PARAMETRIC OPTIMIZATION OF GMAW WELDING PROCESS

[1] **Prof. S. A. Mahajan**

Lecturer[1], Mechanical Engineering Department, Manav School of Engineering Vyala Akola[1]

swapnilmahajan0.01@gmail.com[1]

ABSTRACT

The paper presents the Hallmark of Fabrication parameters and their intensive impact of current, voltage, and speed on ultimate tensile strength (UTS) of AISI 1030 mild steel material During Fabrication. A plan of experiments based on Taguchi technique Method has been Carried out. Orthogonal array, signal to noise (S/N) Ratio, Analysis of variance (ANOVA) are employed for studying the welding characteristics of material & to optimize the weld parameters. The result Obtained are the output from each parameter, through which optimal parameters are found out for maximum tensile strength. Observation-welding current and welding speed are major parameters has a deep impact on the tensile strength of welded joint.

KEYWORDS: MIG welding, optimization, orthogonal array, S/N ratio ANOVA.

INTRODUCTION

The Obstruction faced the manufacturer is to control the process input parameters and to obtain a good welded joint with the required weld quality. It is necessary to study the weld input parameters for welded product to obtain a welded joint with the desired output Characteristics. It takes a time-consuming trial and error development method.

Welded joints are examined whether they meet the requirement or not. Apparently 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 be formed with very different combination of parameters. In order to overcome this problem, various optimization methods can be employed to define the desired output variables with the development of mathematical models to specify the relationship between the input parameters and output variables.

Design of experiment (Doe) techniques has been applied to carry out such optimization. Taguchi method has been adapted for many applications in different areas.

LITERATURE SURVEY

REVIEW ON EFFECT OF SURFACE ACTIVE ELEMENT ON WELD PENETRATION

M TANAKA Studied Effects of surface active elements on weld pool formation using TIG arcs oxygen and halogen elements with a high electron affinity, contained within activating flux, are evaporated within the arc plasma and these evaporated elements combine with electrons within plasma at the arc peripheral zone, which is considered to be at a relatively low temperature within the arc, and the arc is thus constricted due to the formation of negative ions and consequently deep penetration can be obtained by increasing the heat input density to the base metal.

Arc constriction is observed during A-TIG welding and this is caused by changes within the arc plasma for the distribution of metal vapor from the weld pool, accompanied by variation in the size and the surface temperature of the weld pool. The constriction of either the arc or the arc root does not play a central role as the deep penetration mechanism during A-TIG welding but cannot be ignored as an auxiliary factor for deep penetration, as seen in high S stainless steel helium TIG welding [7].

R.-I. Hsieh, Y.-T. Pan, and H.-Y. Liou studied effect of Minor Elements and Shielding Gas on Penetration in TIG Welding of Type 304 Stainless Steel The results show that oxygen and sulfur are beneficial in increasing a depth/width ratio because of the increased surface tension / temperature gradient. Elements, such as aluminum, that have a deleterious effect on the depth/width ratio will combine with oxygen and reduce the soluble oxygen content in the weld pool. On the other hand, silicon and phosphorus have a minor effect on the depth/width ratio. Shielding gas using Ar + 1% O2 or Ar + 5% H2 can significantly promote the depth/width ratio. The former contains increased soluble oxygen content in the weld pool, and the latter produces an arc that is hotter than that produced by pure argon [9].

Analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments to determine the percentage contribution of each parameter against a stated level of confidence .Taguchi suggests two different routes for carrying out the complete analysis. In the standard approach the results of a single run or the average of the repetitive runs are processed through the main effect and ANOVA. The second approach, which Taguchi strongly recommends for multiple runs, is to use the signal-to-noise (S/N) ratio for the same steps in the analysis [10]. Current controls the heat which generated according to the (Q = I2Rt.this shows that the current has more influence on the amount of heat generated Optimum results have been found by Taguchi method using medium current of 6.8 KA, medium pressure of 0.79KPa and high holding time of 5 seconds [10].

Ugur Esme studied Application of Taguchi method for the optimization of resistance spot welding Low carbon steel is extensively used for deep drawing of motor car bodies, motor cycle parts, and other domestic applications. Therefore, the present work was planned to optimize the resistance spot welding parameters of SAE 1010 steel sheets with different thicknesses. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and electrode force, whereas electrode diameter and welding time were less effective factors. The results showed that welding current was about two times more important than the second ranking factor (electrode force) for controlling the tensile shear strength. An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of signal-to-noise (S/N) ratio. The confirmation tests indicated that it is possible to increase tensile shear strength significantly by using the proposed statistical technique [11].

S. V. Sapakal, M. T. Telsang Studied Parametric optimization of MIG Welding using Taguchi method for enhancing Weld penetration.MS C20 of dimension length 300 mm, width 150mm, thickness 5mm used as work material with CO2 as Welding Gas. Welding current in the range 60, 90 & 120A, Welding voltage 15, 22.5, 30V and Welding speed 2, 4, 6mm/s is used. The corresponding L9 OA is selected from the set of predefined OAs according to the number of factors and their levels that will be used. 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. Welding current is found to be most significant parameter as per ANOVA.60A Current, 22.5Voltage and 2mm/s is the optimum level of factors found for enhancing weld penetration [12].

