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Research Paper Engineering

Optimization Of Process Parameters For Gas Tungsten Arc Welding Aluminum Alloy A6061 By Taguchi Method

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ABSTRACT

The Work was carried-out to analyze the effect of welding parameters on mechanical properties of TIG welded Aluminum Alloy 6061.Travel Speed, Current and Filler Rod Diameter play a significant role in the assessment of Mechanical Properties. Experiment has been carried-out and Twenty- seven joints have been made on 6061 Al Alloy of same nature and tested for its tensile properties. Using ANOVA and signal to noise ratio of robust design, effect on yield strength, tensile strength of GTAW process parameters is evaluated and optimum welding condition for maximizing tensile strength is determined. In order to correlate process parameters and measured tensile strength, a mathematical model has been developed.

Keywords : Aluminum Alloy, GTAW, Taguchi method, Tensile strength, ANOVA

Introduction

Gas Tungsten Arc Welding (GTAW) process is frequently used for welding of Aluminum Alloys as heat input during welding can be precisely controlled. Rolled plates of 6 mm thickness have been used as the base material for preparing single pass butt welded joints. The filler metal used for joining the plates is AA4043 (Al-5Si (wt %)) grade aluminum alloy. Taguchi techniques have been widely used for product or process on determining parameters and their performance measure with minimum variation optimization in material processing. It appears that optimization of GTAW process parameters of Aluminum Alloy 6061 (Al-Mg-Si Alloy) used in the fabrication of Food Processing Equipment, Chemical Containers, Passenger Cars, Road Tankers and Railway Transport Systems has to be optimized by using taguchi method. This paper by using full factorial experimental design (3^3) with taguchi design concept analysis effect filler diameter, Current, and Travel Speed for tensile strength of GTA Welded joints of A6061 Alloy.

Experimental work : Experimental set-up used in Present Work. Rolled plates of 6mm thickness Al Alloy 6061 have been used as base material with 600 groove angle with single pass butt welded joints. Before welding, edges were cleaned in order to remove dirt, oil and grease. The plates are then kept on backing bars and ends were clamped in order to maintain the root gap and alignment. The filler metal used for joining the plates is AA4043 (Al-5 Si (wt %)) grade aluminum alloy.

Experimental Procedure

Process involved: The following procedure was adopted while carrying out the experimentation in the welding lab:

Cutting Aluminum strip: The base metal sheets of dimensions 125mm x 70mm x 6.0mm were cut on shearing machine.

Job preparation : As the thickness of the plates is 6.0mm a V groove butt joint of 60o groove angle is required. Edge preparation is done as per dimensions shown in Fig -1. The designed V groove butt joint with its configuration is as shown in Fig -2.

Welding: Before welding, edges were cleaned in order to remove dirt, oil and grease. The plates are then kept on backing bars and ends were clamped in order to maintain the root gap and alignment shown in Fig-3 and the welding machine and its specifications shown in Table-1. Joint Fabrication: The methodology for joint considered in GTAW process consists 6061 Al Alloy of 6mm thickness plate (125mm x 70mm).the chemical composition and physical properties of Al 6061 is shown in Table 2,3.

Filler Wire: The chemical composition properties of filler wire used in experiment was given in Table-2. The AWS recommended filler wire for AA-6061 is E-4043 and the same is employed as the welding consumable

Analysis of the Joint : The analysis is carried on the joints for their mechanical properties. The specimens are prepared for testing as shown in Figure -5

Specimen for Tensile Testing : The specimens thus prepared are extracted at the mid thickness region to obtain conservative test results. Transverse tensile specimens are machined to test the performance of the joint in tension. The GTAW specimens are then machined for dumble shape to evaluate Yield strength and UTS as shown in figure. The Figure-6 shows the photographs of the GTAW tensile test specimen before testing.

Conducting Experiments: The MTS machine used for tensile testing is a MTS system corporation manufactured machine with a capacity of 10 metric tons which has been changed for 40 tons. The machine is a hydraulic powered and water cooled.

