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PARAMETRIC INVESTIGATION FOR WELDING OF SS316 USING GTAW

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Abstract:- *Quality and productivity play significant role in today's manufacturing market. From customers' viewpoint quality is very important because the extent of quality of the procured product influences the degree of satisfaction of the consumers during usage of the procured goods. GTAW welding is most popular method for welding of stainless material. SS316 is commonly used for producing milk silo in dairy industry, marine application and kitchen equipment. The objective behind this research is to optimize process parameter and to determine the influence of process parameter on the quality of weld. Welding current, gas flow and speed is process parameter selected for experimental work. Tensile test hardness test is performing as an output parameter to determine the strength and hardness of the weld joint. From the result it is observe that strength of weld is influence by current, gas flow and speed is identify for weld metal deposition.*

Keywords- *TIG welding, automatic welding, optimization, process parameter, design, speed, GTAW welding, SS316.*

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. GTAW welding is most commonly used to weld thin sections. For welding stainless steel we use direct current with negative electrode.[8] Direct current with positive electrode is very less common and used rarely.

The flow rate of shielding gas and their effects are investigated from the previous reports published in literatures. A strong correlation exists between no passes and shielding gas flow level while some colorizations produced on backside of the weld though well covered by shielding gas. It is essential to address this issue by designing effective fixture for shielding gas placement and supply.[12] Research indicates that there is a reduction in strength due to the microstructure changes due to heat input. However, impact properties indicated reasonable improvement in TIG welded samples. Literatures are indicating maximum works being carried in thicker part of these materials which is extending for thin sheets in this study.

2. SELECTION OF MATERIAL

Most stainless steels are considered to have good weld ability and may be welded by several welding processes including the arc welding processes, resistance welding, electron and laser beam welding and friction welding**.** SS316 3mm thin plate having the thickness of 3 mm respectively are chosen for this study. The base material properties are listed in the Table 1&2.

SS316							
Ca	**Mg**	**Ph**	**Su**	**Si**	**Cr**	**Ni**	**Mo**
0.037	1.13	0.042	0.016	0.42	16-18	10-14	2-3

Table 1: Chemical Composition

SS316				
Specific heat capacity (j/g-℃)	**Thermal conductivity (W/m-k)**	**Melting point** ℃	**Solidus** ℃	**Liquidus** ℃
0.5	16.2	1400-1420	1400	1420

Table 2: Thermal Properties

Most stainless steels are considered to have good weldability and may be welded by several welding processes including then arc welding processes, resistance welding, electron and laser beam welding, friction welding and brazing. For any of these processes, joint surfaces and any filler metal must be clean.

3. METHODOLOGY

Design of Experiments is a statistical method to resolve complex and costly situations with considering minimal number of experiments and the results to be verified by statistical methods.

Experiments can be statistically designed by orthogonal approach array by Taguchi method, ANOVA method, within which one can pick full factorial, partial factorial. Size of experiments is dependent on number of factors to be chosen and numbers of level of each factor.

3.2 Selection of variables

The different parameters selected for experiments are current gas flow rate and welding speed.

Machining parameter	Level 1	Level 2	Level 3
Current (A)	125	150	175
Gas Flow Rate (lit/min)	10	12	14
Welding speed (mm/min)	260	300	340

Table 3: Values of process parameters and their levels

3.3 Experimental setup

The experiment of welding was carried out in GTAW machine available at our college. All the experiment perform under this setup.

Figure 1: Automated TIG welding setup

Configuration of GTAW Machine

Company name : Parmo
Current range : 20 to 200 amp.
Gas flow capacity : 5 to 30 lit/min

4. EXPERIMENTAL WORK

4.1 Selection of standard specimen size

We select standard specimen size for tensile testing. SS316 plate standard dimension selected based on ASTM standard. With the help of hack-saw machine and grinding machine to prepare standard specimen for tensile test. ASTM standard dimension is shown in figure 2.

