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Optimization of GTAW Process Parameters on Aluminum Alloy 6063 on Taguchi Method.

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Abstract - *This paper aims to optimize process parameters for gas tungsten arc welding (GTAW) of Aluminium alloy AA6063 using Argon as inert gas. The Taguchi method is used to obtain the Optimization parameters of Tungsten Inert Gas welding on 6063 Aluminum Alloy. Taguchi method is by ANOVA and Regression analysis is used to determine the effect of the individual parameters and a appropriate combination was found out. We have used Non destructive testing to find out weld defects for different levels of input parameters. The optimal parameters of TIG welding process is resolute and the experimental results demonstrate the proposed approach.*

Key Words: **Aluminum, Taguchi, Analysis of Variance, AA6063, Optimization, Design of experiment, Regression, Hardness, Impact Strength, ANOVA.**

1. INTRODUCTION

Welding is a perpetual joining process used to join diverse materials like metals, composites or plastics, together at their reaching surfaces by utilization of warmth or potentially weight. Weld capacity of a material relies upon various components like the metallurgical changes that happen amid welding, changes in hardness in weld zone because of quick hardening, degree of oxidation because of response of materials with environmental oxygen and inclination of split arrangement in the joint position.

1.1 TIG welding Aluminum Failure

Usually welding failure occurs due to

1. On TIG welding Transformers, forgetting to put high frequency to continuous when TIG welding of aluminum. This will result in the machine stuttering at low amperage because the alternating current will lose some of its half cycles when the direction of the current changes.

2. Wrong size terminal

3. Wrong size filler rod

4. An excess of argon on the light .

5. Insufficient anode stand out

6. Utilizing unadulterated tungsten …

1.2 Process parameters of TIG welding

The parameters that affect the quality and outcome of the TIG welding process are given below.

a) Welding Current

Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. preset current mode will vary the voltage to maintain a constant arc current.

b) Welding Voltage

Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance.

c) Inert Gases

The choice of shielding gas is depends on the working metals and effects on the welding cost. Argon or Helium may be used successfully for TIG welding applications

d) Welding speed:

Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases.

1.3 Scope of Work

In this work, design of Experiment are done by conducting several Welding in the test specimens and the effect of each parameters and hardness is analyzed, And optimized parameter is determined through Taguchi method.

Aluminium welding

Aluminium can be joined in many ways - a critical requirement in fabrication as whole products are usually formed from a number of parts. Joining methods consist of demountable systems for example bolting as well as more permanent methods including welding, especially where continuity of joining is required.

2. EXPERIMENTAL WORK

2.1 Tig Welding Machine Specification

TIG Welding Machine:

Amps : 20 -300-AT/TIG

TIG : 16 Amps /415v

Cooling : Air cooling

Frequency : 50Hz

It has a good surface finish; high corrosion resistance is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.

2.2 Chemical Properties

Table-1: Chemical composition of aluminium alloy 6063

Element	Percentage
Si	0.2 to 0.6
Fe	0.0 to 0.35
Cu	0.0 to 0.1
Mn	0.0 to 0.1
Mg	0.45 to 0.9
Zn	0.0 to 0.1
Ti	0.0 to 0.1
Cr	0.1
Al	Balance

2.3 Physical Properties

Table 2: Physical Properties of aluminium alloy 6063

Density	2700 kg/m^3
Melting Point	600°C
Modulus of Elasticity	69.5 GPa
Electrical Resistivity	0.035x10^{-6} Ω.m
Thermal Conductivity	200 W/m.K
Thermal Expansion	23.5 x 10^{-6} /K

2.4 Taguchi Approach

The Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then altered into a signal– to – noise (S/N) ratio for measuring the quality characteristics deviating from the desired values Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the–lower–better, the–higher–better, and the–nominal–better. The optimal level of the process parameters is the level with the greatest S/N ratio

The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. They are

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

3 DESIGN OF EXPERIMENT

Table-3 Process parameters and their levels

Levels	Process Parameters		
	Peak Current	Base Voltage	GAS PR Kg/Cm2
1	130	20	4
2	150	25	5
3	170	30	6

3.1 Input Parameter

Table-4 Input Parameter

Peak Current	Base Current	Gas Pressure
130	20	4
130	25	5
130	30	6
150	20	5
150	25	6
150	30	4
170	20	6
170	25	4
170	30	5

3.2 Rockwell Hardness Test

Rockwell Hardness systems use a direct readout machine determining the hardness number based upon the depth of penetration of either a diamond point or a steel ball. Deep penetration indicated a material having a low Rockwell Hardness number.

