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Parameter Optimization of Tig Welding Using Austenitic Stainless Steel

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ABSTRACT:

Welding is a manufacturing process, which is carried out for joining of metals by Tungsten Inert Gas (TIG) Welding. This paper presents the influence of welding parameters like welding current, welding voltage and gas flow rate on hardness of austenitic stainless steel on 304 grade material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data, An Orthogonal array and signal to noise (S/N) ratio are employed to investigate the welding characteristics of butt joint and optimize the welding parameters. To find out percentage contribution of each input parameter for obtaining optimal conditions, we were used analysis of variance (ANOVA) method. Finally the conformations tests have been carried out to compare the predicted values with the experimental values to confirm its effectiveness in the analysis of hardness.

Keywords: TIG welding, Optimization, ANOVA, S/N ratio.

I. INTRODUCTION

Situations arise in industrial practice which calls for joining of materials. The materials employed are location dependent in the same structure for effective and economical utilization of the special properties of each material. Welding is a process of joining similar or dissimilar materials Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. Welding is carried out by the use of heat or pressure or both and with or without added metal. There are many types of welding including Metal Arc, Tungsten Arc Submerged Arc, Resistance Butt, Flash, Spot, Stitch, Stud and Projection. Inert gas welding is faster than traditional welding methods. It can produce cleaner, longer continuous welds. There are two main types of inert gas welding they are Tungsten Inert Gas Welding (TIG) and Metal Inert Gas welding (MIG). This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces. Only in this way can the designer use most suitable materials for each part of a given structure. The growing availability of new materials and higher requirements being placed on materials and the welding processes. Gas tungsten arc welding, also known as tungsten inert gas (TIG) welding, produces an arc between a tungsten electrode and work piece. An inert gas shields the arc, electrode, and molten pool from atmospheric contamination. When welding thinner materials, edge joints, and flanges, welders generally do not use filler metals. However, for thicker materials, welders primarily use externally fed filler metal. TIG welding is a popular technique for joining thin materials in the manufacturing industries. This type of welding achieves a high quality weld for stainless steels. Stainless steel is selected for corrosion is deterioration of essential properties in a material due to reactions with its surroundings. Millions of dollars are lost each year because of corrosion. Much of this loss is due to the corrosion of iron and steel, although many other metals may corrode as well. The problem with iron as well as many other metals is that the oxide formed by oxidation does not firmly adhere to the surface of the metal and flakes off easily causing “pitting”. Extensive pitting eventually causes structural weakness and disintegration of metal. To solve all this problem austenitic stainless steel is used. It has corrosion resistance property. 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. When welding stainless steel it is advisable to follow the general welding guidelines valid for the type of steel, e.g. austenitic stainless steel have, due to their chemical compositions, a higher thermal elongation compared to mild steels. This may increase weld deformation. Dependent of weld metal microstructure might also be more sensitive to hot cracking and sensitive to intermetallic precipitations compared to mild steels. Austenitic grades are those alloys which are commonly in use for stainless applications. The austenitic stainless steel, because of their high chromium and nickel content, are the most corrosion resistant of the stainless group providing unusually fine mechanical properties. Type 304: The most common austenitic grades, containing approximately 18%

chromium and 8%nickel. 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 product to obtain a welded joint with the required quality. To do so, requires a time-consuming trial and error development method. Then welds are examined whether they meet the requirement or not. Finally the weld parameters can be chosen to produce a welded joint that closely meets the joint qualities. Also, what is not achieved or often considered is an optimized welding parameters combination, since welds can often he formed with very different parameters. In other words, there is often a more ideal welding input parameters combination, which can be used. In order to overcome this problem, various optimization methods can be useful to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. Taguchi method has been adopted for many applications in different areas.

