# Parameters Optimization for Tensile Strength & Hardness of MIG Welding Joint of HSS & Mild Steel by Using Taguchi Technique

Er. Rahul Malik[1], Er. Surjeet Gahlot[2], Dr. S.K. Jarial[3]

[1]Head-cum- Assistant Professor, Department of Mechanical Engineering, P.M. College of Engineering, Sonepat
[2]Assistant Professor, Department of Mechanical Engineering, IITM, Murthal, Sonepat
[3]Associate Professor, Department of Mechanical Engineering, DCRUST, Murthal, Sonepat

**ABSTRACT**

**Nowadays, the customer satisfaction is the major duties and responsibilities of organizations management. On the other hand, employees as the internal customers play a vital role in the organizations' achievement. So, organizations should try to determine their staff's needs to maintain, improve and enhance service quality and attract their satisfaction.In this regard we try to reach the goal of customer. welding is a sculptural process which is use to join two same or different material by causing fusion , with the help of solid consumable electrode manual or automatic feeding and a shielded gas used. this welding can be done in any physical place by using optimise welding parameters and equipment. This paper effort to find the best optimise welding input parameters like welding, gas flow rate and welding current for the maximize the strength of welded joint and hardness of welded joint. The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there are an intermediate number of variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly. This study presented an efficient method for determining the optimal Gas Metal Arc welding parameters for increasing weld ability of High Speed Steel of grade M2 & Low carbon steel under varying conditions through the use of the Taguchi parameter design process. Taguchi design of experiment technique can be very efficiently used in the optimization of welding parameters in manufacturing operations.**

**KEYWORDS: Welded Joint, Taguchi Technique.**

## 1. INTRODUCTION

### WELDING

Welding is a cheaper fabrication process that joins materials permanently, usually or dissimilar metals by the use of heat causing fusion with or without the application of pressure. Based on the method of heat generation and its application the welding processes can be grouped into six main classes, i.e.
(1) Arc welding processes
(2) Resistance welding processes
(3) Solid-state welding processes
(4) Radiant energy welding processes
(5) Thermit welding
(6) Gas welding

Arc welding among these welding processes is the most popular welding process the world over. Arc welding in its present form appeared on the industrial scene in 1880‘s. Arc welding however, was not accepted for fabrication of critical components till about 1920. However, the demand for large scale production of heavy items like ships, pressure vessels, construction of bridges etc. provided the necessary impetus for welding to come of age and the Second World War firmly established it as the major fabrication process.

**METAL INERT GAS WELDING (MIG)**

**Metal Inert Gas** (**MIG**) **welding** or **Metal Active Gas** (**MAG**) **welding**, is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt, and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. The people who determine what and how the metals can be welded are called metallurgists or welding engineers depending on whom you ask. The three most commonly welded metals are steel, stainless steel, and aluminum.

· Steel is the easiest to weld and has the least amount of problems.
· Stainless steel welds very well, but requires a lot more skill and preparation than steel.
· Aluminum is on the more difficult side to weld. Aluminum welds easily with the TIG and MIG processes, but can also be welded with the other processes.

**GAS METAL ARC WELDING WQUIPMENTS**

The equipment required to perform gas metal arc welding, the basic necessary equipment is a welding gun, a wire feed unit, a welding power supply, an electrode wire, and a shielding gas supply.

· Power Supply
· Welding Torch
· Shielding Gas, Gas Cylinder, Pressure Regulator and Flow Meter
· Wire feeding mechanism

## 2. LITERATURE SURVEY

- **SUNIL R.WADHOKAR, S. D. AMBEKAR ( Jan 2015)** studied is to investigate the influence of welding parameters on the penetration. The optimization for Gas metal arc welding process parameters (GMAW) of Martensitic Stainless steel work piece AISI 410 using Taguchi method is done. Sixteen experimental runs (L16) based on an orthogonal array Taguchi method were performed. This paper presents the effect of welding parameters like welding speed, welding current and wire diameter on penetration. The ANOVA and signal to noise ratio (S/N ratio) is applied , which have been obtained from the analysis, are giving valid the results. The confirmation test is conducted and found the results closer to the optimize results. These results showed the successful implementation of methodology.