Using the "B" Scale;

a. Use a Diamond indenter

b. Major load: 100 Kg, Minor load: 10 Kg

Table-5 Hardness values

Peak current	Base Current	Gas pressure	HRB VALUE
130	20	4	84
130	25	5	106
130	30	6	99
150	20	5	96
150	25	6	95
150	30	4	103
170	20	6	113
170	25	4	102
170	30	5	96

Hardness And S/N Ratios Values For The Experiments

Table-6 Hardness (Analysis of Result)

TRIAL NO.	DESIGNATION	PEAK	BASE	GP	HARD	SNRA1
1	$A_1B_1C_1$	130	20	4	84	-38.4856
2	$A_1B_2C_2$	130	25	5	106	-40.5061
3	$A_1B_3C_3$	130	30	6	99	-39.9127
4	$A_2B_1C_2$	150	20	5	96	-39.6454
5	$A_2B_2C_3$	150	25	6	95	-39.5545
6	$A_2B_3C_1$	150	30	4	103	-40.2567
7	$A_3B_1C_3$	170	20	6	113	-41.0616
8	$A_3B_2C_1$	170	25	4	102	-40.1720
9	$A_3B_3C_2$	170	30	5	96	-39.6454

Hardness Response For Each Level Of The Process Parameter

Table-7 Response Table for Signal to Noise Ratios
Smaller is better

Level	PEAK	BASE	GP
1	-39.63	-39.73	-39.46
2	-39.82	-40.08	-40.11
3	-40.29	-39.94	-40.18
Delta	0.66	0.35	0.71
Rank	2	3	1

Table-8 Response Table for Means

Level	PEAK	BASE	GP
1	96.33	97.67	94.33
2	98.00	101.00	101.33
3	103.67	99.33	102.33
Delta	7.33	3.33	8.00
Rank	2	3	1

General Linear Model: Hard Versus Peak, Base, Gp

Table-9 Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% CONTRIBN
PEAK	2	88.7	88.7	44.3	0.31	0.765	17
BASE	2	16.7	36.8	18.4	0.13	0.887	3
GP	2	134.1	134.1	67.1	0.46	0.683	25
Error	2	288.5	288.5	144.3			54
Total	8	528					

