A Review on Optimization of Welding Parameters in Arc Welding Process using Taguchi Parametric Optimization Technique

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Abstract— Before starting any dissertation work, the review of the topic is must, because it helps us in knowing the amount of work that has been done in that topic by the different researchers. It also helps us in doing the further work by taking the reference of the previous work done in the best possible way. This paper presents the review of relevant past work on parametric optimization of MIG welding by different methods. The MIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. welding parameter contains welding current, welding voltage, welding speed, shielding gas, arc travel, etc. mechanical properties like tensile strength, hardness etc.

Key words: MIG Welding, Welding Current, Shielding Gas, Arc Travel

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.

A. GMAW can be done in Three Different Ways:

1) Semiautomatic Welding

Equipment controls only the electrode wire feeding. Movement of welding gun is controlled by hand. This may be called hand-held welding.

2) Machine Welding

Uses a gun that is connected to a manipulator of some kind (not hand-held). An operator has to constantly set and adjust controls that move the manipulator.

3) Automatic Welding

Uses equipment which welds without the constant adjusting of controls by a welder or operator. On some equipment, automatic sensing devices control the correct gun alignment in a weld joint.

B. Working Principle of MIG 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$CCCC$) 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.

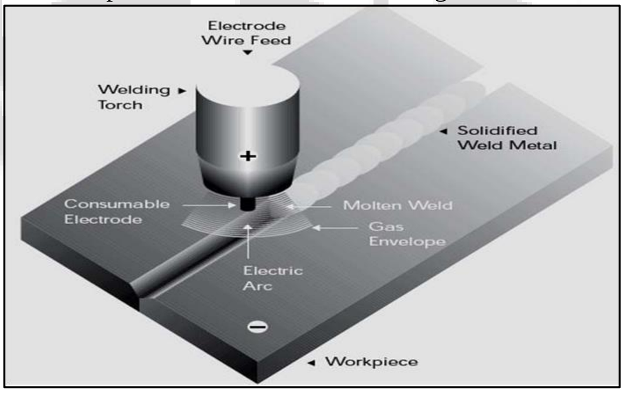

Fig. 1: Working Condition of Work Piece

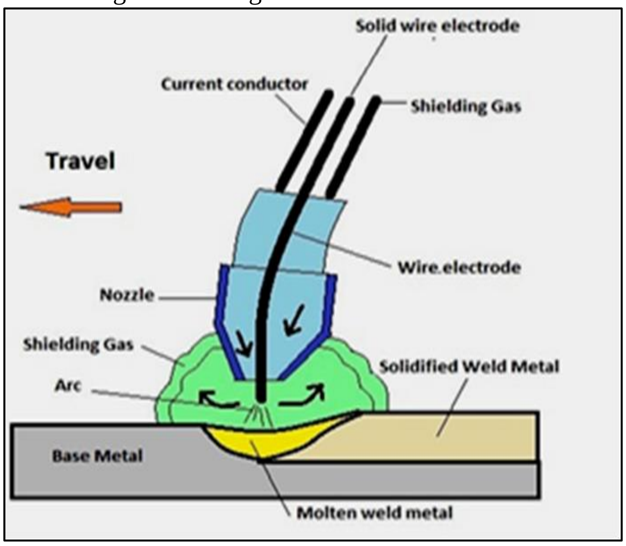

Fig. 2: Working Principles of GMAW

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.

C. GMAW / MIG Welding Applications

MIG may be operated in semiautomatic, machine, or automatic modes. All commercially important applicable metals such as carbon steel, high-strength, low-alloy steel, and stainless steel, aluminium, copper, titanium, and nickel alloys can be welded in all positions with this process by choosing the appropriate shielding gas, electrode, and welding variables.

D. MIG Welding Effecting Parameters

Weld quality and weld deposition rate both are influenced very much by the various welding parameters and joint geometry. Essentially a welded joint can be produced by various combinations of welding parameters as well as joint geometries. These parameters are the process variables which control the weld deposition rate and weld quality.

The weld bead geometry, depth of penetration and overall weld quality depends on the following operating variables.