II. LITERATURE REVIEW

S.P.Gadewar investigated the effect of process parameters of TIG welding like weld current, gas flow rate, work piece thickness on the bead geometry of SS304. It was found that the process parameters considered affected the mechanical properties with great extent. **N.Lenin** optimized the welding input process parameters for obtaining greater welding strength in manual metal arc welding of dissimilar metals. The higher-the-better quality characteristic was considered in the weld strength prediction. Taguchi method was used to analyse the effect of each welding process parameters and optimal process parameters were obtained. **K.Kishore et al. [1]** analysed the effect of process parameters for welding of AA6351 using TIG welding. Several control factors were found to predominantly influence weld quality. The % contributions from each parameter were computed through which optimal parameters were identified. ANOVA method was used to checking the adequacy of data obtained. The experimental revealed that low current values have created lack of penetration and high travel speed has caused lack of fusion in welding AA6351. **Ugur Esme** investigated multi response optimization of TIG welding process to yield favorable bead geometry using Taguchi method and Grey relation analysis. The significance of the factors on overall quality characteristics of the weldment has been evaluated quantitatively by ANOVA. The experimental results show that the tensile load, HAZ, area of penetration, bead width, and bead height are greatly improved by using grey relation analysis in combination with Taguchi method. **T.Senthil Kumar** studied the effect of pulsed TIG welding parameters and pitting corrosion potential of aluminium alloy. ANOVA method was used to find significant parameters and regression analysis has been used to develop the mathematical model to determine the pitting corrosion potential. It was found that peak current and pulse frequency have direct proportional relationship, while base current and pulse-on-time have inverse proportional relationship with the pitting corrosion resistance. **Ahmed Khalid Hussain** studied the influence of welding speed on tensile strength on welded joint in GTAW process of aluminium alloys. Experiments were conducted on specimen of single V butt joint having different bevel angels and bevel heights. The experimental results show that depth of penetration weld bead decreases with increase in bevel height. The tensile strength increased with lower weld speed and decreasing heat input rate. It was also found that bevel angle of the weld joint has profound effect on the tensile strength. **Prof.Sandip Chaudhary et al. [2]** studied, various cutting parameters like, welding current, wire diameter and wire feed rate have been evaluated to investigate their influence of MIG welding and TIG welding. By use of ANOVA analysis. From the ANOVA it is conclude that the welding current is most significant parameter for MIG and TIG welding. **S.V.Sapakal et al. [6]** studied, various cutting parameters like, welding current, welding voltage welding speed on penetration depth of MS C20 material during welding. 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 MS C20 material & optimize the welding parameters. **S.R.Patil** studied the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) of AISI 1030 mild steel material during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal-to-noise (S/N) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for maximum tensile strength.

III. TAGUCHI'S DESIGN METHOD

Optimization of process parameters is the key step in the Taguchi method for achieving high quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. Basically, classical process parameter design is complex and not easy to use. A large number of experiments have to be carried out when the number of process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only. A loss function is then define to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of loss function to measure the deviation of the quality characteristics from the desired value. The value of the loss function is further transformed into signal-to-noise (S/N) ratio.
There are 3 Signal-to-Noise ratio of common interest for optimization

(1) Smaller-The-Better:
N= - 10 Log10 [mean of sum of squares of measured data]
(2) Larger-The-Better:
N= - 10 Log10 [mean of sum squares of reciprocal of measured data]
(3) Nominal-The-Best:
N=10 Log10 (square of mean)/Variance.

A. WORK MATERIAL

The work material used for present work is austenitic stainless steel the dimensions of the work piece length 100mm, width 75mm, thickness 0.5mm. Argon is used as a shielding gas.

"Table 1. Welding parameters and their levels"

Parameters	*Symbol*	*Level1*	*Level2*	*Level3*
Welding current [Amp]	A	100	150	200
Welding voltage [Volt]	B	23	25	30
Gas flow rate [CFH]	C	20	23	25

B. L9 TAGUCHI ORTHOGONAL ARRAY

Taguchi's orthogonal design uses a special set of predefined arrays called orthogonal arrays (OAs) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affects the process performance (process responses). 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. 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 in Table3. The ranges and levels are fixed based on the screening experiments. The interaction effect between the parameters is not considered.

"Table2.Orthogonal array"

Expt no	*Process parameters*		
	A	*B*	*C*
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

C. ANALYSIS OF S/N RATIO

In the Taguchi method the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (standard deviation) for the output characteristic. Therefore, the S/N ratio to the mean to the S.D. S/N ratio used to measure the quality characteristic deviating from the desired value. The S/N ratio S is defined as S= -10 log (M.S.D.) where, M.S.D. is the mean square deviation for the output characteristic. To obtain optimal welding performance, higher-the-better quality characteristic for Hardness must be taken. The M.S.D. is the higher-the-better quality characteristic can be expressed

$$M.S.D. = \sum 1/P_i2$$

Where P_i is the value of penetration.

