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EXPERIMENTAL INVESTIGATION OF GTAW FOR AUSTENITIC STAINLESS STEEL USING DOE

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Abstract*: Gas tungsten arc welding is a fusion welding process having wide applications in industry. In this process proper selection of input welding parameters is necessary in order to control weld distortion and subsequently increase the productivity of the process. In order to obtain a good quality weld and control weld distortion, it is therefore, necessary to control the input welding parameters. In this research work, experiments were carried out on Austenitic stainless steel 304 plates of 5mm thick using gas tungsten arc welding (GTAW) process. Full Factorial method is used to formulate the experimental design. The exhaustive survey suggests that some control factors viz. current, welding speed, Groove etc. predominantly influence the weld distortion. A plan of experiments based on full factorial technique has been used to acquire the data. An analysis of variance (ANOVA) is employed to investigate the welding characteristics of Austenitic stainless steel 304 material & optimize the welding parameters. Furthermore, output obtained through multiple regression analysis is used to compare with the developed artificial neural network (ANN) model output. It was found that the welding strength predicted by the developed ANN model is better than that based on multiple regression analysis.

***Keywords*: GTAW, SS304, Distortion, Full factorial (Design of Experiment).**

I. INTRODUCTION

Tungsten inert gas welding, TIG is widely applied in manufacturing process for different types of materials like Aluminum, Mild steel (MS) and different type of stainless steel alloy grades. The optimization of TIG welding process parameters play important role for the final product quality in terms of weld distortions, joint efficiency and mechanical properties. As welding process involves the heating and cooling process in non-uniform manner, the distortions are unavoidable.

The weld process contributes to the development of several kinds of distortions like longitudinal, transverse or angular distortions. Taguchi method is one of the best practical technique which offers the effective selection process parameters with minimum number of experiments. TIG welding is a process which uses the heat of electric arc between the non-consumable Tungsten electrode and work piece for melting of faying surfaces and inert gas is used for shielding the arc zone from atmospheric gases. TIG welding is widely used for welding of metals like stainless steel, some alloy grades of Aluminium, Mg materials. It is used in critical applications like for precision welding in nuclear structural materials fabrication, air craft, chemical, petroleum, automobile and space craft industries. The Tungsten arc process is being employed widely from the precision joining of critical components which require controlled heat input. The small intense heat provided by the Tungsten arc is ideally suited to the controlled melting of the thin sheets, some times without filler rods. Advantages of TIG welding are concentrated arc, no slag, no splatter, little smoke or fumes, good weld penetration, preferred for stainless steel alloys. Disadvantages are slow process, good skill requirement for manual operation.

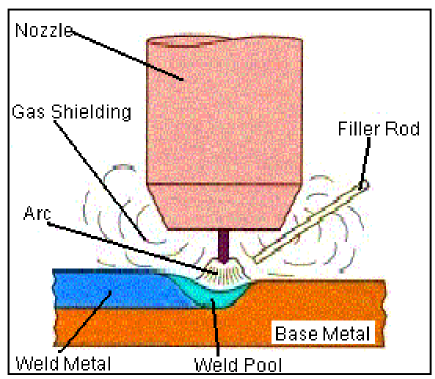

Fig. 1: GTAW Process

II. LITERATURE REVIEW

I. Dongjie Li et.al A double-shielded TIG method was proposed to improve weld penetration and has been compared with the traditional TIG welding method under different welding parameters (i.e., speed, arc length and current). The strength of the Marangoni convection was calculated to estimate the influence of the welding parameters on the variations in weld pool shapes [2].

J.J. del Coz Díaz et.al In this study, thermal stress analyses were performed in the tungsten inert gas (TIG) welding process of two different stainless steel specimens in order to compare their distortion mode and magnitude. The growing presence of non-conventional stainless steel species like duplex family generates uncertainty about how their material properties could be affected under the welding process distribution function [3].

S.Akellaa, B. Ramesh Kumar 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 [4].

Wang Rui, Liang Zhenxin, Zhang Jianxun The dynamic progress and residual distortion of out-of-plane of aluminum alloy 5A12 were investigated under different welding conditions of TIG welding. The dynamic out-of-plane distortion was measured by self-developed distortion measuring system [5].

Mr. L. Suresh Kumar1 at.al In this Paper we discuss about the mechanical properties of austenitic stainless steel for the process of TIG and MIG welding. As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW or MIG welding is used to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embitterment if they come in contact with the electrode, the arc, or the welding metal [6].