- **Ghosh, Nabendu**, **Pal, Pradip Kumar**, **Nandi, Goutam (feb 2015)** used to detect invisible sub surface defects. Because nothing has to be destroyed, we may consider this method to be less expensive; however, the initial cost of the equipment for most of these tests is considerable. Welding input process parameters play a very significant role in determining the quality of the welded joint. Only by properly controlling every element of the process can product quality be controlled. For better quality of MIG welding of ferritic stainless steel, precise control of process parameters, parametric optimization of the process parameters, prediction and control of the desired responses ( quality indices) etc., In the present work, visual inspection and X-ray radiographic test has been conducted in order to detect surface and sub-surface defects of weld specimens made of 409 ferritic stainless steel.

- **Priti Sonasale ( Dec 2015),** studied about the five control factors such as wire feed rate, arc voltage, welding speed, nozzle to plate distance and gas flow rate are considered. The welding parameters such as bead width, dilution and depth of HAZ have been considered. By using DOE method, the weld parameters were optimized. Analysis is done using ANOVA to determine the significance of parameters. Finally the confirmation test is carried out to compare the predicated values with the experimental values confirm its effectiveness in the analysis of bead width, dilution and depth of HAZ.

- **Javed Kazi1, Syed Zaid, Syed Mohd. Talha, Mukri Yasir, Dakhwe Akib (Feb 2015)** studied to understand various welding techniques and to find the best welding technique for steel. Special focuses have been put on TIG and MIG welding. On hardness testing machine and UTM various characteristics such as strength, hardness, modulus of rigidity, ductility, breaking point, % elongation etc. at constant voltage were analyzed.

- **P. Venkadeshwaran, R. Sakthivel, R. Sridevi, R.Ahamed Meeran, K.Chandrasekaran (feb 2015)** work of Gas Metal Arc Welding (GMAW) show the effect of current (A), voltage (V), and gas flow rate (L/min) on Ultimate Tensile Strength (UTS) of aluminum alloy 2014 material. experiment we done experiment by using L9 Orthogonal Array to find out UTS and also perform confirmatory experiment to find out optimal run set of current, voltage and gas flow rate.

- **Amit Pal (April 2015)** used to present the effect of different welding parameters like welding voltage, filler wire rate and v-butt angle on the strength of the weld joint and elongation produced during the tensile test. These all parameters have different effect on welding quality. In order to optimize these parameters for better weld quality Taguchi Orthogonal array has been used. The medium carbon steel slabs have been used as welding material. The ANOVA is also employed to predict the percentage effect of each parameter on results.

- **Amit Pal, Sachin Handuja(2014) used** to present the effect of different welding parameters like welding voltage, filler wire rate and v-angle etc. on the strength of the weld joint and elongation produced during the tensile test. These all parameters have different effect on welding quality. In order to optimize these parameters for better weld quality Taguchi Orthogonal array and Grey relational analysis has been used. The medium carbon steel slabs have been used as welding material. The Taguchi orthogonal array and ANOVA is also employed to predict the results.

- **Pradip D. Chaudhari, Nitin N. More (May 2014)** studied about the central composite design matrix to find the effect of process control parameters: voltage, wire feed rate, welding speed and gas flow rate on tensile strength. The tensile testing of the welded joint is tested bya universal tensile testing machine and results are evaluated. MINITAB software is used to draw the direct and interactive graphs which show the effect of welding input process parameters on tensile strength.

- **Anoop C A, Pawan kumar (May 2013)** used Taguchi method to design process parameters that optimize mechanical properties of weld specimen Aluminum alloy 7039 used in aircraft, automobiles, infantry combat vehicles and high speed trains. In this research the process parameters of Pulsed GRAW setup were considered as Pulse Current, Base current and Pulse Frequency. Theses process parameters was assigned to L-9 orthogonal array, experiments were conducted and optimization condition was obtained along with the identification of most influencing parameters using signal to noise (S/N) analysis, mean response analysis and ANOVA.

## 3. TAGHUCHI'S EXPERIMENTAL DESIGN METHOD

**TAGUCHI'S PHILOSOPHY**:

Taguchi's comprehensive system of quality engineering is one of the great engineering achievements of the 20th century. His methods focus on the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop-floor quality engineering. Upstream methods efficiently use small-scale experiments to reduce variability and remain cost-effective, and robust designs for large-scale production and marketplace. Shop-floor techniques provide cost-based, real time methods for monitoring and maintaining quality in production. The farther upstream a quality method is applied, the greater leverages it produces in the improvement, and the more it reduces the cost and time. Taguchi's philosophy is founded on the following three very simple and fundamental concepts.

- Quality should be designed into the product and not inspect into it.
- Quality is the best achieved by minimizing the deviations from the target. The product or process should be so designed that it is immune to uncontrollable environmental facters.
- The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide.

