Optimization of Process Parameter in TIG Welding using Taguchi approach (Mild Steel) using Ultrasonic Testing

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Abstract— This paper presents the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) mild steel material during welding. The Non-destructive testing and evaluation of materials has become increasingly important and plays crucial role in industrial sector. In this report the non-destructive testing is conducted on similar weld plate made of mild steel using Tungsten inert gas Welding(TIG). The weld plates are welded at different current, voltage and welding speed. The current was varied between 110,120,130 and 140 amp while the voltage was varied between 25, 30, 35 and 40 volts and welding speed is varied between 2, 2.5, 3 and 3.5mm/s. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio is employed to study the welding characteristics of material & optimize the welding parameters. It was found that the weld specimen produced at 130amp, 30volts, and 2.5mm/s were the best quality.

Key words: Gas Tungsten Arc Welding, Welding Parameters, Welding Defects, Taguchi Method, Non-Destructive Testing, Ultrasonic Inspection

I. INTRODUCTION

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. The weld area and electrode is protected from oxidation or other atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. The Tungsten inert gas Welding (TIG) is most widely used welding process by metal workers in fabrication, maintenance, repair of parts, structures. Another reason for choosing this process is low cost, flexibility, portability and versatility.

The welding parameters are, current, arc voltage and welding speed. These parameters will affect the weld characteristics to a great extent. Because these factors can be varied over a large range, they are considered the primary adjustments in any welding operation. Their values should be recorded for every different type of weld to permit reproducility. A schematic diagram of TIG process is shown in Figure 1.

The quality of weld joint is major aspect in question is how to be able to detect the internal defect formed in the weld zone, hence a Non Destructive testing(NDT) is most appropriate in this regard. The NDT has more importance in identification and analysis of welding defects of different types which occur during welding, which may be due to improper follow up welding parameters like current, voltage, welding speed, position etc. In NDT many different types exist, the most commonly used ones being Ultrasonic testing, radiographic testing, magnetic particle testing, liquid penetration testing etc.

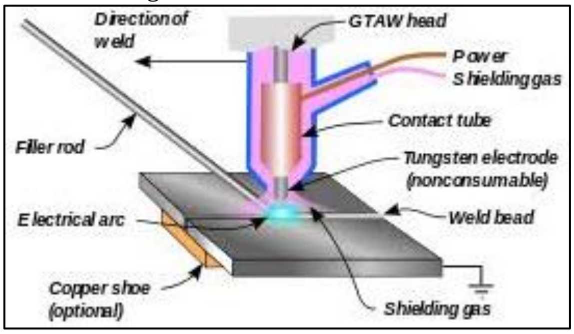

Fig. 1: Tungsten inert gas Welding (TIG)

II. TAGUCHI'S DESIGN METHOD

Taguchi Technique is applied to plan the experiments. It is developed by Dr.Genichi Taguchi. The Taguchi technique has become a powerful tool for improving the productivity during research and development. So that high quality products can be produced quickly at low cost. Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. The taguchi conducts balanced (orthogonal) combinations of experiments, which makes the Taguchi design even more effective compared to other techniques. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all factors that affect the performance parameter.

The signal-to-noise (S/N) ratio for each level was based on the S/N ratio analysis. Based on the tensile strength of the weld joint (larger-the-better), a higher S/N ratio produced a better quality. The standard S/N ratio formula for this type of response is:

$$(S/N) = -10 \log (M.S.D.)$$

Where, M.S.D. is the mean square deviation for the output characteristic.

$$n_i = -10 \log \left[\frac{1}{n} \sum_{i=1}^{n} \frac{1}{Y2ij} \right]$$

Where 'i' is the number of a trial; 'Yij' is the quality of the ith trial and jth experiment; 'n' is the total number of experiments.

III. EXPERIMENTAL SETUP

The experiments were conducted at Indian steel works, Gulbarga on mild steel plates of 10mm thickness. The dimensions of workpiece length 100mm, width of 100mm, thickness 10mm.

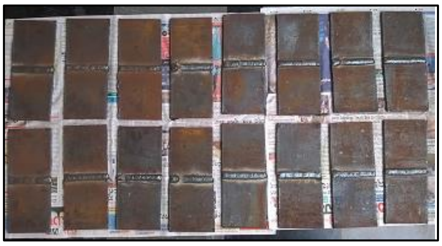

Fig. 2: A Schematic drawing of welding Samples

A. Base Metal Selection

The base metal used for experiment is Mild steel and chemical composition is shown in table below.

Element	C	Si	Mn	P	S	Fe
Weight	0.07	0.08	0.39	0.063	0.065	97.05

Table 1: Chemical Composition of Mild steel.

B. Process Parameters and their levels

The number of variables considered in this welding process are welding current, welding voltage, welding speed. The process parameters of Tungsten Inert Gas Welding should be selected after base metal. The number of levels selected are four.

Parameters	Welding current(c)	Welding voltage(v)	Welding speed(s)
Unit	amp	volts	mm/s
Level 1	110	25	2
Level 2	120	30	2.5
Level 3	130	35	3
Level 4	140	40	3.5

Table 2: Welding process parameters and their Levels.

