A Study on the effect of process parameter variation in TIG welding

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Abstract – *TIG (Tungsten Inert Gas) welding is the most widely used process in industry. The welding parameters effect the properties of the weld joint. The study shows experiments planned according to L9 orthogonal array to find the influence levels of the parameters (Voltage, Current and Gas flow rate) on the weld joint. Signal to noise ratio(S/N ratio) and analysis of variance (ANOVA) are used to investigate the optimal level of parameters*

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

1. INTRODUCTION

Tungsten Inert Gas (TIG) or Gas Tungsten Arc (GTA) welding is the arc welding process in which arc is generated between non consumable tungsten electrode and work piece. The tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium.

TIG welding is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, TIG welding is comparatively more complex and difficult to master, and further more, it is significantly slower than most other welding techniques.

2. METHODOLOGY

Taguchi method is a statistical method developed by Taguchi. Initially it was developed for improving the quality of goods manufactured (manufacturing process development), later its application was expanded to many other fields in Engineering. Professional statisticians have acknowledged Taguchi's efforts especially in the development of designs for studying variation. Success in achieving the desired results involves a careful selection of process parameters and bifurcating them into control and noise factors. Selection of control factors must be made such that it nullifies the effect of noise factors. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments[1]. Results of these experiments are used to analyze the data and predict the quality of components produced.

Optimization of process parameters is done to have great control over quality, productivity and cost aspects of the process. Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. Analysis of variance (ANOVA) is used to study the effect of process parameters on the welding process. [4]The approach is based on Taguchi method, the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) are employed to study the performance characteristics.

Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions is based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings "of control parameters. Thus the marriage of Design of Experiments(DOE) with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum)experiments & desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

Design of Experiment (Doe's)

I. Design and Communicate the Objective.

II. Define the Process.

III. Select a Response and Measurement System.

IV. Ensure that the Measurement System is Adequate.

V. Select Factors to be studied.

VI. Select the Experimental Design.

VII. Set Factor Levels.

VIII. Final Design Considerations.

Steps in Taguchi Methodology:

Step-1: Identify the main function, side effects, and failure mode.

Step-2: Identify the noise factors, testing conditions, and quality characteristics.

Step-3: Identify the objective function to be optimized.

Step-4: Identify the control factors and their levels.

Step-5: Select the orthogonal array matrix experiment.

Step-6: Conduct the matrix experiment.

Step-7: Analyze the data, predict the optimum levels and performance.

Step-8: Perform the verification experiment and plan the future action.

3. EXPERIMENTAL PROCEDURE

The work material used for present work is Aluminum 8011. The dimensions of the work piece are: length 150 mm, width 150 mm and thickness 3 mm. The filler rod used is ER 4043 of 1.6mm diameter. The setup has been made ready and prepared for doing TIG welding. weld joints are made under varied conditions of welding as given by orthogonal array of Taguchi method. The selected welding parameters[2] and levels for each factor are given in Table 1.

Table 1: Welding parameters and their levels

Factors	Level 1	Level 2	Level 3
Voltage(V)	120	130	140
Current(I)	110	120	130
Gas Flow Rate(GF)	8	10	12

Orthogonal arrays are the standard arrays which are selected based on number of parameters selected and levels of parameters.[3] L9 orthogonal array is chosen from Minitab 18 software as shown in Table 2.

Table 2: L9 Orthogonal array

Experiment	Variable 1	Variable 2	Variable 3
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

After the experiments are performed tests are conducted on the welded joints. Mechanical properties are tested of the joint which are tensile test, hardness test and bending test.

4. RESULTS

In this study focus have been given on the mechanical properties of weld joint. The tests conducted on the joint are tensile test, hardness test and bend test. In the bend test we find out that specimen 2 and 9 break at the weld joint ,the bending load applied was 2.42KN.Test results are displayed along with the specimen images(fig 3).

Table 3: Tensile and hardness test results

EXP NO.	ULTIMATE TENSILE STRENGTH(UTS) Mpa	HARDNESS(H)
1	78.108	64.10
2	55.019	58.06
3	85.800	50.26
4	71.775	52.33
5	88.368	50.26
6	90.775	52.50
7	65.494	51.30
8	54.537	57.96
9	55.345	52.50

Fig 1: Tensile Test Specimen

Fig 2: Hardness Test Specimens

Fig 3: Bending Test Specimens

5. ANALYSIS

S/N Ratio:

The method uses the concept of quadratic quality loss function which is a statistical measure of performance called Signal to Noise (S/N) ratio. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The S/N ratio takes both the variability and mean into account. It depends on the quality characteristic of the product or product to be optimized.

