Optimization of Special Purpose Rotational MIG Welding by Experimental and Taguchi Technique

Mohan B. Raut, S. N. Shelke

Abstract: ***This paper presents the case study to find the design optimization for special purpose MIG welding operation . The MIG Welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the effect of welding parameters like welding current, welding voltage, welding speed , gas flow rate, rotational speed of work piece, filler wire feed rate on MIG welding. Experiments are conducted based on Taguchi Technique to achieve the required data. An Orthogonal Array, Signal to Noise (S/N) ratio and analysis of varience (ANOVA) are used to find out the welding characteristics and optimization parameters. Finally the confirmations tests have been carried out to compare the predicted values with the experimental values.***

Keywords: MIG welding, optimization, Design of Experiments (DOE), Analysis of Variance (ANOVA), Signal to Noise (SNR) ratio

I. INTRODUCTION

1.1. Metal Inert Gas (MIG) Welding

Metal Inert Gas (MIG) Welding is a process in which the source of heat is an arc format between consumable metal electrode and the work piece, and the arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of gas either inert such as argon, helium or an argon-helium mixture or active such as carbon dioxide, argon-carbon dioxide mixture, which is chemically active or not inert (Karadeniz et al. 2007). Initially GMAW was called as MIG Welding because only inert gasses were used to protect the molten puddle. The application of this process was restricted to aluminum, deoxidized copper and silicon bronze. Later it was used to weld ferrite and austenitic steels, and mild steel successfully by using active gasses in place of inert gasses and hence was term MAG (Metal Active Gas) welding (Suban and Tusek, 2003, Quinn et al. 1999). The American Welding Society refers to the process Gas Metal Arc Welding process to cover inert as well as active shield gasses. GMAW is basically a semi automatic process, in which the arc lengths of electrode and the feeding of the wire are automatically controlled. The welding operator's job is reduced to positioning the gun at a correct angle and moving it along the seam at a controlled travel speed. Hence less operator skill is required with this process as compare to TIG and manual metal arc process. Yet basic training is required in the setting up of the equipment and manipulation of the gun must be provided to the operator to ensure quality GMAW welding (Jang et al. 2005, Praveen and Yarlagadda, 2005).

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Prof. Mohan B. Raut, Department of Mechanical Engineering, Sandip Polytechnic, Nashik, Maharashtra, India.

Prof. S. N. Shelke, Department of Engineering, SVIT, Chincholi, Nashik, Maharashtra, India.

GMAW welding process overcome the restriction of using small lengths of electrodes and overcome the inability of the submerged-arc process to weld in various positions. By suitable adjusting the process parameters, it is possible to weld joints in the thickness range of 1-13 mm in all welding position (Kuk et al. 2004, Murugan and Parmar, 1994)

1. 2 Factors Affecting MIG welding

Welding voltage

It determines the shape of fusion zone and weld reinforcement height. The power supply is referred as CV or Constant Voltage power supply. It produces electrical current to create an arc to weld the metal.

Welding speed

It is defined as the rate of travel work piece under electrode.

Wire Feed Rate

MIG welding requires a wire feed system which feeds the electrode or filler wire to the weld joint. The wire feed is regulated in IPM or Inches per Minute. This is how the speed of the filler wire is regulated and set.

Shielding Gas

This is a complicated area with many various mixtures available, but the primary purpose of the shielding gas in the MIG process is to protect the molten weld metal and heat affected zone from oxidation and other contamination by the atmosphere. The shielding gas should also have a pronounced effect on the following aspects of the welding operation and the resultant weld.

