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PARAMETRIC OPTIMIZATION OF TIG WELDING ON SS 304 AND MS USING TAGUCHI APPROACH

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Abstract – *In this research paper we used stainless steel 304 and mild steel material. In which stainless steel 304 material has good inter-granular corrosion resistance which increase the life span of pressure vessels and automobile components. TIG welding is most vital and common operation used for joining of two similar or dissimilar parts with heating the material or applying the pressure by using the filler material for increasing productivity with less time and cost constrain. We have used Taguchi's method of optimization to optimize the various process parameters such as Current, Voltage, and Gas Flow Rate (GFR) which has influence on tensile strength and hardness of the joint. A Taguchi Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of dissimilar joint and optimize the welding parameters.*

Key Words: **TIG Welding, Taguchi Orthogonal Array, Tensile Strength, Hardness, S/N Ratio, ANOVA**

1. INTRODUCTION

Welding is a process in which we join two similar or dissimilar metals or non metals by applying pressure or non pressure. Gas tungsten arc welding, GTAW, also known as tungsten inert gas welding, is an arc welding process that uses a non consumable tungsten electrode for establishing an electric arc. Weld area is protected by shielding gases like argon or helium. It is generally used for welding hard-to-weld metals such as Stainless Steels, Magnesium, Aluminium, and Titanium. TIG welding is most commonly used to weld thin sections. For welding stainless steel we use direct current with negative electrode. Direct current with positive electrode is very less common and used rarely.

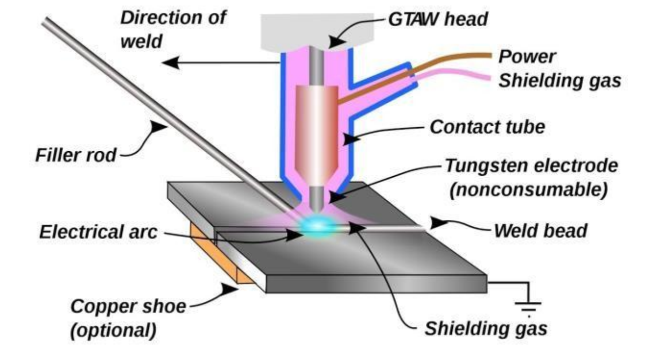

Fig :-1 Principle Of TIG Welding

Ramesh Rudrapati [6] who carried out experiment on Parametric Optimization of TIG Welding Process in Butt Joining of Mild Steel and Stainless Steel. In this paper welding parameters are analyzed and optimized in TIG welding of dissimilar materials (mild steel and stainless steel) to maximize the ultimate load and breaking load simultaneously by using grey relational analysis combined with Taguchi method. Kumar Rahul Anand [4] who carried out experiment on parametric optimization of CO_2 welding which is done on stainless steel the process parameter where current, voltage and gas flow rate (GFR) statistical technique, analysis of variance (ANOVA),signal to noise ratio and graphically main effect plot have been used to study the effect of welding parameters on which ultimate load of weld specimen optimum parametric condition obtained by the Taguchi method. Ajit Khatter [11] in this paper, the use of the L9 orthogonal array, with three control parameters allowed this study to be conducted with a sample of 18 work pieces.

The study found that the control factors had varying effects on the Tensile strength, welding voltage having the highest effects. Ravinder & S.K.Jarial [9] studied the Parametric Optimization of TIG welding on stainless steel (202) and mild steel by using Taguchi method and found the control factor which had varying effect on the tensile strength, arc voltage having the highest effect and also found the optimum parameter for tensile strength current 80 A, Arc voltage 30 V and GFR 6 lt/min.

2. Taguchi Method

Taguchi method is a powerful problem solving tool, which is used to improve the performance of a process without having to conduct a large number of experiments. This saves time and reduces the cost of experimentation .This technique has been applied for carrying out robust design of processes and products and solving many critical problems in manufacturing industries. It joins the experimental design theory and quality reduce function concept for solving problem, critical situations arise when a large number of process parameters to be dealt with, as the number of trials to be conducted have to match with the number of influencing parameters, to reach at any tangible real conclusion. In such cases, it is possible to find the most influential parameter for improving the overall efficiency of any process using Taguchi concept by conducting few experiments.

