OPTIMIZATION OF TIG WELDING PROCESS USING TAGUCHI METHOD

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ABSTRACT

Manufacturer's often face the problem to achieve a good welded joint with the required quality due to control of the input process variables. The main objective of this investigation is to find best process parameters for good quality weld in TIG welding. Gas Tungsten arc welding (GTAW) is a popular choice of welding process when high level of weld quality or considerable precision welding operation is required. Taguchi Method with L₉ orthogonal array was used to find best settings of welding current, filler rod diameter, gas flow rate and root gap. Further the mechanical testing was performed. Tensile strength is chosen as the response values. The study of the welding parameter's effect on tensile strength of weld specimen were carried out by statistical technique i.e. analysis of variance (ANOVA) with Signal to Noise (S/N) ratio. The optimum parametric conditions were found out by Taguchi method. Confirmatory test was performed to achieve the validity of the results.

KEYWORDS: TIG Welding, Taguchi Method, DOE, L₉ Array, ANOVA & Signal to Noise Ratio

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1. INTRODUCTION

Welding is a common process for joining metals using a large variety of applications. Welding occurs in several locations, from outdoors settings on rural farms and construction sites to inside locations, such as factories and job shops. Welding processes are fairly simple to understand, and basic techniques can be learned quickly. Welding is the joining of metals at a molecular level. At the simplest level, welding involves the use of four components: the metals, a heat source, filler metal, and some kind of shield from the air. The metals are heated to their melting point while being shielded from the air, and then a filler metal is added to the heated area to produce a single piece of metal. It can be performed with or without filler metal and with or without pressure.

2. LITERATURE REVIEW

[1]. A.KSrirangan and S.P Raj found that in TIG welding, welding current exerted significance influence on multiple responses followed by welding speed and Voltage.[2]. S.C. Juang et al carried out the selection of the process parameters of TIG welding and experimentally concluded that the front height, front width, back height and back width of the weld pool are greatly improved by using Taguchi Technique.[3]. Paulo J. Modenesi et al found that operational characteristics of the TIG process were not very different from those of conventional TIG welding.[4]. Ajay et al., stated that high quality can be achieved by optimizing various quality attributes or by selecting an optimal process environment that is efficient enough to fetch the desire requirements for quality.

Taguchi method has been found to be a powerful tool to improve overall process quality by optimizing the welding process parameters in a way that variation is reduced to the barest minimum. [5]. Kim and Lee, They used the method to suggest optimal combinations for process factors of hybrid welding methods to optimize the welding parameters of resistance spot welding process. [6]. Alexandra P Costaa et al. worked on the laser beam welding hard metals to steel and examined laser beam weldability of hard metals to steel with high power CO₂ laser and Nd: YAG laser.[7]. Dhavalkumar K Soni et al. conducted an experimental investigation and prediction of the laser welding process for mild steel 2062 sheets of 1 mm using a fiber laser. They predicted the output responses by Artificial Neural Network (ANN) using MATLAB.[8]. D Kalita and P. B Barua investigated the effect of the process parameters of Metal Inert Gas Welding such as welding current, arc voltage and shielding gas flow rate on Impact strength of welded joints by the Taguchi Optimization method and they concluded that welding voltage has significant effect, both on mean and variation of the Tensile strength of the weld having 87.019% and 85.398% contribution respectively.[9]. Gadakh et al. were of the opinion that multi-objective optimization (or programming), also known as multi criteria or multi-attribute optimization, was the process of simultaneously optimizing two or more conflicting attributes (objectives) subject to certain constraints. The knowledge gap implies advance use of Taguchi process for accurate optimization Process.

3. METHODOLOGY

3.1 Fabrication of Weld Joint

The fabrication involves preparation of base metal for weld, welding of base metal according to give input parameters values and preparation of specimen for tensile test.

3.1.1 Preparation of base metal for weld: The preparation process consists of following operation marking, cutting, grooving grinding and filing. This operation are by various equipment.