II. LITERATURE REVIEW

1. Satyaduttsinh P. Chavda, Jayesh V.Desai, Tushar M. Patel presented in the paper the influence of **welding parameters like welding current, welding voltage, Gas flow rate, wire feed rate, etc. on weld strength, weld pool geometry of Medium Carbon Steel material during welding.** By using DOE method, the parameters can be optimized and having the best parameters combination for target quality. The analysis from DOE method can give the significance of the parameters as it give effect to change of the quality and strength of product or does not. A plan of experiments based on Taguchi technique has been used to acquire the data. **An Orthogonal array and analysis of variance (ANOVA) are employed** to investigate the welding characteristics of Medium Carbon Steel material and optimize the welding parameters. Finally the **conformations tests** have been carried out to compare the predicated values with the experimental values confirm its effectiveness in the analysis of weld strength and Depth of penetration. In MIG Welding method, we will optimize other parameters which are not used in this experiment and

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This experiment will be done for same method or workpice by other DOE method or other optimization techniques and also if you can be compared Experimental result with prediction result by using Finite Element Analysis. Taguchi's DOE or ANOVA, Orthogonal Array shall be used to conduct the experiments. The parameters selected for controlling the process are welding voltage, current and gas flow rate, wire feed rate, wire diameter. **Strength of welded joints shall be tested by a UTM.** From the results of the experiments, DOE- FEA models shall be developed to study the effect of process parameters on tensile strength and weld pool geometry. Optimization shall be done to find optimum welding conditions to maximize tensile strength and weld pool geometry, depth of penetration etc. of welded specimen. Confirmation tests shall also be conducted to validate the optimum parameter settings.

2. Nirmalendhu Choudhury, Ramesh Rudrapati and Asish Bandyopadhyay have presented study pertains to the improvement of ultimate load of stainless steel – mild steel weld specimen made of tungsten inert gas (TIG) welding. **L16 orthogonal array (OA) of Taguchi method** has been used to conduct the experiments using several levels of **current, gas flow rate and filler rod diameter**. Statistical techniques analysis of variance (**ANOVA), signal-to-noise (S/N) ratio and graphical main effect plots** have been used to study the effects of welding parameters on **ultimate load of weld specimen.** Optimum parametric condition obtained by Taguchi method. Confirmatory test has been conducted to validate the predicted setting. This paper has described the use of Taguchi method and statistical techniques ANOVA and S/N ratio for analyzing and optimizing the ultimate load in TIG welding of stainless steel – mild steel specimens. From the study, the further conclusions are drawn **-** From the ANOVA results, it is found that none of the welding parameter does not effecting the ultimate load. Main effects plots revel that **current and gas flow rate are the factors which has considerable influence on ultimate load**. Filler rod has small / lesser influence. The optimum welding condition obtained by Taguchi method is: current = 100 A, gas flow rate = 18 l/min and filler rod = 2 mm. Confirmation test is confirms the improvement of the UL which also indicates the validity of the present optimization procedure by using Taguchi methodology.

3. S R. Patil , C. A. Waghmare studied the influence of welding parameters like **welding current, welding voltage, welding speed on ultimate tensile strength (UTS)** of AISI 1030 mild steel material during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for maximum tensile strength. From this study, it is observed that welding current and welding speed are major paremeters which influence on the tensile strength of welded joint. In this research study, the mild steel failure problems encountered by loads were successfully addressed by applying the Taguchi Method. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance (AVOVA) were used for the optimization of welding parameters. The optimum levels obtained are A3B3C3. It is found that **welding speed has major influence** on tensile strength of welded joints.

4. S.R. Meshram, N.S. Pohokar worked on a grey-based **Taguchi method** is adopted to optimize the Gas Metal Arc Welding Process parameters. Many quality characteristic parameters are combined into one integrated quality parameter by using grey relational grade or rank. The welding process parameters considered in this analysis are **voltage, wire feed rate, Welding Speed, Nozzle to Plate Distance and Gas Flow.** The quality parameters consider are **Penetration, Reinforcement, and Bead Width.** Analysis of variance has been performed to find out the effect of individual process parameter on the quality parameters. Experiments with the optimized parameter settings, which have been obtained from the analysis, are given to validate the results The Process parameters such as depth of Penetration, Bead width and bead height are studied and optimized. The present study is carried to discuss an application of the Taguchi Method for investigating the effect of process parameter on **Penetration, Reinforcement and Bead Width** in GMAW welding process of stainless steel (AISI410).It is observed that the **welding speed is most influencing factors** and Gas flow rate is least influencing factor. The optimal parameter setting for GMAW process was selected by using grey-based Taguchi method so as to improve a cost function made of important welding quality parameters. An **L25 orthogonal array was adopted to conduct the experiment suggested by MINITAB15 Statistical software.** The multiple quality characteristic parameters were combined into one integrated quality parameter by using grey relational grade or rank. ANOVA was performed to find the impact of process parameters on the individual quality parameters and also on the overall grey relational grade. It is observed that by using grey based analysis the optimum combination of the machine is found that **5-3-4-1-4** of Voltage, Feed Rate, Welding speed, Nozzle to Plate Distance and Gas Flow Rate.