2. METHODOLOGY

a) Selection of material (SS 304 and Mild Steel (Low Carbon).
b) Process Parameter Selection (Welding Current, Arc Voltage, & Gas Flow).
c) Sample Preparation (Cutting, Welding etc.).
d) Specimen for Tensile Test and Rockwell Hardness Test.
e) Analysis of results.

Material Selection

Stainless Steel

Stainless steels are most notable for the corrosion resistance, which increases with increasing chromium content. Additions of molybdenum increase corrosion resistance in reducing acids and against pitting attack in chloride solutions. Thus, there are numerous grades of stainless steel with varying chromium and molybdenum contents to suit the environment the alloy must endure. Stainless steels resistance to corrosion and staining, low maintenance, and familiar luster make it an ideal material for many applications where both the strength of steel and corrosion resistance are required.

Chemical Composition

Element	Cr	Ni	Mn	N	S	C	Si	P
%	18	8	2	0.10	0.03	0.08	0.75	0.045

Mild steel

Mild steel is a type of carbon steel with a low amount of carbon – it is actually also known as “low carbon steel.” Although ranges vary depending on the source, the amount of carbon typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having carbon content from 0.30% to 2.0%. If any more carbon than that is added, the steel would be classified as cast iron.

Element	C	Si	Mn	S	P
%	0.16-0.18	0.40	0.70-0.90	0.040	0.040

Signal to Noise (S/N) Ratio

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

1.Larger the better

$$SN_L = -10\ log\left[\frac{1}{n}\sum_{i=0}^{n} {}^{1}/_{y_i^2}\right]$$

2.Smaller the better

$$SN_s = -10\ log\left[\frac{1}{n}\sum_{i=0}^{n} y_i^2\right]$$

3.Nominal the best

$$SN_{N} = 10\ log\left(\frac{\bar{y}^2}{s^2}\right)$$

Where, n= Number of trials or measurement, Y =

Where,
n = Number of trials or measurement
yi = measured value
ȳ = mean of measured value
s = standard deviation

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 n_m can be calculated as, SST $= \Sigma\ (n_i - n_m)^2$
Where,
n_i = S/N ratio experiment.
n_m = total mean of S/N ratio.

3. Experimentation and work

The plan has been made and work-piece materials (i.e. mild steel and stainless steel304) have been cut into desired dimensions (150*150*6mm). The welding parameters to this project are taken as current, voltage and gas flow rate. The S/N ratio for each level of process parameters is computed based on S/N analysis. Further, statistical ANOVA was performed to indicate which process parameters are significant. Welds are made under varied conditions of welding as given L9 orthogonal array of Taguchi method.

Table-1: Process Parameters

Sr. No.	Process Parameter	Unit s	level		
			1	2	3
1	Welding Current	Amp	150	200	250
2	Arc Voltage	Volt	22	24	26
3	Gas Flow Rate	L/mi n	10	12	14

Table-2: Universal Testing Machine Results

Run	Current	Voltage	Gas Flow Rate	Tensile	Hardness
1	150	22	10	368.38	82.3
2	150	24	12	403.333	82.1
3	150	26	14	504.94	88.8
4	200	22	10	403.76	83.33
5	200	24	12	375.57	78.5
6	200	26	14	314.30	78.4
7	250	22	10	340.77	62.6
8	250	24	12	343.61	70.9
9	250	26	14	319.72	80.4

4. Result & Discussion

Tensile Test

Tensile testing has been done on the welded specimens. It was done on Universal Testing Machine (UTM). The value of tensile strength has been observed and then S/N ratio has been calculated manually as well as using software called MINITAB. The effect of each parameter on welding has been calculated and with the help of ANOVA, their percentage contribution is also evaluated.

