International Journal of Material Sciences and Technology.
ISSN 2249-3077 Volume 10, Number 1 (2020), pp. 1-14

http://www.ripublication.com

Process Parameters for Metal Inert Gas Welding of Mild Steel by Using Taguchi Technique – A Review

Dr. S V Anil Kumar[*1], **Dr. R Gandhinathan**[2]

[*1]*Assistant Professor, Department of Mechanical Engineering, PES College of Engineering,Mandya-571401, India.*

[2]*Professor, Department of Production Engineering, PSG College of Technology, Coimbatore*-641004*, India.*

Abstract

The present review paper, study the effect of different process parameters such as welding current, voltage, gas flow rate, welding speed and gas pressure on mechanical properties like tensile strength and percentage of elongation of MIG welded joints of AISI 1018 mild/low carbon steel plates.MIG welding is a high deposition rate welding process in which wire is continuous feed from a gun or spool. MIG welding offers several advantages like all position capable, long weld can be made, no slag etc. Optimization was done to find optimum welding conditions to maximize tensile strength and percentage elongation of welded joints. The confirmation test was also conducted to validate the optimum parameters settings. From the review papers study, it is found that when the welding current, voltage, Gas Flow Rate increased, the tensile strength decreases, but when welding speed increases, the tensile strength also increases forAISI 1018 steel weld joint.AISI 1018 is non-hardenable ductile steel belonging to low carbon steel categories. It has been widely used for machining applications like machine parts, rod, bolts, studs etc. It shows that good weld ability and also used for carburized parts.

Keywords: MIG welding, AISI 1018, optimization, orthogonal array, process parameters,

1. INTRODUCTION

Welding is a process of joining two similar and dissimilar metals with the application of heat and pressure, but in some cases without the application of pressure the process has been done. The filler wire is used to join the metal in Metal Inert Gas (MIG) welding process with the help of spool gun. MIG Welding is used for making permanent joints. It is used for the manufacturing of automobile parts, railway wagons, aircraft frames, machine parts, tanks, structural works, boilers, ship building furniture etc. Welding is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The arc and the weld pool are shielded from atmospheric contamination by passing a suitable gas through the nozzle to form a protective shield around the welding area as shown in Figure. 1.

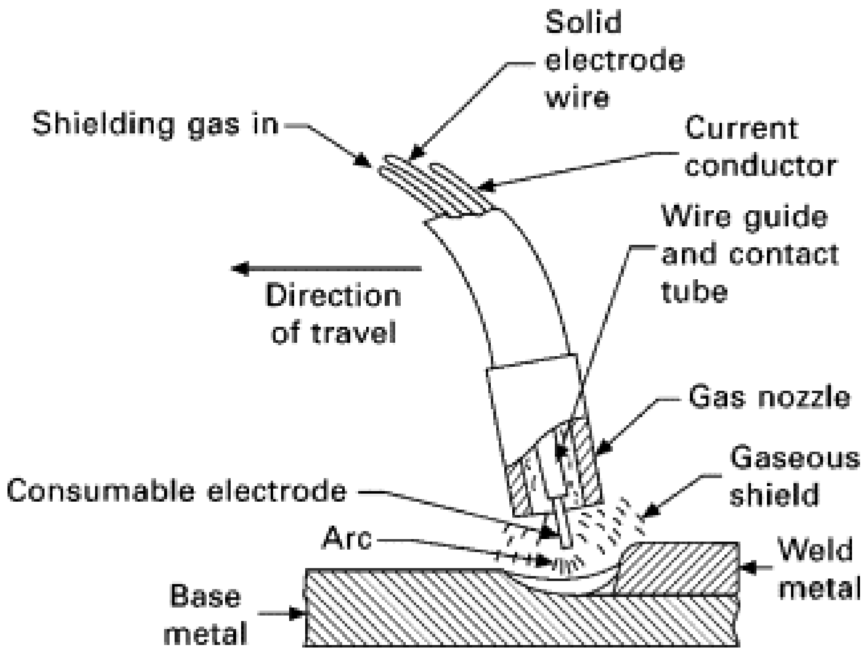

Figure. 1 Gas Metal Arc Welding Process [1]

The problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality. Traditionally, it has been necessary to study the weld input parameters for welded product to obtain a welded joint with the required quality. To do so, requires a time-consuming trial and error development method. Then welds are examined whether they meet the requirement or not. Finally the weld parameters can be chosen to produce a welded joint that closely meets the joint qualities. Also, what is not achieved or often considered is an optimized welding parameters combination, since welds can often be formed with very different parameters. In other words, there is often a more ideal welding input parameters combination, which can be used.

In order to overcome this problem, various optimization methods can be useful to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. Design of experiment (DoE) techniques has been applied to carry out such optimization. Taguchi methods have been adapted for many applications in different areas.

1.1 Types of welding joint

According to the American Welding Society, there are basically five types of welding joints and these are Butt, Corner, Lap, Tee and edge joint as shown in figure2.

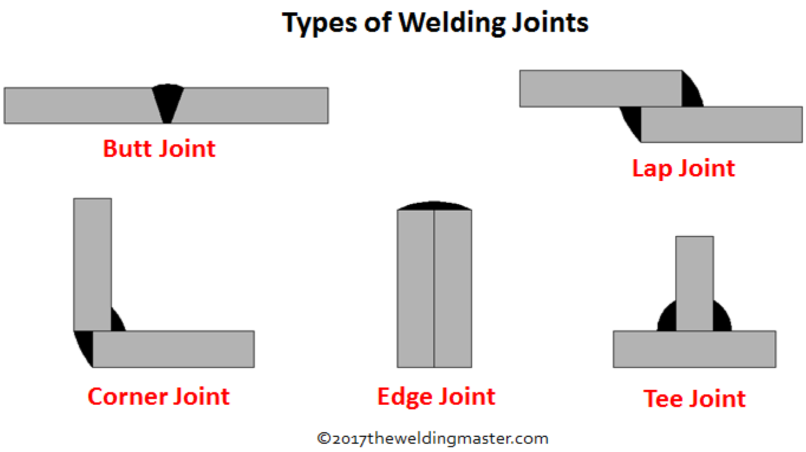

Figure 2. Types of welding joints [2]

1.1.1 Butt joint

The joint which is formed by placing the ends of two parts together is called butt joint. In butt joint the two parts are lie on the same plane or side by side. It is the simplest type of joint used to join metal or plastic parts together.The different weld types in butt welding areSquare Butt weld, Bevel groove weld, V-groove weld, J-groove weld, U-groove weld, Flare-V-groove weld and Flare-bevel-groove butt weld.

1.1.2. Corner Joint

The joint formed by placing the corner of two parts at right angle is called corner joint. Two parts which is going to be weld with corner joint forms the shape of L.The different weld types in corner joint are as follows Fillet weld, Spot weld, Square-groove weld or butt weld, V-groove weld, Bevel-groove weld, U-groove weld, J-groove weld, Flare-V-groove weld, Edge weld and Corner-flange weld.

1.1.3. T-Joint

The joint which is made by intersecting two parts at right angle (i.e at 90 degree) and one part lies at the centre of the other. It is called as T joint as the two part welded look like english letter ‘T’.The types of welds in T joint are Fillet weld, Plug weld, Slot weld, Bevel-groove weld, J-groove weld, Flare-bevel groove and Melt-through weld.

1.1.4. Lap Joint

The lap joint is formed when the two parts are placed one over another and then welded (see fig above). It may one sided or double sided. These types of welding joints are mostly used to join two pieces with different thickness.The Various weld types in lap joint areFillet weld, Bevel-groove weld, J-groove weld, Plug weld, Slot weld, Spot weld and Flare-bevel-groove weld.