5. Meenu Sharma and Dr. M. I. Khan have gievn the details of application of **Taguchi technique** to determine the optimal process parameters for submerged arc welding (SAW).A planned **experimental work** has been carried out on semiautomatic submerged arc welding machine and **signal to noise ratios are computed.** Contribution of each factor is validated by analysis of variance (ANOVA). The results of the present investigation indicate that the **welding voltage in the most significant parameter** that controls the **bead penetration** as compared to other controlling parameters. The contribution of voltage, current trolley speed and nozzle-to-plate distance are respectively: 60.8%, 9.86%, 3.54% and 13.8%. Optimum results have been obtained by using 26V, 475A at a trolley speed of 0.25 and NPD OF 16 mm.

1. The response of S/N ratio with respect to Penetration indicates the **welding voltage** to be the most significant parameter that controls the weld penetration whereas the other are comparatively less significant in this regard.

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2. The contribution of **voltage, current, travel speed and nozzle to plate distance** are 60.8%, 9.86%, 3.54% and 13.8% respectively as determined by the ANOVA method for tensile penetration.
3. Optimum results have been obtained by using Taguchi method at a voltage of 26V, current of 475A, trolley speed of 0.25 and NPD of 16mm.

6. Sonu Prakash Sharma and Amit Bhudhiraja have discussed an investigation into the use of **Taguchi's Parameter Design methodology** for Parametric Study of MIG Welding of Austenitic Stainless Steel & Low Carbon Steel. This paper represent bead on plate welds were carried out on AISI 304 & Low Carbon Steel plates using MIG welding process. Taguchi method is used to formulate the experimental design. Design of experiments using orthogonal array is employed to develop the weld ments. Ideal combination of controllable factor levels was determined for the hardness to calculate the signal-to-noise ratio. After collecting the data signal-to-noise (S/N) ratios were calculatedand used in order to obtain optimum levels for every inputparameter. Subsequently, using analysis of variance (ANOVA) the significant coefficients for each input parameter on tensile strength & Hardness (PM, WZ & HAZ) were determined and validated. We can conclude that **Arc Current** is significantly affects the Hardness of Weld Zone, Parent Metal &Heat Affected Zone with contribution of 52.45% followed by **arc voltage** with contribution of 15.66 % and Gas flow rate with contribution of 15.10%. In this paper, the optimization of the process parameters for GMA welding of stainless steel and low carbon steel with greater weld strength has been reported. The Nominal-the-better quality characteristic is considered in the hardness prediction. The Taguchi method is adopted to solve this problem. The experimental result shows that the hardness is greatly improved by using this approach.

