A Review on Effects of GMAW and GTAW Mechanical Properties on Weld Zone of Aluminium Alloy by Taguchi Design of Experiment Technique

Ram Gopal[1] and R.S. Jadoun[2]

Department of Industrial & Production Engineering[1, 2], G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

ABSTRACT

Gas metal arc welding (GMAW) and Gas tungsten arc welding (GTAW) is an arc welding process that uses a consumable and non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas, and a filler metal is normally used. The power is supplied from the power source, through a hand-piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is created between the tungsten electrode and the work piece using a constant current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapors. The optimization of parameter of tungsten inert gas arc welding on the morphology, microstructure, tensile and hardness properties of welded joints of aluminium alloy have been studied. Results show that the increase of welding current and the decrease of welding speed bring about the large amount of heat input in the welding pool and the enlargement of width and deepness of the welding pool. The increase of impulse frequency has the same effect on the microstructure compared with the increase of welding current. The effect of welding parameters on the tensile strength and hardness was analyzed. It is found that the root of welding joint is unwelded when the welding current is lower, so that the strength and the elongations of welded joint are inferior. This paper reviews the research work carried out from the inception to the Parameters optimization for GMAW and GTAW of aluminium alloy 3003-H_2 (IS-737) by Taguchi design of experiment technique of welded joint. Within the past decade & also briefly describing the current research technique and GMAW and GTAW research direction.

Keywords - GMAW, GTAW, Mechanical properties, Shielding gas, non consumable, consumable Electrode, DOE, Taguchi, ANOVA.

1. INTRODUCTION

Welding is a manufacturing process of making a permanent joint obtained by fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler (same or different) materials through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding processes has been developed. During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be achieved. Among all types of welding processes arc welding is widely used for different types of materials. Common types of arc welding process are:

1. Gas Metal Arc Welding (GMAW) or Metal inert or active gas welding: (MIG/MAG): In this type of welding process a continuous and consumable wire electrode is used. A shielding gas generally argon or sometimes mixture of argon and carbon dioxide are blown through a welding gun to the weld zone. MIG welding, also known as Gas Metal Arc Welding (GMAW), is a process that utilizes a continuously fed solid electrode, shielding gas from an externally supplied source, and electrical power to melt the electrode and deposit this molten material in the weld joint[6].
   - Electrode – composition, diameter and packaging
   - Shielding Gas – type (composition), purity and flow rate
   - Process Variables – current, voltage, mode of metal transfer and travel speed
   - Equipment – power source, welding gun and wire feeder
2. Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas (TIG): GTAW or TIG welding process is an arc welding process uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. With the

development of TIG welding process, welding of difficult to weld materials e.g. Aluminium and Magnesium become possible [24].

MIG and TIG 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) and tungsten inert gas (TIG) 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. MIG and TIG welding is a gas shielded process that can be effectively used in all positions [39].

a. GMAW/GTAW can be done in three different ways

- **Semiautomatic Welding:** equipment 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 [36].

b. WORKING PRINCIPLE OF MIG WELDING

Gas metal arc welding (GMAW) is an arc welding process which incorporates the automatic feeding of a continuous, consumable electrode that is shielded by an externally supplied gas. Since the equipment provides for automatic self regulation of the electrical characteristics of the arc and deposition rate, the only manual controls required by the welder for semiautomatic operation are gun positioning, guidance, and travel speed. The arc length and the current level are automatically maintained. Process control and function are achieved through these three basic elements of equipment as shown in Fig. 1:

- Gun and cable assembly
- Wire feed unit
- Power source

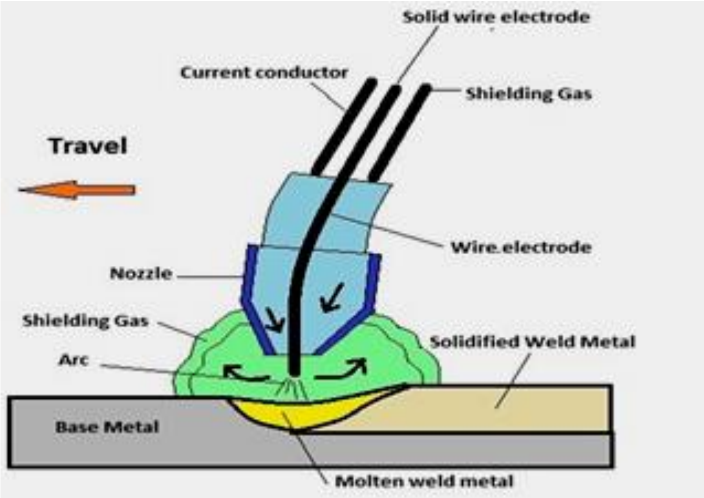

Fig. 1 GMAW operatation process [18]

2. APPLICATIONS OF MIG WELDING

- The process can be used for the welding of carbon, silicon and low alloy steels, stainless steel, aluminium, copper, nickel, and their alloys, titanium etc.
- For welding tool steel and dies.
- MIG welding has been used successfully in industries like aircraft, automobile, pressure vessel, and ship building.
- Due to increases in speed and efficiency, MIG welding is well suited for fabrication and manufacturing.