Taguchi's proposes an "off-line" strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design. In the present work Taguchi's parameter design approach is used to study the effect of process parameters on the surface roughness of CNC tuning process.

## EXPERIMENTAL DESIGN STRATEGY

Taguchi recommends orthogonal arrays (OA) for laying out of experiments. These OA's are generalized Graeco-latin squares. To design an experiment is to select the most suitable OA and to assign the parameters and interactions of interest to the appropriate columns. The use of linear graphs and triangular tables suggested by Taguchi makes the assignment of parameters simple. The array forces all experimenters to design almost identical experiments. In the Taguchi method the results of the experiments are analyzed to achieve one or more of the following objectives:

- To estimate the best or the optimum condition for a product or process.
- To estimate the contribution of individual parameters and interactions.
- To estimate the response under the optimum condition.

The optimum condition is identified by studying the main effects of each of the parameters. The main effects indicate the general trend of influence of each parameter. The knowledge of contribution of individual parameter is a key in deciding the nature of control to be established on a production process. The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments in determining the percent contribution of each parameter against a stated level of confidence. Study of ANOVA table for a given analysis helps to determine which of the parameters need control. Taguchi suggests two different routes to carry out the complete analysis of the experiments. First the standard approach, where the results of a single run or the average of the repetitive runs are processed through main effect and ANOVA analysis (Raw data analysis). The second approach which Taguchi strongly recommends for multiple runs is to use signal-to-noise (S/N) ratio for the same steps in the analysis. The S/N ratio is a concurrent quality metric linked to the loss function. By maximizing the S/N ratio, the loss associated can be minimized. The S/N ratio determines the most robust set of operating conditions from variation within the results. The S/N ratio is treated as a response parameter (transform of raw data) of the experiment.

Taguchi recommends the use of outer OA to force the noise variation into the experiment i.e. the noise is intentionally introduced into the experiment. Generally, processes are subjected to many noise factors that in combination strongly influence the variation of the response. For extremely 'noisy' systems, it is not generally necessary to identify controllable parameters and analyze them using an appropriate S/N ratio. In the present investigation, both the analysis: the raw data analysis and S/N data analysis have been performed. The effects of the selected parameters on the selected quality characteristics have been investigated through the plots of the main effects based on raw data. The optimum condition for each of the quality characteristics have been establish through S/N data analysis. No outer array has been used and instead, experiments have been repeated three times at each experimental condition.

## LOSS FUNCTION

The heart of Taguchi method is his definition of nebulous and elusive term 'quality' as the characteristic that avoids loss to the society from the time the product is shipped. Loss is measured in terms of monetary units and is related to quantifiable product characteristics. Taguchi defines quality loss via his 'loss-function'. He unites the financial loss with the functional specification through a quadratic relationship that cones from Taylor series expansion.

$$L(y) = k (y - m)^2 \quad \text{(Equation-3.1)}$$

Where, L = loss in monetary unit
m = value at which the characteristic should be set
y = actual value of the characteristic
k = constant depending on the magnitude of the characteristic and the monetary unit involved.

The traditional and the Taguchi loss function concept have been illustrated in figure 4.1 the following two observations can be made from figure.

- The further the product's characteristic varies from the target value, the greater is the loss. The loss is zero when the quality characteristic of the product meets its target value.
- The loss is a continuous function and not a sudden step as in the case of traditional approach .

This consequence of the continuous loss function illustrates the point that merely making a product within the specification limits does not necessarily mean that product is of good quality.
In a mass production process the average loss per unit is expressed as:

$$L(y) = \{k (y_1 - m)^2 + k (y_2 - m)^2 + \ldots\ldots + k (y_n - m)^2\}$$

Where $y_1$ , $y_2$, …, $y_n$ = values of characteristics for units 1, 2, ……n respectively
n = number of units in a given sample
k = constant depending upon the magnitude of characteristic and the monitory unit involved
m= Target value at which characteristic should be set.

Equation (3.1) can be written as:
L(y) =k (MSD)

Where, MSD denotes mean square deviation, which presents the average of squares of all deviations from the target value rather than around the average value. Taguchi transformed the loss function into a concurrent statistic called S/N ratio, which combines both the mean level of the quality characteristic and variance around this mean into a single metric. The S/N ratio consolidates several repetitions (at least two data points are required) into one value. A high value of S/N ratio indicates optimum value of quality with minimum variation. Depending upon the type of response, the following three types of S/N ratio are employed in practice.

