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METAL INERT GAS WELDING – A DETAILED ANALYSIS

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Abstract**-- Streamlining is done on MIG welding process parameters AA 5456 weldments utilizing DOE. Taguchi is utilized generally as a part of all improvement procedure. The fundamental target of this work is to improve the MIG welding Process parameters on AA 6061 to yield most extreme elasticity and hardness utilizing Taguchi technique. Four parameters and two levels has been chosen. Tests have been led according to parametric blend of L8 Orthogonal Array for this anticipate work.**

Index Terms **— AA 5456, DOE, Metal Inert Gas Welding.**

I. INTRODUCTION

Semiautomatic welding controls only the electrode wire feeding. Movement of welding gun is controlled by hand. This may be called hand-held welding. 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. 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 MIG welding is carried out on DC electrode (welding wire) positive polarity (DCEP). However DCEN is used (for higher burn off rate) with certain self shielding and gas shield cored wires.DC output power sources are of a transformer- rectifier design, with a flat characteristic (constant voltage power source). The most common type of power source used for thisprocess is the switched primary transformer rectifier with constant voltage characteristics from both 3-phase 415V and 1-phase 240V input supplies.The output of direct current after full wave rectification from a 3-phase machine is very smooth. To obtain smooth output after full wave rectification with a 1- phase machine, a large capacitor bank across the output is required.Because of the expense of this, many low cost 1-phase machines omit this component and therefore provide a poorer weld characteristic. The switches to the main transformer primary winding provide the output voltage steps at the power source output terminals. Another method of producing different voltages at the power source output terminals is to use a Thyristor or a Transistor rectifier instead of a simple diode rectifier. This system offers continuously variable output voltage, which can be particularly useful on robot installations and the cost of this type of rectifier can be partly offset with no need for primary voltage switch or switches and a single tapped main transformer primary winding.Most MIG power sources have a contactor or relay used to switch the output ON/OFFwith operations of the trigger on the MIG torch. GMAW power source is shown in Fig.1.

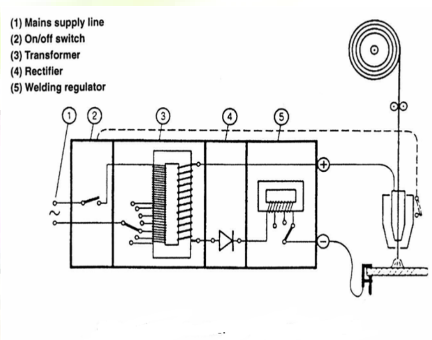

Fig.1. GMAW power source

The switch off operation of this contactor is normally delayed to allow the welding wire to Burn back out of the molten weld pool. A thermostat is fitted on the hottest point in the power source, in series with the contactor coil to provide thermal protection to the machine. Power source performance is measured by it's ability to provide a certain current for a percentage of a 10 minute period before "Thermal Cut-Out". This is the "Duty Cycle".

The wire-feed unit, or sub-assembly where this is mounted in the power source cabinet (known as a composite MIG), provides the controlled supply of welding wire to the point to be welded. According to the welding wire size and Arc voltage provided by the power source, a constant rate of wire speed is required, in MIG welding the power source provides Arc voltage control and the wire feed unit provides welding wire speed control, (in MIG this equates to welding current). Most modern wire feed units control the wire feed speed via a DC motor and thyristor control PCB to provide continuous control of Armature volts and hence RPM of motor. The wire feed motor spindle has a feed roller fitted and another pressure roll, adjustable spring mounted to lightly grip the wire and push it up the length of the MIG torch. Various combinations of drive system are used by different manufacturers, these include: driven feed roll and pressure driven pressure roll driven feed roll and driven pressure roll two driven feed rolls and pressure driven pressure roll two driven feed rolls and two driven pressure rolls also rifled V-shaped feed rolls size dependant grooves V-shaped feed rolls size dependant grooves, U-shaped feed rolls size dependant groovesflat, plain pressure rolls flat, knurled pressure rolls, V-shaped pressure rolls size dependant grooves, U-shaped pressure rolls size dependant grooves

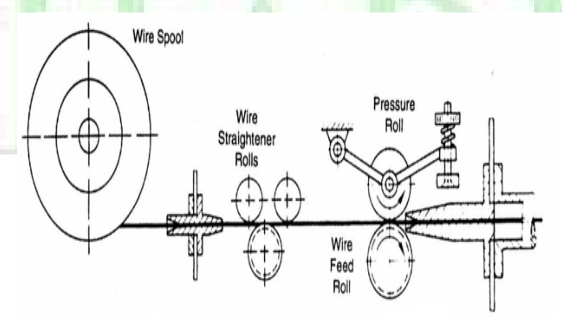

Fig.2. Wire feed roll

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 bythe atmosphere.The shielding gas should also have a pronounced effect on the following aspects of the welding operation and the resultant weld. Christo Ananth et al.[4] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