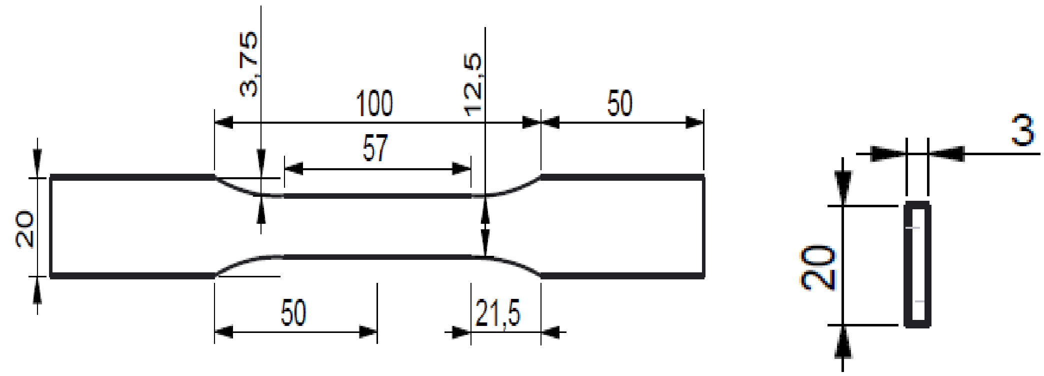

Figure 2: ASTM Standard specimen size

3.1 Taguchi method

Taguchi method has been used mostly in engineering fields for the analysis and consist of a plan of experiments. The main advantage of this method is the reduction in experimental time, cost and discovering significant factors quickly. Taguchi's robust design method is very effective tool for the design of a high quality system. In addition to the S/N ratio, a statistical ANOVA can be used to show the effects of factors of the process on tensile strength and hardness for welded part.

According to taguchi method based on 3 input process parameters and 3 levels of design L27 orthogonal array was selected which is shown below with tensile strength and hardness value.

Figure 3: Experiment base on L27 Orthogonal Array

Exp No.	Current (A)	Gas flow rate (lit/min)	Speed (mm/min)	Tensile strength (Mpa)	Hardness (HV)
1	125	10	260	226.5	142.7
2	125	10	300	478.5	191.0
3	125	10	340	337.3	175.4
4	125	12	260	403.2	187.2
5	125	12	300	388.7	180.0
6	125	12	340	347.0	177.9
7	125	14	260	321.3	172.6
8	125	14	300	427.1	199.5
9	125	14	340	393.2	189.7
10	150	10	260	366.4	178.5
11	150	10	300	400.0	202.4
12	150	10	340	433.4	211.4
13	150	12	260	527.2	209.0
14	150	12	300	547.9	203.7
15	150	12	340	549.0	207.0
16	150	14	260	357.6	188.2
17	150	14	300	366.1	182.9
18	150	14	340	372.8	174.3
19	175	10	260	432.7	185.0
20	175	10	300	378.0	176.1
21	175	10	340	398.9	182.8
22	175	12	260	445.2	198.0
23	175	12	300	402.7	192.4
24	175	12	340	376.0	168.7
25	175	14	260	430.5	196.5
26	175	14	300	451.2	198.6
27	175	14	340	274.2	148.3

Table 4: Measurement of tensile strength and hardness of welded parts

5. OPTIMIZATION USING TAGUCHI'S S/N RATIO ANALYSIS

The outcome of Experimental work of tensile strength and hardness value is analyzed using Taguchi Design in Minitab software and S/N ratio values are determined. The Optimum levels of influential parameters are determined based on the obtained S/N ratios.

Exp No.	S/N ratio for Tensile strength	S/N ratio for hardness
1	47.1014	43.0885
2	53.597	45.6207
3	50.5603	44.8806
4	52.1104	45.4461
5	51.7923	45.1055
6	50.8066	45.0035
7	50.1382	44.7408
8	52.6106	45.9989
9	51.8923	45.5613
10	51.2791	45.0328
11	52.041	46.1242

12	52.737	46.4856
13	54.439	46.5021
14	54.774	46.1798
15	54.791	46.3194
16	51.0680	45.4924
17	51.2720	45.2443
18	51.4295	44.8259
19	52.7237	45.3434
20	51.5498	44.9152
21	52.0173	45.2395
22	52.9711	45.9333
23	52.0996	45.6841
24	51.503	44.5423
25	52.679	45.8673
26	53.087	45.9596
27	48.7613	43.4228

Table 5: S/N ratio calculation for tensile strength and hardness

6. RESULTS AND DISCUSSIONS

6.1 Process parameter's influence based on S/N ratio

Levels	**Factors**		
	Current (A)	Gas flow rate (lit/min)	Welding speed (mm/min)
1	47.09	47.27	47.35
2	47.98	47.87	47.84
3	47.38	47.31	47.26
Delta	0.88	0.60	0.58
Rank	1	2	3

Table 6: Response table for tensile strength

Table 6 shows that current is most predominant factor followed by gas flow rate and welding speed for tensile strength.

Levels	**Factors**		
	Current (A)	Gas flow rate (lit/min)	Welding speed (mm/min)
1	45.05	45.19	45.27
2	45.80	45.64	45.65
3	45.21	45.23	45.14
Delta	0.75	0.44	0.51
Rank	1	3	2

Table 7: Response table for hardness value

Table 7 shows that current is the most predominant factor followed by gas flow rate and welding speed.

