A review on techniques for optimizing process parameters for TIG Welding Aluminium

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Abstract—Tungsten inert gas welding is one of the widely used techniques for joining ferrous and non-ferrous metals. TIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, absence of slag etc. Gas tungsten arc welding, GTAW, uses a non consumable electrode to produce the weld. Weld area is protected from atmospheric contamination by a shielding gas (usually inert gas such as argon) and a filler material is normally used. The weld pool is easily controlled such that unbaked root passes can be made, the arc is stable at very low welding currents enabling thin components to be welded and the process produces very good quality weld metal, although highly skilled welders are required for the best results. The welding parameters are selected by operator based on experience or from a handbook. However, this does not ensure that the selected welding process parameters can produce the optimal or near optimal weld pool geometry for that particular welding machine and environment. The aim of this paper is to review the techniques of optimizing process parameters of TIG welding process.

Key words: Aluminium TIG, Tungsten inert gas welding, GTAW, Gas Tungsten Arc Welding, Process Parameter optimization

I. INTRODUCTION

A. Welding

Welding is a fabrication process that joins materials, usually metals or thermoplastics by causing coalescence. In this process coalescence of materials is produced by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material. Welding is used for making permanent joints. It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

B. Gas Tungsten Arc Welding

TIG is an acronym for "Tungsten Inert Gas" welding. TIG is a commonly used and accepted slag term. The proper terminology is "Gas Tungsten Arc Welding" or GTAW. This is the term used by welding engineers on blueprints, and in welding procedures.

Gas tungsten arc welding, GTAW, uses a non consumable electrode to produce the weld. Weld area is protected from atmospheric contamination by a shielding gas (usually inert gas such as argon) and a filler material is normally used. When TIG was introduced around the 1940's it used to be referred to as "HeliArc" because the shielding gas used was helium. Now-a-days, it is no longer called HeliArc process because in most cases the shielding gas used is Argon. In TIG welding, the welding arc acts as a heat source only and the welding engineer has the choice of whether or not to add a filler wire. The weld pool is easily controlled such that unbaked root passes can be made, the arc is stable at very low welding currents enabling thin components to be welded and the process produces very good quality weld metal, although highly skilled welders are required for the best results.

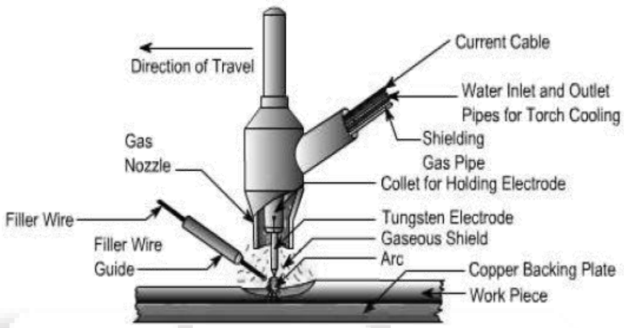

Fig. 1: Schematic diagram of TIG welding torch

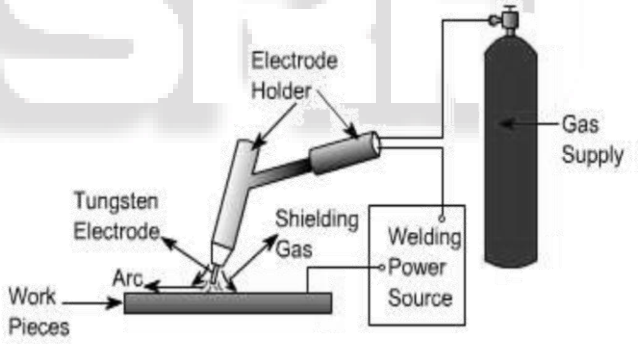

Fig. 2: Schematic diagram of TIG welding process

C. GTAW / TIG welding applications

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium and copper alloys.

D. Welding of Aluminium alloys

Aluminium and its alloys are routinely welded and brazed in industry by a variety of methods. As expected they present their own requirements for the welded joint to be a success. Welding aluminium alloys are not more difficult or complicated than welding steel as it is just different and requires specific training.

Aluminium and its alloys are easy to weld, but their welding characteristics need to be understood and the proper procedures employed. Aluminum is an excellent conductor of heat, thus it requires large heat inputs when welding starts, since much heat is lost in heating the surrounding base metal.

