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Optimization of process parameters of Metal Inert Gas welding

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Abstract: *The MIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. This report presents the influence of welding parameters like welding current, welding voltage, Gas flow rate, etc. on weld strength of Mild Steel material during welding. By using DOE method, the parameters can be optimize 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 are employed to investigate the welding characteristics of Mild 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.*
Keywords: *MIG parameters, Optimization, Taguchi method, Minitab 17, L9 Orthogonal array*

I. Introduction

Metal Inert Gas welding as the name suggests, is a process in which the source of heat is an arc formed between a 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 inert gas such as argon, helium or an argon-helium mixture. No external filler metal is necessary, because the metallic electrode provides the arc as well as the filler metal. It is often referred to in abbreviated form as MIG welding. MIG is an arc welding process where in coalescence is obtained by heating the job with an electric arc produced between work piece and metal electrode feed continuously. A metal inert gas (MIG) welding process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. Gas metal arc welding is a gas shielded process that can be effectively used in all positions.

There are many researches done on DOE or optimization techniques for Process parameter for mechanical Properties and weld penetration, weld bead geometry. But I found that are very few researches done on IS7887GR-7M Mild steels so we want to do research on this material. We like to use Design of experiment for parametric optimization. Welding current, arc voltage, welding speed, type of shielding gas, gas flow rate, wire feed rate, diameter of electrode etc. are the important control parameters of Metal Inert Gas Welding process. They affect the weld quality in terms of mechanical properties and weld bead geometry. The value of depth of penetration increased by increasing the value of welding current and the grain boundaries of the microstructure are varied when the welding parameters are changed.

Taguchi Technique shall be used to conduct the experiments: - The Taguchi method has become an influential tool for improving output during research and development, so that better quality products can be produced quickly and at minimum cost. Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has established a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control variables. Thus the marriage of Design of Experiments with optimization of control parameters to find best results is attained in the Taguchi Method. "Orthogonal Arrays" (OA) gives 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 in optimization, help in data analysis and The purpose of the analysis of variance (ANOVA) is to examine which design parameters significantly affect the quality characteristic and estimation of optimum results. The Factorial Design, Taguchi Method, Response surface method can be applied as the DOE (Design of Experiment). And we can also use Optimization techniques like, artificial neural network, Grey relation analysis, Genetic algorithm, S/N ratio etc. MINITAB software is a useful aid for the above purpose.

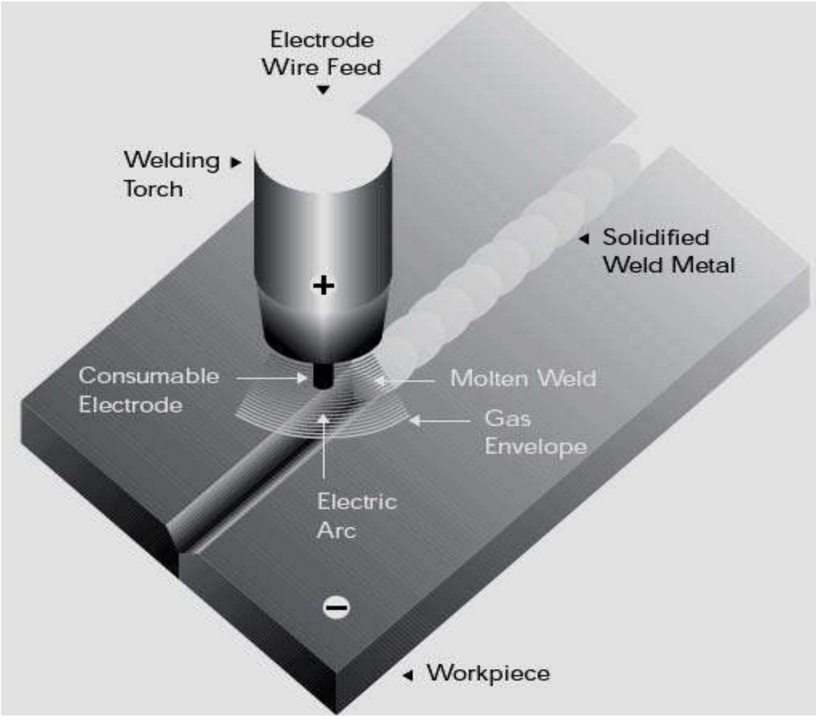

Fig. Working condition of work piece

1.1. Principle of Metal inert gas welding

As shown in fig. the electrode in this process is in the form of coil and continuously fed towards the work during the process. At the same time inert gas (e.g. argon, helium, or carbon dioxide) is passed around electrode from the same torch. Inert gas usually argon, helium, or a suitable mixture of these is used to prevent the atmosphere from contacting the molten metal and HAZ. When gas is supplied, it gets ionized and an arc is initiated in between electrode and work piece. Heat is therefore produced. Electrode melts due to the heat and molten filler metal falls on the heated joint.

