PARAMETERIC OPTIMIZATION OF TIG WELDING ON JOINT OF STAINLESS STEEL(316) & MILD STEEL USING TAGUCHI TECHNIQUE.

Kumar Rahul Anand[1], Vijay Mittal[2]

[1]P.G.Scholar,Gateway Institute of Engineering and Technology.
[2]Principal,Gateway Institute of Engineering and Technology.

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Abstract - *As we know that the use of stainless steel in different industrial sector such as oil and gas, aerospace, automobile, power plant, manufacturing etc. is high due to their higher tensile strength and toughness etc. Therefore need has arrived to think out in the merger of stainless steel with other metal which are compatible and stronger such as stainless steel. So, in this paper we have studied the mechanical properties of the joint of austenitic stainless steel (AISI 316) and mild steel welded by TIG welding. In this paper with the use of Taguchi method of optimization we have tried to optimized the various process parameter such as current, voltage and gas flow ratio (GFR) which has influence on tensile strength and hardness of the joint. However, investigation is based on the Taguchi approach of orthogonal array using analysis of variance (ANOVA) to determine the influence of process parameter and to optimize them.*

Key Words: Austenitic Stainless steel, mild steel, TIG welding, Hardness ,Tensile strength.

1.INTRODUCTION

In the age of rising industrialization welding process is one of the most widely used process. A process known as TIG welding is also mostly used in the industries for better strength of weld which consist of non-consumable tungsten electrode, power source, shielding gas (mainly helium and argon) and filler material.

Sanjeev Gupta [1] performed the experiment to optimize the condition for performing the welding on Utra-90 specimen in which he varies the current and voltage while keeping the gas flow rate constant and observed that welding joint not made properly below 50A and above 200A since then burning of specimen stated. Ravinder & S.K.Jarial [3] 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. Mrugesh Solanki & Ketan Shah [5] investigated and found successfully weld of copper and AISI 316 stainless steel with UTS at 229.600 and micro hardness is 134.214. The effect of root gap is there is slight decrease with increase in ultimate tensile strength when root gap is higher side effect of joint angle. Ultimate Tensile Strength increase with increase in current. The formation of steel globules in copper matrix and copper globules in the fusion zone and delta ferrite phase in the austenitic grain boundaries at the SS side. R..Ramchandran [7] studied the various effect of the TIG welding on the Austenitic stainless steel 316L on micro structural changes through destructive and nondestructive method and various parameters such as tensile strength, hardness on varying the current, voltage and gas flow ratio respectively. N.Choudhury et al. [9] were carried out parameter optimization of TIG Welding of stainless steel and mild steel . The process parameters were current, gas flow rate and filler rod diameter. Statistical techniques analysis of variance (ANOVA), signal-to-noise (S/N) ratio and graphical main effect plots have been used to study the effects of welding parameters on ultimate load of weld specimen. Optimum parametric condition obtained by Taguchi method.

2. METHODOLOGY

a).Selection of base material (AISI 316 and Mild Steel).
b).Process Parameter Selection (Welding Current, Arc Voltage, & Gas Flow).
c).Sample Preparation (Cutting, Welding etc.).
d).Specimen for Tensile Test and Hardness Test.
e).Result Analysis.

3. TAGUCHI METHOD

Genichi Taguchi a Japanese Scientist, developed a technique called Orthogonal Array which is mostly used in the manufacturing industries. The aim of this technique is to provide a high quality product at very low cost. Taguchi have orthogonal array through which the mean and variance of the process parameter get affected when different parameters is applied. However he provided equal weighted to each factor by this , Taguchi showed that the variability is caused by individual factor and that can be controlled individually. Regardless of the environment in which it is used this process is designed with the aim to produce consistent output.

SIGNAL TO NOISE (S/N) RATIO

Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The three types of S/N ratio are:-

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 is best:

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

Where, n=Number of trials or measurement, Y_i= measured value of i^{th} run, $\bar{y}$= mean of measured value, s = standard deviation.

ANOVA (Analysis Of Varience), the total sum of squared deviations SS_T from the total mean S/N ratio n_m can be calculated as,

$SS_T = \Sigma (n_i - n_m)^2$

where,n_i = S/N ratio of i^{th} run or experiment.n_m = total mean of S/N ratio.

In this paper 3x3 parameter level are selected, so L9 orthogonal array has been selected. The array are given below in table 1.

Table-1.