A variety of welding processes can be used to join aluminium, including the fusion methods GMAW (standard MIG, plasma and pulse) and GTAW (standard TIG and plasma) giving high quality, all-position welding, manual, either mechanized or fully automatic. Furthermore, resistance, MMA (metal arc, stick) and advanced processes such as solid state and friction stir welding are used. Choice of the process is based on technical and/or economic reasons. For the most structural, economic and quality welds, TIG and MIG are recommended for aluminium.

E. Applications of Aluminium alloys

Applications of aluminium alloys include aircraft structures, construction of boats, bicycle frames and components, automobile parts, cans for packing of food stuffs and beverages. Aluminium alloys have good mechanical properties and also exhibit good weld ability. Aluminium based alloys are being widely used in automobile structures due to their unique properties such as high strength to eight ratio.

F. TIG Welding Aluminium alloys

TIG welding is widely used for welding aluminium, and it produces welds of good appearance and quality. A constant current AC power source with a continuous high frequency is used with water or air-cooled TIG torch and an externally supplied inert shielding gas. The AC process is used to provide a degree of cleaning of the aluminium surface during the electrode positive cycle though this is not a substitute for proper cleaning of the base material. The tungsten electrode diameter is usually about 2, 4 mm, and the method can be used with or without filler metal. The filler material is fed into the weld bead from outside. TIG welding gives the welder very good control, but welding speed is normally slower than for MIG which requires higher welder competence.

G. TIG welding and weld bead geometry

Basically, TIG weld quality is strongly characterized by the weld pool geometry. This is because the weld pool geometry plays an important role in determining the mechanical properties of the weld. Therefore, it is very important to select the welding process parameters for obtaining optimal weld pool geometry.

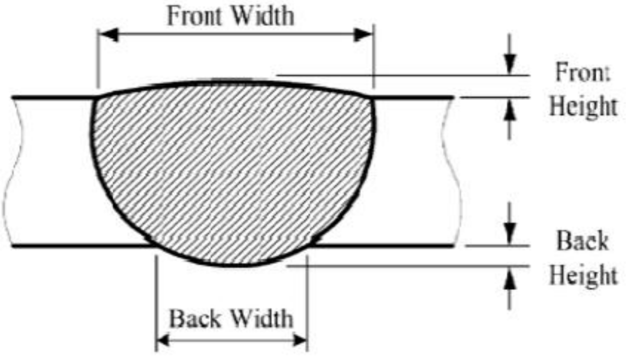

Fig. 3: Schematic diagram of weld bead geometry

H. Process parameter selection

The welding parameters are selected by operator based on experience or from a handbook. However, this does not ensure that the selected welding process parameters can produce the optimal or near optimal weld pool geometry for that particular welding machine and environment. A literature review has been done in this regards and an attempt has been made to analyse the effect of different process parameters on weld bead geometry.

II. LITERATURE REVIEW

Chandresh N. Patel used full factorial method for Design of Experiment for optimization work. By use of the experimental data optimal process parameter combination was achieved by grey relational analysis (GRA) optimization technique. In this work, input parameters for MIG welding were 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 was hardness. AISI 1020 or C20 material was used for welding. Experiments were performed on plates of thickness 5 mm and double V-groove joint is used. For Experimental design full factorial method ($L=m^n$) was used 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. Grey relational analysis (GRA) optimization technique was used for optimization of different values. A grey relational grade obtained from the grey relational analysis is used to optimize the process parameters. By use of ANOVA analysis the percentage contribution of MIG welding for welding current is obtained 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. By use of ANOVA analysis the percentage contribution of TIG welding for welding currents 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. From the ANOVA it is conclude that the welding current is most significant parameter for MIG and TIG welding. Welding current is found to have effect on hardness.

Increase in welding current, the value of hardness is increase in both welding. 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. 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 [1].

Dinesh Mohan Arya, Vedansh Chaturvedi, Jyoti Vimal studied to search out the optimum process parameters for Metal inert gas welding (MIG). The optimization of MIG welding process parameters was carried out for alloy steel work piece using grey relational analysis method and Taguchi method. The effect of welding parameters like wire diameter, welding current, arc voltage, welding speed, and gas flow rate were optimized based on bead geometry of welding joint. The objective function was 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. The signal to noise ratio (S/N ratio) is also applied to identify the most significant factor and predicted optimal parameter setting. Optimal parameters collection of the MIG operation was obtained via grey relational analysis for this study [2].