6.2 Process parameters effect on output parameters based on response table

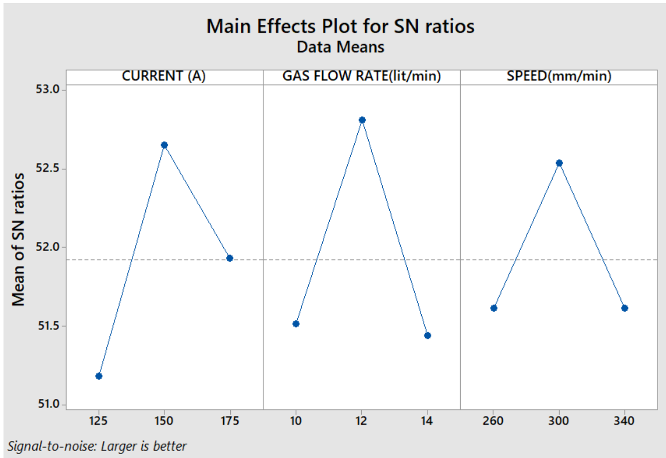

Figure 4: Main effect plot for S/N ratio (Tensile Strength)

Figure 4 shows that for better value of tensile strength in parameter selected should be current is 150, gas flow rate is 12 lit/min, welding speed is 300 mm/min.

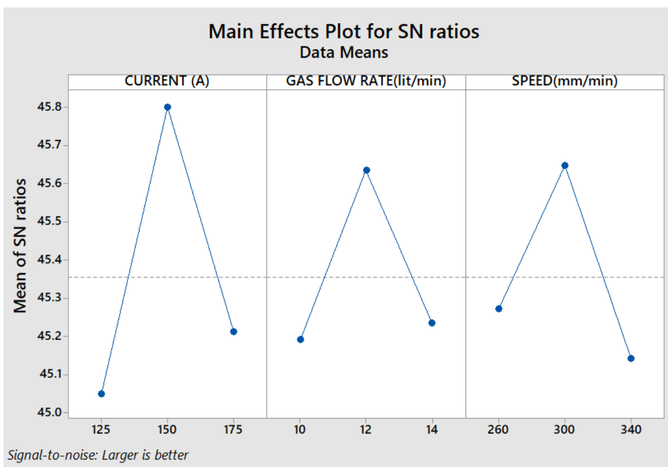

Figure 5: Main effect plot for S/N ratio (Hardness value)

Figure 5 shows that for better value of hardness in parameter selected should be current is 150, gas flow rate is 12 lit/min, welding speed is 300 mm/min.

6.3 ANOVA (Analysis of variance)

6.3.1 ANOVA for Tensile Strength

Source	**DF**	**Seq.SS**	**Contribution**	**Adj.SS**	**Adj.MS**	**F-value**	**P-value**
Current (A)	2	19917	46.99%	19917	9959	2.28	0.128
Gas flow rate (lit/min)	2	23752	34.24%	23752	11876	2.72	0.090
Speed (mm/min)	2	8812	6.30%	8812	4406	1.01	0.382
Error	2	87342	12.47%	87342	4367		
Total	8	139822	100.00%				

Table 8: ANOVA for Tensile strength

Table 8 shows that current has most statistical and physical contribution i.e. 46.99% followed by gas flow rate and welding speed. The total error related to anova is 12.47%.

6.3.2 ANOVA for Hardness value

Table 9 shows that current has most statistical and physical contribution i.e. 47.44% followed by gas flow rate and welding speed. The total error related to anova is 19.42%.

Source	DF	Seq.SS	Contribution	Adj.SS	Adj.MS	F-value	P-value
Current (A)	2	1268.8	47.44%	1268.8	634.4	2.51	0.106
Gas flow rate (lit/min)	2	458.8	26.31%	458.8	229.4	0.91	0.419
Speed (mm/min)	2	497.0	6.83%	497.0	248.5	0.98	0.391
Error	2	5051.0	19.42%	5051.0	252.5		
Total	8	7275.6	100.00%				

Table 9: ANOVA for Hardness value

7. CONCLUSION

1) Maximum value of Tensile strength is 549.0 Mpa for experiment no. 15 and maximum value of Hardness is 211.4 for experiment no. 12.

2) ANOVA for Tensile strength shows that current has most statistical and physical contribution i.e. 46.99% and gas flow rate has contribution i.e. 34.24% and welding speed has least contribution i.e. 6.30%.

3) ANOVA for Hardness value shows that current has most statistical and physical contribution i.e. 47.44% and gas flow rate has least contribution i.e. 26.31% and welding speed least contribution i.e. 6.83%.

4) From grey relational analysis have the best welded part when current is 150 A, gas flow rate 12 lit/min and welding speed is 260 mm/min.

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