S. P. Tewari, Ankur Gupta, Jyoti Prakash analyze Effect of Welding Parameters on Weld Penetration in MIG Welding Mild Steel specimens having dimensions 50mm× 40mm× 6 mm welded by metal arc welding were investigated. The welding current, arc voltage, welding speed, heat input rate are chosen as welding parameters. The depth of penetrations were measured for each specimen after the welding operation on closed butt joint and the effects of welding speed and heat input rate parameters on depth of penetration were investigated. Voltage (24v) and current (105A) are taken constant and arc time is varied during the welding of specimens. The depth of penetration increases with increasing welding speed up to 110.39 mm/min which was optimum value to obtain maximum penetration, because it begins to decrease linearly after this point. Increasing the speed of travel and maintaining constant arc voltage and current increases penetration until an optimum speed is reached at which penetration is maximum. Increasing the speed beyond this optimum results in decreased penetration. So it can be concluded from experimental analysis that for the mild steel specimen having dimension 50mm×40mm× 6 mm, optimum weldability can be achieved by considering the welding parameters as welding speed,110.39 mm/min with current 105 Amp, arc voltage 24 V and electrode(E 6011) diameter 2.5mm [13].

During arc welding, the driving forces acting on the fluid flow of weld pool include the buoyancy, electromagnetic force, aerodynamic drag, and surface tension As a result; the liquid metal convection of weld pool is driven by a combination of various forces. It is generally agreed that the surface tension gradients are the major driving force contributing to liquid metal convection in the weld pool. The surface tension gradient is established by the temperature difference along the pool surface. Arc heating makes the temperature of the pool surface significantly higher at the center than at the edge. For TIG welding without flux, the surface tension will be highest level at the edge of weld pool and lowest level near the centre of weld pool. Surface tension gradient therefore produces liquid metal outwards from the centre of pool surface resulting in a shallow and wide weld as shown in the surface active elements, such sulfur or oxygen, exceed a certain concentration in the weld pool, the temperature coefficient of surface tension dramatically changes from negative to positive This means that the surface tension of liquid metal increases with the increase in temperature. For TIG welding with oxide flux, the surface tension is highest near the centre of weld pool. The liquid metal will be inwards along the pool surface towards the centre and then down to pool root [17].

Chunlin Dong performed Preliminary study on the mechanism of Arc Welding with the activated flux type 304 austenitic stainless steel with different S content. Individual flux compound such as TiO_2, Cr_2O_3, SiO_2, ZrO_2 is used it is found that Weld Penetration depth dramatically increase in presence of some individual Oxides. it is found that fluid flow appear n outward direction in case of ZrO_2 [19].

Wu PAN and Ka SHI performed Research on the effect of Technical Parameters on the Modeling of the Weld by A-TIG Welding the effect of welding parameters on the modeling of a 4mm thickness mild steel plate is studied. The arc voltage, weld speed and other parameters are fixed with different welding current 60A to 120A, weld speed 285mm/s, gas flow rate 12 l/mm, arc length 3mm, voltage 11 V with the increase of welding current, the gap of weld penetration between A TIG and TIG increase too. With arc contraction theory as the active flux added, the surface activating flux evaporates and surrounded by outlying regions of the arc as atom from the high temperature of the weld arc. The evaporated atoms size electrons and shape n to negative ion in the outlying regions of the lower temperature of the region. This result in a decrease trend of the number of electrons in the weld arc. The arc conductivity decreased that automatic contraction and the heat and the arc force concentrated. Therefore the weld penetration increased. In the center of the arc as the temperature is high enough to make the atomic ionization and the combination of particle and electron into negative ion is a exothermic reaction. With the current increase, the active agent in the volatile effect of oxides increase, further increasing the weld penetration depth [20].

SIGNAL TO NOISE RATIO

1) Larger the Better: (S/N)HB = -10 log (MSDHB).

Where ,MSDHB = (1/R) Σ ($1/y^2_j$).

2) Smaller the Better: (S/N)LB = -10 log (MSDLB)

Where, MSDLB = (1/R) Σ (y^2_j).

3) Nominal the Best: (S/N) NB = -10 log (MSDNB)

Where, MSDNB = (1/R) Σ $(y_j-y_0)^2$.

SELECTION OF ORTHOGONAL ARRAY

Taguchi 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. 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 the present experimental work, three factors with their three levels are used for which the corresponding orthogonal array is L9 which is shown in Table.

Table 4.2: L-9 Orthogonal Array

Exp No	Process Parameter		
	Welding Current	Gas flow rate	Welding Speed
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

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 S.D.S/N ratio used to measure the quality characteristic deviating from the desired value.