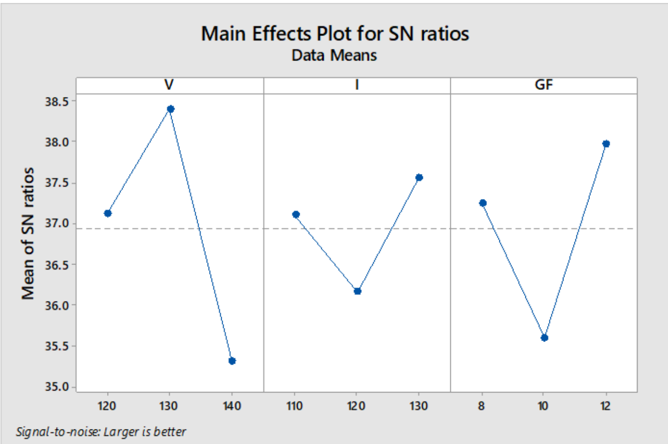

Chart 1: SN ratios graph for Ultimate tensile strength (UTS)

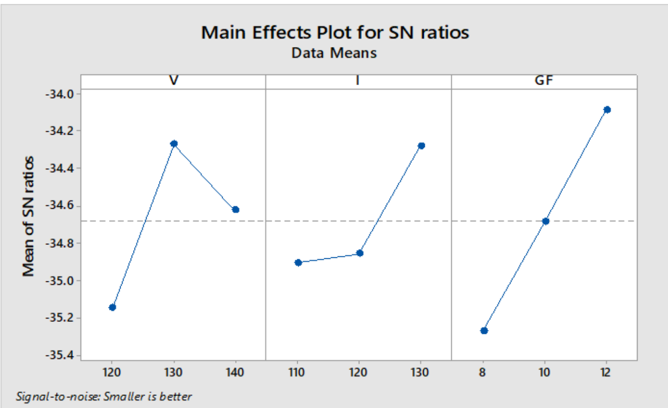

Chart 2: SN ratios graph for Hardness

ANALYSIS OF VARIANCE (ANOVA):

ANOVA is a collection of statistical models used to analyze the difference between group means and their associated procedures. ANOVA is the statistical method used to interpret experimental data to make the necessary decisions. Through ANOVA, the parameters can be categorized into significant and insignificant process parameters. A statistical analysis of variance is performed to see which process parameters are statistically significant at 95% confidence level. In addition to the S/N ratio, analysis of variance can be employed to indicate the impact of process parameters on mechanical properties of weld joints. The purpose of ANOVA experimentation is to reduce and control the variation of a process. The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. In ANOVA tests, F-tests value of the parameters are comparing with the standard F table value (F0.05) at 5% significance level (95% confidence level). Statistically, F-test provides a decision at some confidence level as to whether these estimates are significantly different. Larger F-value indicates that the variation of the process parameter makes a big change on the performance. If P-values in the table are less than 0.05 then the corresponding variables considered as statistically significant. This means that if P value for all parameters is greater than 0.05 means none of these parameters do have significant effect on the response factor at 95% confidence level [5]. The relative importance of the welding parameters with respect to the ultimate tensile strength and hardness was investigated to determine more accurately the optimum combinations of the welding parameters by using ANOVA.

Table 4(1): ANOVA table for UTS

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of contribution
V	2	958.52	479.26	41.90	0.023	54.44
I	2	192.67	96.33	8.42	0.106	10.94
GF	2	586.31	293.16	25.63	0.038	33.3
Error	2	22.88	11.44			
Total	8	1760.38				

Table 4(2): ANOVA table for Hardness

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of contribution
V	2	50.939	25.470	6.89	0.127	29.018
I	2	31.005	15.502	4.19	0.193	17.66
GF	2	86.205	43.102	11.66	0.079	49.108
Error	2	7.392	3.696			4.21
Total	8	175.541				100

6. CONCLUSIONS

Taguchi gave optimum combination for the required properties. From the S/N ratio graphs, we found that at V=130, I=130, GF=12 for UTS and at V=120, I=130, GF=8 optimal parameter combination for UTS and Hardness. From the ANOVA table we can conclude that the major parameter contribution is from Voltage for UTS and for hardness major parameter contribution is that of gas flow rate. The base metal 8011 H14 has a tensile strength of 125-160MPa but the maximum tensile strength obtained in this experimental specimen weld joint is 90MPa, therefore it can be conclude that TIG welding resulted in decrease of tensile strength at the joint. The hardness of the base metal is found to be 25 to 50 BHN equivalent to 490MPa maximum and hardness of the tested specimens we find that the maximum Vickers hardness is 64 HV which is equivalent to 628 MPa. There fore we can conclude that the hardness of the weld joint has increased.

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