A REVIEW PAPER ON PARAMETRIC OPTIMIZATION OF GMAW PROCESS FOR AUSTENITIC STAINLESS STEEL (AISI 304L) MATERIAL BY USING TAGUCHI METHOD

[1]Khatiwala Fenil, [2]Mr. Tejas Vyas
[1]Post Graduate Student, [2]Faculty of Engineering & Technology
[1]Mechanical Engineering Department,
[1]Parul Institute of Technology, Baroda, Gujarat

Abstract : Gas metal arc welding is a fusion welding process having wide application in industry. In this process proper selection of input welding parameters is necessary in order to obtain a good quality weld and subsequently increase the productivity of the process. In order to obtain a good quality weld, it is therefore, necessary to control the input welding parameters. One of the important welding output parameters in this process are microstructure, tensile strength, hardness and good weld quality. In this investigation using design of experiment was developed using parameters such as welding current, Gas flow rate, root gap and Different joints. After collecting the data, it is used in order to obtain the optimum level for every input parameter. Subsequently, using analysis of variance the significant coefficients for each input factor will be obtained.

***Index Terms* – GMAW, MIG Welding, Stainless-steel (304L), Root gap, Different weld joint**

I. Introduction

Welding is a metallurgical fusion process. This is a process of permanently joining two or more metals or non-metals with or without application of heat, pressure and filler material. Welding is recognized all over the world, today as a remarkable versatile means of metal fabrication. Though there are a number of well-established welding processes, arc welding with coated electrodes is still the most popular welding process. Among the arc welding techniques Shielded metal arc welding (SMAW) was invented first, followed by Submerged arc welding (SAW) and Gas tungsten arc welding (GTAW). Gas metal arc welding (GMAW) was invented in 1940’s. SAW is used to weld thick plates where GTAW provides best quality weld with low productivity for thinner joints. GMAW is a versatile process to weld a wide range of materials with high quality and productivity [16]. Presently, MIG welding is renamed as GMAW and dominating the high speed, high quality welding fields.

II. Gas Metal Arc Welding

Gas metal arc welding (GMAW) is a semi-automatic or automatic arc welding process that yields coalescence of metals by heating with a welding arc between continuous filler metal (consumable) electrode and the work-piece, welding being done in the protective shield of a gas or a gas mixture.

The gas or gas mixture may be either,

- Inert type (helium/ argon/ mixture of them) or
- Active type (CO_2/ O_2/ mixture of them) or
- Mixture of inert and active gases (argon + CO_2/ argon + CO_2 + O_2/ argon + He + CO_2 etc).

When inert gases are used as shielding gas, this process is called Metal Inert Gas (MIG) welding and when active gases are used as shielding gases, this process is referred as Metal Active Gas (MAG) welding.

III. Working Principal

The continuous wire electrode which is drawn from a reel by an automatic wire feeder, is fed through the contact tip inside the welding torch. It is melted by the internal resistive power and heat is transferred from the welding arc. Heat is concentrated by the welding arc from the end of the melting electrode to molten weld pools and by the molten metal that is being transferred to weld pools. Molten weld pools and electrode wire are protected from contaminants of the atmosphere by a shielding gas or a gas mixture which is supplied through the gas nozzle. In figure 1, fundamental features of a basic GMAW process are shown.