3. 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 [11].

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

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.

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.

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

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.

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.

4. WORKING PRINCIPLE OF TIG WELDING

The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000oC and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding are shown in fig. 1 & fig. 2 respectively.

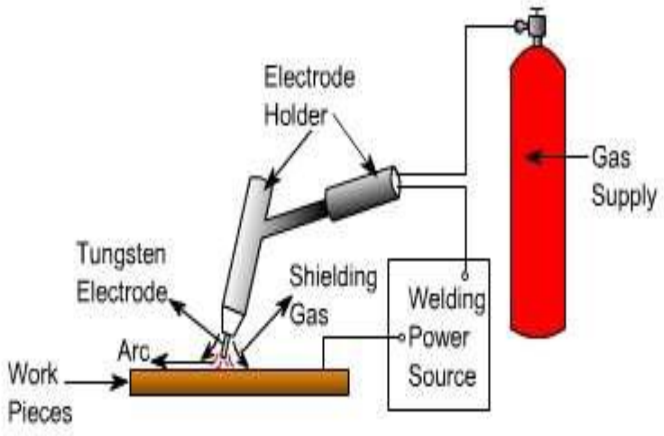

Fig. 2 Working process of GTAW [24]

Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and 150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source (en.wikipedia.org/wiki/GTA).

5. Applications of GTAW

The TIG welding is a highly controllable and clean process needs very little finishing or sometimes no finishing. This welding process can be used for both manual and automatic operations. The TIG welding process is extensively used in the so-called high-tech industry applications such as:

- Nuclear industry
- Aircraft
- Food processing industry
- Maintenance and repair work
- Precision manufacturing industry
- Automobile industry
- The offshore industry
- Combined heat and power plants
- The petrochemical industry
- The food industry
- The chemical industry
- The nuclear industry

6. TIG WELDING EFFECTING PARAMETERS

Electrode size: Pure tungsten electrodes can be used for TIG welding. Thoriated and zirconiated types give easier starting and better arc stability and are generally preferred. Thoriated tungsten electrodes contain 2% thoria (thorium oxide) and are used for dc welding. Zirconiated tungsten electrodes contain 2% zirconia (zirconium oxide) and are recommended for arc welding of aluminium. The diameter of the electrode is chosen to match the current. The minimum current depends on arc stability. The maximum current a given diameter of electrode can carry is determined by the onset of overheating and melting [6].

Welding current: Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials. Fixed current mode will vary the voltage in order to maintain a constant arc current.

Welding voltage: Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance. Too high voltage, can lead to large variable in welding quality.

Shielding gas: The choice of shielding gas is depends on the working metals and effects on the welding cost, weld temperature, arc stability, weld speed, splatter, electrode life etc. it also affects the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness and brittleness of the weld material. Argon or Helium may be used successfully for TIG welding applications. For welding of extremely thin material pure argon is used. Argon generally provides an arc which operates more smoothly and quietly. Penetration of arc is less when Argon is used than the arc obtained by the use of Helium.

Travel speed: Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed or travel speed is primarily control the bead size and penetration of weld. It is interdependent with current. Excessive high welding speed decreases wetting action, increases tendency of undercut, porosity and uneven bead shapes while slower welding speed reduces the tendency to porosity [33].

7. LITERATURE REVIEW

1. GMAW of aluminium and others alloy

James, M.N. et al. (2008) [1] investigation of the single-line residual stress profiles for 8 mm 5083-H321 aluminium plates joined by gas metal arc (MIG) welding. The data were obtained by synchrotron diffraction strain scanning. Weld metal stresses (up to 7 mm either side of the centreline) are quite scattered and unreliable because of the large epitaxial grain size in the fusion zone. The effect on residual stress and strain values of a sequence of applied fatigue loads was also considered and reported.

Simone Matteı, et al. (2009) [2] studied in the order to deepen the understanding of the differences between laser and laser-arc hybrid welding, comparisons were undertaken using thermograph. The experiments were carried out for a T assembly of aluminium alloy plates. Modelling, based on the finite element method approach, was realized using IR temperature measurements and seam geometry.