Table-3: Reading of Tensile Strength and S/N ratio

Run	current (amp)	voltage (volt)	GFR (lt/min)	Tensile strength (mpa)	S/N ratio
1	150	22	10	368.38	51.32
2	150	24	12	403.333	52.11
3	150	26	14	504.94	54.06
4	200	22	10	403.76	52.12
5	200	24	12	375.57	51.19
6	200	26	14	314.30	49.94
7	250	22	10	340.77	50.64
8	250	24	12	343.61	50.72
9	250	26	14	319.72	50.09

Calculation for S/N Ratio:

We know S/N ratio for larger is better is: For 1st run: n = 1 because we get the result in single trial y = **368.38 (observed value)** So, S/N = -10 log (1/ 368.38) = 51.32 Similarly we have calculated S/N Ratio for every run.

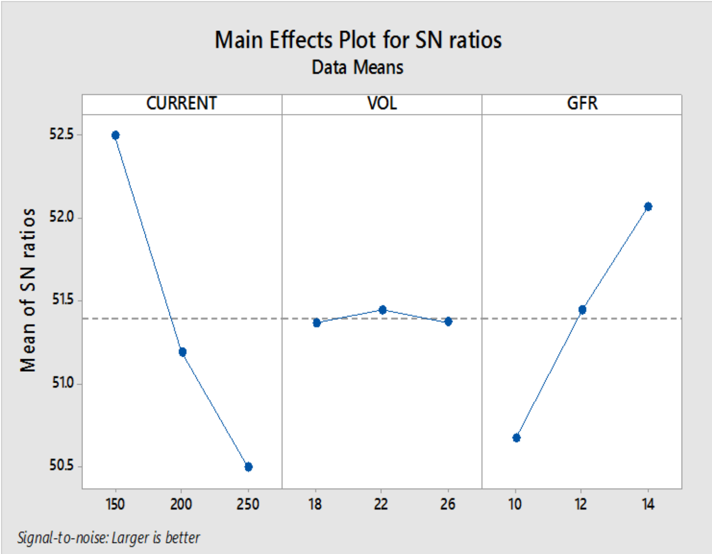

Fig-3: Graph for S/N Ratio of Different parameters For Tensile Strength.

Table-4: Mean Response Table for Signal to Noise Ratio for Tensile Strength Larger is better

Level	Current	Voltage	Gas Flow Rate
1	**52.50**	51.37	50.66
2	51.19	**51.44**	51.44
3	50.49	51.37	**52.07**
Delta	2.01	0.08	1.40
Rank	1	3	2

In Taguchi experiments, we always want to Maximize the S/N ratios and the means were maximized. when the Current was 150, the Gas Flow Rate was 10 and the arc voltage was 24. Based on these results, we should set the factor at the calculated value.

Table No:-5 Analysis of Variance for Transformed Response

Source	DOF	Seq ss	Contribution	Adj SS	Adj MS	F-Value	p-Value
CURRENT	2	9693.4	48.55 %	9693.4	4846.7	1.89	0.34
VOL	2	817.0	4.09%	817.0	408.5	0.16	0.863
GFR	2	4331.9	21.70 %	4331.9	2165.9	0.85	0.542
ERROR	2	5124.9	25.67 %	5124.9	2562.5		
Total	8	19967.1	100.00 %				

Hardness Test

The Rockwell hardness test method, as defined in ASTM E-18, is the most commonly used hardness test method. The micro-structure of each zone has also been observed and captured for better understanding. The samples were prepared accordingly and all 9 samples are tested for hardness. The 9 samples for hardness test are prepared on a mould of Bakelite Powder.

Table-6: Response of Hardness with S/N ratio:

Run	Current	Voltage	Gas Flow Rate	Hardness	S/N ratio
1	150	22	10	82.3	38.30
2	150	24	12	82.1	38.28
3	150	26	14	88.8	38.96
4	200	22	10	83.33	38.41
5	200	24	12	78.5	37.89
6	200	26	14	78.4	37.88
7	250	22	10	62.6	35.93
8	250	24	12	70.9	37.01
9	250	26	14	80.4	38.10