Metal transfer across the arc

The operating characteristics of MIG welding is described by the four basic modes of weld metal transfer from the electrode to the work:

- Short circuiting transfer
- Globular transfer
- Spray transfer
- Pulsed spray transfer

The mode of weld metal transfer is determined by the following:

- Welding current
- Electrode size
- Electrode composition
- Electrode stick out
- Shielding gas

II. ALUMINIUM ALLOYS

Al–Mg alloys are extensively used in defence and aerospace applications. Tungsten inert gas (TIG) welding is an arc welding process that produces coalescence of metals by heating them with an arc between a non- consumable electrode and the base metal.TIG welding process is generally used for welding of Al–Mg alloys. The initial strength of the non-heat treatable aluminum alloys depends primarily upon the hardening effect of alloying elements such as silicon, iron, manganese and magnesium. These elements increase the strength either as dispersed phase or by solid solution strengthening. The welding of non-heat treatable aluminum alloys typically have distinct effects when the heat input is increased, i.e. the width of the heat affected zone (HAZ) is increased and the minimum reduction in the mechanical properties are observed. Alloys 5XXX series with more than 3.0% magnesium are not recommended for elevated temperatures above 150 _F because of their potential for sensitization and subject susceptibility to stress corrosion cracking . The minimum HAZ strength approximates to that of the annealed parent metal regardless of the starting temperature. During welding, vaporization of alloying elements like magnesium can occur and this vaporization loss of any alloying elements can influence the mechanical properties of the welded joints by affecting the chemistry of the weld pool. The gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) welding processes are very often used for welding of these alloys. However, GTAW process is generally preferred because it produces a very high quality Distortion is the major problem in welding of thin sections. However, the distortion is controlled in pulsed and magnetic arc oscillation GTAW process. Metallurgical advantages of pulsed and magnetic arc oscillation welds that are frequently reported in the literature includes grain refinement in the fusion zone, reduced width of HAZ, less distortion, control of segregation, reduced hot cracking sensitivity and

reduced residual stresses . The purpose of the present investigation is to optimize the pulsed TIG welding process parameters for increasing the mechanical properties using Taguchi method. Taguchi method is a systematic approach to design and analyze experiments for improving the quality characteristics. Taguchi method permits evaluation of the effects of individual parameters independent of other parameters and interactions on the identified quality characteristics, i.e. ultimate tensile strength, yield strength, hardness, etc. Nowadays, Taguchi method has become a practical tool for improving the quality of the output without increasing the cost of experimentation by reducing the number of experiments. Welds are made with the use of obtained optimum condition,and these welds are subjected to cold planishing process. The roll planishing is an effective process in which weld is passed between two steel rollers. During the planishing operation, the internal stresses which are induced during welding are relived and the grains are deformed. Hence, the mechanical properties of the welds have been improved.

Aluminium alloy 6061 is a medium to high strengthheat-treatable alloy with a strength higher than 6005A.It has very good corrosion resistance and very good weldability although reduced strength in the weld zone. It has medium fatigue strength. It has good cold formability in the temper T4, but limited formability in T6 temper. Not suitable for very complex cross sections.

Physical properties

Table 1.1 Physical Properties of AA 6061

Property	Value
Density	2.70 g/cm^3
Melting Poin	650 degree celsius
Thermal Expansion	23.4×10^{-6}/k
Modulus of Elasticity	70 Gpa
Thermal conductivity	166 W/m.K

DESIGN OF EXPERIMENTS

Design of experiments is the branch of applied statistics deals with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters. A strategically planned and executed experiment may provide a great deal of information about the effect on a response variable due to one or more factors. Many experiments involve holding certain factors constant and altering the levels of another variable. This One-Factor-at-a-Time approach to process knowledge is, however, inefficient when compared with changing factor levels simultaneously. Many of the current statistical approaches to designed experiments originate from the work of R. A. Fisher in the early part of the 20th century. Fisher demonstrated how taking the time to seriously consider the design and execution of an experiment before trying it helped avoid frequently encountered problems in analysis. Key concepts in creating a designed experiment include blocking, randomization and replication. Blocking: When randomizing a factor is impossible or too costly, blocking lets restrict randomization by carrying out all of the trials with one setting of the factor and then all the trials with the other setting**.** Randomization**:** Refers to the order in which the trials of an experiment are performed. A randomized sequence helps eliminate effects of unknown or uncontrolled variables. Replication**:** Repetition of a complete experimental treatment, including the setup. A "full factorial" design which studies the response of every combination of factors and factor levels, and an attempt to zone in on a region of values where the process is close to optimization.