S = 12.0111 R-Sq = 45.35% R-Sq(adj) = 0.00%

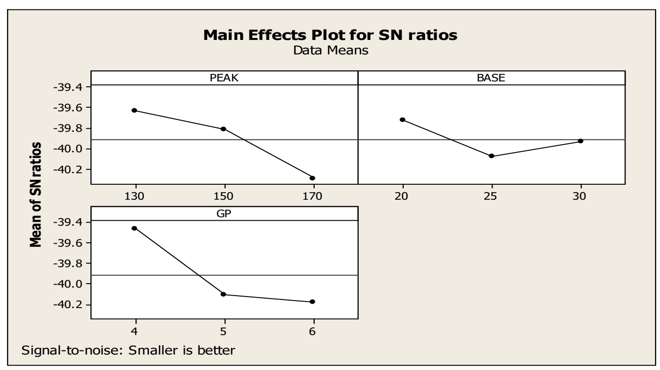

Fig 1.Main Effects Plot for Means

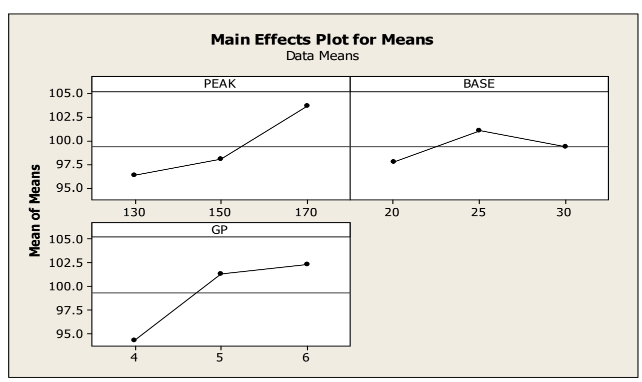

Fig 2. Main Effects Plot for SN ratios

Taguchi Analysis: HARD versus PEAK, BASE, GP

Response Table for Signal to Noise Ratios
Smaller is better

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2	98.00	101.00	101.33
3	103.67	99.33	102.33
Delta	7.33	3.33	8.00
Rank	2	3	1

Main Effects Plot for Means

Factor	Type	Levels	Values
PEAK	fixed	3	130, 150, 170
BASE	fixed	3	20, 25, 30
GP	fixed	3	4, 5, 6

Analysis of Variance for HARD, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PEAK	2	88.7	88.7	44.3	0.31	0.765
BASE	2	16.7	36.8	18.4	0.13	0.887
GP	2	134.1	134.1	67.1	0.46	0.683
Error	2	288.5	288.5	144.3		
Total	8	528.0				

S = 12.0111 R-Sq = 45.35% R-Sq(adj) = 0.00%

3.3 Impact Test

Impact testing is an ASTM method of determining impact strength. A notched specimen is generally used to find out the impact strength.

The dimensions of a standard specimen for ASTM D256 are 4 x 12.7 x 3.2 mm (2.5" x 0.5" x 1/8"). Almost common specimen thickness is 3.2 mm (0.125"), but width can be varying between 3.0 and 12.7 mm (0.118" and 0.500").

3.4 Charpy Impact Strength

Energy Range = 0 – 300 J
Least Count (1 Division) = 2J
Specimen size = 10 X 10 X 55 mm
Notch = V NOTCH
Notch Depth = 2mm

Table: 10 Impact Test

PEAK CURRENT	BASE CURRENT	GAS PRESSURE	ENERGY OBSERVED IN JOULES
130	20	4	12
130	25	5	11
130	30	6	26
150	20	5	16
150	25	6	19
150	30	4	22
170	20	6	23
170	25	4	19
170	30	5	15

Impact Srength (Analysis Of Result)

Hardness And S/N Ratios Values For The Experiments

Table 11 Hardness And S/N Ratios Values For The Experiments

T.NO	DESIGNATION	PEAK	BASE	GP	IMPACT SRENGTH	SNRA1
1	$A_1B_1C_1$	130	20	4	12	21.5836
2	A1B2C2	130	25	5	11	20.8279
3	A1B3C3	130	30	6	26	28.2995
4	A2B1C2	150	20	5	16	24.0824
5	A2B2C3	150	25	6	19	25.5751
6	A2B3C1	150	30	4	22	26.8485
7	A3B1C3	170	20	6	23	27.2346
8	A3B2C1	170	25	5	19	25.5751
9	A3B3C2	170	30	4	15	23.5218

Impact Response For Each Level Of The Process Parameter

Table 12 Response Table for Signal to Noise Ratios Larger is better

Level	PEAK	BASE	GP
1	23.57	24.30	23.98
2	25.50	23.99	23.50
3	25.44	26.22	27.04
Delta	1.93	2.23	3.54
Rank	3	2	1

Table 13 Response Table for Means

Level	PEAK	BASE	GP
1	16.33	17.00	16.33
2	19.00	16.33	15.33
3	19.00	21.00	22.67
Delta	2.67	4.67	7.33
Rank	3	2	1

Table -14 Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
PEAK	2	14.22	14.22	7.11	0.30	0.768	7
BASE	2	38.22	48.76	24.38	1.04	0.491	19
GP	2	105.42	105.42	52.71	2.24	0.308	52
Error	2	47.02	47.02	23.51			22
Total	8	204.89					100