7. M. Aghakhani, E. Mehrdad, and E. Hayati has studied that gas metal arc welding is a fusion welding process having wide applications in industry. In this process proper selection of input welding parameters is necessary in order to obtain a good quality weld and subsequently increase the productivity of the process. In order to obtain a good quality weld, it is therefore, necessary to control the input welding parameters. One of the important welding **output** parameters in this process is **weld dilution** affecting the quality and productivity of weldment. In this research paper using Taguchi's method of design of experiments a mathematical model was developed using parameters such as **wire feed rate (W)**, **welding voltage (V)**, **nozzle-to-plate distance (N)**, **welding speed (S)** and **gas flow rate (G)** on weld dilution. After collecting data, signal-to-noise ratios (S/N) were calculated and used in order to obtain the optimum levels for every input parameter. Subsequently, using analysis of variance the significant coefficients for each input factor on the weld dilution were determined and validated. Finally a **mathematical model based on regression analysis** for predicting the weld dilution was obtained. Results from this research work show that **wire feed rate (W), arc voltage (V)** have increasing effect while nozzle-to-plate distance (N) and welding speed (S) have decreasing effect on the dilution whereas gas Flow rate alone has almost no effect on dilution but its interaction with other parameters makes it quite significant in increasing the weld dilution. This paper has presented an application of the parameter design of the Taguchi method in the optimization in the GMAW parameters. A five -factor five level Taguchi experimental design was used to study the relationships between the weld dilution and the five controllable input welding parameters such as, wire feed rate, welding voltage, nozzle-to-plate distance ,welding speed, gas flow rate. The following conclusions can be drawn based on the experimental results of this research work:
1-Taguchi's robust orthogonal array design method is suitable to analyze this problem as described in this paper.
2-It is found that the parameter design of Taguchi method provides a simple, systematic and efficient methodology for the optimization of the GMA welding parameters.
3-For main effects wire feed rate, welding voltage, welding speed, nozzle-to-plate distance; have significant effect on the **weld dilution**. This is consistent with the conclusions from the study of other investigators.
4- The wire feed rate has the most significant effect on the weld dilution
5-The gas flow rate did not have any significant effect as such as far as the dilution is concerned.

8. Dinesh Mohan Arya, Vedansh Chaturvedi and Jyoti Vimal studied to investigate the optimization process parameters for Metal inert gas welding (MIG). The optimization of MIG welding operating parameters are for alloy steel work piece using **grey relational analysis method.** Sixteen experimental runs based on an orthogonal array **Taguchi method** were performed. 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 width, Bead height, Penetration and Heat affected zone (HAZ)** for quality target. Optimal parameters contribution of the MIG operation was obtained via grey relational analysis. By analysis the grey relational grade, preprocessed data, and grey relational coefficient of grey relational controllable process factor on the individual quality characteristic targets additionally the analysis of variance (ANOVA) is also applied to identify the welding current is the most significant factor. Experiment with the optimized parameter setting, which have been obtained from the analysis, are giving to validate the results. In the present study, Taguchi optimization technique pair with grey relational analysis has been adopted for evaluating parametric complex to carry out acceptable **Tensile strength and Penetration higher is better**. **Bead width, Bead height and Heat affected zone (HAZ) lower is better** of the alloy steel element to acquired by using Metal inert gas welding. After identify the predict optimal parameter setting with the help of (ANOVA) 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

9. Chandresh N. Patel has studied about welding as a manufacturing process, which is carried out for joining of metals by metal inert gas (mig) welding and tungsten inert gas (tig) welding. All welds will be prepared by MIG and TIG welding technique. I have studied **Design of Experiment** method (Full factorial method) for this work and by use of the **experimental data** have optimized by **grey relational analysis (GRA)** optimization technique. In which input parameters for MIG welding are **welding current, wire diameter and wire feed rate** and the **output parameter is hardness**. Also the input parameters for TIG welding are welding current, wire diameter and the output parameter is hardness. We were used AISI 1020 or C20 material for welding. It is a plain carbon steel and also known as "soft" or mild steel. Small scale trial welding experiments, in the light of field joint of plate have been planned to perform on 5 mm plate thicknesses of low alloy steel AISI 1020 or C20 and double V-groove joint is used. For Experimental design we were used full factorial method (L=m?) to find out number of readings. To find out percentage contribution of each input parameter for obtaining optimal conditions, we were used analysis of variance (ANOVA) method. We take a grey relational analysis (GRA) optimization technique for optimization of different values. A grey relational grade obtained from the grey relational analysis is used to optimize the process parameters. By analyzing the Grey relational grade we find the optimum parameters. In this dissertation work, various cutting parameters like, **welding current, wire diameter and wire feed rate** have been evaluated to investigate their influence for MIG welding and TIG welding. Based on the result obtained, it can be concluded as follows:

1. By use of ANOVA analysis the percentage contribution of MIG welding for welding current is 94.01 %, wire diameter of 0.402 % and wire feed rate of 0.016 % and the error is of 5.56 %. This error is due to human ineffectiveness and machine vibration.
2. By use of ANOVA analysis the percentage contribution of TIG welding for welding current is 73.36 % and wire diameter of 23.90 % and the error is of 2.74 %. This error is due to human ineffectiveness and machine vibration.
3. From the ANOVA it is concluded that the **welding current** is most significant parameter for MIG and TIG welding.
4. Welding current is found to have effect on hardness. Increase in welding current, the value of hardness is increase in both welding.
5. By use of GRA optimization technique the optimal parameter combination is meeting at experiment 6 and its parameter value is 100 Amp welding current, 1.2 mm wire diameter and 3 m/min wire feed rate for **MIG welding.**
6. By use of GRA optimization technique the optimal parameter combination is meeting at experiment 1 and its parameter value is 80 Amp welding current and 0.8 mm wire diameter for TIG welding.

10. Lenin N., Sivakumar M. and Vigneshkumar D has studied welding as a basic manufacturing process for making components or assemblies. Recent welding economics research has focused on developing the reliable machinery database to ensure optimum production. In this paper, the optimization of welding input process parameters for obtaining greater weld strength in the manual metal arc (MMA) welding of dissimilar metals like stainless steel and carbon steel is presented. The **Taguchi method** is adopted to analyze the effect of each welding process parameter on the **weld strength**, and the optimal process parameters are obtained to achieve greater weld strength. Experimental results are provided to illustrate the proposed approach. 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 characteristic is considered in the weld strength prediction. **The Taguchi method** is adopted to solve this problem. The experimental result shows that the weld strength is greatly improved by using this approach.

11. MOHD. SHOEB, Prof. Mohd. Parvez, prof. Pratibha Kumari studied the various welding parameters such as **welding speed, voltage and gas flow rate** were varied on HSLA steel and the the effects of these parameters on weld bead geometry such as **penetration, width & height** have been studied. Mathematical equations have been developed using factorial technique. And the result of various effects are shown in tables. (Numerical Values).

12. Biswajit Das, B. Debbarma, R. N. Rai, S. C. Saha studied the effect of various welding process parameters on the **weldability** of Mild Steel specimens of grade EN-3A having dimensions 150mm, 100mm, 6 mm, welded by **metal inert gas welding** were investigated. The **welding current, arc voltage, welding speed** are chosen as welding parameters. The **depth of penetrations** were measured for each specimen after the welding operation is done on closed butt joint and the effects of welding speed, current, voltage parameters on depth of penetration were investigated an experimental study has been done for finding the depth of penetration of welded joint in MIG welding process for welding a mild steel specimen of grade EN-3A. T

13. Vinod Kumar has studied the paper to investigate the effects of process parameters on weld bead width of austenitic stainless steel SS-310 in **tungsten inert gas welding**. The four parameters namely **welding current, type of gas, gas flow rate and included angle of weld plates** during butt joint were varied at three levels. The DOE approach was used to design experimental conditions. **Orthogonal array L9** was used for carrying out experimentation. The **optimization of weld bead width** in tungsten inert gas welding of austenitic stainless steel alloy was done using ANOVA. The minimum value of bead width of SS 310 is 8.27 mm at current value 130A.

1. The optimization of weld bead width in tungsten inert gas welding of austenitic stainless steel alloy was done using **ANOVA**. The minimum value of bead width of SS 310 is 8.27 mm at current value 130A.
2. The **current** is the most important parameter having the most significant effect on the bead width. The **shielding gas type has sub-significant effect**, whereas **flow rate and groove angle have almost negligible effect** on the same

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3. On increasing the current, the value of bead width increases which is not desirable. Among all gases, **argon** helps to keep bead width minimum.

4. Main effect plot shows that bead width is minimum for first level current value i.e. 130 A and first level gas type i.e. argon. 5. The confidence interval predict with 95 % confidence so that the value of bead width for SS 310 would be 7.977 mm.