"Table3. Experimental result for Hardness and S/N ratio"

Expt No	*Welding current [Amp]*	*Welding voltage [Volt]*	*Gas flow rate [CFH]*	*Hardness [BHN]*	*S/N ratio*
1	100	23	20	186	45.390
2	100	25	23	187	45.436
3	100	30	25	187.54	45.461

4	150	23	23	184	45.296
5	150	25	25	182	45.201
6	150	30	20	185.5	45.367
7	200	23	25	184	45.296
8	200	25	20	184.50	45.320
9	200	30	23	188	45.483

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio. The S/N response table for hardness is shown in Table4 below

“Table4. S/N response table for Hardness”

Symbol	*Cutting parameters*	*Level 1*	*Level 2*	*Level 3*
A	Welding current [Amp]	45.43	45.29	45.37
B	Welding voltage [Volt]	45.33	45.32	45.44
C	Gas flow rate [CFH]	45.36	45.41	45.32

IV. 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 to 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 can be calculated

“Table5. Result of analysis of variance for Hardness”

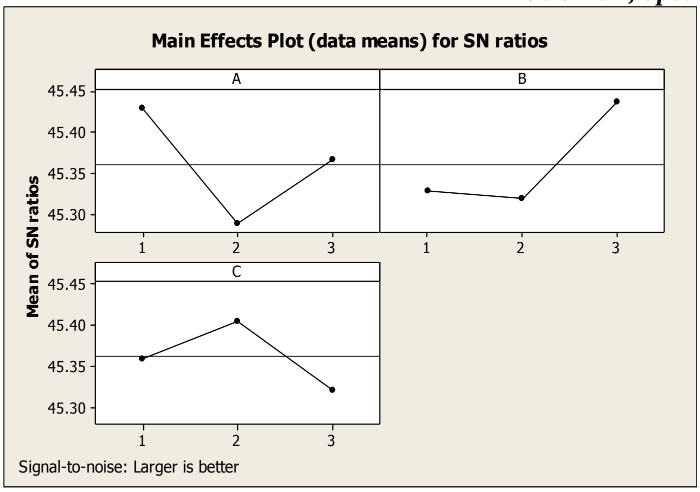
Symbol	*Welding Parameters*	*DF*	*Sum of Sq. Dev.*	*Mean e*	*F*	*%*
A	Welding current [Amp]	2	13.55	6.778	244	44.60
B	Welding voltage [Volt]	2	11.72	5.861	211	38.59
C	Gas flow rate [CFH]	2	5.055	2.527	91	16.63
Error		2	0.055	0.0278		0.18
Total		8	30.38			100

V. CONFORMATION TEST

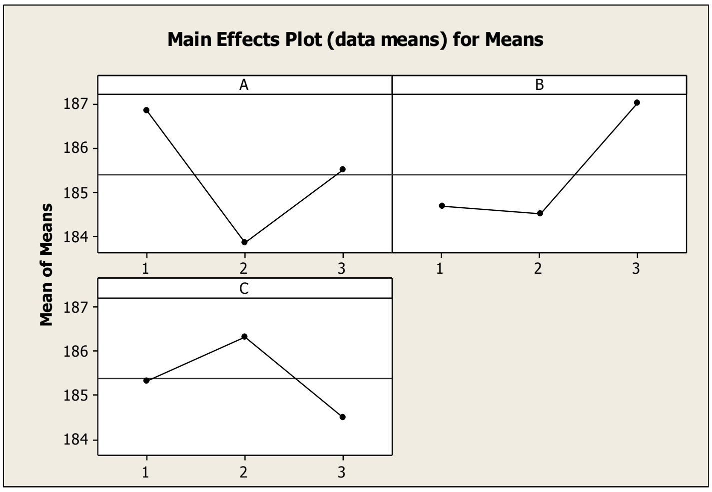
Once the optimal level of design parameters has been selected, the final step is to predict and verify the improvement of the quality characteristic using the optimal level of design parameters. The estimated S/N ratio using the optimal level of the design parameters can be calculated. The comparison of the predicted hardness with actual hardness using the optimal parameters, good agreement between the predicted and the actual hardness being observed which is shown in the table

”Table6. Result of the conformation experiment”

	Initial welding parameter	**Optimal welding parameter**	
		Prediction	**Experimental**
Level	A3B3C2	A1B3C2	A1B3C2
Hardness	188.00	189.41	188.70
S/N ratio	45.48	45.55	45.51



"Figure1. Main Effect plot for S/N ratio V/S Welding parameter"



"Figure2. Main Effect plot for Hardness V/S Welding Parameter"

VI. Conclusion

Taguchi optimization method was applied to find the optimal process parameters for hardness. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for optimization of welding parameters. A conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method. The improvement of S/N ratio is 0.04. The experiment value that is observed from optimal welding parameters, the Hardness is 188.70 BHN & S/N ratio is 45.51.

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