Palani. P.K, Saju. M applied Response Surface Methodology was used to conduct the experiments. The parameters selected for controlling the process are welding speed, current and gas flow rate. Strength of welded joints was tested by a UTM. Percent elongation was also calculated to evaluate the ductility of the welded joint. From the results of the experiments, mathematical models have been developed to study the effect of process parameters on tensile strength and percent elongation. Optimization was done to find optimum welding conditions to maximize tensile strength and percent elongation of welded specimen.
Confirmation tests were also conducted to validate the optimum parameter settings [3]. Prachya Peasuraa, Anucha Watanapab studied the effect of shielding gas parameter on mechanical properties and microstructures of heat-affected zone and fusion zone on gas tungsten arc welding (GTAW) in aluminium alloy AA 5083.
The factorial experiment was designed for this research. The factors of AA 5083 weld used in the study types of shielding gas in argon and helium, gas flow rate at 6, 10 and 14 liters per minute. Then the results were using microstructure and Vickers hardness test. The result showed that types of shielding gas and gas flow rate interaction hardness at heat affected zone and fusion zone with a P–value $< .05$. The factor which was the most effective to the hardness at heat affected zone and fusion zone was argon with a flow rate of 14 liters per minute at heat-affected zone with 74.27HV and fusion zone with 68.97HV. Experimental results showed that the argon condition provided smaller grain size, suitable size resulting in higher hardness both in weld metal and HAZ. They also indicated that the grain size and precipitation Mg affect the hardness of sample [4].

G. Haragopal, P V R Ravindra Reddy, G Chandra Mohan Reddy and J V Subrahmanyam presented a method to design process parameters that optimize the mechanical properties of weld specimen for aluminium alloy (Al-65032), used for construction of aerospace wings. The process parameters considered for the study were gas pressure, current, groove angle and pre-heat temperature. Process parameters were assigned for each experiment. The experiments were conducted using the L9 orthogonal array. Optimal process parameter combination was obtained. Along with this, identification of the parameters which were influencing the most was also done. This was accomplished using the S/N analysis, mean response analysis and ANOVA. They indicated that the Gas pressure is the most significant factor for proof stress. Optimum mechanical properties are found at a groove angle of 60 degrees. Current is the most influencing factor on UTS. Effect of pre-heat has a considerable effect on proof stress, % elongation and impact energy. Optimum condition for maximization of mechanical properties can be found using S/N analysis, mean response analysis and mechanical properties at optimum conditions can be predicted using this method [5].

III. CONCLUDING REMARKS

From above literature review it is indicated that

- Welding current, arc voltage, welding speed, type of shielding gas, shielding gas flow rate, etc. are the important control parameters of Gas Tungsten Arc Welding process.
- They affect the weld quality in terms of mechanical strength and weld bead geometry.
- The Factorial Design, Taguchi Method and Response Surface Methodology can be applied as the DOE (Design of Experiment).
- The methods that can be applied for welding process parameter optimization work are Grey Relation Analysis and ANOVA (Analysis of variance).
- MINITAB software is a useful aid for the above purpose.

IV. SCOPE OF WORK

Tungsten inert gas welding is one of the widely used techniques for joining ferrous and non-ferrous metals. TIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, absence of slag etc. TIG weld quality is strongly characterized by weld bead geometry. A high penetration to width ratio means a narrow weld. This also means a good quality of the weld.

The Aluminium alloys are challenging to weld due to their high thermal conductivity and absorptivity of Hydrogen causing porosity in weld pool. Hence it is proposed to go for TIG welding of Aluminium alloys. It is proposed to perform the process parameter optimization work for Gas Tungsten Arc welding. The DOE (Design of Experiment) shall be done by Response Surface Method.

Response Surface Methodology shall be used to conduct the experiments. The parameters selected for controlling the process are welding speed, current and gas flow rate. Strength of welded joints shall be tested by a UTM. Percent elongation shall also be calculated to evaluate the ductility of the welded joint. From the results of the experiments, mathematical models shall be developed to study the effect of process parameters on tensile strength and percent elongation. Optimization shall be done to find optimum welding conditions to maximize tensile strength and percent elongation of welded specimen. Confirmation tests shall also be conducted to validate the optimum parameter settings.

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