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PARAMETRIC STUDY OF TIG WELDING ON SS 316

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ABSTRACT: Welding is widely used by manufacturing engineers and production personnel to manufacture new products.Tungsten Inert Gas welding is one of the most widely used techniques for joining ferrous and non ferrous metal. Tungsten Inert Gas Arc Welding is a commonly used welding technique due to its versatility and ease that can be maintained in almost all type of working conditions. Stainless Steel (SS316) possessing high strength and toughness is usually known to offer major challenges during its welding. In this work, Taguchi's DOE approach is used to plan and design the experiments to study the effect of welding process parameters. In this process we use various parameters like welding current ,welding voltage ,gas flow rate ,etc. Subsequently, using analysis of variance (ANOVA) the significant coefficients for each input parameter on tensile strength & the Hardness (PM, WZ & HAZ) can be determined.
Keywords: TIG welding, tensile test ,SS 316, taguchi.

I. INTRODUCTION

Welding is a cheaper fabrication process that joins materials permanently, usually or dissimilar metals by the use of heat causing fusion with or without the application of pressure.

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld.

The weld area is protected from atmospheric contamination by an inert shielding (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it.

GTAW 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, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc.

The equipment required to perform tungsten inert gas arc welding, the basic necessary equipment is a welding gun, a wire feed unit, a welding power supply, an electrode wire, and a shielding gas supply.

II. METHODOLOGY

2.1 Design Methodology

Experimentation:-

Tungsten Inert Gas Welding (TIG) process was used to weld the test specimens. The welding machine used is ESAB SSR 400-T.

Table 2.1: Technical Specification of ESAB SSR 400-T.

TECHNICAL DATA	ESAB SSR 400-T
Input voltage	3*415 V
Frequency	50 Hz
Output voltage	100 V
Current range	5-400 Amp
Recommended Tig Torches 4/8 M	T*H 200(gas cooled) T*H 400(water cooled)
Dimension L*H*W mm	675*350*690

Fig 2.1: ESAB SSR 400-T Welding Setup.

Fig 2.2: Front view of Tig Tig welding machine

2.2 Material selection:-

In the present project work a 10mm thick stainless steel 316 grade plates were used.. For selection of work-piece, reference of the procedure handbook of Tig Welding & Welding Process Technology by P. T. Houldcroft is referred. Three different types of joints V-butt joint, U-butt joint and square joint samples were taken. Pure argon gas was used for preventing oxidation of molten steel.

Material : Stainless Steel 316
Material Dimension : 200*150*10 mm
Filler wire thickness : 1.6 mm
Number of samples : 9

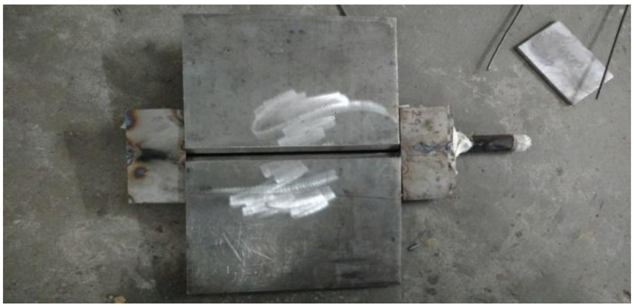

Fig 2.3: Sample piece of SS316 of type V-butt having 30 degree.

Fig 2.4: Filler wire

Table 2.2: Chemical Composition of 316 stainless Steel

Elements	Weight percentage
Carbon	0.08
Manganese	2.00
Phosphorous	0.045
Sulphur	0.030
Silicon	0.75
Chromium	16.0-18.0
Nickel	10.0-14.0
Nitrogen	0.10
Molybdenum	2.0-3.0

2.3 Experimental Setup:-

The experiment was done by considering two major parameters i.e current and gas flow.

Fig 2.5: Performance of Welding Test was carried out.

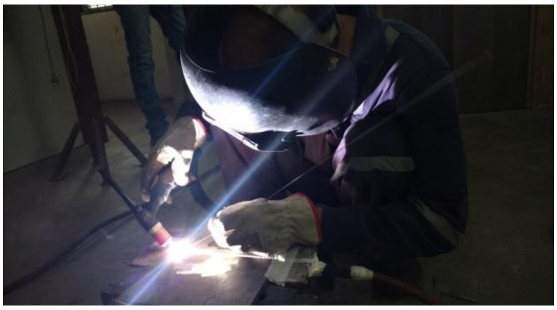

Fig 2.6: Welding of V-butt joint.

Fig 2.7: Welding Sample of V-butt joint.