The arc may be produced between a continuously fed wire and the work. Continuous welding with coiled wire helps high metal depositions rate and high welding speed. The filler wire is generally connected to the positive polarity of DC source forming one of the electrodes. The work piece is connected to the negative polarity. The power source could be constant voltage DC power source, with electrode positive and it yields a stable arc and smooth metal transfer with least spatter for the entire current range.

The gas shield around it does not ionized, which prevents weld against atmospheric co contamination and surface oxidation. Some torch has water cooling systems .MIG welding is also called Gas Metal Arc Welding. The filler metal is transmitted from electrode to joint by different methods. It is dependent on the current passing through the electrode and voltage.

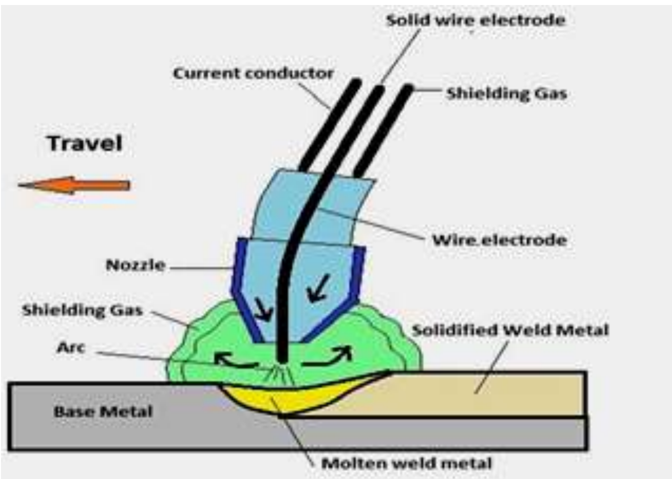

Fig .Working principle of MIG

1.2. Need

Today mostly for the welding of any ferrous and nonferrous materials in an industry are done by means of Metal Inert Gas (MIG) welding. The control of welding variables in manual welding operation, which affect the weld penetration, geometry and to achieve the best weld quality are done by the welder. The selection of proper welding variables like welding current, welding voltage, travel speed, wire electrode size, position helps in increasing the quality of weld.

II. Parameters in MIG

1) Electrode Size:

The electrode diameter influences the weld bead configuration (such as the size), the depth of penetration, bead width and has a consequent effect on the travel speed of welding. As a general rule, for the same welding current (wire feed speed setting) the arc becomes more penetrating as the electrode diameter decreases. To get the maximum deposition rate at a given current, one should have the smallest wire possible that provides the necessary penetration of the weld. The larger electrode diameters create weld with less penetration but welder in width. The choice of the wire electrode diameter depends on the thickness of the work piece to be welded, the required weld penetration, the desired weld profile and deposition rate, the position of welding and the cost of electrode wire. Commonly used electrode sizes are (mm): 0.8, 1.0, 1.2, 1.6 and 2.4. Each size has a usable current range depending on wire composition and spray- type arc or short- circuiting arc is used.

2) Welding Current:

The value of welding current used in MIG has the greatest effect on the deposition rate, the weld bead size, shape and penetration. In MIG welding, metals are generally welded with direct current polarity electrode positive (DCEP, opposite to TIG welding), because it provides the maximum heat input to the work and therefore a relatively deep penetration can be obtained. When all the other welding parameters are held constant, increasing the current will increase the depth and the width of the weld penetration and the size of the weld bead.

3) Welding Voltage:

The arc length (arc voltage) is one of the most important variables in MIG that must be held under control. When all the variables such as the electrode composition and sizes, the type of shielding gas and the welding technique are held constant, the arc length is directly related to the arc voltage. High and low voltages cause an unstable arc. Excessive voltage causes the formation of excessive spatter and porosity, in fillet welds it increases undercut and produces narrower beads with greater convexity, but an excessive low voltage may cause porosity and overlapping at the edges of the weld bead. And with constant voltage power source, the welding current increase when the electrode feeding rate is increased and decreased as the electrode speed is decreased, other factors remaining constant. This is a very important variable in MIG welding, mainly because it determines the type o metal transfer by influencing the rate of droplet transfer across the arc. The arc voltage to be used depends on base metal thickness, type of joint, electrode composition and size, shielding gas composition, welding position, type of weld and other factors.