Vikram Singh at.al A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of Mild steel of AISI 1016 material & optimize the welding parameters[7].

III. EXPERIMENTATION SETUP

The experiments have been conducted using a Unitor UWI 400 Power Source and an Automated Welding Set up. In this welding machine automated Tungsten Inert Gas torches as well as automatic feeler wire feeding units are provided. For experimentation, servo motors are used for maintaining welding speed during actual welding. This would be rather different with hand held manual torch. While using automated TIG torch welding speed can be set to specific value directly on this machine as it is a controlled automation.

A. Material selection

As the stainless steel is classified in different categories like austenitic, ferrite, martens tic etc, from this we have chosen austenitic stainless steel (304) because of its low cost, easy availability in the market.

Design of Experiment:

Design of Experiment (DOE) is a technique of defining and investigating all the possible combinations in an experiment involving multiple factors and to identify the best combination.

Fig. 2: Experiment setup

Table1. Chemical composition

ASTM No. (type)	Composition wt%						Microstructure
	C	Si	Mn	Cr	Ni	Mo	Austenite - A Ferrite – F
304	0.08	0.75	2.0	18/20	8/11	- -	A+2/8%F

In this, different factors and their levels are identified. DOE is also useful to combine factors at appropriate levels, each within the respective acceptable range to produce the best results and yet exhibit minimum variation around the optimum results. We have used factorial design, and used full factorial design. For a full factorial design, if the numbers of levels are same then the possible design N is

$$N=L^m$$

Where L=number of levels for each factor, and m=number of factors.

Experimental parameters:

Input parameters:

Welding Current, Groove Angle& Welding speed

Output parameters:

Welding Distortion in mm

Table 5.4: Welding Parameters and their Levels

Parameter	Unit	Level 1	Level 2	Level 3
		Low	Medium	High
Current	Ampere	150	175	200

Groove angle	Degree	45	60	75
Speed	mm/sec	2	2.5	3

Experimental Work:

Welding specimen has been prepared to fabricate TIG welded joints. SS 304 specimen in the dimension 200mm x 150mm x 5mm was considered for welding with different angle Vee butt joints. Welding process has been carried out in TIG welding machine. Experiments were conducted based on full factorial design.

Table. 2: Experiment Results

Sr. No.	Current(Ampere)	Groove angle (Degree)	Welding speed (mm/sec)	Distortion (mm)
1	150	45	2	8.9
2	150	45	2.5	8.54
3	150	45	3	8.35
4	150	60	2	9.47
5	150	60	2.5	8.95
6	150	60	3	8.69
7	150	75	2	9.75
8	150	75	2.5	9.35
9	150	75	3	8.8
10	175	45	2	9.7
11	175	45	2.5	10.1
12	175	45	3	10.4
13	175	60	2	9.53
14	175	60	2.5	9.79
15	175	60	3	10.2
16	175	75	2	9.5
17	175	75	2.5	9.65
18	175	75	3	10
19	200	45	2	10.3
20	200	45	2.5	10.7
21	200	45	3	11
22	200	60	2	10.1
23	200	60	2.5	10.2
24	200	60	3	10.8
25	200	75	2	9.87
26	200	75	2.5	10.2
27	200	75	3	10.3