Manoj Singla, et al. (2010) [3] discussed Gas Metal Arc Welding is a process in which the source of heat is an arc format between consumable metal electrode and the work piece with an externally supplied gaseous shield of gas either inert such as argon, helium. This experimental study aims at optimizing various Gas Metal Arc welding parameters including welding voltage, welding current, welding speed and nozzle to plate distance (NPD) by developing a mathematical model for sound weld deposit area of a mild steel specimen.

Suresh Kumar, L. at al. (2011) [4] In this Paper we discussed about the mechanical properties of austenitic stainless steel for the process of TIG and MIG welding. As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW or MIG welding is used to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embitterment if they come in contact with the electrode, the arc, or the welding metal.

Lihui, Lu. et al. (2012) [5] discussed the double-variable decoupling control scheme was proposed for GMAW-P process of aluminium helping to efficiently develop welding procedure. Weld pool width and arc length were both measured through vision sensing in welding process. Weld bead shape was improved by changing the current waveforms to adjust the heat input while the arc length was controlled to stabilize the welding process.

Pawan Kumar, et al. (2013) [6] investigated about the 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.

Patil, S.R. et al. (2013) [7] discussed 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.

Priti Sonasale, et al. (2014) [8] carried out the Metal arc Welding (MIG) process finds wide application because 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.

Deepak Kumar, et al. (2014) [9] discussed Gas metal arc welding is a fusion welding process having wide applications in industry. The process parameters play a very significant role in determining the quality of a welded joint in Gas Metal Arc Welding (GMAW). L9 orthogonal array of Taguchi`s experimental design was used for optimization of welding current, voltage and gas flow rate on welded joints.

Mohan, B. et al. (2014) [10] carried out 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 variance (ANOVA) are used to find out the welding characteristics and optimization parameters.

Satyaduttsinh, P. et al. (2014) [11] investigated the MIG 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 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 optimize and having the best parameters combination for target quality.

Costa, J.D.M. et al. (2014) [12] observation of Friction stir processing (FSP) is an emerging metalworking technique that can provide localized modification and control of microstructures in near-surface layers of processed metallic components. In this research the FSP was applied on Metal Inert Gas (MIG) T-fillet welds performed in 6082-T651 aluminium alloy plates of 6 mm thickness. FSP potential benefits were studied through microstructural analysis, hardness measurements, tensile strength and fatigue testing.

De Jesus, J.S. et al. (2014) [13] studied of several tool geometries were developed and their effect on weld morphology, material flow, microstructure and hardness of processed regions was analyzed. Their effect on fatigue strength of welds was also examined for the most promising tools. The feasibility of FSP MIG T welds was proved.

Vivek Saxena, et al. (2015) [14] discussed days Alloy of aluminium is widely used due to its versatility especially in automotive industry. Most of the component is made by casting but some may require welding too. These components are loaded statically and dynamically as per application. Due to these reason corresponding strength is needed to be insured for the product having welded joint. This paper unveiled the influence of welding parameters on tensile strength of AM-40(EN AW 5083) aluminium alloy material during welding. A Set of experiments on MIG Welding Set up based on Taguchi technique has been used.

Vikas Chauhan, et al. (2015) [15] studied scope of arc-welding, have increased in the various engineering field like aerospace, nuclear, and underwater industries where complex geometry and hazardous environments necessitate fully automated systems. Even traditional applications of arc welding such as off-highway and automotive manufacturing have increased their demand in quality, cost, accuracy, and volume to stay competitive.

Prasenjit Mondal, et al. (2015) [16] discussed the dissimilar metal welded joints are integral parts of modern-day power and process plant equipment. Among the various types of material combinations, welded joints of austenitic stainless steels and mild steel are very common in nuclear and chemical industries. The dissimilar metal joints have been emerged as a structural material for various industrial applications which provides good combination of mechanical properties like strength, corrosion resistance with lower cost. Selections of joining process for such materials are difficult because of their physical and chemical properties.

Mohit Singhmar, et al. (2015) [17] discussed the objective of this research was to study influence parameters affecting to mechanical property of austenitic stainless steel grade 304 (AISI 304) with Gas Metal Arc Welding (GMAW). The research was applying Taguchi Method on an austenitic stainless steel specimen of dimensions 110 × 40 × 3 mm, which have following interested parameters: arc current at 150, 200, and 250 Amps, gas flow rate at 10, 20, and 30 kg/hr and arc voltage at 15, 20 and 25 Volt. The study was done in following aspects: Ultimate tensile strength. The present paper aims at the study of factors affecting to mechanical property of austenitic stainless steel with Gas Metal Arc Welding (GMAW) at different welding parameters.

