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PARAMETRIC OPTIMIZATION IN TIG WELDING BY TAGUCHI APPROACH OF (LOW CARBON STEEL) AISI 304

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***Abstract*—Tungsten inert gas welding (TIG) is a high quality welding process commonly used to join plates of higher thickness in load bearing components. This process provide a pure and clean high volume weldments. The main purpose of present work is to investigate and correlate the relationship between various parameters and hardness and tensile strength of single square butt joint and predicting weld bead qualities before applying to the actual joining of metal by welding. Changing different welding parameters like effect of Gas flow, voltage and welding current on the tensile strength of the weld joint has been investigated . Hardness value of the welded zone has been measured at the cross section to understand the change in mechanical property of the welded zone. In this study we see which parameter most effectively effect the weld strength. Weld strength varies under various conditions. By using Taguchi and ANNOVA technique an optimal solution is found out, which provides us an optimal results of the varying condition**

***Index Terms*— Dissimilar metals welding, TIG welding, Taguchi method, optimal parameters hardness& tensile test, Chemical composition.**

I. Introduction

Modern welding technology started just before the end of 19th century with the development of methods for a generating hightemperature in localized zone. Welding generally requires a heat source to produce a high temperature zone to melt raw material, though it is possible to weld two metal pieces without much increasing temperature. As the demand for welding new materials and larger thickness components increase, mere gas flame welding, which was first known to the welding engineer, is no longer satisfactory and improved such as metal inert gas welding, tungsten inert gas welding, electron and laser beam welding have been developed .Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both. A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding. The basic equipment for TIG welding comprises a power source, a welding torch, a supply of an inert shield gas, a supply of filler wire and perhaps a water cooling system. Type 304: The most common austenitic grades, containing approximately 12% carbon and 80% Iron. It is used for chemical processing equipment, for food, dairy, and beverage industries, for heat exchangers, and for the milder chemicals. As the stainless steel is classified in different categories like austenitic, ferritic, martenstic etc., from this we have chosen austenitic stainless steel (304) because of its low cost, easy availability in the market. The problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality. Traditionally, it has been necessary to study the weld input parameters for welded material.

II. TUNGSTEN INERT GAS WELDING

TUNGSTEN INERT GAS WELDING (TIG): It is a welding process in which arc forms between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt, and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. The people who determine what and how the metals can be welded are called metallurgists or welding engineers depending on whom you ask. The three most commonly welded metals are steel, stainless steel, and aluminum.

a) Steel is the easiest to weld and has the least amount of problems.
b) Stainless steel welds very well, but requires a lot more skill and preparation than steel.
c) Aluminum is on the more difficult side to weld. Aluminum welds easily with the TIG and MIG processes, but can also be welded with the other processes.

The equipment required to perform gas metal arc welding, the basic necessary equipment is a welding gun, a wire feed unit, a welding power supply, an electrode wire, and a shielding gas supply.

- Power Supply
- Welding Torch
- Shielding Gas, Gas Cylinder, Pressure Regulator and Flow Meter Wire feeding mechanism.

III. TAGUCHI'S PHILOSOPHY

Taguchi's comprehensive system of quality engineering is one of the great engineering achievements of the 20th century. His methods focus on the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop-floor quality engineering. Upstream methods efficiently use small-scale experiments to reduce variability and remain cost-effective, and robust designs for large-scale production and marketplace. Shop-floor techniques provide cost-based, real time methods for monitoring and maintaining quality in production. The farther upstream a quality method is applied, the greater leverages it produces in the improvement, and the more it reduces the cost and time. Taguchi's philosophy is founded on the following three very simple and fundamental concepts.

- Quality should be designed into the product and not inspect into it.
- Quality is the best achieved by minimizing the deviations from the target. The product or process should be so designed that it is immune to uncontrollable environmental facters.
- The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide.

Taguchi's proposes an "off-line" strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design. In the present work Taguchi's parameter design approach is used to study the effect of process parameters on the surface roughness of CNC.