1.1.5. Edge Joint

The joint formed by welding the edges of two parts together are called edge joint. This joint is used where the edges of two sheets are adjacent and are approximately parallel planes at the point of welding. In this joint the weld does not penetrates completely the thickness of joint, so it cannot be used in stress and pressure application.The various weld types in this welding joint areSquare-groove weld or butt weld, Bevel-groove, weld, V-groove weld, J-groove weld, U-groove weld, Edge-flange weld and Corner-flange weld.

2. MATERIAL

AISI 1018 mild/low carbon steel has excellent weldability and produces a uniform and harder case and it is considered as the best steel for carburized parts. AISI 1018 mild/low carbon steel offers a good balance of toughness, strength and ductility. Provided with higher mechanical properties, AISI 1018 hot rolled steel also includes improved machining characteristics and Brinell hardness. This alloy of steel has a small percentage of manganese to help achieve these properties. 1018 steel is more easily manufactured and machined, reducing its cost. The properties of 1018 make it ideal for a wide array of components such as pins, rods, shafts, spindles and sprockets. Primary elemental component in this material is iron. Carbon content is kept between 0.14 to 0.20 percent by wt. this low carbon content produces mild steel that is easily formed and machined. The addition of between 0.6 to 0.9 percent by weight of manganese helps to increase hardness. The chemical composition of 1018 steel creates a strong and ductile material that has relatively low toughness and hardness compared with other alloys.

Table1. Mechanical Propertiesof AISI 1018

Sl. No.	**Mechanical Properties**	**Range**
1	Shear Modulus	80 GPa
2	Machinability	70%
3	Poisson Ratio	0.290
4	Bulk Modulus	140 GPa
5	Modulus of Elasticity	205 GPa
6	Yield Strength,	370 MPa
7	Elongation	15.0%
8	Ultimate Tensile Strength,	440 MPa
9	Vickers Hardness	131
10	Rockwell Hardness	71
11	Knoop Hardness	145
12	Brinell Hardness	126

3. EFFECT OF MIG WELDING PROCESS PARAMETERS

From this study, it is observed that Welding Current, Welding Voltage, Arc Travel Speed, Electrode Extension, Electrode Size, Gas Flow Rate and Types of shielding gases are process parameters which influence on the tensile strength and percentage elongation of welded Joints.

3.1. Welding Current

Among various welding parameters such as welding current, voltage and speed probably welding current is most influential parameters affecting weld penetration, deposition rate, weld bead geometry and quality of weld metal as shown in figure.3. However, arc voltage directly affects the width of weld bead. An increase in arc voltage in general increases the width of the weld. Welding current is primarily used to regulate the overall size of weld bead and penetration. Too low welding current results pilling of weld metal on the faying surface in the form of bead instead of penetrating into the work piece. These conditions increase the reinforcement of weld bead without enough penetration. Excessive heating of the work piece due to too high welding current causes weld sag. Optimum current gives optimum penetration and weld bead width.

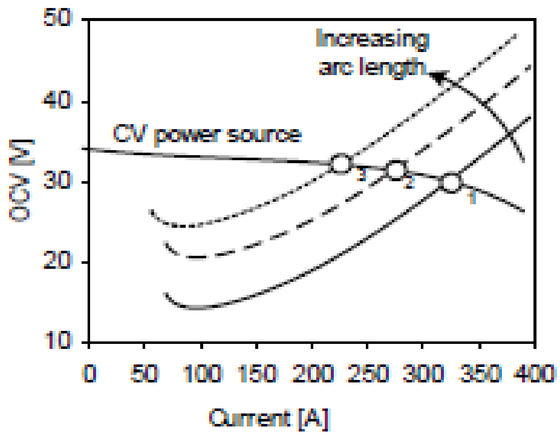

Figure 3. Effect of welding current on melting of electrode of different diameters.

The value of welding current used in MIG has the greatest effect on the deposition rate, the weld bead size, shape and the 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. The oxide removal effect of the DCEP, which is very important in the welding of aluminium and magnesium alloys, contributes to clean the weld deposit. 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. In a constant voltage system, the wire feed speed and welding current are controlled by the same knob. As the wire feed speed is increased the welding current also increases, resulting in increases in the wire melt-off rate and the rate of deposition.

