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Experimental Investigation of welding distortion of Austenitic Stainless Steel 316 in TIG Welding

S.M.Ahir[1], N.B. Patel[2], K.A.Patel[3]
Research Scholar[1], Assistant Professor[2,3]
[1,2]Department of Mechanical Engineering, MEC, Basna
[3]Department of Mechanical Engineering, L.D.R.P. Institute of technology and research, Gandhinagar

***Abstract* - Tungsten Inert Gas (TIG) welding is a widely applied manufacturing process. The present work carried on the optimization of weld process parameters with Taguchi approach for the distortion control applied to Austenitic stainless steel 316 structures of 8.5 mm thickness with two pass TIG weld process. Taguchi is applied for the optimization of weld parameters control. In this study the distortion of TIG, welding process was evaluated using weld current, Weld Angle and the weld speed as the main parameters. A L9 orthogonal array was selected for the design of experiments towards the distortion optimization caused by butt welding. ANOVA was perfumed to obtain significant parameter which gives the percentage contribution of each process parameter under operating Condition.**

***Key word* - GTAW, austenitic stainless steel, distortion, Taguchi method, ANOVA analysis, parameter optimization**

I. INTRODUCTION

Tungsten inert-gas (TIG) welding or gas tungsten arc welding (GTAW) is an inert-gas shielded arc welding process using non-consumable electrode. The electrode may also contain 1 to 2 % thorium oxide mix along with the tungsten with 0.15 to 0.40% zirconium oxide. The pure tungsten are less expensive but they will carry less current. The thorium tungsten electrodes carry high currents and more desirable because they can strike and maintain a stable arc with ease. The zirconia added tungsten electrodes are better than pure tungsten but they in farrier to thoriated tungsten electrode.

A typical tungsten inert-gas welding setup is shown in fig.1It consists of a welding torch as the center of which is the tungsten electrode. The inert-gas is supply to the welding zone through the annular path surrounding the tungsten electrode to effectively displace the atmosphere around puddle. The smaller weld torches may not be provided with any cooling devices for the electrodes.

Power sources the power sources used are always of the constant-current type. Both direct current (DC) and alternative current (AC) power supplies can be used for TIG welding. When DC is used, the electrode can be negative (DCEN) or positive (DCEP).

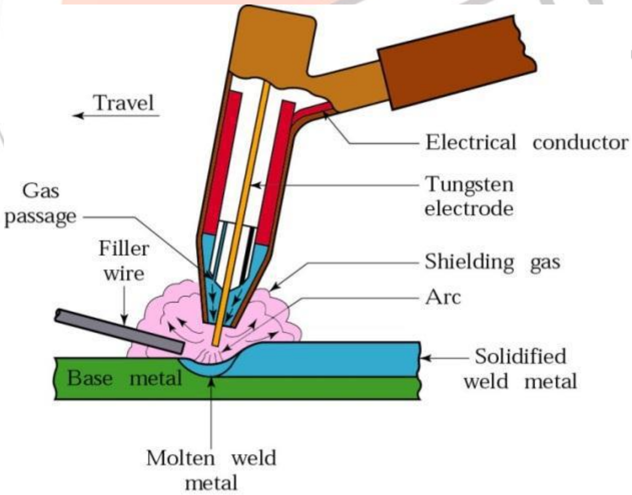

Fig.1 TIG Welding Process (Serope Kalpakjian, 2006) [8]

This work is taken up as there are many variables and there is enough scope to study TIG welding. Using Taguchi's method a set of experiments is designed at different levels of weld parameters to obtain weld distortion. Analysis of variance and signal-to-noise ratio of robust design were employed to investigate the influence of different welding conditions on weld distortion. This is a field that has been discussed due to its use in electrical appliances and automobile industries aero space industries and following are some important observations reported by researchers.

Deepak malik at. al[1] angular distortion has positive effect with increase in length of plates and diameter of electrode. Angular distortion has negative effect with increase in current and time gap between passes.

Mamatha.K at. al[2] the optimization of welding input parameters leads to determining the best settings and tolerances for Xs to optimize Ys, thus reducing the welding angular distortion of fillet weld of Deck height.
S.Akellaa, at. al[3] design of experiments towards the distortion optimization caused by butt welding. It was found from these experiments that Root gap has a major contribution of 43% and Weld current of 36% influence on distortion.
Liang Tian at. al[4] Welding experiment is performed to verify the accuracy of the FE model developed. It is found that the angular distortion first increases to its maximum value at the threshold of heat input, then decreases with the further increasing of heat input, while the transverse shrinkage increases with the increasing of heat input continuously.
G.Karthik at. al[5] the weld ability properties of, namely tensile strength of the Shielded metal arc welded and welded and Tungsten inert gas welded austenitic 304 stainless steel were studied. And it shows the yield strength and ultimate strength of TIG welding properties were better than the SMAW welding properties.
Mr. L. Suresh Kumar et. al [6] the ultimate load of TIG welded specimen is 57600 N where as for the MIG welded specimen is 56160N. Therefore we can say that TIG welded specimen can bear higher loads than MIG welded specimen. The ultimate tensile strength of TIG welded specimen is 675.22 MPa where as for the MIG welded specimen is 652.029 N/mm square. Therefore we can say that TIG welded specimen has higher tensile strength.