- Electrode size, Welding current, Arc voltage
- Arc travel speed, Welding position
- Gas Flow rate, Shielding Gas composition
- Electrode extension (length of stick out)

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. [21]

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. [21]

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. [21]

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. [21]

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. [21]

II. LITERATURE REVIEW

A. Nabendu Ghosh et.al.

Presented the Parametric Optimization of Gas Metal Arc Welding Process by using Taguchi method on Ferritic Stainless Steel AISI409. In this work welding parameters: welding current, gas flow rate and nozzle to plate distance, on ultimate tensile strength (UTS) and percentage elongation (PE) in MIG welding of AISI409 ferritic stainless steel materials are studied and analyzed. Experiments have been conducted as per L9 orthogonal array of Taguchi method. The visual inspection and X-ray radiographic test has done in order to detect surface and sub-surface defects of welded specimens. The observed data of UTS and PE have been interpreted, discussed and analyzed with use of Taguchi methodology and analysis of signal to noise ratio. [1]

B. Bahrudin Hrnjica et.al.

Has analyzed the welded joint tensile strength testing of new and used material. this research examines testing of butt welded joint constructed of 40 years old exploited material, as well as unused material of the identical composition testing procedure involved a number of prerequisite procedures, prior to tensile strength testing itself. Beside the selection of the adequate welding technology, extraction of old steel plates from the tank had to be carried out, and welded to the new material. Initially old material for welding is prepared, conducted welding procedure, examined the weld using microscopic and macroscopic tests, cut out the samples and tested them for tensile strength. This paper also covers welding technology used in the process of welding new material with the one that has been exploited for over 40 years. [2]

C. Amity Pal

Has done research on Mug Welding Parametric Optimization Using Taguchi's Orthogonal Array and Analysis of Variance. In this work made an effort to review the investigations of 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. [3]

D. Vivek Saxena et.al.

Has made effort for optimization of MIG welding parameters on tensile strength of aluminum alloy by taguchi approach. this work unveiled the influence of welding parameters on tensile strength of am-40(en aw 5083) aluminum alloy material during welding. Set of experiments on mig welding set up based on taguchi technique has been used. An analysis of variance (annova) accompanied with regression analysis and orthogonal array of size l9, is employed to study the characteristics of welding for a material & optimizes the welding parameters. [4]

E. S.V. Sapakal et.al.

Presented the parametric optimization of mig welding using taguchi design method. This work presented the influence of welding parameters like welding current, welding voltage, welding speed on penetration depth of ms c20 material during welding. Experiments based on taguchi technique have 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 ms c20 material & optimized the welding parameters. [5]

F. Ajit Hooda et.al.

Has worked on optimization of mig welding process parameters to predict maximum yield strength in AISI 1040. In this research work an attempt was made to develop a response surface model to predict tensile strength of inert gas metal arc welded AISI 1040 medium carbon steel joints. The process parameters such as welding voltage, current, wire speed and gas flow rate were studied the experiments were conducted based on a four-factor, three-level, face cent red composite design matrix.. Response surface methodology (rsm) was applied to optimizing the MIG welding process parameters to attain the maximum yield strength of the joint. The similar weld joint of AISI 1040 material was developed effectively with MIG welding with selected range of input variable parameters. [6]

G. D. Ananthapadmanaban et.al.

Has analysed the study of mechanical properties of friction welded mild steel to stainless steel joints. This work aims the study of mechanical property variation under different friction welding conditions for mild steel stainless steel joints. Yield strength, ultimate tensile strength, percentage elongation of the welded joints and hardness variations across the weld interface has been reported. [7]

H. Ahmed Khalid Hussain et.al.

Has presented the Influence of Welding Speed on Tensile Strength of Welded Joint in TIG Welding Process. In this work the investigation of effect of welding speed on the tensile strength of the welded joint. Experiments are conducted on specimens of single v butt joint having different bevel angle and bevel heights. The material selected for preparing the test specimen is Aluminium AA6351 Alloy. [8]

I. Nabendu Ghosh et.al.

has made effort on Parametric Optimization of Gas metal arc welding processby PCA based Taguchi method on Austenitic Stainless Steel AISI 316L. In this work AISI 316L stainless steel samples have been welded by MIG welding. Butt joints have been made. Plate thickness is kept constant (= 3mm). Several butt-welded joints have been made. Each sample of the joints has been prepared under certain combination of welding parameters. The parameters considered for variation are welding current, gas flow rate and nozzle to plate distance. The design of experiment has been done using L9 Taguchi design of experiment. The influence of the process parameters (mainly current, gas flow rate and nozzle to plate distance) has been examined visually and also through X-ray radiographic tests. [9]

J. Kapil B. Pipavat et.al.

Has presented the Optimization of MIG welding Process Parameter using Taguchi Techniques. This work presented the influence of welding parameters like welding current, welding voltage, welding speed etc. on mechanical properties like tensile strength, hardness etc. on austenitic stainless steel AISI 316. 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 austenitic stainless steel AISI 316 material and optimize the welding parameters. The techniques used for obtaining optimal process parameters with the use of experimental data have been reviewed. [10]

K. Diganta Kalita et.al.

Has worked on Taguchi Optimization of MIG Welding Parameters Affecting Tensile Strength of C20 Welds. this research work investigated the effect of the three process parameters of Metal Inert Gas Welding (MIG), welding current, voltage and shielding gas flow rate on tensile strength of welded joints having Grade C20 Carbon Steel as parent metal and ER70S-4 electrode. An experiment has been designed using Taguchi's Orthogonal Array L9, taking welding current, voltage and shielding gas flow rate as factors having three levels each. [11]