A. SIGNAL TO NOISE (S/N) RATIO

Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The S/N ratio can be used in three types :

1. Larger the better
2. Smaller the better
3. Nominal the best

1. Formula-S/N= $-10 \log\{(1/n) (\Sigma(1/x^2)\}$
2. Formula-S/N= $-10 \log(x/S^2x)$
3. Formula-S/N= $-10\log \{(1/n)(\Sigma(x^2))\}$

B. ANOVA (ANALYSIS OF VARIANCE)

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error. First, the total sum of squared deviations SST from the total mean S/N ratio nm can be calculated as, SST = Σ(ni - nm).

TABLE 1-*CHEMICAL COMPOSITION OF LOW CARBON STEEL(AISI 304)FOR SPECIMEN 1 IN WEIGHT%*

Element	C	O	Fe
%	11.55	7.74	80.71

TABLE 2-*CHEMICAL COMPOSITION OF LOW CARBON STEEL(AISI 304)FOR SPECIMEN 1 IN ATOMIC%*

Element	K	K	L
%	33.27	16.73	49.99

TABLE 3-*CHEMICAL COMPOSITION OF LOW CARBON STEEL(AISI 304)FOR SPECIMEN 2 IN WEIGHT%*

Element	C	O	Fe
%	15.00	19.61	65.39

TABLE 4-*CHEMICAL COMPOSITION OF LOWCARBON STEEL(AISI 304)FOR SPECIMEN 2 IN ATOMIC%*

Element	K	K	L
%	34.26	33.62	32.12

IV. EXPERIMENTATION

The determination of the parameters to investigate hinges upon the product or process performance characteristics or responses of interest. Several methods are suggested by Taguchi for determining which parameter s to include in an experiment. The identified process parameters are shown below. The selection of parameters of interest was base on some experiment preliminary. The following process parameters were thus selected for the present work:

a) Welding Current - (A)
b) Voltage - (B)
c) Gas Flow Rate - (C)

TABLE 5-SELECTION OF PROCESS PARAMETERS

S. No.	**Symbol**	**Process Parameter**	**Unit**
1	A	Welding Current	Amp
2	B	Arc Voltage	Volt
3	C	Gas Flow Rate	L/min

Orthogonal array Experiment

In the present study, three 3-level process parameters i.e. welding current, welding voltage and gas flow rate are considered. The values of the welding process parameters are listed below. The ranges and levels are fixed based on the screening experiments. The interaction effect between the parameters is not considered

TABLE 6

PARAMETERS	CODE	LEVEL 1	LEVEL 2	LEVEL 3
WELDING CURRENT(AMP)	A	160	210	260
ARC VOLTAGE(VOLT)	B	18	20	22
GASFLOW RATE(CFH)	C	16	18	20

The total degrees of freedom of all process parameters are 8. The degrees of freedom of the orthogonal array should be greater than or at least equal to the degrees of freedom of all the process parameters. Hence, L9-3 Level Taguchi Orthogonal Array chosen which has 8 degrees of freedom. This is shown in Table 7 Below:

TABLE 7-(L9-3) LEVEL TAGUCHI ORTHOGONAL ARRAY

No of runs	Control factors		
	A	B	C
1	L1	L1	L1
2	L1	L2	L2
3	L1	L3	L3
4	L2	L1	L2
5	L2	L2	L3
6	L2	L3	L1
7	L3	L1	L3
8	L3	L2	L1
9	L3	L3	L2

TABLE 8-THE EXPERIMENT MATRIX

RUN	CURRENT (amp)	VOLTAGE(volt)	GFR (L/min)
1	160	18	16
2	160	20	18
3	160	22	20
4	210	18	18
5	210	20	20
6	210	20	16
7	260	18	20
8	260	22	16
9	260	22	18

TABLE 9-TAGUCHI ANALYSIS FOR TENSILE STRENGTH & S/N RATIO

RUN	CURRENT (Amp)	VOLTAGE (Volt)	GFR (CFH)	TENSILE STRENGTH (MPa)	**S/N RATIO S/Ni**
1	160	18	16	604.3	56.6394
2	160	20	18	662.7	57.4394
3	160	22	20	674.8	57.5394
4	210	18	18	643.7	57.2872
5	210	20	20	635.6	57.1773
6	210	20	16	640.3	57.2548
7	260	18	20	602.5	56.4566
8	260	22	16	470.7	54.3917
9	260	22	18	605.2	56.7809