Hee-keun Lee, et al. (2015) [18] discussed an asymmetric undercut and black-colored deposit (smut) are created on the surface of Plasma-MIG Hybrid (PMH) weld in Al alloys. For the purpose of defect formation control, the effect of plasma current on surface defects in the PMH weld was investigated through arc phenomena with high speed imaging and metallurgy analysis as compared with MIG weld. It was found that the asymmetric undercut is created near the left fusion line of PMH welds by the electromagnetic stirring force induced by high plasma currents over 200 A. Consequently, the plasma current influences the weld pool flow and type of smut by changing the metal transfer mode and strong plasma arc forces.

Vineeta Kanwal, et al. (2015) [20] parametric optimization of MIG welding for Hardness has been performed by using Taguchi method. Welding Speed, Welding Current and Welding Voltage were chosen as welding parameters. The materials used for this purpose were aluminium alloys of grades 6061 and 5083 having dimensions (75x60x6) mm. Argon was used as a shielding gas. Filler wire 4043 of diameter 1.2 mm was used. An orthogonal array, L9 was used to conduct the experiments. Signal to noise (S/N) ratio and analysis of variance (ANOVA) were employed to study the welding characteristics of material. Optimization of parameters was done by Taguchi method using statistical software MINITAB-17. Confirmation tests were carried out with optimal levels of welding parameters to validate the Taguchi's optimization method. Measurement tests were conducted on Rockwell hardness testing machine.

8. GTAW of aluminium and others alloy

Wang Rui, et al. (2008) [22] carried out the dynamic progress and residual distortion of out-of-plane of aluminium alloy 5A12 were investigated under different welding conditions of TIG welding. The dynamic out-of-plane distortion was measured by self-developed distortion measuring system. Out-of-plane distortion mechanism and the effecting parameters on distortion process were analyzed, and the effect of plate thickness and welding heat input on distortion was discussed.

Jun Yan, et al. (2009) [23] investigated the microstructure and mechanical properties of 304 stainless steel joints by tungsten inert gas (TIG) welding, laser welding and laser-TIG hybrid welding. The X-ray diffraction was used to analyze the phase composition, while the microscopy was conducted to study the microstructure characters of joints. Finally, tensile tests were performed and the fracture surfaces were analyzed.

Ahmed khalid Hussain, et al. (2010) [24] discussed Tungsten Inert Gas welding is one of the widely used techniques for joining ferrous and non ferrous metals. TIG welding process offers several advantages like joining of unlike metals, low heat effected zone, absence of slag etc compared to MIG welding. The accuracy and quality of welded joints largely depends upon type of power supply (DCSP or DCRP or ACHF), welding speed, type of inert gas used for shielding.

Wang, Q. et al. (2011) [25] investigated the influences of parameters of tungsten inert gas arc welding on the morphology, microstructure, tensile property and fracture of welded joints of Ni-base super alloy have been studied. Results show that the increase of welding current and the decrease of welding speed bring about the large amount of heat input in the welding pool and the enlargement of width and deepness of the welding pool. The increase of impulse frequency has the same effect on the microstructure compared with the increase of welding current. The effect of welding parameters on the tensile strength and fracture was analyzed

Parthiv, T. et al. (2012) [26] investigated Gas tungsten arc welding, GTAW, is one of the widely used techniques for joining ferrous and non-ferrous metals. In this study experiments were carried out as per central composite design and regression analysis was conducted to determine input output relationships of the process.

Pasupathy, J. et al. (2013) [27] carried out 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.

Anoop, C. A. et al. (2013) [28] discussed Aluminium alloy 7039 is an Al-Mg-Zn alloy employed in aircraft, automobiles, infantry combat vehicles and high speed trains due to their low density, high specific strength and excellent corrosion resistance. Pulsed Gas Tungsten Arc Welding is used in this study for welding AA7039. The influence of the various GTAW process parameters, i.e. Pulse Current, Base current and Pulse Frequency on welds were studied for properties of weld like microhardness, ASTM grain size number and heat affected zone (HAZ) width.

He Lin, et al. (2014) [29] studied the hot rolled plates of high boron Fe-Ti-B alloys were butt-welded by gas tungsten arc welding (TIG) using base metal as the filler. The microstructures of the TIG weld joints were analyzed. 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. The microstructures of the weld metal and the heat affected zone are different from that of the base metal significantly.