Design of experiments helps us in understanding the behavior of a (mechanical) System. Data collected by systematic variation of influencing factors helps us to quantitatively describe the underlying phenomenon or phenomena; the goal of any experimental activity is to get the maximum information about a system with the minimum number of well designed experiments. An experimental program recognizes the major "factors" that affect the outcome of the experiment. The factors may be identified by looking at all the quantities that may affect the outcome of the experiment. The most important among these may be identified using a few exploratory experiments or from past experience or based on some underlying theory or hypothesis. The next thing one has to do is to choose the number of levels for each of the factors. The data will be gathered for these values of the factors by performing the experiments by maintaining the levels at these values.

Factorial designs allow for the simultaneous study of the effects that several factors may have on a process. When performing an experiment, varying the levels of the factors simultaneously rather than one at a time is efficient in terms of time and cost, and also allows for the study of interactions between the factors. Interactions are the driving force in many processes. Without the use of factorial experiments, important interactions may remain undetected. Full factorial designs. In a full factorial experiment, responses are measured at all combinations of the experimental factor levels. The combinations of factor levels represent the conditions at which responses will be measured. Each experimental condition is called "run" and the response measurement an observation. The entire set of runs is the "design." Factorial designs in which one or more level combinations are excluded are called fractional factorial designs. Fractional factorial designs are useful in factor screening because they reduce down the number of runs to a manageable size. The runs that are performed are a selected subset or fraction of the full factorial design. Fractional factorial designs are used to minimize time and cost.

Response Surface designs are used to examine the relationship between one or more response variables and a set of quantitative experimental variables or factors. These methods are often employed after identified a "vital few" controllable factors and to find the factor settings that optimize the response. The common response surface designs are central composite design and Box-Behnken design. Response surface methods may be employed to find factor settings (operating conditions) that produce the "best" response, to find factor settings that satisfy operating or process specifications, identify new operating conditions that produce demonstrated improvement in product quality over the quality achieved by current conditions and model a relationship between the quantitative factors and the response .Many response surface applications are sequential in nature in that they require more than one stage of experimentation and analysis.

Mixture designs are a special class of response surface experiments in which the product under investigation is made up of several components or ingredients. Designs for these experiments are useful because many product design and development activities in industrial situations involve formulations or mixtures. In these situations, the response is a function of the proportions of the different ingredients in the mixture. For example, to develop a pancake mix that is made of flour, baking powder, milk, eggs. In the simplest mixture experiment, the response (the quality or performance of the product based on some criterion) depends on the relative proportions of the components.The quantities of components, measured in weights, volumes, or some other units, add up to a common total. In contrast, in a factorial design, the response varies depending on the amount of each factor.

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. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. 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 varied. 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 is an intermediate number of a variable (3 to 50), few interactions between variables, and when only a few variables contribute significantly.

Another Taguchi's contributions is the signal-to-noise (S/N) ratio. It was developed as a proactive equivalent to the reactive loss function. For example, when a person puts his/her foot on the brake pedal of a car, energy is transformed with the intent to slow the car, which is the signal. However, some of the energy is wasted by squeal, pad wear, heat and so forth is the noise. Signal factors (y) are set by the designer or operator to obtain the intended value of the response variable.

Noise factors (s^2) are not controllable or very expensive or difficult to control. The S/N ratio units are decibel (DB), which are tenths of Bel and are a very common unit in electrical engineering. A loss function is defined by Taguchi is used to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the deviation of the quality characteristic from the desired value. The value of the overall loss function is further transformed into a signal-to-noise (S/N) ratio. Usually, there are three categories of the quality characteristic in the analysis of the S/N ratio, i.e. the lower-the-better, the larger-the-better, and the more-nominal-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the quality characteristic, a larger S/N ratio corresponds to a better quality characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. The optimal combination of the process parameters can

The signal to noise ratio for nominal -the-better is used for wherever there is a nominal or target value, such as dimensions, voltage, weight and so forth. The equation for signal to noise ratio for the nominal-the-better is shown in equation

$$S/N_N = 10\log_{10}[y^2/s^2) - (1/n)]$$

The S/N ratio is larger-the better is used where the largest value is desired such as weld strength, gasoline mileage, or yield. The equation for signal to noise ratio for the larger-the-better is as below:

$$S/N_L = -10\log_{10}[MSD] = -10\log_{10}[\sum(1/y^2)/n].$$

The negative sign is used to ensure that the largest value gives the optimum value for the response variable and therefore robust design. Mean standard deviation (MSD) is given to show the relationship to the loss function. The signal to noise ratio for smaller-the-better is used for situations where the largest target value is zero, such as computer response time, automotive emissions, corrosion. The equation for signal to noise ratio for the smaller-the-better is shown in equation

$$S/N_S = -10\log_{10}[MSD] = -10\log_{10}[\sum(y^2)/n]$$

Tolerance design is a process of determining the statistical tolerance around the target. During the parameter-design, low cost tolerancing should be used. Only when the values are beyond the low cost-tolerancing limits are this concept implemented. Tolerance design is the selective tightening of tolerances and/or upgrading to eliminate excessive variation. It uses analysis of variance (ANOVA) to determine which factors contribute to the total variability and the loss function to obtain trade-off between quality and loss.