3.2 Welding Voltage

The arc length 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. For example, normal arc voltage in carbon dioxide and helium is much higher than those obtained in argon. A long arc length disturbs the gas shield; the arc tends to wander and thus affects the bead surface of the bead and the penetration. In MIG the arc voltage has a decided effect upon the penetration, the bead reinforcement and bead width. By increasing the arc voltage the weld bead becomes flatter and wider, the penetration increases until an optimum value of the voltage is reached, at which time it begins to decrease.

3.3 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 beads and higher heat input to the base metal because of the longer heating time. The high heat 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.

3.4 Electrode extension

Stick out of the electrodes (electrode extension) affects the weld bead penetration and metal deposition rate because it changes the electrode heating due to electric resistance. Increase in stick out increases the melting rate and reduces the penetration due to increased electrical resistive heating of the electrode itself. Selection of welding current is influenced by electrode stick out and electrode diameter. In general, high welding current is preferred for large diameter electrodes with small electrode extension in order to obtain optimal weld bead geometryas shown in figure.4. Increase in welding speed reduces the penetration.

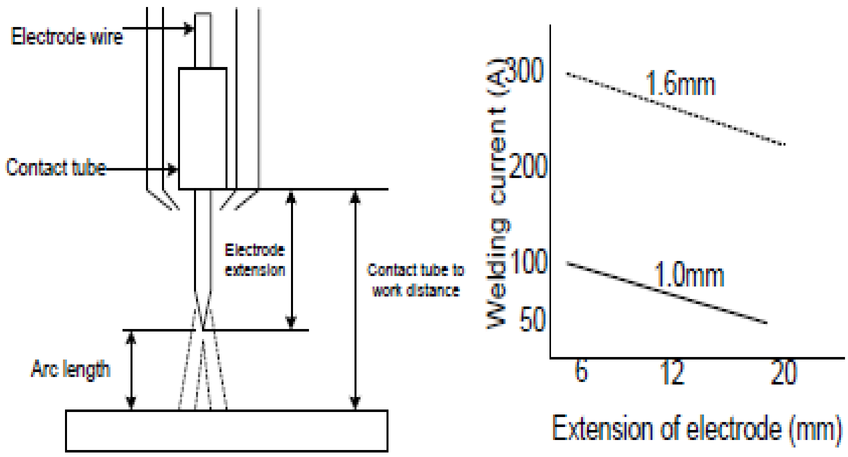

Figure 4 Schematic diagram showing electrode extension and effect of electrode extension on welding current for different electrode diameters

3.5 Electrode Size

The electrode diameter influences the weld bed configuration (such as the size), the depth of penetration, bed reinforcement and bed width and has a consequent effect on the travel speed of welding. As a general rule, for the same welding current the arc becomes more penetrating as the electrode diameter decreases. A larger electrode in general requires a higher minimum current for the same characteristics. 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 welds with less penetration but wider 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. For many purposes small diameter wires are good for thin sections and for welding in vertical and overhead positions. Large diameter wires are desirable for heavy sections and hard surfacing and built-up works with low current applications because of less weld penetration.

3.6 Type of Shielding Gas

Figure.5 shows the different types of shielding gases are used in the MIG process, and the melting rate, bead profile and penetration of weld changes due to gas type. At the same time, the type of the shielding gas affects the spattering, welding speed and the mode of metal transfer and thus the overall mechanical properties of the weld metal. Pure carbon dioxide or argon-carbon dioxide and argon-oxygen mixed gases are generally used for welding of iron based metals. For the same welding current the high melting rate, greater penetration, large and convex weld profile will be obtained when carbon dioxide is chosen as a shielding gas. When pure carbon dioxide shielding is used, a complex interaction of forces occurs around the metal droplets at the wire tip. These unbalanced forces cause large unstable droplets to grow and transfer to the molten metal in a random action. This is the reason for an increase in spatter along the weld bead. Also pure carbon dioxide generates more fumes. As shown in the illustration opposite, the electrode extension or sickout is the length of the filler wire between the end of the contact tip and the end of the electrode. This is the only section of the wire electrode which conducts the welding current. Therefore an increase of the extension results in an increase of its electrical resistance and also causes the electrode temperature to rise because of the resistance heating. This preheat can reach a temperature value approaching the melting point of the electrode so that an arc heat of small intensity will be enough for it to become molten at the point of welding. In a constant voltage power source, the increase of the resistance of the stickout produces a greater voltage drop from the contact tip to the work