4) Shielding Gas:

The primary function of shielding gas is to protect the arc and molten weld, pool from atmosphere oxygen and nitrogen. If not properly protected it forms oxides and nitrites and result in weld deficiencies such as porosity, slag inclusion and weld embrittlement. Thus the shielding gas and its flow rate have a substantial effect on the following: Arc characteristics, Mode of metal transfer, penetration and weld bead profile, speed of welding, cleaning of action, weld metal mechanical properties. Argon, helium and argon-helium mixtures are used in many applications for welding non-ferrous metals and alloys. Argon and Carbon dioxide are used in Carbon steel

5) Arc Travel Speed:

The travel speed is the rate at which the arc travels along the work- piece. It is controlled by the welder in semiautomatic welding and by the machine in automatic welding. The effects of the travel speed are just about similar to the effects of the arc voltage. The penetration is maximum at a certain value and decreases as the arc speed is varied. For a constant given current, slower travel speeds proportionally provide larger bead and higher heat input to the base metal because of the longer heating time. The high input increases the weld penetration and the weld metal deposit per unit length and consequently results in a wider bead contour. If the travel speed is too slow, unusual weld build-up occurs, which causes poor fusion, lower penetration, porosity, slag inclusions and a rough uneven bead. The travel speed, which is an important variable in MIG, just like the wire speed (current) and the arc voltage, is chosen by the operator according to the thickness of the metal being welded, the joint fit-up and welding position.

III. Design of Experiment

1. Specimen:

Fig. specimen

- Specimen diameter at welding section: 12 mm
- Specimen diameter at knurling section: 16mm
- Specimen length: 220 mm

2. Welding setup:
- Filler metal: M.S. special graded
- Gas used in MIG: Carbon dioxide
- Voltage range of MIG welding machine: 0-100 V
- Current range of MIG welding machine: 0-240 A
- Gas flow rate range of MIG welding machine: 0-25 Litre per minute

3. Process Parameter for optimization:
- Welding Voltage
- Welding Current
- Welding Gas Flow Rate

4. Method Used For Optimization

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering. Taguchi's techniques have been used widely in engineering design. The Taguchi method contains system design, parameter design, and tolerance design procedures to achieve a robust process and result for the best product quality. The main trust of Taguchi's techniques is the use of parameter design, which is an engineering method for product or process design that focuses on determining the parameter (factor) settings producing the best levels of a quality characteristic (performance measure) with minimum variation. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. To determine the best design, it requires the use of a strategically designed experiment, which exposes the process to various levels of design parameters. Experimental design methods were developed in the early years of 20th century and have been extensively studied by statisticians since then, but they were not easy to use by practitioners. Taguchi's approach to design of experiments is easy to be adopted and applied for users with limited knowledge of statistics; hence it has gained a wide popularity in the engineering and scientific community.

- Steps in Taguchi method:

a) First of all identify the main objective of the experiment.
b) Identify the output response and its system of measurement.
c) Find out the different factors that may affect the output response, level and main interactions.
d) Choose the suitable orthogonal array.
e) Perform the experiments given by the trials in the OA.
f) The data can be analysed by using the statistical techniques signal to noise ratio, the analysis of variance and factor effects to find the significance of process parameters.
g) Find out the optimal levels of variables.
h) Confirmatory experiments done for the verification of the optimal design parameters.

5. Software used for Optimization process:

Minitab 17 software we are using for optimization and analysis .Minitab is a statistics package developed at the Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972. It began as a light version of OMNITAB 80, a statistical analysis program by NIST. Statistical analysis software such as Minitab automates calculations and the creation of graphs, allowing the user to focus more on the analysis of data and the interpretation of results. It is compatible with other Minitab, Inc. software.

