# Parameters Optimization for Gas Metal Arc and Gas Tungsten Arc Welding of Aluminium Alloy 31000-H2 (IS 737) by Taguchi Design of Experiment Technique.

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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. Manufacturer face the problem of control the process input parameters to obtain a good welded joint with the required weld quality. Traditionally, it has been necessary to study the weld input parameters for welded product to obtain a welded joint with the required quality. It requires a time-consuming trial and error development method. The purpose of this study is to propose a method to decide optimal settings of the welding process parameters in Gas Metal Arc and Gas Tungsten Arc welding. Properties include the Tensile strength, Impact strength, Hardness, etc also influenced process parameters. In this study which parameter is most effectively effect the weld strength. Weld strength varies under various conditions. By using Taguchi and ANOVA technique an optimal solution is find out, which provides us an optimal results of the varying condition.

**Index Terms**— Gas Metal Arc, Gas Tungsten Arc welding setup, Aluminium alloy, Taguchi, L9 array, ANOVA & S/N ratio

## 1 Introduction

Gas Metal Arc welding (GMAW) and Gas Tungsten Arc welding are a welding process that is now widely used for welding a variety of materials, ferrous and non-ferrous. In manual welding operation, the welder has to have control over the welding variables which affect the weld penetration, bead geometry and overall weld quality. A proper chances of welding variables like welding current, welding voltage, travel speed, wire electrode size, type of shielding gas, Electrode angle, weld joint position, will increase the chances of producing welds of a satisfactory quality. Aluminium alloy plates are joined by Gas Metal Arc welding (GMAW) and Gas Tungsten Arc welding (GTAW). Three main parameters of GMA and GTA welding viz., current, voltage, and travel speed are taken for the analysis. Taguchi Design of experiment techniques are used to find out optimization of welding parameters. The analysis of signal to noise ratio was done using MINITAB 17 software for higher the better quality characteristics.We discussed about the mechanical properties of aluminium alloy for the process of GMA and GTA welding. As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW or MIG welding is used to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embitterment if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc. We used the TIG and MIG process to find out the comparison of the characteristics of the metal after it is welded. The various characteristics such as strength, hardness, ductility, grain structure, modulus of elasticity, tensile strength breaking point, Weld Zone are observed in two processes and analyzed and finally concluded.

## 2. Review Stage

**Dinesh Mohan arya et al. (2006) [2]** studied to investigate the optimization process parameters for Metal Inert Gas welding (MIG). This paper presents the influence of welding parameters like wire diameter, welding current, arc voltage welding speed, and gas flow rate optimization based on bead geometry of welding joint. The objective function have been chosen in relation to parameters of MIG welding bead geometry tensile strength, Bead height, Penetration and Heat affected zone (HAZ) for quality target. The most significant factor also found in this case welding current is having maximum percentage contribution. So it is most significant factor in this result.

**Narayana N et al. (2006) [3]** describe the optimizing weld bead geometry by process variables viz current, speed, wire feed rate, nozzle plate distance. If some more parameters like inclination of nozzle to the plate, wire diameter, polarity etc can be used optimize bead geometry more precision.

**Lenin N et al. (2010) [4]** studied welding as a basic manufacturing process for making components or assemblies. In this paper, the optimization of the process parameters for MMA welding of stainless steel and low carbon steel with greater weld strength has been reported. The higher-the-better quality characteristics are considered in the weld strength prediction.

**Aghakhani M et al. (2011) [5]** studied that gas metal arc welding is fusion welding process having wide applications in industry. One of the important welding output parameters in this process is weld dilution affecting the quality and productivity of weldment. The wire feed rate has the most significant effect as such as far as the dilution is concerned.

**Suresh kumar L et al. (2011) [6]** studied that TIG welded spe-

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cimen can bear higher load than MIG welded specimen.

**Harigopal G et al. (2011) [7]** presented current is the most influencing parameter on UTS with a contribution of 57.5% at 99% confidence level. Pressure is the most significant parameter for proof stress.

**Vagh A.S et al. (2012) [8]** studied that tool design is the main process parameter that has the highest statistical influence on mechanical properties. However other parameter such as tool rotation speed and Tool travel speed has also significant effect on mechanical properties.

**Sapakal S.V et al. (2012) [9]** discussed the selected input parameter are welding current, wire feed and output are tensile strength and hardness.

## 3 Taguchi method

Taguchi design of experiment is one of these techniques which are used widely. The Taguchi method involves reducing the variation in a process through robust design experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting and the levels at which they should be varies. “Orthogonal Arrays” (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi’s Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

There are 3 Signal-to-Noise ratios of common interest for optimization.

$$\frac{S}{N}HB = -10\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{1}{\sqrt{yi}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\frac{S}{N}LB = -10\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\sqrt{yi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\frac{S}{N}NB = -10\log_{10}\frac{1}{n}\sqrt{(yi-M)^4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

### 3.1 Design of experiments

The term experiment is defined as the systematic procedure carried out under controlled conditions in order to discover an unknown effect, to illustrate a known effect. Experimental design can be used at the point of greatest leverage to reduce design costs by speeding up the design process, reducing late engineering design changes, and reducing product material and labor complexity. Design experiments are also powerful tools to achieve manufacturing cost savings by minimizing process variation and reducing rework, scrap and the need for inspection [1]. In other words, it is used to find cause-and-effect relationships. This information is needed
to manage process inputs in order to optimize the output.