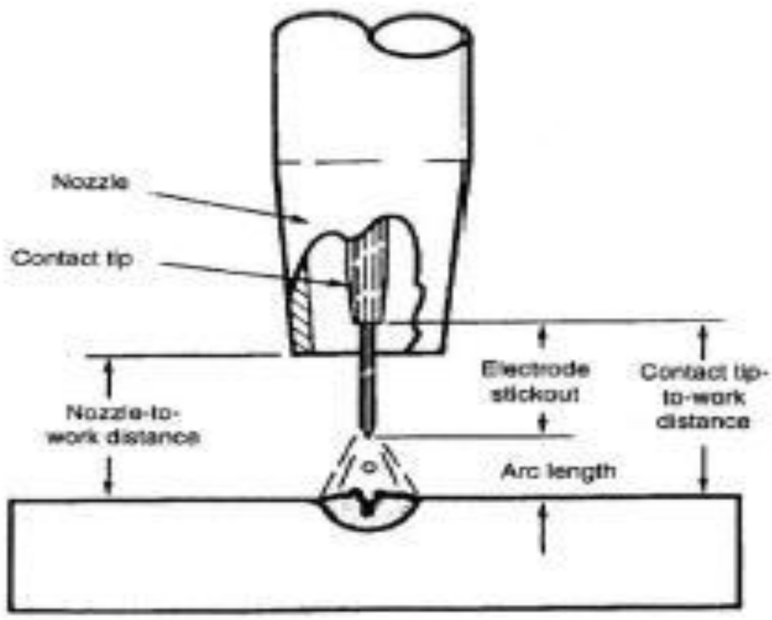

Figure 5schematic of type of shielding gas

The advantages of MIG welding are as follows: this method is financially attractive dueto a high welding speed and because a long arc time can be maintained as there is no frequent changing of electrode rods. This method gives the opportunity for rational welding of materials which are difficult to weld. Welding is possible in all positions. The arc and the weld pool are clearly visible. MIG is usually used with Aluminium, ordinary mild steels, Stainless steels, Copper and copper alloys. In addition to the above metals this method is suitable for magnesium, nickel and a number of other metals and their alloys. It has been used successfully in industries like aircraft, automobile and ship building. It gives high surface hardness and a soft core to parts that include studs, worms, ratchets, dogs, chain needles, pins, liners, machinery frames, special bolts, oil tool slips, tie rods, anchor pins, etc.

4. TAGUCHI'S DESIGN METHOD

Taguchi method is a robust statistical tool that allows the independent evaluation of the responses with minimum number of experiments. It employs orthogonal arrays for experimental design and S/N ratio instead of responses itself to determine the optimum settings of control factors and thus, neglects the variations caused by uncontrollable factors. With this method, experimental results can be analysed through S/N ratio and ANOVA along with simultaneously evaluating the significance of the factors in terms of their contribution to the response values.

5. LITERATURE REVIEW

This study reviews the literature concerned with the optimization of process parameters for metal inert gas welding of mild steel by using Taguchi technique. The purpose of this study is to highlight the state of the art technology available in the field of research and its limitations are available below.

Ghosh et al. (2016) reviewed that the plate of 3mm thickness is used for preparing the welding butt joint. The X ray test result shows that lack of penetration and visual inspection indicate the undercut spatter and blow holes in some sample. The optimum parameters founded by method are current 10A,gas flow rate 20l/min and nozzle distance 15mm and current is more significant as compared to gas flow rate and nozzle distance.[3]

Prakash et al. (2016) the present work deals with optimization of welding process variables by using MIG welding. In this process input variables are arc voltage (V), current (A) and welding speed(S) with tensile properties, hardness &penetration as responses of low carbon steel (ASTM A29). Design of experiments based on taguchiL9 orthogonal array and analysis of variance (ANOVA) is used to determine the impact of parameters with the optimal condition [4].