S = 4.84883 R-Sq = 77.05% R-Sq(adj) = 8.20%

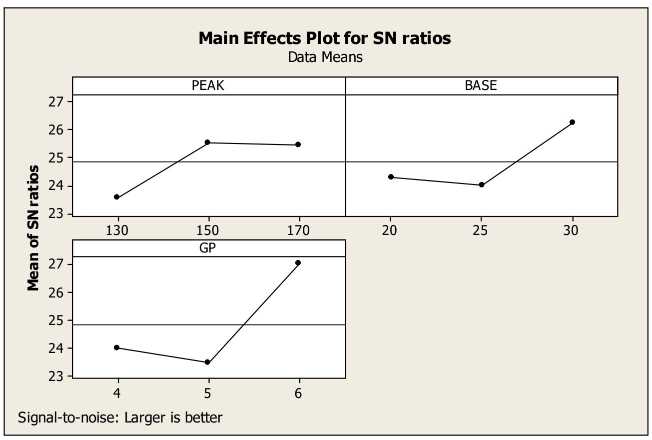

Fig 3.Main Effects Plot for SN Ratio

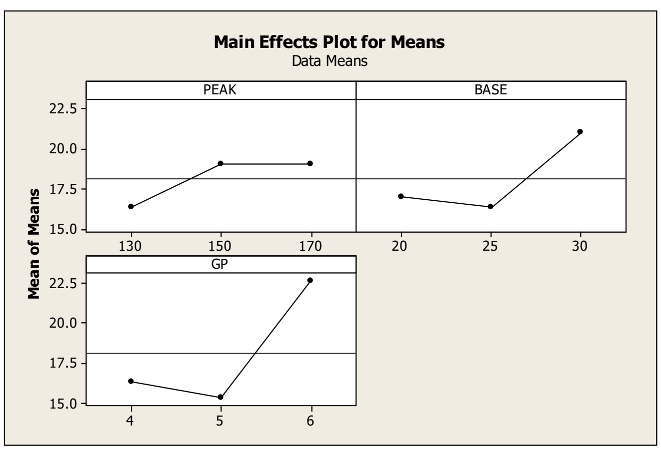

Fig 4.Main Effects Plot for Means

Taguchi Analysis: IS versus PEAK, BASE, GP

Response Table for Signal to Noise Ratios

Larger is better

Level	PEAK	BASE	GP
1	23.57	24.30	23.98
2	25.50	23.99	23.50
3	25.44	26.22	27.04
Delta	1.93	2.23	3.54
Rank	3	2	1

Response Table for Means

Level	PEAK	BASE	GP
1	16.33	17.00	16.33
2	19.00	16.33	15.33
3	19.00	21.00	22.67
Delta	2.67	4.67	7.33
Rank	3	2	1

Main Effects Plot for Means

Factor	Type	Levels	Values
PEAK	fixed	3	130, 150, 170
BASE	fixed	3	20, 25, 30
GP	fixed	3	4, 5, 6

Analysis of Variance for IS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PEAK	2	14.22	14.22	7.11	0.30	0.768
BASE	2	38.22	48.76	24.38	1.04	0.491
GP	2	105.42	105.42	52.71	2.24	0.308
Error	2	47.02	47.02	23.51		
Total	8	204.89				

S = 4.84883 R-Sq = 77.05% R-Sq(adj) = 8.20%

3.5 Depth Of Penetration

Not proper weld bead dimensions example shallow depth of penetration may contribute to failure of a welded structure since penetration determines the stress carrying capacity of a welded joint .To avoid such occurrences the input or welding process variables which influence the weld bead penetration must therefore be properly selected and optimized to obtain an acceptable weld bead penetration and hence a high quality joint . To expect the effect of welding process variables on weld bead and hence quality researchers have employed different techniques .

