# Optimization of GTAW Process Parameters for AL6063

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*Abstract*— Welding is widely used by manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products. This experiment discusses an investigation into the use of Taguchi's Parameter Design methodology for Parametric Study of Gas Tungsten Arc Welding of Al 6063. In this research work, bead on plate welds were carried out on Al6063 plates using gas tungsten arc welding (GTAW) process. Taguchi method is used to formulate the experimental design. Design of experiments using orthogonal array is employed to develop the elements. The input process variables considered here include welding current, welding voltage & Root gap rate. A total no of 9 experimental runs has to be conducted using an L9 orthogonal array, and the ideal combination of controllable factor levels has to be determined for the hardness to calculate the signal-to-noise ratio. After collecting the data signal-to-noise (S/N) ratios were calculated and used in order to obtain optimum levels for every input parameter. Subsequently, using analysis of variance (ANOVA) the significant coefficients for each input parameter on impact & Hardness has to be determined. Depth of penetration also has to be investigated through IMAGE J software.

***Key words:*** Aluminum, Taguchi, Analysis of Variance, AA6063, Optimization, Design of Experiment, Regression, Hardness, Impact Strength, ANOVA

## I. 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. Amid welding, the work-pieces to be joined are dissolved at the interface and after cementing a perpetual joint can be accomplished. Now and again a filler material is added to forma weld pool of liquid material which after cementing gives a solid bond between the materials. 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.

### A. 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 …

### B. Process parameters of TIG welding

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

*1) 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.

*2) 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.

*3) 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

*4) 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.

a) 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.

b) 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.

## II. Experimental work

### A. Tig Welding Machine Specification

*1) 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.

### B. Chemical Properties

| 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 |

Table 1: Chemical composition of aluminium alloy 6063

### *C. Physical Properties*

| | |
|---|---|
| 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 |

Table 2: Physical Properties of aluminium alloy 6063

### *D. 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.

## III. DESIGN OF EXPERIMENT

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

Table 3: Process parameters and their levels

### *A. 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 |

Table 4: Input Parameter

### *B. 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.

*1) Using the "B" Scale;*

1) Use a Diamond indenter
2) Major load: 100 Kg, Minor load: 10 Kg

| 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 |

Table 5: Hardness values

| 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 |

### *C. Hardness and S/N Ratios Values for the Experiments*

Table 6: Hardness (Analysis of Result)

| 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 |

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 | 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 |

Table 8: Response Table for Means

| 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%

General Linear Model: Hard Versus Peak, Base, Gp

Table 9: Analysis of Variance

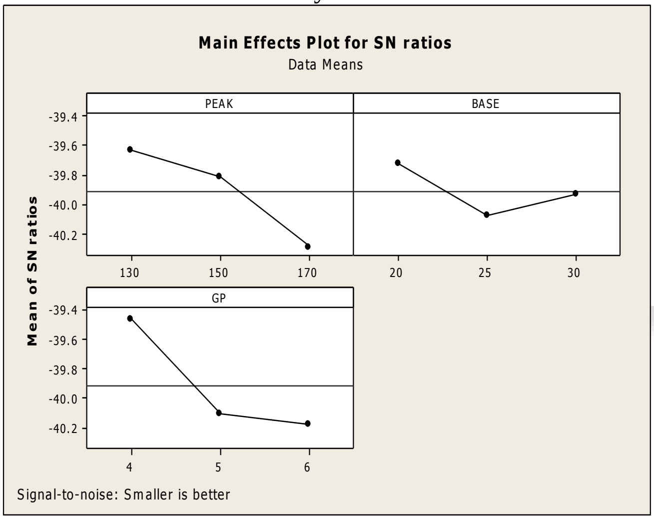


Fig. 1: Main Effects Plot for Means

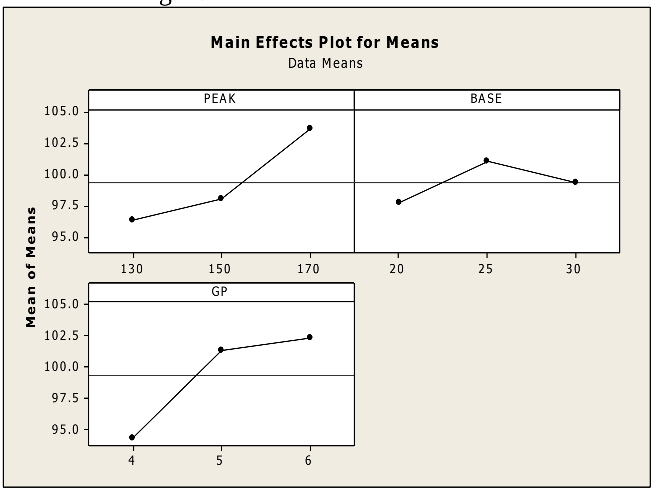


Fig. 2: Main Effects Plot for SN ratios

## D. *Taguchi Analysis: HARD versus PEAK, BASE, GP*

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 |

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 |

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 P | 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%