3.1.2 Marking: It is the initial state of preparation process in which the long flat bars in to predefined dimensions, each plate as 150 X 50 mm. We are using vernier caliper for measuring and scriber for marking.

3.1.3 Cutting and grinding: This operation is used to cut the marked specimens with the help of power hacksaw and make with no blurr edges and to get exact dimensions. For grinding we used power and hand grinding machines. The cutting and grinding process are shown in Fig 3.1 and 3.2 respectively.

3.1.4 Grooving : The weld groove on a work piece surface between workpiece edges is done following: Groove specifications is shown in Fig 3.3. Root opening - 2.5, Effective throat- 10 mm, Groove angle- 60°

3.1.5 Filing : Filing is a material removal process in manufacturing. Filing operations can be used on a wide range of materials as a finishing operation. Filing helps achieve workpiece function by removing some excess material and deburring the surface. Filing operations can be used on a wide range of materials as a finishing operation

Figure 3.1: Cutting

Figure 3.2: Grinding

Figure 3.3: Groove specifications

3.2 Control Factors

The following control factors were identified as affecting the tensile strength. The optimum process parameters using Taguchi method for the control factors is identified.

Table 4.1: Control parameters and levels

S.No	Parameters	Level 1	Level 2	Level 3
A	Current (Amps)	130	140	150
B	Filler Rod diameter (mm)	1.6	2.4	3.2
C	Gas Flow rate (lit/min)	7-10	10-12	12-15
D	Root Gap (mm)	2.5	3.15	4.0

3.3 Design of Orthogonal Array

Dependiing upon no of control and no of levels orthogonal array is defined. Many standards orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels. To conduct the an experiment to understand the influence of four different independent variables with each variable having three set values, then an L₉ orthogonal array might be the right choice. The L₉ orthogonal array is meant for understanding the effect of four indeendent factors each having three factor level values. The defined orthogonal array is shown in table 3.1

Table 3.1: L₉ Orthogonal array

Experiment No.	Control factors (Variables)			
	Current(Ampere)	Gas flow rate(lit/min)	Filler rod Dia(mm)	Root gap(mm)
1	130	1.6	7-10	2.5
2	130	2.4	10-12	3.15
3	130	3.2	12-15	4.0
4	140	1.6	10-12	4.0
5	140	2.4	12-15	2.5
6	140	3.2	7-10	3.15
7	150	1.6	12-15	3.15
8	150	2.4	7-10	4.0

9	150	3.2	10-12	2.5
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Totally 9 experiments to be conducted and each experiment is based on the combination of level values as shown in the Table.3.1.

3.7 Welding According to Defined OA

The first setup is to predefined experimental input values according to L_9 orthogonal array employed to carry out the design of experiment. Select the MS 2062 metal flat bars and put into fabrication with TIG setup with proper D.C. power source to work piece and electrode respectively. Turn on the power supply and generate the arc. Root pass is done with the defined root gap. After that hot pass and filling is done. In the same way the remaining experiments are done according to defined orthogonal array values. After completing the joining process the weld specimens were taken for finding out the tensile strength using universal testing machine. The processed parameters were optimized by Taguchi method by taking S/N ratio with quality characteristic larger-the-better. The welded specimens are shown in Fig 3.5.

3.9 Testing of Weld Joint: The testing of weld joint of MS-2062 is done by using universal testing machine for tensile strength. First we load the workpiece in to UTM machine. We take the yield strength of the joint by taking the reading of indicator. This results are used in finding of S/N ratio. Signal to noise ratio were used to transform the experimental result. By selecting larger the better taguchi loss function. We find out the optimum process parameter with the obtained results.