6. Levels of welding process parameter:

Table. Levels of process parameter

Welding parameters	Unit	Level1	Level 2	Level 3
Welding voltage	V	18	20	22
Welding current	A	90	100	110
Gas flow rate	LPM	6	8	10

7. Orthogonal array for Taguchi method:

Table. Orthogonal array L9

Sr.no.	Voltage	Current	Mass flow rate
1	18	90	6
2	18	100	8
3	18	110	10
4	20	90	8
5	20	100	10
6	20	110	6
7	22	90	10
8	22	100	6
9	22	110	8

8. Procedure of Experiment:

a) Preparing circular M.S. rod of size Diameter 12 mm and length of 220mm in shaping machine for performing MIG welding.
b) Cleaning the work pieces for any oil or dust
c) Checking and preparing arc of MIG for performing the MIG welding operation.
d) Carrying out MIG welding operation as per orthogonal array combination for each experiment
e) Checking and preparing the tensile testing machine ready for performing the tensile testing operation.
f) Placing the specimens in the jaws correctly
g) Applying the load.
h) Measuring the ultimate tensile strength of each specimen.

Fig. MIG weld specimen for tensile test

Fig. Photographs of specimens after tensile test

Table. Ultimate Tensile strength for L9 orthogonal array

Sr.no	Voltage V	Current A	Mass flow rate LPM	UTS MPA
1	18	90	6	132.63
2	18	100	8	117.07
3	18	110	10	256.60
4	20	90	8	304.18
5	20	100	10	336.72
6	20	110	6	352.28
7	22	90	10	305.95
8	22	100	6	248.82
9	22	110	8	299.23

IV. Sofware Analysis Of Mig

Table. Analysis of Variance for S/N ratios

Software analysis is done on Minitab 17 and results from software as follows

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	67.955	67.955	33.977	24.64	0.039
I	2	14.229	14.229	7.114	5.16	0.162
S	2	12.641	12.641	6.320	4.58	0.179
Residual Error	2	2.758	2.758	1.379		
Total	8	97.582				

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

Level	V	I	S
1	44.00	47.28	47.10
2	50.38	46.61	46.85
3	49.05	49.55	49.48
Delta	6.38	2.94	2.63
Rank	1	2	3

Table .Response Table for Means

level	V	I	S
1	168.8	247.6	244.6
2	331.1	234.2	240.2
3	284.7	302.7	299.8
Delta	262.3	68.5	59.6
Rank	1	2	3

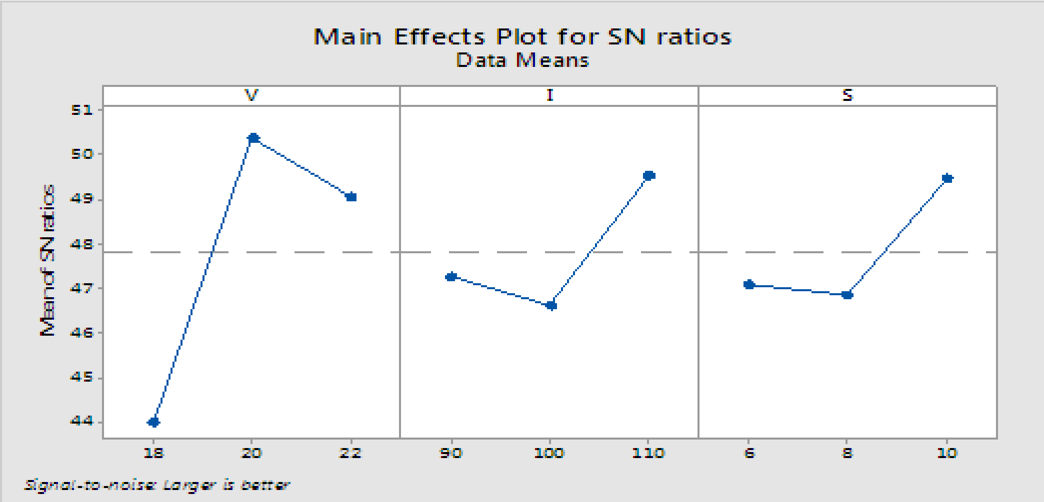

Fig . Graph from minitab S/N ratio vs process parameter

- From Minitab

Regression Equation

UTS = -704 + 29.0 V + 2.76 I + 13.8 S

V. Remarks

- Main effect plots reveal that voltage and current has significant influence on Tensile strength.
- The optimum welding condition obtained by Taguchi method for maximum strength is IS7887GR-7M Mild steels (i.e. current = 110 ampere, voltage = 20 volts, gas flow rate = 6LPM) and for minimum strength are IS7887GR-7M Mild steels (i.e. current = 100 amperes, voltage = 18 volts, gas flow rate= 8LPM).
- Maximum ultimate tensile strength found on maximum current, intermediate level voltage and low level gas flow rate. Minimum ultimate tensile strength found on low level voltage and intermediate level current and gas flow rate.

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