Singhmar et al. (2015)reviewed that the various combination of parameters were obtained by conducting the experiment as per the orthogonal array. Arc current has the highest influence on the tensile strength with contribution of 41%followed by Arc voltage with contribution of 20% and gas flow rate with contribution of 16%.[5]

Kalita et al. (2015) In the present work the effect of three important parameters of MIG welding were welding voltage, current and shielding gas flow rate on the tensile strength of C20 steel has been studied. An experiment has been designed using Taguchi's L9 orthogonal Array with three repetitions. All welding work has been carried out using ER70S-4 electrodes. Results shows that welding voltage has most influence factor.Mean and variation contribution of the tensile strength of the weld having 87.019% and 85.398% respectively, whereas welding current has significant effect on mean only (10.807% contribution).Shielding gas flow rate has insignificant effect on the tensile strength of weld. From analysis of experimental data the optimal setting is found to be: Welding current 200 amps. Welding voltage 30V and Shielding gas (CO_2) flow rate was 8lit/min. we can use other variable parameters also like electrode size, root gap, plate thickness &welding speed etc. with other materials combinations [6].

Patil et al. (2014) reviewed that the among main input welding parameters the effect of the welding speed is significant,if increasing the welding speed and decreasing the current influences also increase the ultimate tensile strength of welded joint. In this research work done it was observed that the voltage did not contribute such as to weld strength .Regardless of the set of the quality characteristic, greater S/N ratio relates to better the quality characteristics [7].

Kumar et al. (2013)shows that the result of the analysis of variance (ANOVA) for the Hardness (BM, WZ, HAZ).The analysis of variance was carried out at 95% confidence level. The ANOVA is carried out to investigate the influence of the design parameters on hardness by indicating that which parameter is significantly affected the quality characteristics. In this experimentation work, the authors have generated results for S/N ratios of Hardness (BM, WZ, and HAZ) [8].

Anoop et al. (2013) The reviewed study has discussed an application of the Taguchi method for investigating the effects of process parameters on the weld microhardness, grain size and HAZ width in the GTA Welded aluminium alloy of 7039. From the analysis of the results using the S/N ratio approach, analysis of variance and Taguchi's optimization method, the following can be concluded: Peak current of 150 A ,base current of 75A and pulse frequency of 150Hz are the optimized welding parameters for getting highest micro hardness, smallest eqiuxed weld grains and minimum HAZ width. Out of three selected parameters, peak current has the highest contribution i.e. 61.58% [9].

Chhabra et al. (2013) in this study, the process parameters are optimized by using the Taguchi's techniques based on Taguchi's L9 orthogonal array. Experiments have been conducted based on three process parameters, namely the three shielding gases, welding current and arc travel speed and three levels of each parameter were carefully selected. Micro hardness has been predicted for the optimum welding parameters and parameters percentage of contribution in producing a better joint is calculated, by applying the effect of the S/N ratio and analysis of variance.Based on the study, shielding gas was found to be the most significant variable over the other process parameters while the welding current and arc travel speed took the second and third rank respectively. The optimum parameters for the high microhardness obtained were the combination of process parameters of Ar+CO2 shielding gas, 190 Amp. welding current and 22 cm/min arc travel speed. Maximum hardness, in terms of optimum value of 432 HV is achieved. Shielding gas (Ar+CO2) was most significant with 68.36% contribution, followed by the welding current or 16.30% and arc travel speed of 12.88%.[10]

Patil and Waghmare et al. (2013) evaluated the process parameters of welding current, welding voltage, welding speed to investigate their influence on ultimate tensile strength (UTS) for MIG welded specimen of mild steel by using Taguchi's method. They concluded that the welding speed was most influencing parameter with 88.20% contribution followed by current of 10.76% and voltage of 0.69%.[11]

Kurt and Samur et al. (2013) studied the mechanical properties of 304 stainless steels jointed by tungsten inert gas welding by using 308 stainless steel filler wire. They concluded that the hardness value of welding zone was less than parent metal and higher than heat affected zone. The tensile strength, yield strength and elongation were found to be 1800MPa, 75MPa and 25% respectively. It was also concluded that the ductile fracture was carried out in heat affected zone [12].