NO.OF RUNS	CONTROL	FACTORS	
	A	B	C
1	L1	L1	L1
2	L1	L2	L2
3	L1	L3	L3
4	L2	L1	L2
5	L2	L2	L3
6	L2	L3	L1
7	L3	L1	L3
8	L3	L2	L1
9	L3	L3	L2

Where A,B and C are process parameter & L1,L2,and L3 are levels of each parameter

4. EXPERIMENTATION

The specimen is prepared from the AISI 316 and MS of dimension 100x75x6mm. The welding parameters to this research 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 analysis of variance (ANOVA) was performed to indicate which process parameters are significant. Thus the optimal combination of the process parameters can be obtained.

Table-2: Chemical Composition of Stainless steel 316 in wt.%.

Component	Ni	Cr	Mo	Si	Mn	C	P	S	Fe
Wt.%	12.00	17.00	2.50	1.00	2.00	0.080	0.045	0.030	65.34

Table-3: Chemical composition of Mild steel in wt.%.

Component	C	Mn	S	P	Fe
Wt.%	0.17	0.80	0.04	0.04	98.95

Table-4 : Selection of process parameters.

S. No.	**Symbol**	**Process Parameter**	**Unit**
1	A	Welding Current	Amp
2	B	Arc Voltage	Volt
3	C	Gas Flow Rate	L/min

Table-5: Process Parameter and their level.

Parameters	code	Level 1	Level 2	Level 3
Current(amp)	A	100	150	200
Voltage(volt)	B	18	22	26
GFR(lt/min)	C	10	12	14

Fig-1:- Specimens Before Tensile Test.

Tensile test is used to determine the tensile strength of the welded joint of Austenitic Stainless Steel (AISI 316) and Mild Steel. The test is conducted on Universal Testing Machine (UTM) and the result is shown in table-6.

Fig-2:- Specimens After Tensile Test.

Calculation for S/N Ratio:
We know S/N Ratio for larger is better is:

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

for 1st run:
n = 1 because we get the result in single trial
y = 530.6 (observed value)
so, S/N = -10 log (1/ 530.6^2) = 54.50
similarly we calculate S/N Ratio for every run. The response values measured from the experiments and their corresponding S/N ratio values are listed in table below.

Table-6: Reading of Tensile Strength and S/N ratio.

RUN	ARC CURRENT (amp)	ARC VOLTAGE(volt)	GFR (Lt/ min)	TENSILE STRENGTH (MPa)	S/N RATIO
1	100	18	10	530.6	54.50
2	100	22	12	558.9	54.95
3	100	26	14	560.5	54.97
4	150	18	12	507.3	54.11
5	150	22	14	489.4	53.80
6	150	26	10	559.7	54.96
7	200	18	14	436.6	52.80
8	200	22	10	522.5	54.36
9	200	26	12	493.5	53.85

Hardness may be defined as resistance of metal to plastic deformation usually by indentation. Hardness term is also refer to stiffness, abrasion, cutting and resistance to scratching etc. Hardness measurements were performed to determine the strength. Micro hardness test is performed on the joint of weld metal and the result is shown in table below.

Table-7: Reading of Hardness and S/N ratio.

Run	Current	Voltage	GFR	Hardness (WZ)	Hardness (HAZ)	Hardness (PM)	S/N Ratio
1	100	18	10	207.4	227.0	221.0	26.7508
2	100	22	12	219.0	202.0	225.3	25.0447
3	100	26	14	222.6	215.2	219.6	25.3986
4	150	18	12	229.3	229.1	220.5	33.0728
5	150	22	14	214.0	195.8	224.6	23.2379
6	150	26	10	233.6	245.0	219.2	25.1009
7	200	18	14	220.2	190.2	212.0	22.5294
8	200	22	10	256.0	217.0	225.0	21.0576
9	200	26	12	246.7	236.0	206.7	20.9041

5.RESULT & DISCUSSION

FOR TENSILE STRENGTH

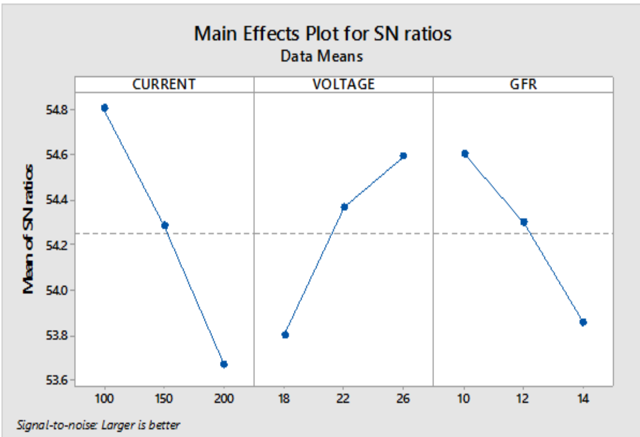

Fig-3: Graph for S/N Ratio of Different parameters For Tensile Strength.