Results and Discussion

Analysis of Variance (ANOVA) : In order to asses influence of factors on response means and s/n for each control factor to be calculated. The Tensile Strength and Yield Strength, of each Specimen is recorded and Presented in the Table-6.

Signals are indicators of effect on average responses and noises are measures of deviations from experiment output. Appropriate S/N ratio must be chosen using previous knowledge, expertise and understanding of the process in this study S/N ratio was chosen to criterion larger the better, in order to maximize response. In Taguchi method s/n ratio is used to determine deviation of quality characteristics from desired value. S/N ratio where 'n' is the number of tests and y is the experimental value, Yeild&Tensile test data was analyzed to determine the effect of GTAW process parameters. Experimental results were transformed into means and S/n ratio in table 8, 9.corresponding graphs are presented.

S/N = -10*log (mean square of the inverse of the response) :

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{y^2}\right)$$

Analysis of variance (ANOVA) has been performed to identify statistically significant process parameters which affect statistically significant process parameters which affect of GTAW joint (table -7).results of ANOVA indicate that selected process parameters are highly significant factors affecting YS&TS of GTAW joints.

Optimizing Tensile Strength : Analysis of mean for each of experiments gives better combination of parameter levels. Mean responses refers to average value performances characteristics for each parameter at different levels. Mean for one level war s calculated as average of all responses that were obtained with that level. Mean response of raw data S/N ratio of TS for each parameter at level 1, 2, 3 were calculated. it has been observed that the optimum parameters for GTAW of Aluminum Alloy 6061 joint strength is maximum at 3.0mm Filler Diameter at 200A Current with 4.2mm/s Travelling Speed in comparison to the joints at other process parameters.

Estimation of Optimum Process Parameters

The methods described in this investigation for responses prediction and optimization can eliminate the need for performing experiments on the basis of the conventional trial and error method which is time consuming and economically not justifiable .The present study is aimed at to identify the most influencing significant parameters and percentage contribution of each parameter on responses of Gas Tungsten Arc Welding 6061 aluminum joints by conducting minimum number of experiments using Taguchi orthogonal array. Based on the highest values of the S/N ratio and mean levels for the significant factors FD,C and TS the overall optimum condition thus obtained were FD2 ,C1 and TS3The optimum value of Yield Strength is predicted at the selected levels of significant levels of significant parameters. The estimated mean of the response characteristics (yield strength) can be computed as Yield Strength

$$(YS) = FD_2 + C_2 + TS_3\ \ 2YS$$

Where YS is the overall mean of Yield strength, MPa, FD_2 is the average yield strength at second level of Filler Diameter 2.4mm, C_2 is the average Yield Strength at second level current,200A, TS_3 is the average yield strength at third level traveling speed, 4.2mm/s. Substituting the values of various terms in Eqn. (6.1),then Yield strength 158.4 + 160.9 +156.2 - 2(152.11) = 173.28 The estimated mean of the response characteristics (Tensile strength) can be computed as Tensile strength

$$(TS) = FD_2 + C_2 + TS_3\ \ 2TS$$

Where TS is the overall mean of tensile strength, Mpa , FD_2 is the average tensile strength at second level of Filler Diameter 2.4mm, C_2 is the average tensile Strength at second level current, 200A, TS_3 is the average tensile strength at third level traveling speed, 4.2mm/s. Substituting the values of various terms in Eqn. (6.2),then Tensile strength 180.3 + 182.2 +177.6 2 (173.48) = 196.14

Confirmation Test for the Responses : The final step is verifying the improvement in responses by conducting experiments using optimal conditions. Three confirmation experiments were conducted at the optimum setting of process parameters. The filler diameter, current, travel speed were set at level2 level 1,and level3 respectively and the average Yield Strength of Gas Tungsten Arc Welding 6061 aluminum alloy was found to be 171MPa, as shown in Table-10, which was within the confidence interval of the predicted optimal of yield strength.