**SIGNAL TO NOISE (S/N) RATIO**

Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The S/N ratio can be used in three types :

1. Larger the better:

2. Smaller the better:

3. Nominal the best:

where,
n = Number of trials or measurement
yi = measured value
ȳ = mean of measured value
s = standard deviation

It is to be mentioned that for nominal the best type of characteristic, the standard definition of MSD has been used. MSD means mean square deviation. It is the ratio of square of mean of data to square of standard deviation. For smaller the better type the target value is zero. For larger the better type, the inverse of each large value becomes a small value and again the target value is zero. Therefore, for all the three expressions the smallest magnitude of MSD is being sought. The constant 10 has been purposely used to magnify S/N number for each analysis and negative sign is used to set S/N ratio of smaller of smaller the better.

**ANOVA (ANALYSIS OF VARIANCE)**

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error. First, the total sum of squared deviations SST from the total mean S/N ratio nm can be calculated as,

$$SST = \Sigma(ni - nm)2$$

where,
ni = S/N ratio of ith run or experiment.
nm = total mean of S/N ratio

## 4. TAGUCHI PROCEDURE FOR EXPERIMENTAL DESIGN AND ANALYSIS

Selection of Process Parameters and No. of Levels
In selecting an appropriate OA, the following prerequisites are required:

- Selection of process parameters and their interactions to be evaluated.
- Selection of number of levels for the selected parameters.

The determination of the parameter to investigate hinges upon the product or process performance characteristic or response of interest. Several methods are suggested by Taguchi for determining which parameters to include in an experiment. These are

a) Brainstorming
b) Flow charting
c) Cause-effect diagrams

Ln =OA designation N = number of trials

The total degrees of freedom (DOF) of an experiment are a direct function of total number of trials. If the number of levels of a parameter increases, the DOF of the parameter also increase because the DOF of a parameter is the number of levels minus one. Thus, increasing the number of levels for a parameter increases the total degrees of freedom in the experiment which in turn increases the total number of trials. Thus, two levels for each parameter are recommended to minimize the size of the experiment. Particular OA is selected for an experiment the following inequality must be satisfied.

FLN $\geq$ Total DOF required for parameter and interactions.

**SELECTION OF ORTHOGONAL ARRAY AND OUTER ARRAY**

If curved or higher order polynomial relationship between the parameters under study and the response is expected, at least three levels for each parameters should be considered. The standard two-level and three-level arrays are:

a) Two-level arrays: L4, L8, L12, L16, L32
b) Three-level arrays: L9, L18, L27

The number as subscript in the array designation indicates the number of trials in that array. The degree of freedom (DOF) available in an OA is:

fLn = N-1

where fLn = total degrees of freedom of an OA

Depending on the number of levels in the parameters and total DOF required for the experiment, a suitable OA is selected.

Taguchi separates factors (parameters) into two main groups:

- Controllable factors
- Noise factors

Controllable factors are factors that can easily be controlled. Noise factors, on the other hand, are nuisance variables that are difficult, impossible, or expensive to control. The noise factors are responsible for the performance variation of a process. Taguchi recommends the use of outer array for noise factors and inner array for the controllable factors if an outer array is used the noise variation is forced into the experiment. However, experiments against the trial condition of the inner array may be repeated and in this case the noise variation is unforced in the experiment. The outer array, if used will have the same assignment considerations.

**EXPERIMENTATION AND DATA COLLECTION**

The experiment is performed against each of the trial condition of the inner array. Each experiment at a trial condition is repeated simply (if outer array is not used) or according to the outer array (if used). Randomization should be carried for to reduce bias in the experiment.

**DATA ANALYSIS**

A number of methods have been suggested by Taguchi for analyzing the data: observation method, ranking method, column effect method, ANOVA, S/N ratio, plot of average responses, interaction graphs etc. In the present investigation, following methods are used.

1. Plot of average response curves
2. ANOVA for raw data
3. S/N ratio method

The plot of average response at each level of a parameter indicates the trend. It is a pictorial representation of the effect of a parameter on the response. Typically ANOVA for 'OA' are conducted in the same manner as other structured experiments. The S/N ratio is treated as a response of the experiment, which is a measure of the variation within a trial when noise factors are present. A standard ANOVA is conducted on S/N ratio, which identified the significant parameters.

**SELECTION OF OPTIMAL LEVELS**

ANOVA of raw data and S/N ratio identifies the control factors, which affect the average response and the variation in the response respectively.