Patel and Chaudhary et al.(2013) evaluated the parameters considered wire diameter, welding current, and wire feed rate to investigate their affect on weld bead hardness for MIG welding and TIG welding by Grey Relational Analysis (GRA). From the study it was concluded that the welding current was most significant parameter for MIG welding and TIG welding. By the use of grey relational analysis optimization technique, the optimal process parameter combination was found to be welding current 100 Amp, wire diameter 1.2 mm and wire feed rate 3 m/min for MIG welding and welding current 80 Amp and wire diameter 0.8 mm for TIG welding.[13]

P. K. Palani et al. (2013) Tungsten inert gas welding is one of the widely used techniques for joining ferrous and non-ferrous metals. Tungsten inert gas welding offers several advantages like the joining of dissimilar metals, low heat affected zone, less of slag etc. The aim of this paper is to investigate the influence of Tungsten inert gas welding process parameters on welding of Aluminium-65032. Response Surface Methodology was used to control the experiments. The input parameters selected for controlling the process are welding current, speed and gas flow rate. Strength of welded joint was tested by a UTM. The Percentage of elongation was also calculated to check the ductility of the welded joint. From the results we found that the mathematical models have been developed to study the effect of process parameters on tensile strength and percentage of elongation. The Optimization and Confirmation, tests were used to find out the optimal welding conditions to validate the optimum parameter settings [14].

Rao and Padmanabhan et al. (2012) evaluated the process parameters considered were voltage, feed rate and electrolyte concentration to investigate their influence on metal removal rate in electro chemical machining of Al/5%SiC composites by Taguchi's method. From the study it was concluded that feed rate was most significant parameter with 58.09% contribution followed by voltage of 16.30% and electrolyte concentration of 7.57%. The optimum parameters for high metal removal rate were found to be voltage 20V, feed rate 0.3 mm/rev and electrolyte concentration 30 lit/min [15].

Chomsamutr and Jongprasithporn et al. (2012) used Taguchi's approach and Response Surface Methodology to design process parameters of MIG welding that optimize tool life of welded joints for mild steel. The process parameters considered were depth of cut, cutting speed and feed rate.L9 orthogonal array was used for designing experiments. It was concluded from the work that the longest tool life found by Taguchi's approach was 670.170 min and by Response Surface Methodology it was found to be 670.230 min. The optimum parameters were found to be depth of cut 0.5 mm, cutting speed 150m/min and feed rate 0.10 mm/rev [16].

Sapakal and Telsang et al. (2012) evaluated the parameters; current, voltage and welding speed to investigate their influence on depth of penetration of MS material by Taguchi's design. It was concluded from the study that voltage was most influencing parameter with percentage contribution of 84.42 followed by welding speed with 6.83% and current with 3.55%.[17]

Aghakhani et al. (2011) used Taguchi's method to design process parameters of GMAW that optimize weld dilution for welded joints. The process parameters considered were feed rate, welding voltage, arc gap, welding speed and gas flow rate. L25 orthogonal array was used for designing experiments. From the study it was concluded that wire feed rate was most significant parameter and gas flow rate was least significant parameter for weld dilution [18].

6. CONCLUSION

From the review paper study, it is found that when the welding current, voltage, gas flow rate increases, the tensile strength decreases, but when welding speed increases, the tensile strength also increases. In the case of elongation is also same to tensile strength. Optimization was done to find optimum welding conditions to maximize tensile strength and percentage of elongation of welded joints. This study presented the optimization of MIG welding parameters of AISI 1018 Mild Steel by Taguchi's experimental design. The process was applied using a specific set of controllable parameters Voltage, Current,Gas Flow Rate for the response variables of Tensile Strength. L9 orthogonal arrays, S/N ratio analysis of variance were used for this study. The Study found that the control factors had varying effects on the response variables.