Sivasankaran, A. et al. (2015) [30] carried out Tungsten Inert Gas (TIG) welding is one of the most widely used processes in industry. The welding parameters are the most important factors affecting the cost and quality of welding. This paper pertains to the improvement of ultimate tensile strength of Aluminium 8011 weld specimen made of tungsten inert gas welding. A plan of experiments based on Taguchi method has been used. L16 orthogonal array has been used to conduct the experiments at different levels of welding parameters like pulse current, peak current, pulse frequency and pulse duty cycle.

Ahir, S.M. et al. (2015) [31] discussed about Tungsten Inert Gas (TIG) welding is a widely applied manufacturing process. The present work carried on the optimization of weld process parameters with Taguchi approach for the distortion control applied to Austenitic stainless steel 316 structures of 8.5 mm thickness with two pass TIG weld process. Taguchi is applied for the optimization of weld parameters control. In this study the distortion of TIG, welding process was evaluated using weld current, Weld Angle and the weld speed as the main parameters.

Jeyaprakash, N. et al. (2015) [32] describe the number of welding methods available for welding materials such as shielded metal arc welding, Gas metal arc welding, Flux cored arc welding, submerged arc welding, electro slag welding, electron beam welding, and Gas Tungsten arc welding methods. In this case study, we discuss the influence of the power source, type of current, gas flow rate, electrodes, filer wire, TIG Machines settings, and shielding gases which are most important in determine arc stability, arc penetration and defect free welds.

Balaram Naik, A. et al. (2016) [33] investigated the welding process was conducted using the TIG (Tungsten Inert Gas) welding technique. TIG is used very commonly in areas, such as rail car manufacturing, automotive and chemical industries. Duplex Stainless steel (2205) is extensively used in industries as an important material, because of its excellent corrosion resistance, higher yield strength and hardness.

9. GMAW and GTAW of aluminium and other alloy

Sushil Kumar Kamat, et al. (2013) [34] carried out the FSW is a solid state new joining process that is presently attracting considerable interest. In this process the two pieces of metal are mechanically intermixes at the place of join, then often them so that the metal can be fused using mechanical pressure. Some aluminium alloys can be welded with electrical resistance techniques, TIG, MIG provided that an extensive surface preparation and the oxide formation is controlled. On the contrary, FSW can be used with success to weld most of Al alloys considering that superficial oxide generation is not deterrent for the process and no particular cleaning operations are needed before welding.

Saurabh Kumar Khotiyan, et al. (2014) [35] investigated the Tungsten Inert Gas welding and MIG (Metal Inert Gas) welding are well known welding techniques, that are using in industries in current age. Aluminium is the most commonly used material in all industries. Aluminum is the second material in case of annual consumption after steel. Pure aluminum melts at 6600C, and its alloys at slightly lower temperature.

The hardness of the weld metal is measured with the help of the Rockwell hardness testing machine at B grade (HRB) and the values of the hardness in the weld region is shown in the following Table 1.

Table 1 Hardness of the weld region

Types of Welding	Hardness of weld region (HRB)
MIG	39
TIG	43

Different types of tensile properties of welded aluminium alloy AA6061 were evaluated such as yield strength, ultimate tensile strength, percentage elongation and joint efficiency. For each condition three specimens were tested and the average properties of the welded joints are taken, these properties are shown in the following Table 2

Table 2 Tensile properties of welded joints

Type of Joint	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)	Joint Efficiency (%)
MIG	140	160	7.2	51.2
TIG	170	200	10.1	64.3

In this study the microstructure of each and every joint has been examined at different locations of the joint. But it is found the joint mainly break/failed at the fusion zone, hence only the microstructure of the weld fusion zone is studied. The weld fusion zone microstructures of different welding processes are shown in the Fig. 3

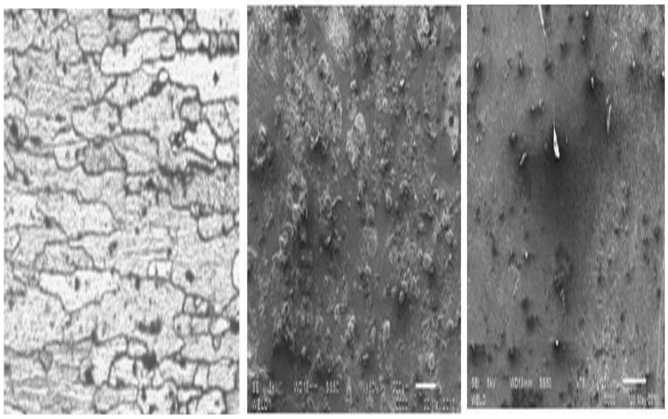

Fig. 3 Microstructure of weld zone at 200μm scale

After the welding by MIG and TIG mechanical properties and microstructure of welds have been tested and following conclusions can be drawn.