III. ANALYSIS AND IMPLEMENTATION:

3.1 Taguchi method analysis:-

In Taguchi method first optimal parameters were determined by using L9 (3^3) orthogonal array. L9 (3^3) means that it will investigate for 3 levels and 3 factors on qualitative index for each factor. Table2 gives the levels and factors which are employed for welding the samples. Table 3 gives the experimental data that is taken for analysis.

Table 3.1 Critical Parameters and Levels

LEVELS	1	2	3
Current (Amp)	115	130	145
Gas Flow Rate	20	15	10
Types Of Joints	V-Butt	U-Butt	Square

Table 3.2. Experimental Data

Sample No.	Current	Gas flow rate	Type of joints
1	115	20	V-butt
2	115	15	U-butt
3	115	10	Square
4	130	20	U-butt
5	130	15	Square
6	130	10	V-butt
7	145	20	Square
8	145	15	V-butt
9	145	10	U-butt

3.2 ANALYSIS OF VARIATIONS (ANOVA) :

The observed values for gas flow rate and current were determined as the influencing factors in welding process. The parameters influencing tensile strength and hardness were found out by using ANOVA technique. From the Table the influencing factors for tensile test are gas flow rate of welding and current for tensile strength. Sum of squares due to mean is given as the number of experiments multiplied by the square of the overall mean. The calculated total sum of squares is given as the difference between grand total sum of squares and sum of squares due to mean. Sum of squares for each parameter is given as 3[(A1-m)2 + (A2-m)2 + (A3-m)2] where, A1, A2, and A3 are the average value of each assigned parameters at levels 1, 2, 3 respectively. Degree of freedom (DOF) error is given by the difference between the DOF for the total sum of squares and sum of DOF for various factors. Mean square is given as the ratio of sum of squares due to each factor to DOF for each factor. Variance ratio is given by the ratio of mean squares due to the factor to mean squares error. Percentage of contribution is the ratio of sum of squares to the total sum of squares. All the values for each parameter were calculated and shown. Similarly the percentage of contribution was calculated for parameters gas flow rate and current. The results of ANOVA for hardness and tensile strength are summarized in Table _ and Table _ respectively.

Statistical Analysis:

1) Tensile Test:

This test is used to determine the modulus of elasticity (E), ultimate tensile strength (UTS). The tensile test was conducted on UTM and their results were studied.

Fig 3.1: Ultimate Tensile Machine

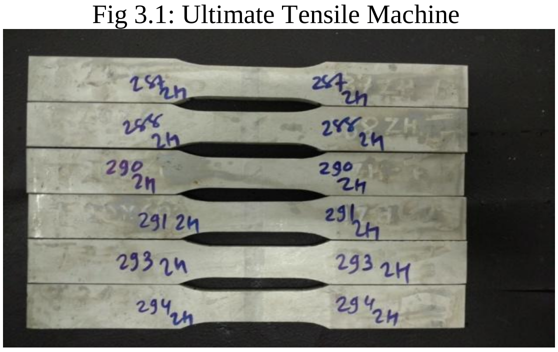

Fig 3.2: Tensile Test Specime

Fig 3.3 : Specimen after Tensile Test

The Single-To-Noise Ratio graph for tensile test of different specimen are as shown in Fig 2.1.From the Table 2.5, it shows that the specimen 6 has highest tensile strength. . The specimen 6 exhibited a tensile strength of 643.438 N/mm2.

Fig 3.4: Signal-to-Noise ratio graph

Table 3.3: Experimental Observations

Sample No.	Ultimate Tensile Strength	S/N Ratio
1	643.080	55.51
2	598.181	56.08
3	607.58	55.78
4	595.002	56.07
5	619.286	55.83
6	643.438	55.52
7	607.937	55.67
8	626.837	55.55
9	599.515	55.94

MEAN RESPONSE OF SIGNAL TO NOISE RATIO FOR TENSILE STRENGTH

Calculation For Mean Response Table of Each Parameter:

(1) For arc current of level 1 (S/NP1,1)
P1,1 means parameter 1 and level 1
S/NP1,1 = (S/N1 + S/N2 +S/N3)/3
= (55.51 + 56.08 + 55.78)/3
= 55.85

Similarly, we can calculate the mean response for arc current for remaining two levels.

(2) For gas flow rate of level 1 (S/NP2,1)

P2,1 means parameter 2 and level 1.
S/NP2,1 = (S/N1 + S/N4 +S/N7)/3
= (55.51 + 56.07 + 55.67)/3
= 55.75

Similarly, we can calculate the mean response for gas flow rate for remaining two levels.