REFERENCES

[1] https://goo.gl/images/9RYCZY

[2] https://en.wikipedia.org/wiki/gas_metal_ arc_welding

[3] Nabendu Ghosh, et al., 2016, "Parametric Optimization of MIG Welding on 316L Austenitic Stainless Steel by Grey-based Taguchi Method," Procedia Technology., 25, pp.1038-1048.

[4] Abhishek Prakash., and Raju, S, S., et al, 2016, "Parametric optimization of metal inert gas welding by using taguchi approach," International Journal of Research in Engineering and Technology, 5 (2), pp. 22-27.

[5] Singhmar, et al., 2015, "Experimental study for welding aspects of austenitic stainless steel on tensile strength by taguchi technique," International Journal of Mechanical Engineering and Robotics Research., 4(6), pp.439-443.

[6] DigantaKalita, et al., 2015, "Taguchi Optimization of MIG Welding Parameters Affecting Tensile Strength of C20 Welds," IJETT, 26 (1)- 2015. Pp86-92.

[7] Patill, et al, 2014, "Optimization of MIG Welding Parameters for Improving Strength of Welded Joints," International Journal of Advanced Engineering Research and Studies, 24, pp25-29

[8] Kumar, P, et al, 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,

3, pp50-58.

[9] Anoop, C, A, et al, 2013, "Application of Taguchi Methods and ANOVA in GTAW Process Parameters Optimization for Aluminium Alloy 7039," International Journal of Engineering and Innovative Technology (IJEIT) 2, pp 82-89.

[10] NischalChhabra, et al, 2013, "Effect of Shielding Gases on Micro Hardness of FE 410 (AISI 1024) Steel Welded Joint in GMAW Process," International Journal on Emerging Technologies, 11, pp95-99

[11] Patil, S, R, et al, 2013, "Optimization of MIG welding parameters for improving strength of welded joints," International Journal of Advanced Engineering Research and Studies,22 (3) pp 185-192.

[12] Kurt, Halil İbrahim, and RamazanSamur, et al, 2013, "Study on microstructure, tensile test and hardness 304 stainless steel jointed by TIG welding," International journal of science and technology 2(2) pp. 163- 168.

[13] Patel, C, N, and Chaudhary, S, et al, 2013, "Parametric Optimization of Weld Strength of Metal Inert Gas Welding and Tungsten Inert Gas Welding By Using Analysis of Variance and Grey Relational Analysis," International Journal of Research in Modern Engineering and Emerging Technology, 16(6), pp24-29.

[14] Palani, P, K, and Saju, M, et al, 2013 "Modelling and Optimization of Process Parameters for TIG Welding of Aluminium-65032 Using Response Surface Methodology, "International Journal of Engineering Research and Applications, 12(5), pp72-78.

[15] Rama, R, S, and Padmanabhan,G, et al, 2012, “Application of Taguchi methods and ANOVA in ptimization of process parameters for metal removal rate in electrochemical machining of Al/5% SiC composites, " International Journal of Engineering Research and Applications (IJERA) 2(3) pp. 192-197.

[16] Chomsamutr, K, and Jongprasithporn, S, et al, 2012, "Optimization Parameters of tool life Model Using the Taguchi Approach and Response Surface Methodology, "International Journal of Computer Science Issues,: 16(4), pp14-18.

[17] Sapakal S,. V., and Telsang M, T., et al, 2012, “Parametric Optimization of MIG Welding Using Taguchi Design Method," International Journal of Advanced Engineering Research and Studies, 1 (4), pp.35-39.

[18] Aagakhani, M, Mehardad, E., and Hayati, E., et al, 2011, "Parametric Optimization of GMAW Process by Tagauchi Method on Weld Dilution," International Journal of Modelling and Optimization, 1(3) pp.14-19.