The final step is verifying the improvement in responses by conducting experiments using optimal conditions. Three confirmation experiments were conducted at the optimum setting of process parameters. The filler diameter, current, travel speed were set at level-2 level-1, and level-3 respectively and the average Tensile Strength of Gas Tungsten Arc Welding 6061 aluminum alloy was found to be 191 Mpa, as shown in Table-11, which was within the Confidence interval of the predicted optimal of tensile strength.

Conclusions

Tensile test is conducted on the joint it was observed that the joint strength is maximum at 3.0mm Filler Diameter. At 200A current it was observed that the joint strength is maximum. Tensile test is conducted on the joint it was observed that the joint strength is maximum at 4.2mm/s Travelling Speed. The joints are welded and fabricated successfully to the required dimensions in the process. During tensile test, all the specimens invariably failed in the weld region, this indicates that the weld region is comparatively weaker than other regions and hence the joint properties are controlled by weld region chemical composition and microstructure. When these alloys are welded using non-heat treatable filler metals(Al-5%Si) to avoid solidification cracking problem, the weld region is composed of fewer Mg2Si precipitates when compared to base metal Hence, the weld region of AA6061 aluminum alloy, when welded with AA4043 filler metal usually contains a lower amount of Mg2Si precipitates compared to the base metal region. In the weld region of GTAW joints, there is a depletion of Mg2Si precipitates.

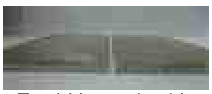


Fig - 1: V-groove butt joint

Fig - 2: Configuration of designed V- groove butt joint

Fig - 3: Tack welds on plates

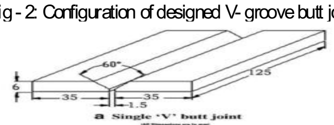


Fig - 4 Single 'V' butt joint

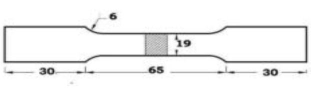


Fig - 5 Dimensions of flat tensile specimen

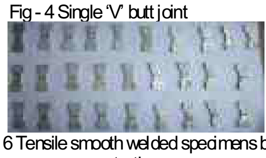


Fig - 6 Tensile smooth welded specimens before testing

Table -1 Welding conditions

Polarity	Pulsed AC
Welding current	175A-225Apulsed current
Electrode length	120mm
Filler rod diameters	2.4mm,3.0mm, & 4.8mm
Gas flow rate	10 l/min
Welding operation	Manual
Upslope time	1 sec
Downslope time	5sec
Gas Pre-flow time	0.5 sec
Gas Post-flow time	1.5 sec

Table - 2 Chemical composition of aluminum 6061 alloy (weight %)

Si	Cu	Mg	Mn	Cr	Zn	Ti	Fe
0.8	0.4	0.15	1.2	0.35	0.25	0.15	0.7

Table - 3 Mechanical Properties of aluminum alloy 6061

Physical Data	Value
Density	2.7 g/cm³
Melting Point	1090 F
Modulus of Elasticity Tension	10
Modulus of Elasticity Torsion	3.8

Table - 4: Chemical properties of E-4043

Grade	Al	Si	Mn	Mg	Fe	Zn
E-4043	93.5	5.25	0.04	0.04	0.8	0.08

Table - 5 Process parameters and design levels

Variables	Code	Unit	Level1	Level2	Level3
Filler rod	FD	mm	2.4	3.0	4.8
Current	C	A	175	200	225
Travel speed	TS	mm/s	3.4	3.8	4.2

