Angular Distortion w.r.t. current is shown graphically in Fig. 5.4.

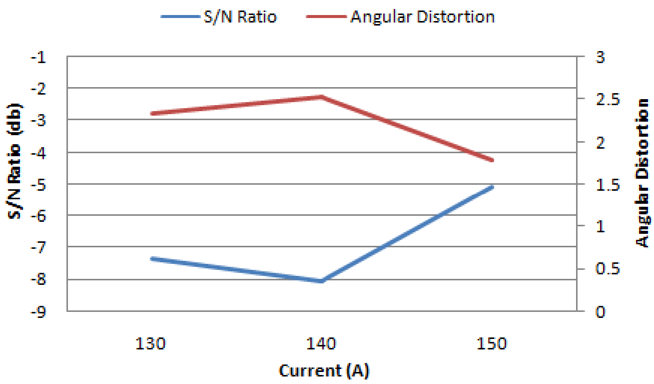

Fig. 5.4 S/N Ratio and Angular Distortion w.r.t. Current

Table 5.6 Variation of S/N Ratio and Angular Distortion w.r.t. Current

S No.	Raw Data	S/N Data	Current(A)
1	2.34	-7.37	130
2	2.53	-8.07	140
3	1.79	-5.07	150

The values of S/N ratio and Angular Distortion w.r.t. to gas flow rate are given in Table 5.7 and the variation of the S/N ratio and Angular Distortion w.r.t. gas flow rate is shown graphically in Fig. 5.5.

Table 5.7 Variation of S/N Ratio and Angular Distortion w.r.t. Gas Flow

S No.	Raw Data	S/N Data	Gas Flow Rate (L/min)
1	2.26	-6.94	12
2	2.22	-6.88	13
3	2.19	-6.69	14

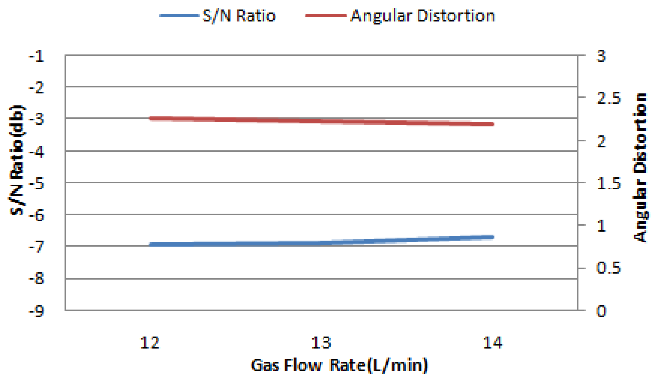

Fig. 5.5 S/N Ratio and Angular Distortion w.r.t. Gas Flow Rate

The values of S/N ratio and Angular Distortion w.r.t. to travel speed are given in Table 5.8 and the variation of the S/N ratio and Angular Distortion w.r.t. travel speed is shown graphically in Fig. 5.6.

Table 5.8 Variation of S/N Ratio and Angular Distortion w.r.t. Travel Speed

S No.	Raw Data	S/N Data	Travel Speed (mm/min)
1	2.31	-7.20	150
2	2.20	-6.75	175
3	2.15	-6.56	200

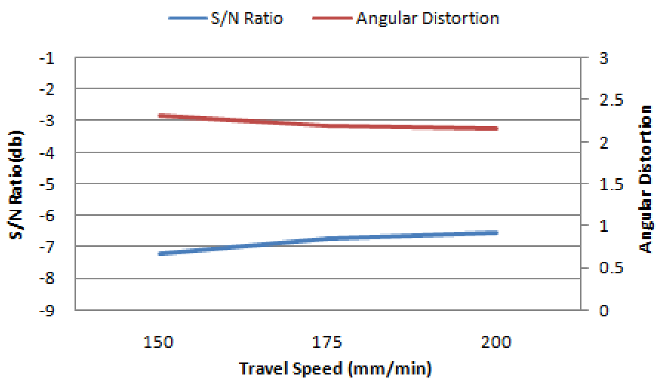

Fig. 5.6 S/N Ratio and Angular Distortion w.r.t. Travel Speed

5.4.1 Optimum Results for Each Parameter of Angular Distortion (With Flux)

A smaller S/N value corresponds to a better performance when smaller the better method is used. Therefore, the optimal level of the angular distortion is the level with the smallest S/N value. Table show the main effect of the process parameter. Based on the analysis of the S/N ratio the optimal angular distortion is obtained for welding current of 140A (level 2), Gas Flow Rate of 12L/min (level 1) and travel speed of 150mm/min (level 1).

5.5 COMPARISON OF ANGULAR DISTORTION BETWEEN WITH FLUX AND WITHOUT FLUX

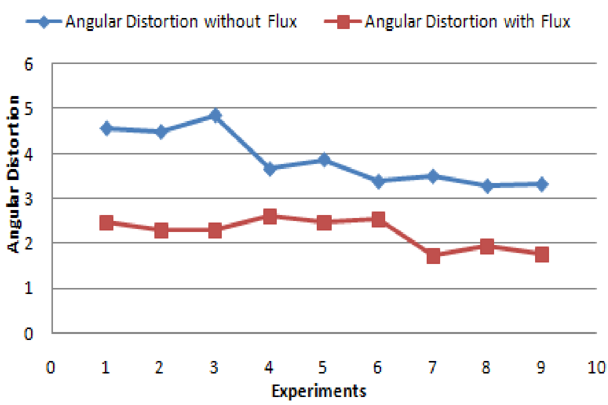

Fig. 5.7 Variation of Angular Distortions of Experiment with Flux and Without Flux

Fig. 5.7 shows that angular distortion line without flux above the angular distortion line with flux. Comparing these two, 42.75 % reductions have been noticed in angular distortion with flux.

VI. CONCLUSION

In the presented study, the effect of different parameters i.e. current, travel speed and gas flow rate on angular distortion with flux and without flux was found. The results of present experimentation work have shown that the application of activating flux in welding can substantially decrease angular distortion as compared to welding without active flux. During this work it was also found that angular distortion can be decreased by using flux powder without clamping the work piece.

VII. FUTURE SCOPES

For obtaining better result other parameters of welding can be choose and find out the effect on angular distortion. Instead of using other costly and time consuming techniques for improvement in angular distortion, it is better to use flux powders like (SiO_2) or others.

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