V. MEAN RESPONSE OF SIGNAL TO NOISE RATIO FOR TENSILE STRENGTH

Calculation For Mean Response Table of Each Parameter:

(1) For arc current of level 1 (S/NP1,1)

P1,1 means parameter 1 and level 1 S/NP1,1 = (S/N1 + S/N2 +S/N3)/3

= (56.6394 + 57.4394 + 57.5394)/3 = 57.2060

similarly, we can calculate the mean response for arc current for remaining two levels and for voltage and gas flow rate respectively, The mean response table for the arc current, arc voltage and gas flow rate is given in table below:

TABLE 10- MEAN RESPONSE TABLE FOR SIGNAL TO NOISE RATIO

Level	**Arc current**	**Arc Voltage**	**Gas flow Rate**
1	57.20	56.79	56.09
2	57.24	56.34	57.17
3	55.88	57.19	57.06
Delta	1.28	0.81	1.01
Rank	1	3	2

TABLE 11- OPTIMUM WELDING PARAMETERS FOR TENSILE STRENGTH

Arc Current	Level 2	210
Arc Voltage	Level 3	22
Gas Flow Rate	Level 2	18

TABLE 12- ANALYSIS OF VARIANCE FOR SIGNAL TO NOISE RATIO

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**% Contribution**
Arc Current	2	44.54	12.726	1.5414	1	0.175	58.266%
Arc Voltages	2	0.9943	0.9943	0.4972	0.93	0.397	39.105%
Gas Flow Rate	2	2.0444	2.0444	1.0222	0.90	0.243	7.449%
Residual Error	2	0.6545	0.6545	0.3273			
Total	8	48.234					

NOTE:(1) DF-Degrees of freedom, (2)Adj SS-Adjusted sum of squares, (3)Adj MS-Adjusted mean squares, (4)-Seq SS-sequential sum of squares, (5) F-It is the test statistic used to determine any models associated with response, (6)P-It is the probability measures evidence against null hypothesis, (7)Contribution-Displays percentage of each source accounts contributes to total variation in response table.

TABLE 13-TAGUCHI ANALYSIS FOR HARDNESS

RUN	**CURRENT (Amp)**	**VOLTAGE (Volt)**	**GFR (CFH)**	**HARDNESS (WZ)**	**HARDNESS (PM)**	**HARDNESS (HAZ)**	**S/N RATIO**
1	160	18	16	290.8	160.3	651	2.2222
2	160	20	18	234.6	240.2	469.2	4.4932
3	160	22	20	240.3	170	220.2	15.7089
4	210	18	18	320	155	463	6.4494
5	210	20	20	324.5	235.5	820.6	2.5986
6	210	20	16	263.3	160	723.3	1.1595
7	260	18	20	283.2	161	717.6	1.0987
8	260	22	16	303.1	263	565.3	5.8976
9	260	22	18	263	262	202	13.2844

NOTE :- (1)WZ-Weld Zone,(2) HAZ-Heat affected zone,(3)PM-Platen Mounting

TABLE 14-ANALYSIS OF VARIANCE TABLE FOR SIGNAL TO NOISE RATIO OF HARDNESS

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**% Contribution**
Arc Current	2	34.77	34.77	17.39	0.48	0.676	12.92%
Arc Voltage	2	113.21	113.21	56.61	1.56	0.290	42.07%
Gas Flow Rate	2	48.58	48.58	23.56	0.67	0.499	18.05%
Residual Error	2	72.53	72.53	33.36			
Total	8	269.09					

NOTE:- (1) DF-Degrees of freedom, (2)Adj SS-Adjusted sum of squares, (3)Adj MS-Adjusted mean squares, (4)-Seq SSsequential sum of squares, (5) F-It is the test statistic used to determine any models associated with response, (6)P-It is the probability measures evidence against null hypothesis, (7) Contribution-Displays percentage of each source accounts contributes to total variation in response table.