Table - 6 Design matrix and experimental results of 6061 Al Alloy

Original Value			Yield StrengthMpa	Tensile Strength Mpa	Yield SN	Tensile SN
FD(MM)	C (A)	TS (mm/s)				
2.4	175	3.4	141	162	42.9844	44.1903
2.4	175	3.8	145	166	43.2274	44.4022
2.4	175	4.2	149	170	43.4637	44.6090
2.4	200	3.4	152	173	43.6369	44.7609
2.4	200	3.8	156	177	43.8625	44.9595
2.4	200	4.2	161	182	44.1365	45.2014
2.4	225	3.4	137	159	42.7344	44.0279
2.4	225	3.8	140	161	42.9226	44.1365
2.4	225	4.2	142	164	43.0458	44.2969
3.0	175	3.4	153	175	43.6938	44.8608
3.0	175	3.8	156	178	43.8625	45.0084
3.0	175	4.2	163	185	44.2438	45.3434
3.0	200	3.4	169	191	44.5577	45.6207
3.0	200	3.8	161	183	44.1365	45.2490
3.0	200	4.2	171	193	44.6599	45.7111
3.0	225	3.4	143	165	43.1067	44.3497
3.0	225	3.8	151	173	43.5795	44.7609
3.0	225	4.2	159	180	44.0279	45.1055
4.8	175	3.4	147	168	43.3463	44.5062
4.8	175	3.8	151	172	43.5795	44.7106
4.8	175	4.2	157	178	43.9180	45.0084
4.8	200	3.4	155	176	43.8066	44.9103
4.8	200	3.8	160	181	44.0824	45.1536
4.8	200	4.2	163	184	44.2438	45.2964
4.8	225	3.4	139	160	42.8603	44.0824
4.8	225	3.8	145	166	43.2274	44.4022
4.8	225	4.2	141	162	42.9844	44.1903

FD = Filler Diameter; C= Current; TS = Travel Speed: Yield versus Filler rod diameter (FD), Current(C) and Travel speed (TS): Larger is better

Table - 7 Main effects of tensile strength for Means.

Level	Filler rod diameter	Current(C)	Travel speed
1	147.0	151.3	148.4
2	158.4	160.9	151.7
3	150.9	144.1	156.2
Delta(max-min)	11.4	16.8	7.8
Rank	2	1	3

Response Table for means

Table-8 Main effects of tensile strength for S/N ratio.

Level	Filler rod diameter	Current(C)	Travel speed
1	43.33	43.59	43.41
2	43.99	44.12	43.61
3	43.56	43.17	43.86
Delta(max-min)	0.65	0.96	0.44
Rank	2	1	3

Response Table for Signal to Noise Ratios

Table -9 ANOVA for Yield strength.

Source	Degree of Freedom	Sum of squares	Mean o f squares	F	Percentage of Contribution (%)
Filler rod(FD)	2	609.56	304.78	17.19	26.1
Current (I)	2	1274.89	637.44	35.97	54.9
Travel speed(TS)	2	274.89	137.44	7.75	11.8
FD*I	4	6.00	1.5	0.02	0.25
FD*TS	4	18.67	4.66	0.26	0.80
I*TS	4	2.89	0.72	0.04	0.12
Error	8	141.78	17.72		6.08
Total	26	2328.67			100

Yield versus Filler rod diameter (FD), Current(C) and Travel speed (TS).

Table - 10 ANOVA for Tensile Strength.

Source	Degree of Freedom	Sum of squares	Mean of squares	F	Percentage of Contribution (%)
Filler rod(FD)	2	694.3	347.15	20.57	27.6
Current (I)	2	1258.96	629.48	37.76	53.6
Travel speed(TS)	2	267.63	133.81	7.93	11.3
FD*I	4	9.85	2.46	0.14	0.41
FD*TS	4	16.96	4.24	0.25	0.74
I*TS	4	2.07	0.51	0.03	0.08
Error	8	134.96	16.87		5.74
Total	26	2348.74			100

Table - 11 Main effects of tensile strength for Means

Level	Filler rod diameter	Current(C)	Travel speed
1	168.2	172.7	169.9
2	180.3	182.2	173.0
3	171.9	165.6	177.6
Delta(max-min)	12.1	16.7	7.7
Rank	2	1	3

Table - 12 Main effects of tensile strength for S/N ratio.