14. OMAR BATAINEH, ANAS AL-SHOUBAKI; OMAR BARQAWI MIG studied that welding is among the most important processes in assembly operations for aluminum alloys. The success of this process in terms of providing weld joints of good quality and high strength depends on the process conditions used in the setup. This study aims at identifying and optimising the main factors that have significant effect on weld joint strength through **factorial design experiments**. The factors that were studied are **arc voltage, filler feed rate, gas flow rate, specimen edge angle and preheat temperature**. Results of factorial design experiments and the analysis of variance (ANOVA) showed that **arc voltage and filler feed rate** are the only significant factors of the five. Optimal settings of arc voltage and filler feed rate were reached using regression analysis at 24 V and 7 in/s, respectively, at which the **mean weld strength is maximum.** MIG welding often has the upper edge over TIG welding of aluminum alloys due to being more productive and economical. In this paper, it was established that several factors affect quality and strength of joints welded by the MIG welding process. These factors include arc voltage, filler feed rate, gas flow rate, specimen edge angle and preheat temperature. Factorial design experiments have shown, based on Daniel's method, that arc voltage and filler feed rate are the only significant factors of the five.Utilizing the analysis of variance (ANOVA) approach in the optimization phase experiments, it was determined that setting arc voltage and filler feed rate at 24 V and 7 in/s, respectively, yields the maximum mean weld strength. In addition, it was possible to fit the relationship between **weld strength as a function of arc voltage and filler feed rate using a linear regression mode**l. However, this model is only approximate as a lack-of-fit was evident due to the presence of nonlinearities in the actual relationship.

15. Pawan Kumar, Dr.B.K.Roy, Nishant has studied that welding is widely used by manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products. This study discusses an investigation into the use of **Taguchi's Parameter Design** methodology for Parametric Study of Gas Metal Arc Welding of Stainless Steel & Low Carbon Steel. In this research work, bead on plate welds were carried out on AISI 304 & Low Carbon Steel plates using gas metal arc welding (GMAW) process. **Taguchi method** is used to formulate the experimental design. Design of experiments using orthogonal array is employed to develop the weldments. The input process variables considered here include **welding current, welding voltage & gas flow rate.** A total no of **9 experimental** runs were conducted using an L9 orthogonal array, and the ideal combination of controllable factor levels was 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 tensile strength & Hardness (PM, WZ & HAZ) were determined and validated. In this paper, the optimization of the process parameters for GMA welding of stainless steel and low carbon steel with greater weld strength has been reported. The Nominal-the-better quality characteristic is considered in the hardness prediction. The Taguchi method is adopted to solve this problem. The experimental result shows that the **hardness is greatly improved** by using this approach.

16. Pradeep Deshmukh, M. B. Sorte suggested that welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as **weld-bead geometry, mechanical properties, and distortion**. Generally, all welding processes are used with the aim of obtaining a welded joint with the desired weld-bead parameters, excellent mechanical properties with minimum distortion. The Submerged Arc Welding (SAW) process finds wide industrial application due to its easy applicability, high current density and ability to deposit a large amount of weld metal using more than one wire at the same time. It is highly emphasized in manufacturing especially because of its ability to restore worn parts. In order to obtain an efficient joint, several process parameters of SAW need to be studied and precisely selected to improve weld quality. SAW is characterized by a large number of process parameters influencing the performance outputs such as deposition rate, dilution and hardness, which subsequently affect weld quality. An exhaustive literature survey indicates that five control factors, viz., **arc current, arc voltage, welding speed, electrode stick-out and preheat temperature,** predominantly influence weld quality. In relation to this, an attempt has been made in this study to analyse the effect of process parameters on outputs of welding using the **Taguchi method.** An experiment was carried out to establish the relationship between process variables and optimization tools are used to find an optimal solution. It is observed that the developed model is a powerful tool in experimental welding optimization, even when experimenter does not have to model the process. Modular network model predicts accurately and corresponding sensitivity analysis revels that **bead width** is highly sensitive to welding current, weld reinforcement and bead hardness are sensitive to electrode stick out and depth of penetration is sensitive to welding speed. A test sample, having same size and dimension as per earlier specification has been taken and performed welding at the optimum predicted process parameters at path, welding current, 650A, Arc voltage 34V, Welding speed 500mm/min and Electrode stick out 33 mm.Then, measured the weld bead width and found 15.0mm. It is within 95% confidence level.