(1)-Null Hypothesis-It is the method where the model does not explain any of the variation in the response table

TABLE 15-MEAN RESPONSE TABLE FOR SIGNAL TO NOISE RATIO FOR HARDNESS

LEVEL	**CURRENT**	**VOLTAGE**	**GFR**
1	7.4747	3.2567	3.09
2	10.2075	4.3298	**8.075**
3	6.7603	10.51	6.468
DELTA	2.7	7.3	5
RANK	3	1	2

TABLE 16-OPTIMUM WELDING PARAMETERS FOR HARDNESS

Arc Current	Level 2	210
Arc Voltage	Level 3	22
Gas Flow Rate	Level 2	18

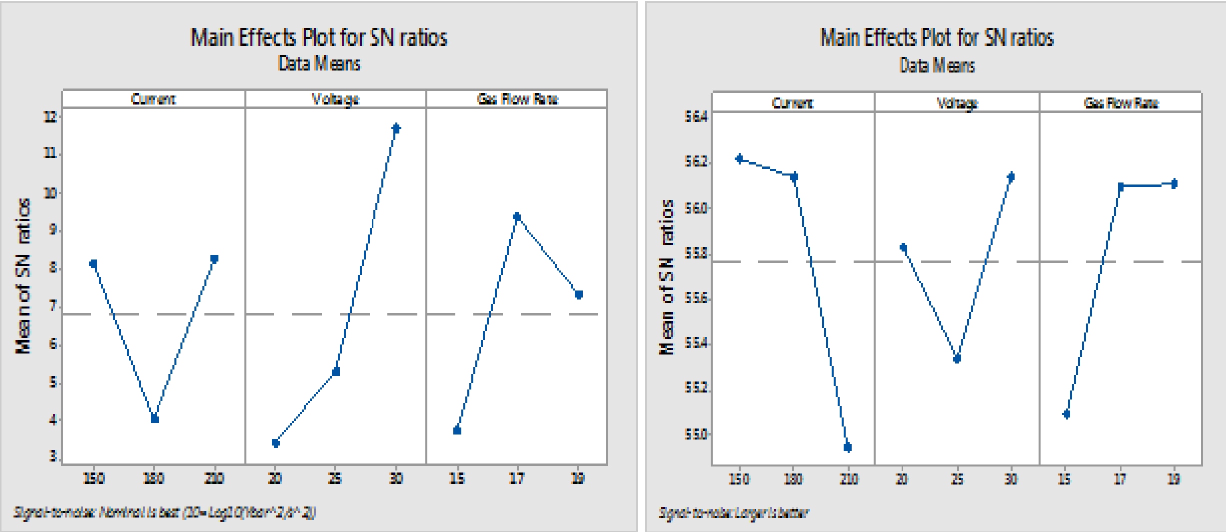

FIG. –(1) PIE CHART FOR % AGE CONTRIBUTION OF DIFFERENT PARAMETERS FOR HARDNESS & TENSILE STRENGTH

VI. CONCLUSION

This study presented an efficient method for determining the optimal Tungusten inert gas welding parameters for increasing weld ability of low carbon steel(AISI 304) under varying conditions through the use of the Taguchi parameter design process . This process was applied using a specific set of control and response variables of Tensile Strength , Hardness of weld zone, Parent Metal & Heat Affected Zone, The use of the $L_9(3^3)$ orthogonal array , with three control parameters (Arc Current , Arc Voltages & Gas Flow Rate) used for this study to be conducted with sample of 9 work pieces. The study found that the control factors had varying effects on the response variables .Arc voltage has greatest effect on tensile Strength followed by Arc current & Gas Flow Rate. For Hardness (WZPM and HAZ) , Arc Current has greatest effects followed by Arc Voltage & Gas Flow Rate.

The Taguchi method offers a strategy for finding optimal , stable results based on a predefined set of analyzed parameter combinations , Robust Design takes up the concepts of the Taguchi method and offers a standard , homogenous procedure based on actual and scientific knowledge. Design of experiment is expected to gain more accurate answers on system behaviour and interaction effects, especially when created on basis of fractional factorial design. In this paper, the optimization of the process parameters for TIG welding of low carbon steel with greater weld strength has been reported. The Nominal-the-better quality characteristic is considered in the hardness.

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