The impact strength of TIG joints is higher than that of the MIG joints.

- It is found that hardness in weld metal region is less than that of the BM. The maximum hardness is found in TIG and the minimum hardness is found in MIG welded joint. The hardness pattern in the weld region in two welding processes is like, TIG > MIG.
- In case of TIG the microstructure is very fine and equiaxed, having uniformly distributed grains with strengthening precipitates as compared to MIG welding processes in which dendritic grain structures is found. Because of fine grain structure the TIG joint possesses good tensile and mechanical properties than that of the MIG welding processes.

On the basis of the above discussion it can be elaborate that the TIG is the best suitable welding process to join aluminium alloy AA6061 as compared to MIG welding processes [56].

Er. Rahul Malik, et al. (2015) [36] investigated 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 varies. 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.

Simhachalam, D. et al. (2015) [37] studied the effect of welding process parameters on the mechanical properties of stainless steel 304(18Cr-8 Ni) welded joint obtained by TIG welding. The welding parameters like welding current, Gas flow rate and filler rod diameter have varying degree of influence on the properties of the welded joint. Impact strength and hardness are determined at Welded Zone. Specimens of size 40x15x5 mm are taken for experimentation it is observed that the welding current has a significant effect on the welding parameters as compared to the filler rod diameter.

10. DESIGN OF EXPERIMENT [DOE]

Design of Experiments (DOE) is a powerful statistical technique introduced by R. A. Fisher in England in the 1920's to study the effect of multiple variables simultaneously. The DOE using Taguchi approach can economically satisfy the needs of problem solving and product/process design optimization projects. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time required for experimental investigations. DOE is a technique of defining and investing all possible combinations in an experiment involving multiple factors and to identify the best combination. Therefore, the objective of a carefully planned designed experiment is to understand which set of variables in a process affects the performance most and then determine the best levels for these variables to obtain satisfactory output functional performance in products.

11. ADVANTAGES OF DESIGN OF EXPERIMENTS ARE AS FOLLOWS

- Number of trials is significantly reduce
- Important decision variables which control and improve the performance of the product or the process can be identified.
- Optimal setting of the parameters can be found out.
- Qualitative estimation of parameters can be made.
- Experimental error can be estimated.
- Inference regarding the effect of parameters on the characteristics of the process can be made.

Thus Design of experiment (DOE) is a method to identify the important factors in a process, identify and fix the problem in a process, and also identify the possibility of estimating interactions.

12. DOE FOR STUDY OF PROCESS PARAMETER EFFECTS IN WELDING

Following are the DOE techniques used process parameter optimization work in welding

- Full factorial technique
- Fractional factorial technique
- Taguchi orthogonal array
- Response Surface method (Central Composite design)

ANOVA stands for Analysis for Variance and it is the tool used for the analysis of contribution of each process parameter on response parameter. Mathematical models are used to establish the relationship between the input and output parameters in welding processes.“MINITAB” and “Design Expert” are the software used for DOE techniques and ANOVA.

13. CONCLUDING REMARK

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 AISI1045 Medium carbon steels so we want to do research on this material. We like to use Design of experiment for parametric optimization. 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.

14. SCOPE OF THE WORK

Metal inert gas welding is one of the widely used techniques for joining ferrous and non ferrous metals. MIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, there is no slag to clean off after welding because no flux used.MIG weld quality is strongly characterized by weld bead geometry. In MIG Welding method, we will optimize other parameters which are not used in this experiment and This experiment will be done for same method or workspace 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.

15. ACKNOWLEDGEMENT

This is to acknowledge that sincere thanks to Dr. R. S. Jadoun Professor & Head Department of Industrial and Production Engineering, College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India co-operate to get the work Successfully and all others from IPED, Pantnagar who assisted me in bringing out this work successfully.

REFERENCES

1.GMAW of aluminium and others alloy

[1]. James M.N, D.J. Hughes, D.G. Hattingh, G. Mills, P.J. Webster (2008) “Residual stress and strain in MIG butt welds in 5083-H321 aluminium As-welded and fatigue cycled” International Journal of Fatigue, 31volume, 28–40.

[2]. Simone Matteı, Dominique Grevey, Alexandre Mathieu, LaetitiaKirchner (2009) “Using infrared thermography in order to compare laser and hybrid (laser+MIG) welding processes” Optics & Laser Technology, 41 volume, 665–670.