17. S. Naveenkumar , Dr. K. SooryaPrakash , G. Gokilakrishnan, N. V. Kamalesh studied that generally, there is a lack of comparative study regarding the performance of the optimization methods, in other words for a given optimization problem which method would suit better. Literature survey reveals that **Taguchi approach** is the best suited to improve mechanical properties of weldment, therefore Taguchi approach is selected to optimize the welding parameters for MIG and TIG welding of low carbon steel (AISI 1019). The main aim of the project work is to obtain an optimal value of MIG and TIG welding process parameters (such as **voltage, current, and welding speed for MIG welding** and Peak current, base current, pulse frequency for TIG welding) resulting in an optimal value of **notch tensile strength, impact toughness and hardness** when welding low carbon steel (AISI 1019) sheet of 3.15 mm and less than 3 mm thickness. The **Fractional factorial experimentation approach** was used to study the impact of welding parameters on the notch tensile strength, impact toughness and hardness of the weldment. An estimate of mean of the optimum values with confidence interval of 90% was calculated for notch tensile strength, impact toughness and hardness. These results were confirmed by further experiments with three repetitions for notch tensile strength, impact toughness and hardness. The results indicate that the selected process parameters significantly affect the welding characteristics. The **future scope** of this project can be analyse and compare the parameters with the existing conditions and the predicted conditions and can be preceded for other types of welding. This literature survey shows the correlation between the input parameters and the output variables, and also presents the optimization of the different welding processes through the mathematical models. The optimal welding parameters for MIG welding process was selected by using Taguchi method. An L9 orthogonal array was adopted to select welding parameter combinations. ANOVA was performed to find the impact of process parameters on the individual quality parameters. For the considered optimization problem, it is found that the **voltage and current** are the most influential factors on the notch tensile strength. High current and high voltage increases heat input, it causes slow rate of cooling thereby increases notch tensile strength. **Current is most important factor on the impact toughness.** And **welding speed is most significant factor on hardness.** Welding joints produced by optimized welding parameter improved the mechanical properties of the weldment compared to existing welding parameter settings.

a. Notch tensile strength increased to 14.05%,

b. Impact toughness increased to 3.7% and

c. Hardness increased to 10.97%.

d. For selected application, notch tensile strength is important, therefore optimum condition is A3B3C1. (i.e.) 26 volts, 135 amps and 250 mm/min are best combinations in MIG welding.

e. Notch tensile strength increased to 21.54%,

f. Impact toughness increased to 8.5% and

g. Hardness increased to 14.69%.

h. For selected application, notch tensile strength is important, therefore optimum condition is A1B3C3. (i.e.) 185 amps, 72 amps and 150 mm/min are best combinations in TIG welding. Of the two welded joints, the joints fabricated by GTAW process exhibited higher strength value and enhancement in strength value is approximately 21% compared to GMAW joints. The strength and hardness value has been increased due to precipitation of chromium carbide and tungsten carbide. The project can also be extended for plasma arc welding and can compare the results using analysis software.

18. J.Pasupathy, V.Ravisankar studied Tungsten Inert Gas welding (TIG) process is an important component in many industrial operations. The TIG welding parameters are the most important factors affecting the **quality, productivity and cost of welding**. This paper presents the influence of welding parameters like **welding current, welding speed on strength** of low carbon steel on AA1050 material during welding. A plan of experiments based on **Taguchi technique** has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of dissimilar joint and optimize the welding parameters. Finally the conformations tests have been carried out to compare the predicted values with the experimental values to confirm its effectiveness in the analysis of strength. Taguchi optimization method was applied to find the optimal process parameters for strength. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for the optimization of welding parameters. A conformation experiment was also conducted and verified for the effectiveness of the Taguchi optimization method. The experiment value that is observed from optimal welding parameters, the strength is 61.37MPa. & S/N ratio is 16.45.