Table-8: Mean Response Table for Signal to Noise Ratio For Tensile Strength Larger is Better

Level	Arc Current	Arc Voltage	Gas Flow Rate
1	**54.80**	53.80	**54.61**
2	54.29	54.37	54.30
3	53.67	**54.59**	53.86
	1.13	0.79	0.75
Rank	1	2	3

From the above table we have observed that the Tensile Strength of taken specimen will be higher when the arc current is maintained at 100A, arc voltage at 26V and gas flow rate at 10 L/min thus we find these parameter optimum for this experiment.

ANOVA of Variance for S/N Ratio Tensile Strength.

The ANOVA is used to investigate which process parameters have significantly affected the quality characteristics. ANOVA gives the detail about the percentage contribution made by the various process parameters and the error. Thus it helps in evaluating importance of process parameter.

Table-10:The ANOVA Results For Tensile Strength

Source	**DOF**	**Seq. SS**	**Adj. MS**	**F**	**P**	**% Contribution**
Arc Current	2	1.9336	0.9668	6081	0.128	47.50 %
Arc Voltages	2	0.9993	0.4996	3.52	0.221	24.55 %
Gas Flow Rate	2	0.8532	0.4266	3.01	0.250	20.96 %
Residual Error	2	0.2839	0.1419			
Total	8	4.0700				

FOR HARDNESS

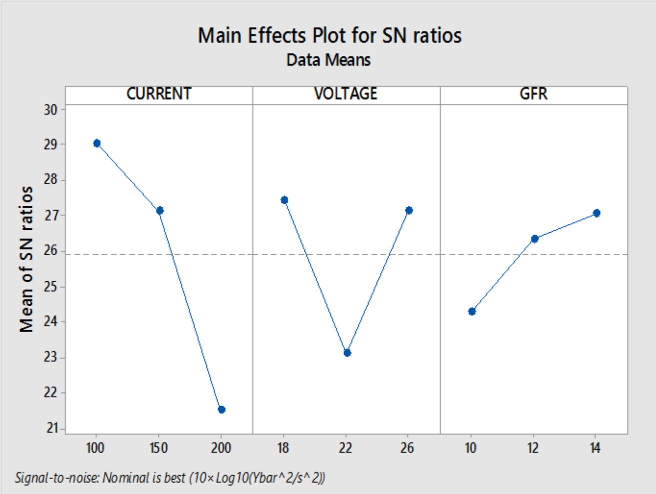

Fig-4:Graph for S/N Ratio of Different Parameters For Hardness.

Table-11: Results Of Optimum Parameters For Hardness

Level	Current	Voltage	GRF
1	**29.06**	**27.45**	24.30
2	27.14	23.11	26.34
3	21.50	27.13	**27.06**
Delta	7.57	4.34	2.75
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 100A, arc voltage at 18V and gas flow rate at 14 L/min thus we find these parameter optimum for this experiment and we have the ANOVA result in below table.

Table-12:The ANOVA Results For Hardness.

Source	**DOF**	**Seq. SS**	**Adj. MS**	**F**	**P**	**% Contribution**
Arc Current	2	92.80	46.398	1.32	0.432	44.06 %
Arc Voltages	2	35.08	17.542	0.50	0.668	16.66 %
Gas Flow Rate	2	12.24	6.118	0.17	0.852	5.811 %
Residual Error	2	70.50	35.252			
Total	8	210.62				

6.CONCLUSION

The present experiment can be concluded in the following steps.

1.In this experiment Taguchi design is used for the optimization of welding parameters for the joint of stainless steel (AISI 316) and mild steel.

2.Optimised parameters for the Tensile Strength is

Arc Current	Level 1	100
Arc Voltage	Level 3	26
Gas Flow Rate	Level 1	10

3.Optimised parameters for the Hardness is

Arc Current	Level 1	100
Arc Voltage	Level 1	18
Gas Flow Rate	Level 3	14

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