The S/N ratio is defined as n=10log (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 can be taken and S/N ratio is calculated for each experiment.

Table 4.4: Analysis of S/N Ratio

Sr No	Welding Current(Amp)	Gas flow rate(LPM)	Welding speed{mm/s)	Weld Penetration(mm)	S/N Ratio
1	150	10.0	6.66	1.6	4.08240
2	150	12.5	3.33	2.5	7.95880
3	150	15.0	1.66	2.7	8.62728
4	175	10.0	3.33	3.0	9.54243
5	175	12.5	1.66	5.0	13.9794
6	175	15.0	6.66	3.0	9.54243
7	200	10.0	1.66	2.5	7.95880
8	200	12.5	6.66	2.5	7.95880
9	200	15.0	3.33	2.0	6.02060

S/N RESPONSE ANALYSIS

The S/N Response is calculated for each level of each parameter as fallows

[1]Welding Current

Level 1=[4.08240+7.95880+8.62728]/3=6.8894

Level 2=[9.54243+13.9794+9.54243]/3=11.0214

Level 3=[7.95880+7.95880+6.02060]/3=7.3127

[2] Gas flow rate

Level 1=[4.08240+9.54243+7.95880]/3=7.1945

Level 2 =[7.95880+13.9794+7.95880]/3=9.9656

Level 3=[8.62728+9.54243+6.02060]/3=8.0634

[3] Welding speed

Level1=[4.08240+9.54243+7.95880]/3=7.1954

Level 2 =[7.95880+9.54243+6.02060]/3=7.84601

Level 3 =[8.62728+13.9794+7.95880]/3=10.1884

Table 4.5: S/N Response Table for Weld Penetration

Symbol	**Input Parameter**	**Mean S/N Ratio**		
		Level 1	**Level 2**	**Level 3**
A	Welding Current	6.889	**11.021**	7.313
B	Gas flow rate	7.195	**9.966**	8.063
C	Welding speed	7.195	7.841	**10.188**

ANALYSIS OF VARIANCE

Analysis of Variance (ANOVA) is a statistically based objective decision making tool for detecting any difference in average performance of groups of items tested. The decision rather than pure judgments, take variation in to account. The experimental design and subsequent analysis like ANOVA are intrinsically tied to each other. Analysis of Variance (ANOVA) breaks total variation down into accountable source and total variations is decomposed into its appropriate components.

The P-value approach is widely adopted in practice risks implied by specific value or level of significance. The P- value is probability that the tests statistics will take on a value that is at least extreme as the observed value of the statistic when the null hypothesis Ho is true. Thus, the P- values convey much information about the weight of evidence against the Ho and so a decision maker can draw a conclusion at any specified level of significance. The P- value is therefore the smallest level of significance that would lead to rejection of the null hypothesis Ho. Detail step for ANOVA are given below for weld penetration in (mm). Calculation of correction factor:

1) Correction Factor (C.F.) $= (\text{Total})^2 / \text{T.C.}$ (4.13)

2) Total Sum of Square (SS_T) $= \sum y^2 - \text{C.F.}$ (4.14)

3) Sum of Squares due to Current (SS_{cur}) $= \sum y_{cur}^2 - \text{C.F.}$ (4.15)

4) Sum of Squares due to gas flow rate $= \sum y_{\text{gas flow tate}}^2 - \text{C.F.}$ (4.16)

5) Sum of Squares due to speed (SS_{speed}) $= \sum y_{speed}^2 - \text{C.F.}$ (4.17)

6) Sum of Squares due to Error (SS_E) $= SS_T - (SS_{cur} + SS_{\text{gas flow rate}} + SS_{speed})$ (4.18)

In order to statistically analyze the result, ANOVA was performed. Process variables having p-value<0.05 are considered significant terms for the requisite response characteristics. The insignificant parameters were having p value larger than 0.05.The ANOVA.

Table 4.6 Analysis of Variance for SNRA1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Welding current	2	3.7422	3.7422	1.8711	60.14	0.016
Gas flow rate	2	1.5622	1.5622	0.7811	25.11	0.038
Welding speed	2	1.8956	1.8956	0.9478	30.46	0.032
Error	2	0.0622	0.0622	0.0311		
Total	8	7.2622				

S = 0.176383 R-Sq = 99.14% R-Sq (adj) = 96.57%

CONFORMATION TEST

The final step is to predict and verify the improvement of quality characteristic using the optimal level of the welding process parameters. The 3 experiments for the optimal inputs, i.e. welding current at level 2 and arc voltage at level 2, & gas flow rate at level 3 are conducted to obtain the greater hardness.

CONCLUSION

In this paper, the optimization of the process parameters for GMA welding of stainless steel and low carbon steel with greater weld strength has been reported. The Nominal-the-better quality characteristic is considered in the hardness prediction. The Taguchi method is adopted to solve this problem. The experimental result shows that the hardness is greatly improved by using this approach.

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