(3) For types of joints of level 1
(S/NP3,1) S/NP2,1 = (S/N1 + S/N6 +S/N8)/3
=(55.51 + 55.52 + 55.55)/3
= 55.52

Similarly, we can calculate the mean response for types of joints for remaining two levels.
The effect of this factor is then calculated by determining the range:
Delta = Max value - Min. value
Delta for arc current will be :
= 56.2251 - 55.0953
= 1.1298
Highest rank is given to max value of all deltas.
The mean response table for the arc current, gas flow rate and types of joints is given in table

Table 3.4 :Mean Response Table for Signal To Noise Ratio

Level	Current	Gas Flow Rate	Types Of Joints
1	55.80	55.81	56.03
2	55.80	55.76	55.52
3	55.73	55.75	55.77
Delta	0.08	0.06	0.51
Rank	2	3	1

Table 3.5 Analysis Of Variance for Signal To Noise Ratio

Source	Degree Of Freedom	Adj SS	Adj MS	F-value	P-value	% contribution
Current	2	101.03	50.516	21.52	0.151	52.42%
Types Of Joints	2	2.80	1.400	0.60	0.675	1.45%
Gas Flow Rate	3	86.50	28.832	12.28	0.206	44.90%
Residual Error	1	2.35	2.347	-	-	1.22%
Total	8	192.65	-	-	-	100%

2) Hardness Test:

The hardness test is conducted on Vickers Hardness Machine(VHM).Their results are studied as shown below:

Fig 3.4 : Vickers Hardness Machine

Fig 3.5 : Hardness Test Specimen

Table 3.6: Experimental Observations

Sample No.	Hardness (WZ)	Hardness (HAZ)	Hardness (PM)	S/N Ratio
1	183.3	178.0	172.0	44.98
2	180.0	174.6	170.0	44.84
3	199.3	181.0	173.3	45.27
4	187.0	179.0	168.0	44.98
5	184.6	177.0	169.0	44.93
6	184.6	179.0	169.0	44.96
7	184.6	177.0	166.0	44.87
8	188.0	181.0	176.0	45.17
9	186.0	177.0	169.0	44.95

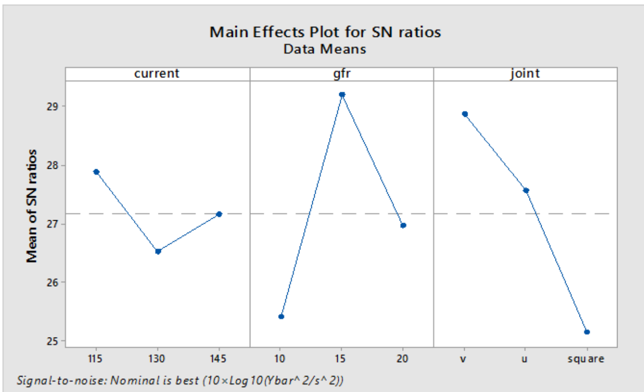

Fig 3.6: Signal to Noise ratio

Table 3.7: Means Response Table for Signal To Noise Ratio

Level	Current	Gas Flow Rate	Types Of Joints
1	27.87	25.41	28.85
2	26.52	29.19	27.56
3	27.15	26.95	25.13
Delta	1.36	3.78	3.72
Rank	3	1	2

Table 3.7Analysis Of Variance for Signal To Noise Ratio

Source	DF	Adj SS	Adj MS	F-value	P-value	% contribution
Current	2	14.442	7.221	0.63	0.592	19.7%
Types Of Joint	2	19.709	9.854	0.86	0.507	26.8%
Gas Flow Rate	1	4.682	4.682	0.41	0.569	6.38%
Residual Error	3	34.469	11.490	-	-	47.12%
Total	8	73.302	-	-	-	100%

IV. RESULT AND CONCLUSION

- It has been observed that current, speed, gas flow rate has some influence on the tensile strength and the hardness of the material.
- Arc current has greatest effect on tensile strength followed by gas flow rate and types of joints.
- For Hardness(PM,WZ and HAZ), types of joints has greatest effect followed by gas flow rate and current.
- From ANOVA and S/N ratio graph,it is shown that the specimen 6 (current-130 amp,gas flow rate-10,joint- v butt) has highest tensile strength.The specimen 6 exhibited tensile strength of 643.428 N/mm^2.
- From ANOVA and S/N ratio graph,it is shown that the specimen with current 115, gas flow rate 15 and joint v-butt has more hardness than the others.

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