## 5. EXPERIMENTATION

### SELECTION OF PROCESS PARAMETERS AND THEIR LEVELS

The determination of the parameters to investigate hinges upon the product or process performance characteristics or responses of interest. Several methods are suggested by Taguchi for determining which parameters to include in an experiment. The identified process parameters are shown in the table 1. The selection of parameters of interest was base on some experiment preliminary. The following process parameters were thus selected for the present work:

a) Welding Current - (A)
b) Voltage - (B)
c) Gas Flow Rate - (C)

**Selection of process parameters**

| S. No. | Symbol | Process Parameter | Unit |
|---|---|---|---|
| 1 | A | Welding Current | Amp |
| 2 | B | Arc Voltage | Volt |
| 3 | C | Gas Flow Rate | L/min |

**Parameters, codes, and level values used for the orthogonal Array**

| Parameters | Code | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| Welding current (Amp) | A | 150 | 180 | 210 |
| Arc Voltage (Volt) | B | 20 | 25 | 30 |
| Gas Flow Rate (L/min) | C | 15 | 17 | 19 |

### SELECTION OF QUALITY CHARACTERSTICS

The second step in the Taguchi method is to determine quality characteristic to be optimized .The quality characteristic is a parameter whose variation has a critical effect on product quality .It is the output or the response variable to be observed .Examples are weight , coast ,corrosion , target thickness ,Hardness , strength of a structure , and electromagnetic radiation etc. There are two quality characteristics selected in this experiment. They are:

- Tensile Strength
- Hardness

### SELECTION OF ORTHOGONAL ARRAY (OA)

The choice and the selection of the parameter were decided by considering the objective of present study. Before selecting a particular OA to be used as a matrix for conducting the experiments, the following two points were first considered:

1. The number of parameter and interactions of interest.
2. The numbers of levels of the parameter of interest.

**The Experiment Matrix**

| RUN | CURRENT (amp) | VOLTAGE(volt) | GFR (L/min) |
|---|---|---|---|
| 1 | 150 | 20 | 15 |
| 2 | 150 | 25 | 17 |
| 3 | 150 | 30 | 19 |
| 4 | 180 | 20 | 17 |
| 5 | 180 | 25 | 19 |
| 6 | 180 | 30 | 15 |
| 7 | 210 | 20 | 19 |
| 8 | 210 | 25 | 15 |
| 9 | 210 | 30 | 17 |

## SELECTION OF BASE METAL

High Speed Steel & low carbon steel is selected as a base metal for performing the experiment work.

## PREPARATION OF STEEL SPECIMAN

To prepare the mild steel plate specimens, 9 austenitic High speed steel & low carbon steel plates of dimension (100 X 65 X 6 mm) were used. After cutting of plates a V joint 60 degree angle was made. Tracking was done on the back side of the plates, to avoid leveling mistake while doing MIG welding.