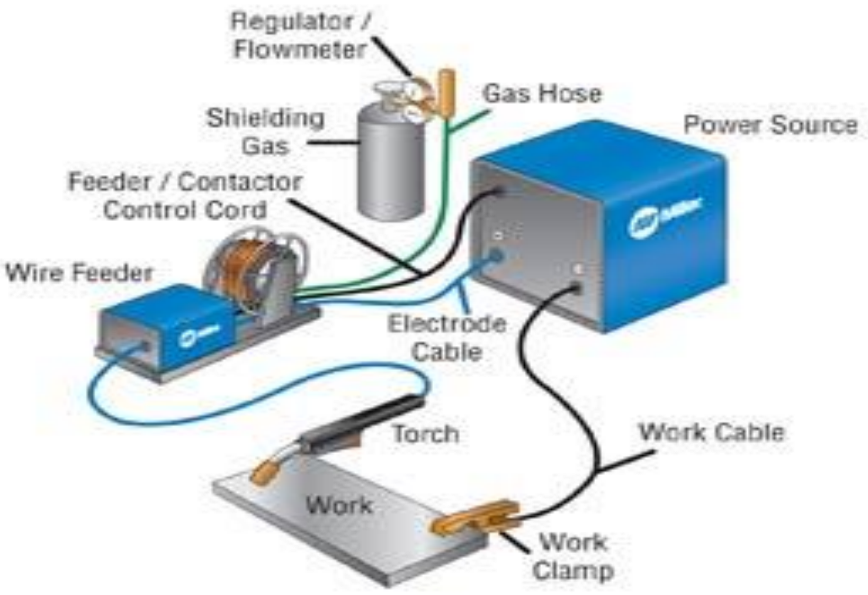

Figure 1: - Schematic diagram of GMAW

IV. Literature Survey

Various process parameters of GMAW interact in a complicated manner and influence directly or indirectly various aspects of weld quality. Several attempts had been made by different researchers to find out the parametric influence on the desired welding characteristics. Also, several works were done to develop mathematical models of heat transfer, mode of metal transfer, etc. Neural-network models had also been made to predict the influence of process parameters on the responses. Process optimization and other related aspects of GMAW had been taken into consideration by many researchers. A literature review is made on it in the context of finding scope and objective of the present work. In earlier sections, while discussing about some general features of welding, GMAW etc., some references have already been mentioned. A literature review is made and given below with emphasis on GMA welding process.

Mohit Singhmar et al [1] study the influencing parameters affecting to mechanical property of austenitic stainless-steel grade 304 (AISI 304) with GMAW by Taguchi Method having parameters: current, gas flow rate, voltage. The 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. 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%.

N R Anand et al [2] study the effect of shielding gas composition on mechanical properties & microstructure of AISI 304L weldments for GMAW process. Different shielding gas compositions such as 100% argon, 80% argon + 20% CO_2, 50% Argon + 50% argon and 100% CO_2 are used. The mechanical properties were determined by performing different tests, viz. Charpy V notch impact test, tensile test, hardness test, bend test. Surface morphology had been analysed by Scanning Electron Microscope (SEM). The results indicated that the shielding gas compositions have great influence on mechanical properties. Results revealed that increase in amount of CO_2 in shielding gas resulted in higher tensile strength and hardness values than the base metal. The study also indicated that shielding gas composition also have an influence on toughness values which further depends upon δ-ferrite content in the weld metal. This δ-ferrite content decreases with increase in CO_2 percentage of shielding gases. Decrease in δ-ferrite content has negative effects on toughness values of weldments. The gas metal arc welding is found to be suitable for welding of AISI 304 L austenitic stainless steels owing to their high welding speed and excellent mechanical properties.

Deepak Kumar et al [3] Optimize the process parameters in GMAW by Taguchi's experimental design method has been performed. An L9 Orthogonal Array was selected to study the relationships between the tensile strength and the three controllable input welding parameters such as voltage, current and gas flow rate and find that tensile strength increases with increase in voltage. But in case of current and gas flow rate, it increases up to the optimum level and decreases on further increasing these values. Voltage is the significant factor for tensile strength but current and gas flow rate are the non-significant parameters in GMAW.

Izzatul Aini Ibrahim et al [4] study the effects of different parameters on welding penetration, microstructural and hardness measurement in mild steel that having the 6mm thickness of base metal by using the robotic gas metal arc welding are investigated. The variables that choose in this study are arc voltage, welding current and welding speed. The arc voltage and welding current were chosen as 22, 26 and 30 V and 90, 150 and 210 A respectively. The welding speed was chosen as 20, 40 and 60 cm/min. As a result, it obvious that increasing the parameters value of welding current it increased the value of depth of penetration. Other than that, arc voltage and welding speed is another factor that influenced the value of depth of penetration. The grain boundaries of microstructure changes from bigger size to smallest size as the variables of welding parameters are changed.

M. Aghakhani et al [5] study the different parameters of GMAW process Feed rate, Voltage, Nozzle-to-plate distance, welding speed, Flow rate on ST-37 steel plate and show the effect on weld dilution for this they use orthogonal array method and conclude that the wire feed rate, voltage have increase effect while nozzle-to-plate distance and welding speed have decreasing effect on weld dilution but gas flow rate only one parameter which effect on weld dilution and other parameter increasing weld dilution.