Figure 3.5: Welded specimens

Figure 3.7: Tensile test specimen

Figure 3.8: Fractured samples of Tensile test

4. RESULT & DISCUSSIONS

The data of Illustration in Table 4.1 is analysed by ANOVA. For each experiment (trial no.), there are one response in table as tensile strength is analysed. Using this data, for each trial, the S/N ratio is computed. Since the objective is to maximize the tensile strength, the objective function is larger the better type of quality characteristic for which the S/N ratio is calculated. For the first trial, the data are 385.067. Substituting the data in below Equation gives

$$\eta_1 = -10 \log \left[\frac{1}{y^2} \right]$$

Where,

$$\eta_1 = \text{S/N ratio}$$

$$Y = \text{Tensile strength in MPa}$$

$$\text{S/N for experiment no. 1, } \eta_1 = -10 \log \left[\frac{1}{385.067^2} \right]$$

Similarly, for the remaining experiment the S/N ratio is calculated by using the above formula.

Table 4.1: S/N Data of Illustration

Experiment No	A	B	C	D	A	B	C	D	Tensile Strength(MPa)	S/N Ratio
1	1	1	1	1	130	1.6	7-10	2.5	385.067	51.71
2	1	2	2	2	130	2.4	10-12	3.15	373.861	51.45
3	1	3	3	3	130	3.2	12-15	4.0	411.867	52.29
4	2	1	2	3	140	1.6	10-12	4.0	389.933	51.81
5	2	2	3	1	140	2.4	12-15	2.5	394.933	51.93
6	2	3	1	2	140	3.2	7-10	3.15	372.333	51.41
7	3	1	3	2	150	1.6	12-15	3.15	378.667	51.56
8	3	2	1	3	150	2.4	7-10	4.3	414.200	52.34
9	3	3	2	1	150	3.2	10-12	2.5	389.400	51.80
Total										466.3
Mean										51.81

The S/N ratio data is analysed through ANOVA. The level totals of S/N ratios are given in table 4.3.

Table 4.2: level totals of S/N ratio Illustration

Factor	Level 1	Level 2	Level 3
A	155.45	155.15	155.70
B	155.08	155.72	155.5
C	155.46	155.06	155.78
D	155.44	154.42	156.44

$$\text{Correction factor (CF)} = \frac{(466.3)^2}{9} = 24159.521$$

$$\begin{aligned} \text{Sum of squares (SS}_A) &= \frac{A_1^2 + A_2^2 + A_3^2}{3} - \text{CF} \\ &= \frac{155.45^2 + 155.15^2 + 155.7^2}{3} - 24159.521 \\ &= 0.05 \end{aligned}$$

Similarly, $\text{SS}_B = 0.09$, $\text{SS}_C = 0.09$, $\text{SS}_D = 0.73$

The ANOVA for Illustration is given in Table 4.4.

Table 4.4: ANOVA for Illustration

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	Fo	C (%)
Current (A)*	15.59	2	7.79	21.05	94.48
Filler Rod Dia (B)	0.09	2	-	-	0.54
Gas Flow rate (C)	0.09	2	-	-	0.54
Root Gap (D)	0.73	2	-	-	4.42
Pooled Error	1.49	4	0.3725		
	Total = 16.5				

Table 4.4 Average Response (S/N Ratio) for illustration

Factors	Level 1	Level 2	Level 3
A	51.81	51.71	51.90
B	51.96	51.93	51.83
C	51.82	51.68	51.92
D	51.81	51.47	52.14

Optimal Levels for the Control Factors

The average response in terms of S/N ratio of each level of all factors is given in Table 4.4. The optimal levels for all the factors are always selected based on the maximum average S/N ratio only irrespective of the objective of the problem. Accordingly, the best levels for the factors are A₃B₁C₃D₃.