[3]. Manoj Singla, Dharminder Singh, Dharmpal Deepak (2010) “Parametric Optimization of Gas Metal Arc Welding Processes by Using Factorial Design Approach” Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.4, pp.353-363.

[4]. Mr.L.Suresh Kumar1 Dr.S.M.Verma, P.RadhakrishnaPrasad, P.Kiran kumar, Dr.T.Siva Shanker (2011) “Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Process of TIG & MIG Welding” International Journal of Engineering Trends and Technology- Volume2, Issue2.

[5]. Lihui Lu, Ding Fan, Jiankang Huang, Yu Shi (2012) “Decoupling control scheme for pulsed GMAW process of aluminum” Journal of Materials Processing Technology, Volume 212, Issue 4, Pages 801–807.

[6]. Pawan Kumar, Dr.B.K.Roy, Nishant (2013) “Parameters Optimization for Gas Metal Arc Welding of

Austenitic Stainless Steel (AISI 304) & Low Carbon Steel using Taguchi's Technique" International Journal of Engineering and Management Research, Vol.-3, Issue-4, August 2013, ISSN No.: 2250-0758.

[7]. **Patil S.R, C. A. Waghmare (2013)** "optimization of MIG welding parameters for improving strength of welded joints" International Journal of Advanced Engineering Research and Studies, E-ISSN2249–8974.

[8]. **Priti Sonasale (2014)** "An Approach to Optimize MIG Welding Parameters by Using Design of Experiments" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),), e-ISSN: 2278-1684,p-ISSN: 2320- 334X, Volume 11, Issue 6 Ver. IV PP 72-84.

[9]. **Deepak Kumar and Sandeep Jindal (2014)** "Optimization of Process Parameters of Gas Metal ARC Welding by Taguchi's Experimental Design Method" International Journal of Surface Engineering & Materials Technology, Vol. 4, No. 1, January, ISSN: 2249-7250.

[10]. **Mohan B. Raut, S. N. Shelke (2014)** "Optimization of Special Purpose Rotational MIG Welding by Experimental and Taguchi Technique" International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-4 Issue-6.

[11]. **Satyaduttsinh P. Chavda, Jayesh V.Desai, Tushar M.Patel (2014)** "A Review on Optimization of MIG Welding Parameters using Taguchi's DOE Method International Journal of Engineering and Management Research, Volume-4, Issue-1, ISSN No.: 2250-0758.

[12]. **Costa J.D.M, J.S. Jesus, A. Loureiro, J.A.M. Ferreira, L.P. Borrego (2014)** "Fatigue life improvement of MIG welded aluminium T-joints by friction stir processing" International Journal of Fatigue, Volume 61, Pages 244–254.

[13]. **de Jesus J.S, A. Loureiro, ,J.M. Costa, J.M. Ferreira (2014)** "Effect of tool geometry on friction stir processing and fatigue strength of MIG T welds on Al alloys" Journal of Materials Processing Technology, Volume 214, Issue 11, Pages 2450–2460.

[14]. **Vivek Saxena, Prof. Mohd. Parvez, Saurabh (2015)** "Optimization of MIG welding parameters on tensile strength of aluminum alloy by taguchi approach" international journal of engineering sciences & research technology, publication impact factor: 3.785, issn: 2277-9655.

[15]. **Vikas Chauhan and Dr. R. S. Jadoun (2015)** "Parametric optimization of MIG welding for stainless steel (ss-304) and low carbon steel using taguchi design method" International Journal of Recent Scientific Research, Vol. 6, Issue, 2, pp.2662-2666.

[16]. **Prasenjit Mondal, Dipankar Bose (2015)** "Optimization of the process parameters for MIG welding of aisi 304 and is 1079 using fuzzy logic method International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 08, e-ISSN: 2395 -0056, p-ISSN: 2395-0072.

[17]. **Mohit Singhmar and Nishant Verma (2015)** "Experimental study for welding aspects of austenitic stainless steel(aisi 304) on tensile strength by taguchi technique" International Journal of Mechanical Engineering and Robotics Research, Vol. 4, No. 1, ISSN 2278 – 0149.

[18]. **Hee-keun Lee, Sang-hyeon Park, Chung-Yun Kang (2015)** "Effect of plasma current on surface defects of plasma-MIG welding incryogenic aluminum alloys" Journal of Materials Processing Technology, 223volume, 203–215.

[19]. **http://www.praxairdirect.com/Industrial-Gas-and-Welding-Information-Center/Welding-Tips-Tricks-and-Information/MIG-Welding.html.**

[20]. **Vineeta Kanwal1, R S Jadoun (2015)** "Optimization of MIG Welding Parameters for Hardness of Aluminium Alloys Using Taguchi Method" SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume 2 Issue 6.