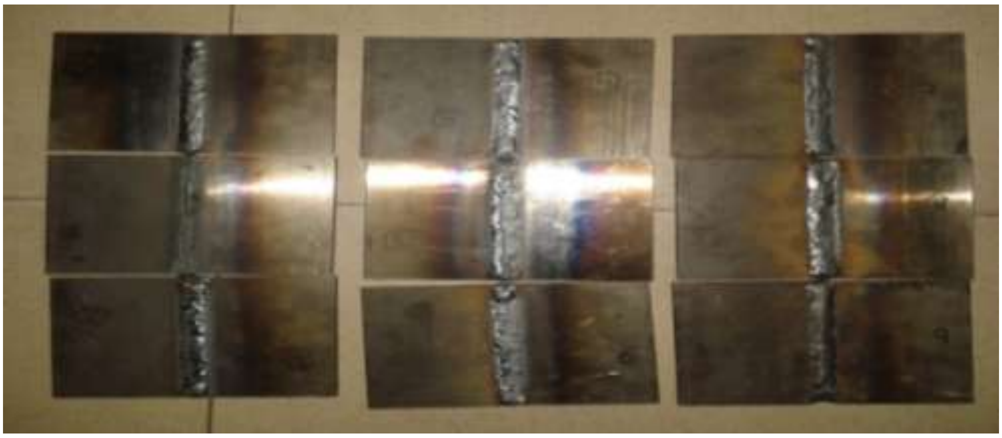


**Figure 3.Weld Specimen after GMAW operation**

## TAGUCHI ANALYSIS FOR TENSILE STRENGTH & S/N RATIO

**Tensile Strength Reading & S/N ratio**

| RUN | CURRENT (Amp) | VOLTAGE (Volt) | GFR (CFH) | TENSILE STRENGTH (MPa) | **S/N RATIO $S/N_i$** |
|---|---|---|---|---|---|
| 1 | 150 | 20 | 15 | 605.3 | 55.6394 |
| 2 | 150 | 25 | 17 | 663.7 | 56.4394 |
| 3 | 150 | 30 | 19 | 675.8 | 56.5964 |
| 4 | 180 | 20 | 17 | 644.7 | 56.1872 |
| 5 | 180 | 25 | 19 | 636.6 | 56.0773 |
| 6 | 180 | 30 | 15 | 642.3 | 56.1548 |
| 7 | 210 | 20 | 19 | 606.5 | 55.6566 |
| 8 | 210 | 25 | 15 | 472.7 | 53.4917 |
| 9 | 210 | 30 | 17 | 608.2 | 55.6809 |

## MEAN RESPONSE OF SIGNAL TO NOISE RATIO FOR TENSILE STRENGTH

Calculation For Mean Response Table of Each Parameter:

(1) For arc current of level 1 (S/NP1,1)
P1,1 means parameter 1 and level 1
S/NP1,1 = (S/N1 + S/N2 +S/N3 )/3
= (55.6394 + 56.4394 + 56.5964)/3 = 56.2251

similarly, we can calculate the mean response for arc current for remaining two levels.

(2) For arc voltage of level 1 (S/NP2,1)
P2,1 means parameter 2 and level 1.
S/NP2,1 = (S/N1 + S/N4 +S/N7 )/3
= (55.6394 + 56.1872 + 55.6566)/3 = 55.8277

similarly, we can calculate the mean response for arc voltage for remaining two levels.

(3) For gas flow rate of level 1 (S/NP3,1)
S/NP2,1 = (S/N1 + S/N6 +S/N8 )/3
=(55.6394 + 56.1548 + 53.4917)/3
= 55.0953

similarly, we can calculate the mean response for gas flow rate for remaining two levels.
The effect of this factor is then calculated by determining the range:
Delta = Max value - Min. value
Delta for arc current will be :
= 56.2251 - 55.0953 = 1.1298
Highest rank is given to max value of all deltas.
The mean response table for the arc current, arc voltage and gas flow rate is given in table

**Mean Response Table for Signal to Noise Ratio**

| **Level** | **Arc current** | **Arc Voltage** | **Gas flow Rate** |
|---|---|---|---|
| **1** | **56.23** | 55.83 | 55.10 |
| **2** | 56.14 | 55.34 | 56.10 |
| **3** | 54.94 | **56.14** | **56.11** |
| **Delta** | 1.28 | 0.81 | 1.01 |
| **Rank** | 1 | 3 | 2 |

**Optimum Welding Parameters For Tensile Strength**

| | | |
|---|---|---|
| Arc Current | Level 1 | 150 |
| Arc Voltage | Level 3 | 30 |
| Gas Flow Rate | Level 3 | 19 |

**Analysis of Variance for Signal to Noise Ratio**

| **Source** | **DF** | **Seq SS** | **Adj SS** | **Adj MS** | **F** | **P** | **% Contribution** |
|---|---|---|---|---|---|---|---|
| **Arc Current** | 2 | 3.0828 | 3.0828 | 1.5414 | 4.71 | 0.175 | 45.49% |
| **Arc Voltages** | 2 | 0.9943 | 0.9943 | 0.4972 | 1.52 | 0.397 | 14.67% |
| **Gas Flow Rate** | 2 | 2.0444 | 2.0444 | 1.0222 | 3.12 | 0.243 | 30.17% |
| **Residual Error** | 2 | 0.6545 | 0.6545 | 0.3273 | | | |
| **Total** | 8 | 6.7760 | | | | | |

**TAGUCHI ANALYSIS FOR HARDNESS TESTING**

**Hardness Reading & S/N ratio**

| **RUN** | **CURRENT (Amp)** | **VOLTAGE (Volt)** | **GFR (CFH)** | **HARDNESS (WZ)** | **HARDNESS (PM)** | **HARDNESS (HAZ)** | **S/N RATIO** |
|---|---|---|---|---|---|---|---|
| 1 | 150 | 20 | 15 | 292.8 | 159.6 | 751 | 2.2322 |
| 2 | 150 | 25 | 17 | 236.6 | 253.2 | 569.2 | 5.4992 |
| 3 | 150 | 30 | 19 | 241.6 | 180 | 219.6 | 16.7098 |
| 4 | 180 | 20 | 17 | 351 | 165 | 483 | 6.3794 |
| 5 | 180 | 25 | 19 | 334.5 | 245.5 | 817.6 | 3.5986 |
| 6 | 180 | 30 | 15 | 253.2 | 171 | 724.3 | 2.1595 |
| 7 | 210 | 20 | 19 | 273.6 | 171 | 817.6 | 1.6609 |
| 8 | 210 | 25 | 15 | 296.3 | 273 | 585.3 | 6.8967 |
| 9 | 210 | 30 | 17 | 273 | 272 | 206 | 16.2844 |