II. STAINLESS STEEL

Austenitic is the most widely used type of stainless steel. It has a nickel content of at least of 7%, which makes the steel structure fully austenitic and gives it ductility, a large scale of service temperature, non-magnetic properties and good weld ability. The range of applications of austenitic stainless steel includes house wares, containers, industrial piping and vessels, architectural facades and constructional structures.
Austenitic grades are those alloys which are commonly in use for stainless applications. The austenitic grades are not magnetic. The most common austenitic alloys are iron-chromium- nickel steels and are widely known as the 300 series. The austenitic stainless steels, because of their high chromium and nickel content, are the most corrosion resistant of the stainless group providing unusually fine mechanical properties. They cannot be hardened by heat treatment, but can be hardened significantly by cold-working. The special material properties of stainless steels affect all four machinability factors: in general, it can be said that the higher the alloy content of a stainless steel, the more difficult it is to machine. The special properties that make stainless steels difficult to machine occur to a greater or lesser extent in all grades of stainless steels, but are most marked in the austenitic grades. They can be summarized in five points:

- Stainless steels work-harden considerably
- Stainless steels have low thermal conductivity
- Stainless steels have high toughness
- Stainless steels tend to be sticky
- Stainless steels have poor chip-breaking characteristics

As the stainless steel is classified in different categories like austenitic, ferrite, martens tic etc., from this we have chosen austenitic stainless steel.

III. EXPERIMENTS

TIG welding was carried out with 316 SS samples of 100 mm X 50 mm X 8.5 mm of each and the final sample with size of 100 mm X 100 mm X 8.5 mm. The 316 SS samples are fabricated with V grove design (groove angle of 60·, 70· and 80·) design edge preparation with 1.5 mm root gap and 1.5 mm root face joined with two pass TIG welding process. The distortions are observed in all the samples and are measured with vernier height gauge on surface measurement table. The current variation was 125 to 175 Amps.

Experimental setup
The welding process was carried out using TIG M-400 (50-400 amp.) The chemical composition of the work material is shown in table.1. Shows the actual welded samples used for joining TIG welding for different range of weld parameters which are shown in table.2

Fig. 2 Weld Specimen

Fig. 3 Welding machine with specimen

Table: 1 Chemical property

Element Details	Required value in %	Observed Value in %
CARBEN	0.080 MAX	0.026
SILICON	0.750 MAX	0.745
MANGANESE	2.00 MAX	0.947
PHOSPHORUS	0.045 MAX	0.026
SULPHUR	0.030 MAX	0.006
CHROMIUM	16.000 To 18.000	17.630
NICHEL	10.000 To 14.000	11.890
MOLYBDENIUM	2.000 To 3.000	2.219
NITROGEN	0.100 MAX	0.030

IV. IDENTIFICATION OF FACTORS

Control factors and noise factors are two factors used in Taguchi's approach to identify the optimal process settings that are minimally sensitive to noise. Control factors are generally controlled during the manufacturing while noise factors are often uncontrollable.

Table: 2 Parameter and factor

Parameter	Code	Level 1	Level 2	Level 3
Current	A	125 A	150 A	175 A
Speed	B	60 mm/min.	70 mm/min.	80 mm/min.
Groove angle	C	60·	70·	80·

In the present work, welding current, welding speed and groove angle were considered as control factors and varied at three levels as shown in table 2. L9 orthogonal array was found out to be appropriate for the selected level and three interactions involving in the table were considered. Signal-to-noise ratio for every combination of weld parameters was calculated and shown in table 3.