[21]. **http://www.millerwelds.com/resources/tech_tips/TIG_tips/setup.html**

2. GTAW of aluminium and others alloy

[22]. **Wang Rui, Liang Zhenxin, Zhang Jianxun (2008)** "Experimental Investigation on Out-of-Plane Distortion of Aluminum Alloy 5A12 in TIG Welding" Rare Metal Materials and Engineering Volume 37, Issue 7, July 2008.

[23]. **Jun Yan, Ming Gao, Xiaoyan Zeng (2009)** "Study on microstructure and mechanical properties of 304 stainless steel joints by TIG, laser and laser-TIG hybrid welding" Optics and Lasers in Engineering 48 (2010) 512–517.

[24]. **Ahmed khalid hussain, abdul lateef, mohd javed, pramesh (2010)** "Influence of welding speed on tensile strength of welded joint in TIG welding process" international journal of applied engineering research, dindigul volume 1, no 3, 2010.

[25]. **Wang Q, D.L.Sun, Y.Na, Y.Zhou, X.L.Han, J. Wang (2011)** "Effects of TIG Welding Parameters on Morphology and Mechanical Properties of Welded Joint of Ni-base Superalloy" Procedia Engineering 10 (2011) 37–41.

[26]. **Parthiv T. Trivedi, Ashwin P. Bhabhor (2012) "**Experimental Investigation of Process Parameters on Weld Bead Geometry for Aluminium Using GTAW" International Journal of Science and Research (IJSR), ISSN (Online): 2319-7064, Impact Factor: 3.358.

[27]. **Pasupathy J, V.Ravisankar (2013)** "parametric optimization of TIG welding parameters using taguchi method for dissimilar joint" International Journal of Scientific & Engineering Research, Volume 4, Issue 1, ISSN 22295518.

[28]. **Anoop C A, Pawan Kumar (2013)** " Application of Taguchi Methods and ANOVA in GTAW Process Parameters Optimization for Aluminium Alloy 7039" International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 11

[29]. **He Lin, Liu Ying, Li Jun, Li Binghong (2014)** "Microstructure and Mechanical Properties for TIG Welding Joint of High Boron Fe-Ti-B Alloy" Rare Metal Materials and Engineering Volume 43, Issue 2, February 2014.

[30]. **Sivasankaran A (2015)** "Taguchi Optimization of TIG Welding for Maximizing Weld Strength of Aluminium 8011" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Special Issue 6, ISSN(Online) : 2319 – 8753.

[31]. **Ahir S.M, N.B. Patel, K.A.Patel (2015)** "Experimental Investigation of welding distortion of Austenitic Stainless Steel 316 in TIG Welding" IJARIIE-ISSN(O)-2395-4396, Vol-1 Issue-2.

[32]. **Jeyaprakash N, Adisu Haile, M.Arunprasath (2015)** "The Parameters and Equipments Used in TIG Welding: A Review" The International Journal Of Engineering And Science (IJES), Volume 4 Issue 2 Pages PP.11-20, ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805.

[33]. **Balaram Naik A, A.Chennakesava Reddy (2016)** "Experimental Analysis of TIG Welding and Comparison between Activated-TIG and TIG on Duplex Stainless Steel (2205)" International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016, ISSN 2229-5518.

3. GMAW and GTAW of aluminium and other alloy

[34]. **Sushil Kumar Kamat and Ajay Kumar (2013)** "An experimental investigation of mechanical properties of Al 6106 t6 alloy joined by Friction Stir Welding and TIG welding" International Journal of Innovations in Engineering and Technology (IJIET).

[35]. **Saurabh Kumar Khotiyan and Sandeep kumar (2014)** "Investigation of Microstructure and Mechanical Properties of TIG and MIG Welding Using Aluminium Alloy" International Journal of Education and Science Research Review Volume-1, Issue-5, ISSN 2348-6457.

[36]. **Rahul Malik, Er. Surjeet Gahlot, Dr. S.K. Jaria (2015)** "Parameters Optimization for Tensile Strength & Hardness of MIG Welding Joint of HSS & Mild Steel by Using Taguchi Technique", International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 4 Issue 8.

[37]. **Simhachalam D, N. Indraja, M. Raja Roy (2015)** "Experimental Evaluation of Mechanical Properties of Stainless Steel by TIG Welding at Weld Zone", International Journal of Engineering Trends and Technology (IJETT) – Volume 26 Number 3.