### 3.2 Process parameters

A diagram that shows the causes of an event and is often used in manufacturing and product development to outline the different steps in a process, demonstrate where quality control issues might arise and determine which resources are required at specific times. The Ishikawa diagram was developed by Kaoru Ishikawa during the 1960s as a way of measuring quality control processes in the shipbuilding industry. The cause-effect diagram was constructed to identify process parameters which may affect the desired quantity characteristics of the final job. These parameters can be listed in four categories as follows:

- Power source
- Welding equipment
- Work piece properties
- Manpower

3.2.1 Basic concept of cause effect

- One problem/effect
- 7 causes lead to the problem/effect
- The causes are divided into main and side causes

The 7 causes are:

1) Methods
2) Machinery
3) Management
4) Materials
5) Manpower
6) Environment
7) Measurement

Based on cause-effect diagram three variables and three levels are selected

Table 1 : Process parameters and their values at different levels for GMAW

| Si. No. | Parameters | Levels | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1 | Current (A) | 240 | 270 | 300 |
| 2 | Voltage (V) | 20 | 25 | 30 |
| 3 | Speed (cm/min.) | 50 | 55 | 60 |

3.3 L9 3 Level Taguchi Orthogonal Array

Taguchi orthogonal design uses a special set of predefined array called orthogonal arrays (OAs) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affects the process performance (process responses).

Table 2 L9 orthogonal array

| Exp. Trial No. | Process current (A) | Voltage (V) | Speed (cm/min.) |
|---|---|---|---|
| 1 | 240 | 20 | 50 |
| 2 | 240 | 25 | 55 |
| 3 | 240 | 30 | 60 |
| 4 | 270 | 20 | 55 |
| 5 | 270 | 25 | 60 |
| 6 | 270 | 30 | 50 |
| 7 | 300 | 20 | 60 |
| 8 | 300 | 25 | 50 |
| 9 | 300 | 30 | 55 |

### 3.3 Experimental Plan and Details

The consumable electrode (Aluminium wire) is continuously supplied and an arc is discharged between the point of the consumable electrode and the base metal (Aluminium) to be welded, with the space between them filled with inert gas, so that the aluminium is welded melted by the arc heat. Helium is normally used and argon is used as high amount of the shielding inert gas.

### 3.4 Work Material

The work material used for present work is Aluminium alloy, the dimensions of the work piece length 100 mm, width of 40 mm and thickness 5 mm. Argon is used as inert gas.

Table 3: Chemical Composition of Aluminium alloy 31000-H2 (IS 737) as base metal

| Element | Mg | Si | Fe | Cu | Cr | Mn | Zn | Al |
|---|---|---|---|---|---|---|---|---|
| % Age | 0.10 | 0.6 | 0.70 | 0.10 | 0.2 | 0.8-1.5 | 0.2 | Balance |

Table 4: Chemical Composition of Aluminium alloy 4043 as filler metal

| Element | Cu | Mg | Si | Fe | Mn | Cr | others | Al |
|---|---|---|---|---|---|---|---|---|
| % Age | 0.1 | 0.2 | 6.0 | 0.6 | 0.5 | | 0.2 | Balance |

### 3.5 Analysis of Signal to Noise Ratio

In the Taguchi Method the term 'signal' represents the desirable value (mean) for the output characteristics and the term 'noise' represents the undesirable value (standard Deviation) for the output characteristics. Therefore, the S/N ratio to the mean to the Standard Deviation. S/N ratio used to measure the quality characteristics deviating from the desired value. To obtain optimal welding performance, higher-the-better quality characteristics for penetration and higher tensile strength must be taken.

Table 5: S/N response table for penetration

| Level | Current (A) | Voltage (V) | Speed (cm/min.) |
|---|---|---|---|
| 1 | 7.435 | 4.725 | 10.741 |
| 2 | 9.013 | 10.521 | 8.543 |
| 3 | 9.724 | 12.132 | 8.628 |
| Delta | 2.314 | 7.237 | 0.397 |
| Rank | 2 | 1 | 3 |

Table 6: Experimental result for Tensile Strength and S/N ratio

| Exp. Trial No. | Process Current (A) | Voltage (V) | Speed (cm/min) | Tensile strength (Mpa) | S/N Ratio |
|---|---|---|---|---|---|
| 1 | 240 | 20 | 50 | 650 | 44.2476 |
| 2 | 240 | 25 | 55 | 761.78 | 55.6437 |
| 3 | 240 | 30 | 60 | 671.54 | 57.3910 |
| 4 | 270 | 20 | 55 | 691.76 | 54.0828 |
| 5 | 270 | 25 | 60 | 715.83 | 57.7194 |
| 6 | 270 | 30 | 50 | 639.95 | 59.4816 |
| 7 | 300 | 20 | 60 | 810.71 | 58.2024 |
| 8 | 300 | 25 | 55 | 549.44 | 57.9316 |
| 9 | 300 | 30 | 50 | 648.34 | 56.8194 |

Table 7: S/N response table for Tensile Strength

| Level | Current (A) | Voltage (V) | Speed (cm/min.) |
|---|---|---|---|
| 1 | 52.42 | 52.72 | 51.89 |
| 2 | 57.09 | 57.18 | 56.57 |
| 3 | 57.65 | 57.86 | 56.38 |
| Delta | 0.78 | 0.48 | 1.51 |
| Rank | 2 | 3 | 1 |

## CONCLUSION

The optimum value was predicted using MINITAB 17 software. Based on the investigation following conclusion are drawn GMA and GTA Welding process is very successful to join aluminium alloy. Based on the S/N ratio analysis and ANOVA, the process parameters which significantly affects the Tensile Strength was speed, current and Voltage. Confirmation test carried out shows that results coming of at optimum level are under the interval range obtained at 95% confeence level. The effect of parameters on penetration can be ranked has voltage, current and speed. Argon gas has shielding gas has been found to works satisfactory.

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