III. LITERATURE REVIEW

Tanigawa et al (2012) developed the Laser and TIG welding tools for application to the blanket hydraulic connection. For each tool, welding conditions were optimized for all position welding to horizontally located pipes. The obtained parameters such as the weld heat input, allowable misalignment, the lifetime of the tools and amount of spatter and fumes, were assessed comparatively. Considering additional aspects related to the remote handling compatibility, the preferred. Welding technique for the blanket remote maintenance was discussed. He Lin et al (2014) have analyzed the microstructures of the TIG weld joints The results indicate that the welding quality of the high boron Fe-Ti-B alloys is very good, there are no obvious defects such as cracks, lack of fusion, incomplete penetration and strip defects in the butt weld joints. However, the micro-zone composition analysis indicates that the composition of the TIG weld joint is very uniform. Tensile tests were carried out on TIG welded joints after the post weld heat-treatment. The result shows that the welds have slightly higher yield strength (YS),and lower ultimate tensile strength compared to those of the base Sathiya et al (2014) have analysed austenitic steel. In this study, the weld bead geometry such as depth of penetration (DP), bead width (BW) and tensile strength (TS) of the laser welded butt joints made of AISI 904L super austenitic stainless steel are investigated. Full factorial design is used to carry out the experimental design. Artificial neural networks (ANNs) program was developed in MatLab software to establish the relationship between the laser welding input parameters like beam power, travel speed and focal position and the three responses DP, BW and TS in three different shielding gases (argon, helium and nitrogen). The established models are used for optimizing the process parameters using genetic algorithm (GA). Optimum solutions for the three different gases and their respective responses are obtained. Confirmation experiment has also been conducted to validate the optimized parameters obtained from GA. The relationship between input parameters beam power,beam width is established.

Xiangmeng Meng et al (2014) have proposed TIG–MAG hybrid arc welding process to achieve high speed welding. The influences of hybrid arc welding parameters on welding speed and weld appearance were studied through orthogonal experiment. Four levels for each parameters were chosen. Based on the number of levels and parameters L16 orthogonal array was selected and the microstructures, mechanical properties of weld were tested and compared with that of the conventional MAG weld. The mechanical properties of hybrid arc weld were not lower than that of the conventional MAG weld. The assistant TIG arc could effectively stabilize the MAG welding current and MAG arc voltage in high speed TIG–MAG hybrid arc welding process. The stable hybridization obtained by balance between TIG and MAG welding current and proper wire-electrode distance was a key factor to stabilize the welding process. The developed TIG- MAG hybrid arc welding significantly increased the welding speed for both steel plates under the condition of high quality of weld appearance. From the literature reviewed an attempt is made in this work to predict the optimized MIG welding process parameters of AA 6061. Christo Ananth et al. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

IV. EXPERIMENTS

The AA 6061 Sheet were sheared to the required dimensions (200 mm×100 mm × 8 mm). Double 'V' butt joint configuration, as shown in figure was prepared using milling machine to fabricate GMAW welded joints.

Fig.3. Edge preparation

The experiment was conducted at THE GLOBE RADIO COMPANY, pettai, Tirunelveli, India, with the following setup. KEMPACT 2530 semiautomatic MIG welding machine was used to join the Aluminium alloy plates of size 200 mm (length) X 100 mm (width) X 8 mm (Thickness). Filler wire AWS- ER70S-6 is selected for low carbon steels. Copper coated wire AWS-ER70S-6, of diameter
1.2 was used as a consumable. Commercial carbon dioxide (CO_2) was used as the shielding gas for all the experiments. The initial joint configuration was obtained by securing the plates in position using tack welding GMAW welds. All necessary care was taken to avoid joint distortion, and the joints were made with suitable clamps. Double pass welding was carried out to fabricate the joints. The clamping arrangement and experimental setup was shown in Fig.4. and Fig.5. respectively as follows as shown below:

Fig.4. Mig welding machine

Fig.5. Clamping arrangement

V. CONCLUSION

Streamlining is done on MIG welding process parameters AA 5456 weldments utilizing DOE. Taguchi is utilized generally as a part of all improvement procedure. The fundamental target of this work is to improve the MIG welding Process parameters on AA 6061 to yield most extreme elasticity and hardness utilizing Taguchi technique. Four parameters and two levels has been chosen. Tests have been led according to parametric blend of L8 Orthogonal Array for this anticipate work.

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