**Analysis of Variance Table for Signal to noise Ratio of Hardness**

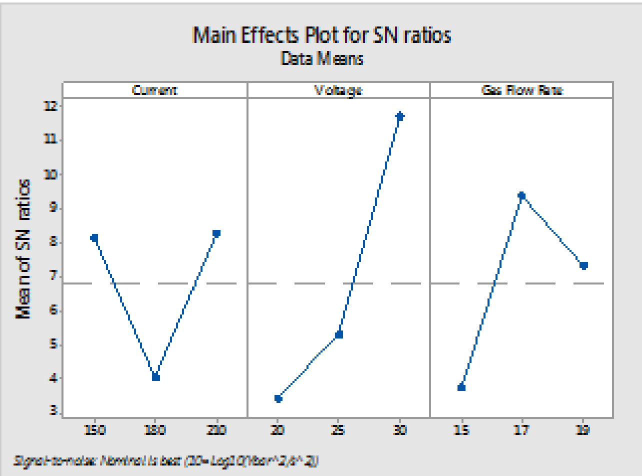
| Source | DF | Seq SS | Adj SS | Adj MS | F | P | % Contribution |
|---|---|---|---|---|---|---|---|
| **Arc Current** | 2 | 34.77 | 34.77 | 17.39 | 0.48 | 0.676 | 12.92% |
| **Arc Voltage** | 2 | 113.21 | 113.21 | 56.61 | 1.56 | 0.390 | 42.07% |
| **Gas Flow Rate** | 2 | 48.58 | 48.58 | 24.29 | 0.67 | 0.599 | 18.05% |
| **Residual Error** | 2 | 72.53 | 72.53 | 36.26 | | | |
| **Total** | 8 | 269.09 | | | | | |

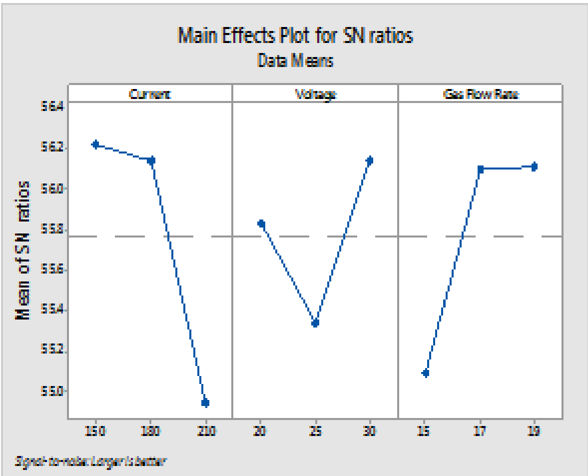
**Mean Response Table for Signal to Noise Ratio For Hardness**

| LEVEL | CURRENT | VOLTAGE | GFR |
|---|---|---|---|
| **1** | 8.147 | 3.424 | 3.763 |
| **2** | 4.046 | 5.332 | **9.388** |
| **3** | **8.281** | **11.718** | 7.323 |
| **DELTA** | 4.235 | 8.294 | 5.625 |
| **RANK** | 3 | 1 | 2 |

**Results of Optimum Parameters For Hardness**

| | | |
|---|---|---|
| **Arc Current** | Level 3 | 210 |
| **Arc Voltage** | Level 3 | 30 |
| **Gas Flow Rate** | Level 2 | 17 |




**Pie Chart for % age Contribution of Different Parameters for Hardness & Tensile Strength**

## CONCLUSION

This study presented an efficient method for determining the optimal Gas Metal Arc welding parameters for increasing weld ability of High Speed Steel of grade M2 & Mild steel under varying conditions through the use of the Taguchi parameter design process . This process was applied using a specific set of control and response variables of Tensile Strength , Hardness of weld zone, Parent Metal & Heat Affected Zone, The use of the $L_9(3^3)$ orthogonal array , with three control parameters (Arc Current , Arc Voltages & Gas Flow Rate) used for this study to be conducted with sample of 9 work pieces. The study found that the control factors had varying effects on the response variables .Arc Voltages has greatest effect on tensile Strength followed by Arc Current & Gas Flow Rate. For Hardness (WZ,PM and HAZ) , Arc Current has greatest effects followed by Arc Voltage & Gas Flow Rate.