IV. RESULT AND DISCUSSION

A. 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.

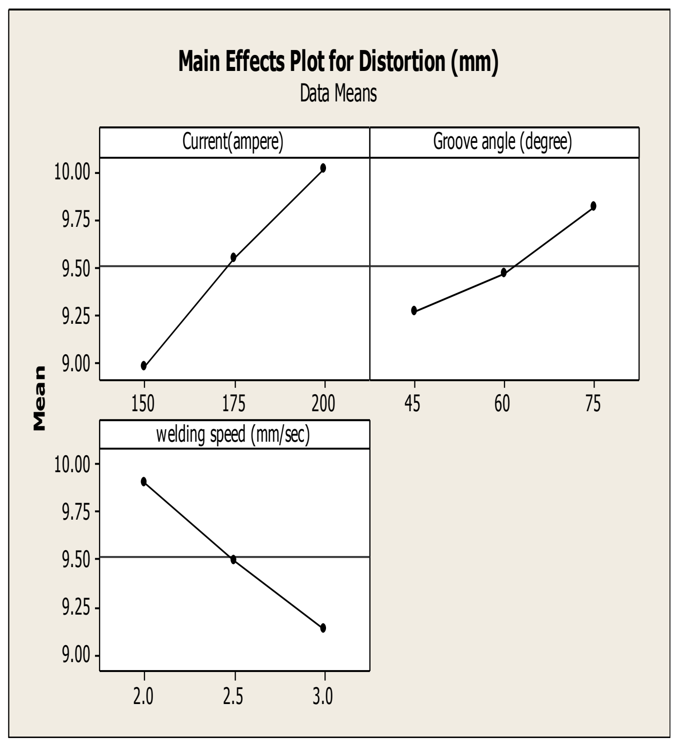

Fig. 3: Main effects plot

According to this main effect plot fig.3, the optimal conditions for minimum welding distortion are:

- Welding current at level 1 (150 ampere)
- Groove angle at level 1 (45^0)
- Welding speed at level 3(3mm/sec).

Table. 3: Results of the ANOVA for welding distortion

Symbol	Welding parameters	Degree of Freedom	Sum of Squares	Mean Squares	F	P (%)
A	Current	2	3.525	1.7628	232.65	52.67
B	Groove angle	2	0.820	0.41027	54.14	15.18
C	Welding speed	2	0.1594	0.7974	105.245	28.52
Error		20	0.1515	0.007577	1	3.59
Total		26	4.6559			100

The percentage contribution of welding current is 52.67%, welding speed 28.52% and Groove angle of 15.18 % and the Error is of 3.59 %. It can be found that the Current is the most significant welding parameters for affecting the distortion during welding.

B. Regression Analysis

Regression analysis is a simple method for investigating the functional relationships among variables expressed in the form of an equation or a model connecting the dependent variable and one or more independent variables. It is commonly used to predict values of one variable (response) when given values of the other independent variables (repressors).

Table. 4: Regression coefficient

Term	Coef.	SE Coef.	T	P
Constant	6.69148	0.289234	23.1351	0.000
Current (ampere)	0.02073	0.001215	17.0641	0.000
Groove angle (degree)	0.01833	0.002025	9.0533	0.000
Speed (mm/sec)	- 0.76333	0.060751	- 12.5649	0.000

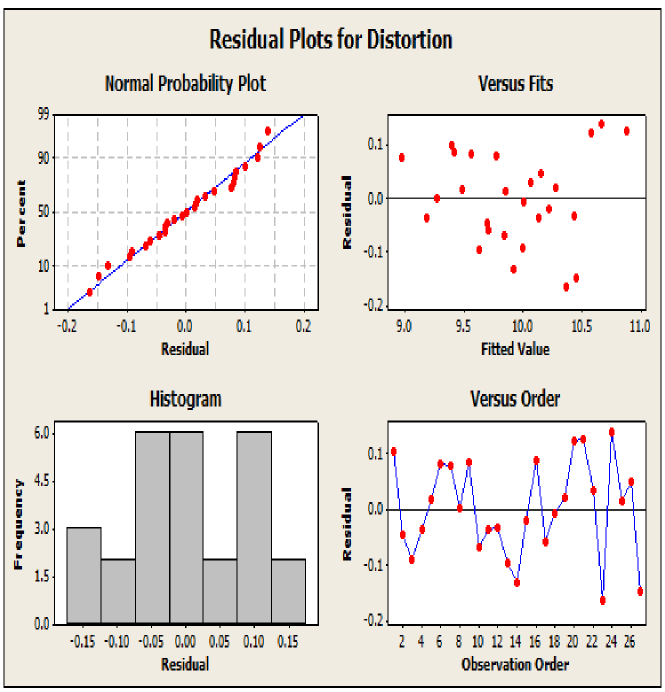

Fig. 4: Residual plot

V. CONCLUSIONS

In this study discuss about the application of Full-factorial, ANOVA and Regression analysis to analyse the effect of process parameters (current, groove angle, welding speed) on welding distortion for SS304 under GTAW welding process. From the analysis of the results obtained following conclusion can be drawn:-

- Based on the experiments, the effect of selected input parameters on the output response like distortion is studied.
- From graphical representation and main effects plot for distortion, the current is the most significant parameter. Welding speed and groove angle also has an effect on distortion but not as current.
- The percentage contribution of current is 52.67%; groove angle of 15.18% and speed of 28.52% on distortion in GTAW process.
- From the ANOVA it is conclude that the welding current is most significant parameter which contributes 52.67%

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