Level	Filler rod diameter	Current(C)	Travel speed
1	44.51	44.74	44.59
2	45.11	45.21	44.75
3	44.70	44.37	44.97
Delta(max-min)	0.60	0.83	0.38
Rank	2	1	3

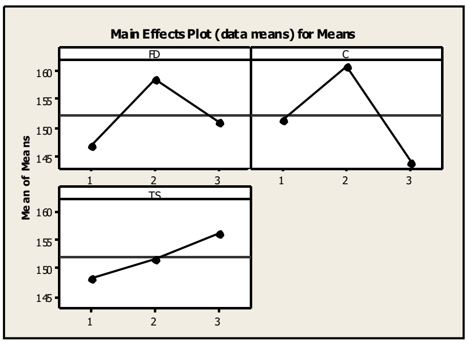
Table - 13 Confirmation experiment for yield strength

	Optimal yield parameters	
	Predicted	Experimental
Setting level	$FD_2C_2TS_3$ (3.0 200 4.2)	$FD_2C_2TS_3$ (3.0 200 4.2)
Yield Strength (Mpa)	173.28	171

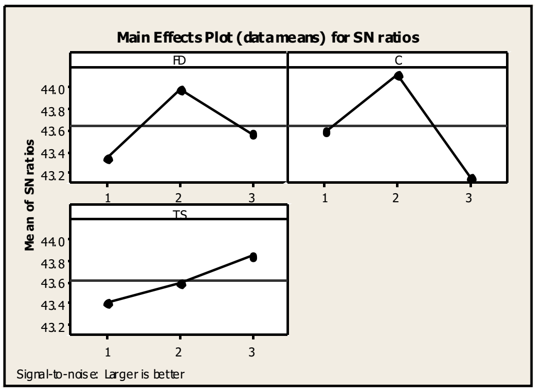
Table - 14 Confirmation experiment for Tensile strength

	Optimal tensile parameters	
	Predicted	Experimental
Setting level	$FD_2C_2TS_3$ (3.0 200 4.2)	$FD_2C_2TS_3$ (3.0 200 4.2)
Tensile Strength (Mpa)	196.14	191

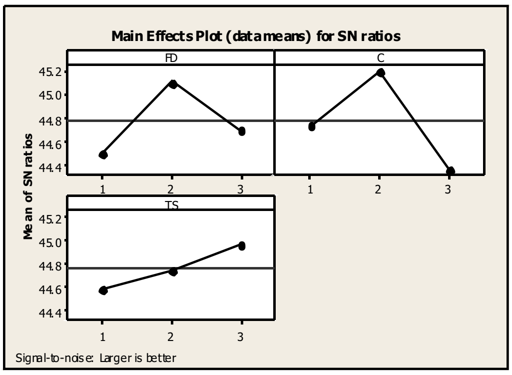
Main Effects Of Plots For Yield Strength



(FD = Filler Rod , C=Current , TS=Traveling Speed)

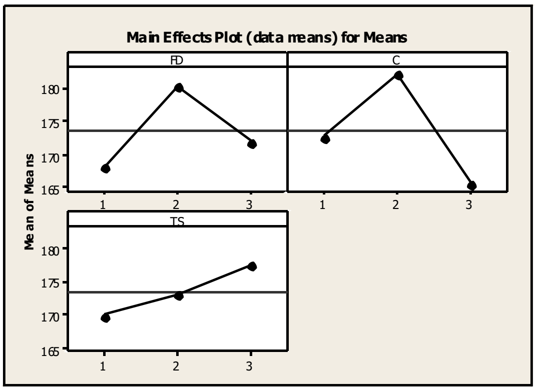


(FD = Filler Rod , C=Current , TS=Traveling Speed)



(FD = Filler Rod , C=Current , TS=Traveling Speed)

Main Effects Of Plots For Tensile Strength



(FD = Filler Rod , C=Current , TS=Traveling Speed)

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