4.1 Predicting the Optimum Process Parameters

Since the contribution of B, and A is negligible, Consider the factors of the process for predicting the optimum response the below formula is used to calculated by equation shown below.

$$\begin{aligned}
 \eta_{opt} &= \bar{\eta} + [A_3 - \bar{\eta}] + [B_2 - \bar{\eta}] + [C_3 - \bar{\eta}] + [D_3 - \bar{\eta}] \\
 &= 51.81 + (51.9 - 51.81) + (51.96 - 51.81) + (51.92 - 51.81) + (52.14 - 51.81) \\
 &= 52.49
 \end{aligned}$$

From the above stated equation, the process parameters with the optimum tensile strength as 418.2 MPa. By conducting the experiment with current, gas flow rate, filler rod diameter and root gap at 150 Amps., 2.4mm, 12-15lit/min and 4mm is 416.2 MPa. Hence the error is very less hence the data is validated.

5. CONCLUSIONS & FUTURE SCOPE OF WORK

The TIG welding system is successfully done on MS-2062 plate with varying the different levels of important process parameters. The variations in tensile strength are observed with the change in process parameters. From ANNOVA table the highest influencing parameters are identified and optimum process parameters are identified. **Scope for Future work:** The present study may also carried out on other advanced material for better results in welding process.

6. REFERENCES

1. A K Srirangan, S P raj (2015). Multi-response optimization of process parameters for TIG welding of Incoloy800HT by Taguchi gray relational analysis, *Engineering Science and Technology, an International Journal*, doi: 10.1016/j.jestch.2015.10.003.

2. S.C. Juang, Y.S. Tarn, (2002). Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel. *Journal of Materials Processing Technology* 122, P 33–37.
3. Mitra, N. S., B. Doloi, and B. Bhattacharyya. "Analysis of traveling wire electrochemical discharge machining of Hylam based composites by Taguchi method." *International Journal of Research in Engineering & Technology* 2.2 (2014): 223-236.
4. Paulo J. Modenesi, Eustaquio R. ApolinaArio, Iaci M. Pereira, (2000). TIG welding with single-component fluxes. *Journal of Materials Processing Technology* 99, P 260-265.
5. Ajay, Saurav, Swapan, Gautan, Application of Vikor Based Taguchi Method for Multi-Response Optimization. A Case Study in Submerged Arc Welding (SAW), *Proceedings of International Conference on Mechanical Engineering (ICME)*, 2009.
6. Rai, K. B., and P. R. Dewan. "Parametric optimization of WEDM using grey relational analysis with Taguchi method." *IMPACT: International Journal of Research in Engineering & Technology*, 2, 109 116 (2014).
7. Kim, H.R., Lee, K.Y., Application of Taguchi Method to Determine Hybrid Welding Condions of Aliminium Alloy. *Journal of International Research*, 68, 296-300, 2009.
8. Alexandra, P. Costa, Luisa Quintino, Martin, Greitmann. 2003. Laser beam welding hard metals to steel. *Journal of Materials Processing Technology*. 141: 163–173.
9. Dhavalkumar K. and Patel D M. 2013. An experimental investigation and prediction of laser welding process. *International Journal of Research in Modern Engineering and Emerging Technology*. 1(4):
10. Yunus, M. O. H. A. M. M. E. D., and MOHAMMAD S. Alsoufi. "A statistical analysis of joint strength of dissimilar aluminium alloys formed by friction stir welding using taguchi design approach, anova for the optimization of process parameters." *IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)* 3.7 (2015): 63-70.
11. DigantaKalita, P.BBarua, Taguchi Optimization of MIG Welding Parameters Affecting Tensile Strength of C20 Welds, *IJETT – Vol.26*, (2015) 43-49.
12. Ahmad, M. Mustafaiz, Et Al. "Optimization Of Process Parameters In Electric Discharge Machining Process." *International Journal of Mechanical Engineering (IJME)* (2016).
13. Gadakh, V.S., Shinde, V.B. and Khemnar, N.S. (2013) Optimization of Welding Process Parameters Using MOORA Method. *The International Journal of Advanced Manufacturing Technology*, 69, 2031-2039. <http://dx.doi.org/10.1007/s00170-013-5188-2>.