The Taguchi methods offers a strategy for finding optimal , stable results based on a predefined set of analyzed parameter combinations , Robust Design takes up the concepts of the Taguchi method and offers a standard , homogenous procedure based on actual and scientific knowledge. Design of experiment is expected to gain more accurate answers on system behaviour and interaction effects , especially when created on basis of fractional factorial design .The present study can be conclude in the following steps:

1. Taguchi design of experiment technique can be very efficiently used in the optimization of welding parameters in manufacturing operations.

2. Optimum parameters setting for Tensile Strength is

| | | |
|---|---|---|
| Arc Current (A) | Level 1 | 150 |
| Arc Voltage (V) | Level 3 | 30 |
| Gas Flow Rate (L/Min) | Level 3 | 19 |

3. Percentage contribution of each parameter on Tensile Strength is :

| PARAMETER | % CONTRIBUTION |
|---|---|
| Arc Current | 45.49% |
| Arc Voltage | 14.67% |
| Gas Flow Rate | 30.17% |

4. Optimum parameters setting for hardness (WZ , PM and HAZ) is :

| | | |
|---|---|---|
| Arc Current (A) | Level 3 | 210 |
| Arc Voltage (V) | Level 3 | 30 |
| Gas Flow Rate (L/Min) | Level 2 | 17 |

5. % contribution of each parameter on Hardness is :

| PARAMETER | % CONTRIBUTION |
|---|---|
| Arc Current | 12.92% |
| Arc Voltage | 42.07% |
| Gas Flow Rate | 18.05% |

## FUTURE SCOPE

· This study provide us an efficient way to find out the optimal Metal Inert Welding parameters for increasing weld ability of High Speed steel of grade M2 & mild steel under different conditions by applying the Taguchi parameter design process.
· Other parameters are also optimized by using Taguchi approach.
· Cost of operations can be reduced by using optimize condition.

## REFERENCES

[1] S. D. Ambekar, Sunil R.Wadhokar "Parametric Optimization of Gas metal arc welding process by using Taguchi method on stainless steel AISI 410", International Journal of Research in Modern Engineering and Emerging Technology, Vol. 3, Issue: 1, January : 2015.

[2] Ghosh, Nabendu, Pal, Pradip Kumar, Nandi, Goutam "Ensuring Weld Quality In Metal Inert Gas Welding Of Aisi 409 Ferritic Stainless Steel", International Journal Of Advanced Scientific And Technical Research, Issue 5 Volume 1, January-February 2015.

[3] Priti Sonasale "An Approach to Optimize Mig Welding Parameters by Using Design of Experiments", Advanced Materials Manufacturing & Characterization Vol 5 Issue 1 (2015).
[4] Javed Kazi, Syed Zaid, Syed Mohd. Talha, Mukri Yasir, Dakhwe Akib "A Review on Various Welding Techniques", International Journal Of Modern Engineering Research (IJMER), Vol. 5 Iss.2 Feb. (2015).
[5] P.Venkadeshwaran, R.Sakthivel, R.Sridevi, R.Ahamed Meeran "Optimization Of Welding Parameter On Aa2014 In Gmaw", International Journal of Emerging Technology and Innovative Engineering, Volume I, Issue 2, February 2015.
[6] Amit Pal "Mig Welding Parametric Optimization Using Taguchi's Orthogonal Array and Analysis Of Variance", International Journal of Research Review in Engineering Science & Technology, VOLUME-4, ISSUE-1, APRIL-2015.
[7] Amit Pal, Sachin Handuja "The analysis of MIG welding parameters for multi response optimization using Taguchi's Orthogonal array and Grey relational approach", International Journal of Advance Research in Engineering, Science & Technology, ( 2014).
[8] Pradip D. Chaudhari, Nitin N. More "Effect of Welding Process Parameters On Tensile Strength", IOSR Journal of Engineering (IOSRJEN), Vol. 04, Issue 05 (May. 2014).
[9] Anoop C A, Pawan Kumar, "Application Of Taguchi Methods And AMOVA In GTAW Process Parameters Optimization For Aluminum Alloy 7038", International Journal Of Engineering And Innovative Technology (IJEIT) Volume 2, Issue 11,May 2013.