19. Vidal, V. Infante, P. Peças, P. Vilaça studied the Friction Stir Welding (FSW) process is still an innovative solid state mechanical processing technology enabling high quality joints in materials previously considered with low weldability such as most of the aeronautic aluminium alloys. The **Taguchi method** was used to find the optimal FSW parameters for improvement mechanical behaviour of AA2024-T351. The Taguchi design is an efficient and effective experimental method in which a response variable can be optimized. The parameters considered were vertical downward forging force, travel speed and pin length. An orthogonal array of L9 (34) was used; ANOVA analyses were carried out to identify the significant factors affecting **tensile strength** (GETS), **bending toughness** (GEB) and **hardness** field. An algebraic model for predicting the best mechanical performance was developed and the optimal FSW combination was determined using this model. The results obtained were validated by conducting confirmation experiments. This paper has presented an application of the parameter design of the Taguchi method in the optimization of FS welding parameters. The following conclusions can be drawn based on the experimental results of this study: Taguchi's robust orthogonal array design method is suitable to analyze this problem as described in this paper. It is found that the parameter design of Taguchi method provides a simple, systematic, and efficient

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methodology for the optimization of the FS welding parameters. The improvement of GETS from initial FS welding parameters to the optimal parameters is about 2.8% and the improvement of GEB from initial FS welding parameters to the optimal parameters is about 10%.

III. EXPERIMENTAL SETUP

Design of experiments: Design of experiment is scientifically setup of the different involved parameters in various combination to do particular operation but generally as the no. Of factors increases the no combination also increase. It becomes difficult to try all possible combination as it consumes money time and effort .Therefore Taguchi based DOE design of experiment is designed using the OA orthogonal array. Taguchi optimization procedure begins with selection of orthogonal array (OA) with distinct number of levels(L) defined for factor (l) such as cutting speed (v),feed rate(f),point angle(θ).

Minimum number of trials in the array is

Na =(L-1)F + 1 ,

=(3-1)3+1

=7≈9

where F = number of factors = 3

therefore we take Orthogonal array of $L9$, experiment set up is designed for three levels of welding voltage, current, wire feed rate, gas flow rate.

L9 3 Level Taguchi Orthogonal Array

Taguchi's orthogonal design uses a special set of predefined arrays 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). The corresponding OA is selected from the set of predefined OAs according to the number of factors and their levels that will be used in the experiment. Below Table shows L9 Orthogonal array.

Expt. No.	Process Parameters		
	Welding Current	Welding Voltage	Welding Speed
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	2
9	3	3	1

IV. ANALYSIS OF S/N RATIO

In the Taguchi Method the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (standard Deviation) for the output characteristic. Therefore, the S/N ratio to the mean to the S. D. S/N ratio used to measure the quality characteristic deviating from the desired value. The S/N ratio η is defined as(11)

η= -10 log (M.S.D.) where, M.S.D. is the mean square deviation for the output characteristic.

To obtain optimal welding performance, higher-the- better quality characteristic for penetration must be taken. The M.S.D. for higher-the –better quality characteristic can be expressed

M.S.D = 1/m*∑(1/ Pi^2)

Where, Pi is the value of penetration

S/N ratio:

Expt. No.	Welding Current	Welding Voltage	Welding Speed	Penetration	S/N ratio
1					
2					
3					
4					
5					
6					
7					
8					
9					

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio. The S/N response table for penetration is shown in Table.

Symbol	Cutting Parameters	Mean S/N ratio		
		Level 1	Level 2	Level 3
A	Welding Current			
B	Welding Voltage			
C	welding Speed			

V. 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 to 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 n m can be calculated as, ( ) ∑ =− 2 imT nnSS

The result of ANOVA is shown in Table. Result of analysis of variance for penetration

VI. CONFORMATION TEST

Once the optimal level of design parameters has been selected, the final step is to predict and verify the improvement of the quality characteristic using the optimal level of design parameters. The estimated S/N ratio using the optimal level of the design parameters can be calculated as Where, is total mean of S/N ratio, is the mean of S/N ratio at the optimal level, and n is the number of main welding parameters that significantly affect the performance.

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The comparison of the predicted penetration with actual penetration using the optimal parameters, good agreement between the predicted and actual penetration being observed which is shown in the table Table 6: Result of the conformation experiment

VII. RESULT AND CONCLUSION

Taguchi optimization method was applied to find the optimal process parameters for penetration. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for the optimization of welding parameters. A conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method. The improvement of S/N ratio is 2.13. The experiment value that is observed from optimal welding parameters, the penetration is 5.25mm. & S/N ratio is 14.40.

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