C. Selection of Orthogonal Array OA

Taguchi's orthogonal design uses a special set of predefined arrays called orthogonal arrays called orthogonal arrays (OAs) to design the plan of experiment. These arrays stipulate the way of full information of all the factors that affects the process performance. The corresponding OA is selected from the set of predefined OAs according to the number of factors and their levels that will be used in the experiment. For present experimental work L16 orthogonal array is used with three factors and four levels as shown in table below.

Expt. No	Process parameters		
	Welding current(c)	Welding voltage(v)	Welding speed(s)
	1	1	1
	1	2	2
	1	3	3
	1	4	4
	2	1	2
	2	2	1
	2	3	4
	2	4	3
	3	1	3
	3	2	4
	3	3	1
	3	4	2
	4	1	4
	4	2	3
	4	3	2
	4	4	1

Table 3: L16 orthogonal array

IV. METHODOLOGY

The present investigation has been in the following sequence.

- Base metal selection
- Process parameters and their levels identification
- Selection of orthogonal array
- Performing the experiments as per the selected orthogonal array
- Non-destructive testing by ultrasonic inspection

V. ULTRASONIC TESTING (UT)

Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used. In flaw detection this frequency is usually in the range of 1MHZ to 6MHZ. Vibrations or sound waves at this frequency have the ability to travel a considerable distance in homogenous elastic material, such as many metals with little attenuation.

Fig. 3: Ultrasonic testing arrangement

VI. TAGUCHI'S ORTHOGONAL ARRAY L16 AFTER ASSIGNING OF PARAMETERS

Expt. No	Process parameters		
	Welding current(c)	Welding voltage(v)	Welding speed(s)
	110	25	2
	110	30	2.5
	110	35	3
	110	40	3.5
	120	25	3
	120	30	2
	120	35	2.5
	120	40	3
	130	25	3
	130	30	2.5
	130	35	2
	130	40	3.5
	140	25	3
	140	30	2.5
	140	35	2
	140	40	3.5

Table 4: Matrix with Actual values of Parameters

VII. RESULTS AND DISCUSSION

The NDT Techniques Ultrasonic testing is used to locate the weld defects in weld samples. In this paper the welding parameters such welding current, voltage, and welding speed are conducted in taguchi orthogonal array to obtain better weld with minimise welding defects. We have conducted ultrasonic testing on weld samples and found sample with number 1,2,5,6,9,13,14 have found minimum defects and sample numbers 3,4,7,8,11,12,15,16 have found maximum defects, hence sample number 10 have not found significant defect and it is considered to be best quality.

Weld specimen no	Weld parameters	Defect Indication	Accept	reject
	110 amp			
1	25 V	RP,UC,S,IP		reject
	2 mm/s			
	110 amp			
2	30 V	IF,IP,RUC		reject
	2.5 mm/s			
	110 amp			
3	35 V	IP,RP,PS		reject
	3 mm/s			
	110 amp			
4	40 V	LIF,IP,S		reject
	3.5 mm/s			
	120 amp			
5	25 V	IF,RP,S		reject
	3 mm/s			
	120 amp			
6	30 V	IP,RP,LSW		reject
	2 mm/s			
	120 amp			
7	35 V	PS,RP,S,IP		reject
	2.5 mm/s			
	120 amp			
8	40 V	P,RUC,IF		reject
	3 mm/s			
	130 amp			
9	25 V	IP,IF,S,RUC		reject
	3 mm/s			
	130 amp			
10	30 V	NSD	Accept	
	2.5 mm/s			
	130 amp			
11	35 V	RP,UC,S,IP		reject
	2 mm/s			
	130 amp			
12	40 V	IP,PS, UC		reject
	3.5 mm/s			
	140 amp			
13	25 V	IF,IP,S		reject
	3 mm/s			
	140 amp			
14	30 V	IP,PS,RUC		reject
	2.5 mm/s			
	140 amp			
15	35 V	UC,IP,IF,P		reject
	2 mm/s			
	140 amp			
16	40 V	IP,LSW,S		reject
	3.5 mm/s			

Table 5: Ultrasonic test Results

- IP- Incomplete Penetration, IF- Incomplete Fusion
- NSD- No Significant Defect, LIF- Lack of interrun fusion, S-Slag inclusion, RUC- Root undercut,
- LSW- Lack of sidewall fusion, P-Porosity
- RP- Lack of penetration, RC- Root Concavity

Description	
Weld joint type	Butt weld
Welding process	GTAW

Equipment	Digital flaw detector
Make	Digiscan
Method	Pulse echo
Couplant	Coconut Oil
Probe	TR,45, 70
Frequencies	2 and 4MHZ
Scanning db	20-24 db
Specimen thickness	10-12mm

Table 6: Ultrasonic test Description

VIII. Conclusion

In this report a present study on parametric analysis has been carried out for identifying the defect on mild steel material of plate thickness 10mm, width 120mm, and length 100mm. Experiments are carried out using Taguchi Technique by varying welding current, welding voltage, and welding speed. Ultrasonic testing Technique successfully detected most of the defects occurred in welded specimens. Current is varied between 110 to 140Amps, voltage is varied between 25 to 40volts, and welding speed is varied between 1.5 to 4mm/s. By conducting ultrasonic testing we have concluded that some of the welding defects are found at each level of current, voltage and welding speed. Hence at welding current (130 Amp), welding voltage (30V), welding speed (2.5 mm/s), there is no significant defect is not found.

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