L. Kumar Rahul Anand et.al.

Has completed the work on parameteric optimization of tig welding on joint of stainless steel (316) & mild steel using taguchi technique. In this work mechanical properties of the joint of austenitic stainless steel (aisi 316) and mild steel welded by tig welding is studied and optimized various process parameter such as current, voltage and gas flow ratio (gfr) which has influence on tensile strength and hardness of the joint by taguchi method of optimization. However, investigation is based on the taguchi approach of orthogonal array using analysis of variance (anova) to determine the influence of process parameter and to optimize them.[12]

M. Midhun Ranjan et.al.

Has made effort on T-Joint weld optimization using Taguchi method. In this work investigation of welded T-joint by TIG welding process with varying gap and angle between the parent materials to determine the breaking stress under tensile load in the weldment has been done. Finite element (FE) analysis is used to carry out the maximum breaking stress using Ansys software. Experimental analysis has been done to find out the maximum breaking stress under tensile load. Taguchi optimization method is used to optimize the fillet weld section in the experimental analysis. [13]

N. Nizamettin Kahraman

Has analysed the influence of welding parameters on the joint strength of resistance spot-welded titanium sheets. In this work commercially pure (CP) titanium sheets (ASTM Grade 2) were welded by resistance spot welding at different welding parameters and under different welding environments. The welded joints were subjected to tensile-shearing tests in order to determine the strength of the welded zones. In addition, hardness and microstructural examinations were carried out in order to examine the influence of welding parameters on the welded joints.[14]

O. A K Lakshminarayanan et.al.

Has presented the Microstructure Tensile and Impact Toughness Properties of Friction Stir Welded Mild Steel. In this work Microstructure, tensile and impact toughness properties and fracture location of friction stir welded AISI 1018 mild steel were revealed. The AISI 1018 mild steel plates with thickness of 5 mm were friction stir welded by tungsten based alloy tool with tool rotational speed of 1000 r/min and welding speed of 50 mm/min. Tensile strength of stir zone is higher (8%) compared to that of the base metal. This may be due to the formation of finer grains in the weld nugget region under the stirring action of the rotating tool. The ductility and impact toughness of the joints are decreased compared to those of the base metal owing to the inclusion of tungsten particles in the weld region.[15]

P. Nirmalendhu Choudhury et.al.

Has made effort on Design optimization of Process Parameters for TIG Welding based on Taguchi Method. This work 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.[16]

Q. K.sivasakthivel et.al.

Has worked on Optimization of Welding Parameter in MIG Welding by Taguchi Method. this work proposed a method to decide optimal settings of the welding process parameters in MIG welding. Properties include Tensile strength, Impact strength; Hardness, etc. also influenced process parameters. This work indicates the parameter which is most effectively effect the weld strength. By using Taguchi and ANOVA technique an optimal solution is found out, which provides an optimal results of the varying condition. The optimum value was predicted using MINITAB 17 software. [17]

R. M. Balasubramanian

Has made effort on Statistical analysis of tensile strength and elongation of pulse TIG welded titanium alloy joints using Weibull distribution. In this study, the tensile strength of a pulsed current tungsten inert gas welded Ti-6Al-4 V plate has been statistically analysed by Weibull distribution. Titanium alloy of 1.6 mm thickness was welded with pulsed current tungsten inert gas welding. Testing of mechanical properties was done to understand the influence of pulsing current on the fabricated joint. But the result obtained has to be consistent and repeatable. Hence, this work investigated a method for predicting the reliability of values obtained for tensile strength and elongation with consistency. [18]

S. L.S. Sutherland et.al.

Presented the work on Statistical experimental design techniques to investigate the strength of adhesively bonded T-joints. Statistical experimental design techniques were used to study the strength of 'T'-Joints representative of various connections used to fabricate marine composite structures via a large test program. The effects of different surface preparations and cleaning methods, and adhesives were investigated.[19]

T. N. I. S. Hussein et.al.

Has presented the Tensile Strength of Orbital Welded Mild Steel Tubes with Dissimilar Thickness. This work

Investigated the process-properties relationship of welded mild steel tube of dissimilar thickness by using Metal Inert Gas (MIG) orbital welding. The effects of weld current and jig rotational speed to the tensile properties of welded mild steel tubes were studied. [20]

III. CONCLUSION

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 AISI 1018 mild/low carbon steel, AISI 4130 alloy steel and AISI 1020 low carbon/low tensile steel so we want to do research on this material of car chassis. I 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.

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