## E. *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").

## F. *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

| 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 |

Table 10: Impact Test

Impact Strength (Analysis of Result)

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 |

Table 11: Hardness and S/N Ratios Values for the Experiments

Impact Response for Each Level of the Process Parameter

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

| 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 13: Response Table for Means

| 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%

Table 14: Analysis of Variance

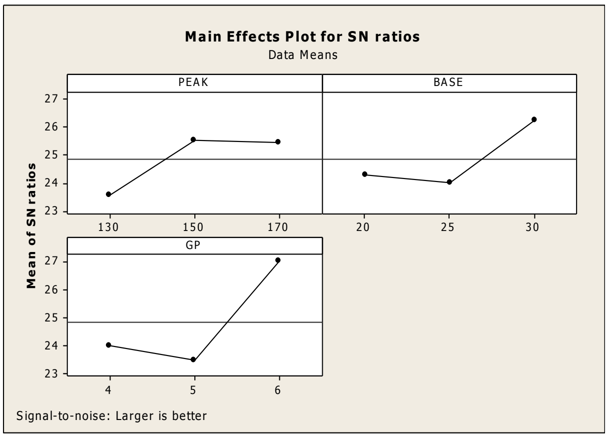


Fig. 3: Main Effects Plot for SN Ratio

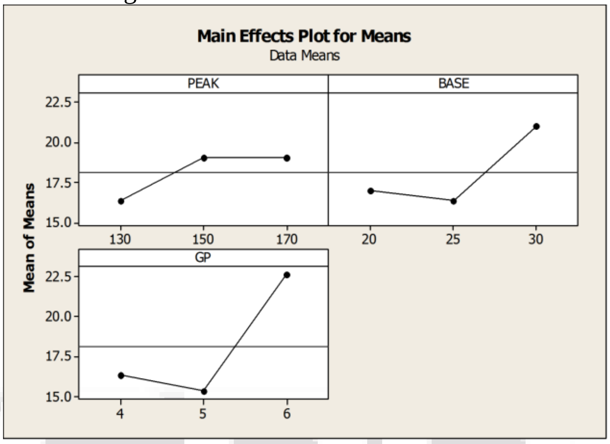


Fig. 4: Main Effects Plot for Means

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%

### *G. 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.

| 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 |

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

## IV. 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.

### *A. 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.

### *B. 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.

*1) Ultrasonic Result:*

MACHINE SPECIFICATION

UT INSTRUMENT: PX20

 

Transducer angle: 70o 4 MHZ,
Technique: pulse Echo,
Material: D3
Thickness: 10MM

| 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 |

Table 16: Ultrasonic Report

## V. 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

### *A. 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)

## REFERENCE

[1] K. M Eazhil, Optimization of Tungsten Inert Gas Welding On 6063 Aluminum Alloy on Taguchi Method. Volume 1, Issue III, August 2014.
[2] Dr. Brajesh Varshney, Optimization of Tungsten Inert Gas Welding Process Parameters ofAI6063/15%Sicp Metal Matrix Composites. International Journal of Engineering Research & Technology (IJERT) ISSN:2278-0181, Vol.311, November-2014.
[3] Mr.Nilesh Landge, A Review paper on Comparative Investigation of V and U Groove Butt Weld Joint For Strength Analysis using Tig Welding.International Journal of Engineering Sciences& Research Technology. ISSNl:2277-9655, (12OR), Publication Impact Factor:3.785, (ISRA), Impact Factor:2.114.
[4] Pankaj.C, Review on Welding Parameter Effects on TIG Welding of Aluminium Alloy. International Journal of engineering Research and General Science Volume3, Issue3, May-June,2015.
[5] Parthiv.T, Experimental Investigation of Process Parameters on Weld Bead Geometry for Aluminium Using GTAW. International Journal of Science and Research (IJSR), ISSN (online):2319-7064, Impact Factor (2012):3.368.
[6] Ravinder, Parametric Optimization of TIG Welding on Stainless Steel (200) & Mild Steel by using Taguchi Method, International Journal of Enhanced Research in Science Technology& Engineering. Vol.4 Issue 6, June-2015, PP:(434-494).
[7] J.P Bergmann, Effects of diode laser superposition on pulsed laser welding of aluminum, Department of Production Technology, Ilmenau University of Technology, Neuhaus 1, D-98693.
[8] Ahmet Durgutlu, Experimental Investigation of the effect of hydrogen in argon as a Shielding gas on TIG welding of austenitic Stainless Steel. Gazi University, Technical Education Faculty, Ankara,