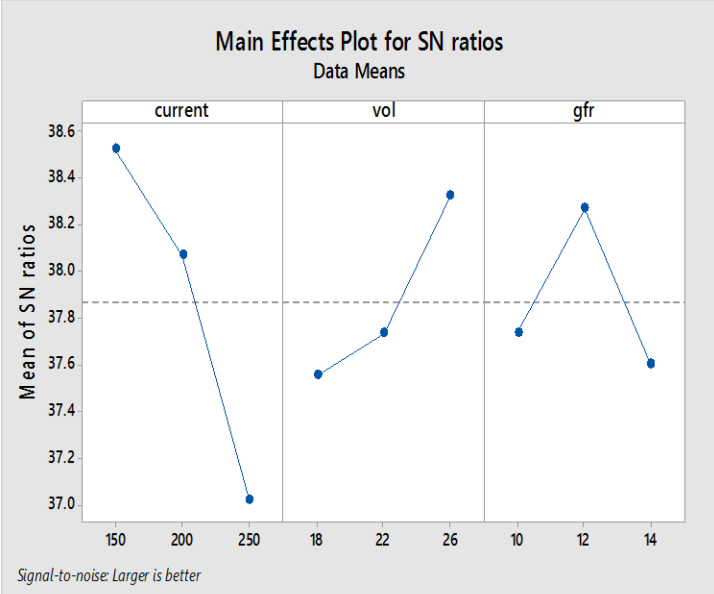

Fig-3: Graph for S/N Ratio of Different parameters For Hardness Test

Table-:7 Mean Response Table for Signal to Noise Ratio For Tensile Strength Larger is Better

Level	Current	Voltage	Gas Flow Rate
1	**38.52**	37.55	37.74
2	38.07	37.73	**38.27**
3	37.02	**38.32**	37.60
Delta	1.50	0.77	0.67
Rank	1	2	3

From the above table we have observed that the Hardness of taken specimen will be higher when the arc current is maintained at 150 A, arc voltage at 22V and gas flow rate at 12 L/min thus we find these parameters are optimum for this experiment and we have the ANOVA result in below table.

Table-8: ANOVA of Variance for S/N Ratio Hardness

Source	DF	Seq ss	Contribution	Adj SS	Adj MS	F-Value	p-Value
CURRENT	2	228.13	58.09 %	228.13	114.07	3.43	0.226
VOL	2	65.89	16.78 %	65.89	32.94	0.99	0.502
GFR	2	32.19	8.20%	32.19	16.10	0.48	0.674
ERROR	2	66.51	16.94 %	66.51	33.26		
Total	8	392.72	100.00 %				

4. Mathematical Model

A mathematical model can be developed for above experiment. Using multiple linear regression and correlation analysis, mathematical models for Ra is obtained as follows: As Ra is a function of more than one independent variable; the matrix equations that express the relationships among the variables can be expanded to accommodate the additional data.

$$Ra = a0 + a1\ x1 + a2\ x2 + a3\ x3 + a4\ x4$$

Where, a0, a1, a2, a3 and a4 are the constant coefficient and

x1= Welding current (I)

x2= Welding voltage (V)

x3= Gas flow Rate (G)

A multivariate model of the data is multiple regressions solves for unknown coefficients by performing a least squares fit. Construct and solve the set of simultaneous equations by forming the regression matrix, X, and solving for the coefficients using the backslash operator. X = [ones (size(x1)) x1 x2 x3]; the least squares fit model of the data is to validate the model, find the maximum of the absolute value of the deviation of the data from the model. Y = X*a;

The regression equation is

Tensile=338 - 0908CURRENT + 1.09VOL + 16.25GFR

Hardness=88.7 - 0.1310CURRENT + 0.808VOL - 0.14GFR

5. Conclusions

1. The use of the L9 orthogonal array, with three control parameters allowed this study to be conducted with a sample of 18 work pieces (9workpiece of SS304 and 9workpiece of Mild Steel).

2. The study found that the control factors had varying effects on the Tensile strength, welding current having the highest effects.

3. Optimum parameter setting for weld strength is obtained at current of 150 amps, 24 volt, and 10-litre/min-gas flow.

4. Formulation of equation for tensile strength- Tensile Strength =338-0.908CURRENT+1.09VOL16.25GFR

5. Optimum parameter setting for Hardness is obtained at current of 150 amps, 22 volt, and 12-litre/min-gas flow.

6.Formulation of equation for hardness, Hardness=88.7 - 0.1310CURRENT + 0.808VOL - 0.14GFR

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