Table 15 Various Sizes of Bead Width, Depth of Penetration and Heat Affected Zone-Ss41-Gtaw

SL.NO	Area	Mean	Min	Max	Angle	Length
1	0.501	186.877	77.409	229.551	-0.902	13.805
	0.256	204.062	50	233	90	7.065
2	0.541	191.515	95.224	234.844	-0.418	14.891
	0.277	176.003	47.424	221.143	89.182	7.609
3	0.371	190.565	75.723	224.085	-1.219	10.219
	0.293	198.578	68.333	229.288	88.452	8.046
4	0.533	212.502	95.467	239.822	179.151	14.675
	0.328	185.885	49.534	230	87.93	9.027
5	0.49	202.053	79.366	253.027	-1.386	13.481
	0.273	207.75	72.333	244.367	88.34	7.503
6	0.501	183.031	59.648	231.333	179.549	13.804
	0.28	200.401	67	239.667	90	7.717
7	0.588	183.822	59.333	235.949	0.385	16.195
	0.368	162.634	20.333	218.011	91.232	10.11
8	0.399	205.419	66.337	240.158	0.567	10.978
	0.328	171.004	42.044	228.819	92.07	9.027
9	0.517	200.97	63.667	239.921	-179.125	14.24
	0.331	167.119	31.333	233	90	9.13

4 NON-DESTRUCTIVE TESTING

Non-destructive Testing is aimed for extracting information on the physical, chemical, mechanical or metallurgical state of materials or structures. This information is obtained through a process of interaction between the information generating device and the object under test. The information can be generated using X-rays, gamma rays, neutrons, ultrasonic methods, magnetic and electromagnetic methods, or any other established physical phenomenon. The process of interaction does not damage the test object or impair its intended utility value. The process is influenced by the physical, chemical and mechanical.

4.1 Non –Destructive Testing Techniques

NDT Methods varies from the simple to the complicate. Visual inspection is the simple one. Surface imperfections invisible to they may be revealed by penetrate or magnetic methods. If serious surface defects are found, there is often little point in proceeding further to the more complicated examination of the interior by other methods like ultrasonic or radiography.

The principal NDT methods are Visual or optical inspection, Dye penetrant testing, Magnetic article testing, Radiography testing and Ultrasonic testing.

In this Experimental work we have been used Liquid penetrant test and Ultrasonic used for find out the good weldment correspondent result also are attached.

4.2 Ultrasonic Testing

Fig 5 experimental setup of ultrasonic testing

Ultrasonic inspection is a NDT method in which beams of high frequency waves are introduced into materials for the detection of subsurface flaws in the material. The sound waves travel through the material with some attendant loss of energy and are reflected at interfaces (cracks or flaws). The reflected beam is visible and then analyzed to find the presence and location of flaws or discontinuities.

Ultrasonic testing is used to find out the size and location of the defects. The most common ultrasonic testing is pulse echo, in which sound is introduced into a test object and reflections are returned to a receiver from internal imperfections or from the parts geometrical surfaces.

ULTRASONIC RESULT

MACHINE SPECIFICATION

UT INSTRUMENT: PX20

Transducer angle : 70o 4 MHZ,

Technique : pulse Echo,

Material : D3

Thickness : 10MM

Table 16 Ultrasonic report

S.NO	PEAK CURRENT	BASE CURRENT	GAS PRESSURE	INDICATIONS
1.	130	20	4	ICP &Por
2.	130	25	5	ICP
3.	130	30	6	Cr
4.	150	20	5	ICP &Por
5.	150	25	6	CR
6.	150	30	4	EP
7	170	20	6	Sl
8	170	25	4	NI
9	170	30	5	Cr

5 CONCLUSION &RESULT

TIG welding can be used successfully to join AL6063 .The processed joints exhibited better mechanical and metallurgical characteristics. The joints exhibited 90-95% of parent material's Hardness value. The specimen failures were associated depending upon the improper changes of heat value. It creates so many metallurgical defects and it is identified by using NDT testing. In our experiment we found out the input parameter value 170 PC/25 BC &Gas pressure 5 Kg/cm2 is the best value and it does not create any major changes and failures in the testing process.

Finally I concluded the suitable input parameter for Al6063 material of 10 mm thickness in GTAW welding process. According to the Taguchi design optimized parameter for maximum tensile strength

OPTIMAL CONTROL FACTOR

1. Impact strength- A3(Peak current -170AMPS)B2(Base current -25 AMPS)C1(Gas pr-4Kg/cm2) According to the Taguchi design optimized parameter for minimum Hardness

2. Hardness- - A2(Peak current -150AMPS)B3(Base current -30)C1(Gas pr-4Kg/cm2)

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