Table: 3 Experimental tested data

Sr.no.	Current	Groove angle	Speed(mm/min)	Distortion(mm)	s/n ratio
1	125	60·	60	1.810	-5.1536
2	125	70·	70	2.925	-9.3225
3	125	80·	80	1.773	-4.9742
4	150	60·	70	1.725	-4.7358
5	150	70·	80	2.025	-6.1285
6	150	80·	60	2.405	-7.6223
7	175	60·	80	2.225	-6.9466
8	175	70·	60	3.178	-10.0431
9	175	80·	70	2.575	-8.2155

To know the effects of the three parameters the overall mean value of S/N rations is calculated as follows:

$$M = \frac{1}{k}(\eta_1 + \eta_2 + \cdots + \eta_k) \quad (1)$$

Where κ is the total number of experimental repetition, η= s/n ratio

Analysis of Variance for various responses: The purpose of ANOVA is to investigate process parameter, which significantly affect the quality characteristic. The calculations are done based on following equations for each factor at each level. The generalized equation is given below:

$$\text{sum of squares } (SS) = 3\left[(M_{A_1} - M)^2 + (M_{A_2} - M)^2 + (M_{A_3} - M)^2\right] \quad (2)$$

Degree of freedom associated with any SS will always be one less than the number of observations whose squares are summed. Here there are 3 observations considered in computing SS and hence degree of freedom is 2 in present case.

$$\text{mean square } (MS) = \frac{\text{sum of squares due to the factor}}{\text{degree of freedom}} \quad (3)$$

Error variance or error mean square is calculated by dividing the lowest value of Sum of Squares (SS) by its degree of freedom.

$$\text{error variance } \sigma_e{}^2 = \frac{\text{sum of squares due to error}}{\text{degree of freedom due to error}} \quad (4)$$

F-test is used to determine which process parameters have a significant effect on the quality characteristic. The variance ratio denoted by F is given by

$$F = \frac{MS}{\sigma_e{}^2} \quad (5)$$

A larger value of F indicates that the effect of that factor is very large as compared to error variance. The larger the contribution of a particular factor to the total sum of squares, the larger is the ability of that factor to influence η. This is expressed in terms of Percent Contribution (%P) which is calculated as follows:

$$\%P = \frac{SS}{\text{total sum of SS}} \qquad (6)$$

V. RESULT AND DISCUSSION

ANOVA Analysis

The analysis of variance is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factors. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not.

Fig. 4 Measuring distortion on welded part

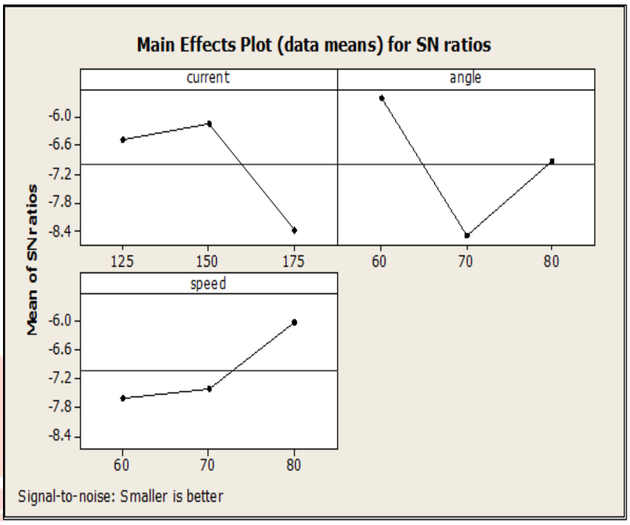

Fig.5 Main Effects Plot for η for weld distortion

According to this main effect plot fig.5, the optimal conditions for minimum welding distortion are:

- Welding current at level 3 (175 ampere)
- Groove angle at level 2 (70· Degree)
- Welding speed at level 1(60 mm/min.)

VI. ANOVA ANALYSIS

Table: 4 Anova Table for Distortion

Source	SS	DF	MS	F	%P
Current	8.806	2	4.403	2.059	29.23%
Angle	12.510	2	6.255	2.923	41.52%
Speed	4.542	2	2.271	1.061	15.06%
Error	4.277	2	2.138	1	14.19%
Total	30.13	8	-	-	100%

The ANOVA analysis of the observations for this parameter shows a better level of significance of percentages. TIG welding for SS 316 have resulted with effect of each parameter contribution as following manner.

1) Current contributes 29.23%
2) Angle contributes 41.52%
3) Welding speed contributes 14.19%

VII. CONCLUSION

- The Present Experiment will be Addressed the Angular Distortion during Welding.
- Tungsten Inert Gas Welding on an Austenitic stainless steel 316 plate has been controlled by Experimental data.
- The Effect of Welding parameter (Speed, Current and Angle of groove) are find.
- From experimental result Parameter Angle has major effect of weld distortion
- This procedure can be effectively used to reduce angular distortion in the design of structures.
- Weld distortion analysis for optimum TIG process parameters control with lowest number of experiments.

VIII. ACKNOWLEDGEMENT

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