Satyaduttsinh P. Chavda et al [6] perform the experiment on medium carbon steel with the different variable parameters like Current, Voltage, Gas flow rate, Feed rate which effect on strength and weld pool geometry of the GMAW process. They using orthogonal array method to optimize the parameters. They also use analysis of variance for investigate the welding characteristics of medium carbon steel. After performing the experiment, they conclude that the depth of penetration is increase with the increase the current.

Yilmaz and Uzun et al [7] compared the results obtained from destructive tests for mechanical properties of austenitic stainless steel (AISI 304L and AISI 316L plates of 5 mm thickness) joints welded by GMAW and GTAW process. The joints were made by GMAW process using ER 316 L Si filler metal and by GTAW process using ER 308L and ER 316L filler metals. Single V shaped groove was prepared. For GTAW process pure Argon was selected as shielding gas and the welding was carried out in double passes. In GMAW process, a mixture of 98% Ar and 2% O2 was used and the welding was carried out in a single pass. Then the mechanical properties of the welded joints were found out by tensile, impact and Vickers microhardness tests. From tensile tests, it was found that better ultimate tensile strength and elongations values were obtained by GTAW process in both types of steel (304L and 316L). Impact test results showed that highest fracture energy was obtained from GTA Welding of 316L. 316L joints consumed more energy than 304L joints for both welding processes. From hardness tests it was found that, GTAW process offered better hardness values than GMAW process. It was concluded that higher tensile strength and toughness values were obtained in GTAW process due to narrower HAZ achieved in that process because of high energy concentration, thus reducing the problems of residual stress and hot cracking sensation of austenitic stainless-steel weldments. The weldments made by GMAW process suffered from low impact energy which might be due to its higher oxygen potential. Presence of more δ-ferrite in the weldments by GTAW process increased its impact energy and hardness values compared to GMAW process.

Nabendu Ghosh et al [8] perform the experiment on the AISI 316L grade Stainless steel plate and study the different parameters like current, gas flow rate and nozzle to plate distance which effect on yield strength, ultimate tensile strength and percentage of the welded specimens. They use Taguchi method for the analysed purpose. After perform the experiment they conclude that the current is found to be more significant than gas flow rate and nozzle to plate distance in influencing the strength of the joint. The optimum parametric combination is current = 100A, Gas flow rate = 20 l/min and nozzle to plate distance = 15mm.

Vikas Chauhan et al [9] study the different parameter of the MIG welding like current, voltage and travel speed and show the effect on the joining the dissimilar metal stainless steel (304) and low carbon steel. They analyse this parameter by using Taguchi method and also use the software MINITAB-13 for higher-quality characteristics. They conclude that the MIG weld easily joint SS-304 and low carbon steel plate. The parameter effect on tensile strength is in decreasing order as follows: voltage > speed > current.

Mr.L. Suresh Kumar et al [10] have main objective is to study the different mechanical properties of austenitic stainless steel for MIG and TIG welding. They take voltage as a constant variable and show the effect on the strength, hardness, ductility, grain structure, modulus of elasticity, tensile strength breaking point, HAZ. They compare this properties for the both welding process. After perform the experiment they conclude that hardness at 40amp for TIG is 162.53 and for MIG is 196.54. Ultimate load of TIG specimen is 57600 N and for MIG specimen 56160 N. Tensile strength for TIG specimen is 675.22 MPa and for MIG welding is 652.029 MPa. Percentage of elongation of TIG welded specimen is 40.500% and for MIG welded specimen is 47.8%, so ductility is high in MIG welding specimen.

S. Alam et al [11] study the different parameter of the MIG welding and show the effect of the parameter on the weld bead shape characteristics. For this they investigate the 144×31×10 mm mild steel specimen investigated and welding current, arc voltage, welding speed and heat input rate are chosen as welding parameters. They perform total 10 experiments with constant welding current (165 amp) and arc voltage (16 V). Welding speed was varied. They show effects of significant interactions between the different parameters in graphical form after perform the experiments. They conclude that the depth penetration and shape factor are increase with the increase the welding speed some optimum level 1450 mm/min.

Prof. Prakash Kumar et al [12] perform the experiment on the mild steel and optimize the different parameters of MIG welding. They consider the welding current, welding voltage and wire feed rate as effacing parameters and show the effect on tensile strength. Taguchi Method has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA)are employed to investigate the welding characteristics of mild steel & optimize the welding parameters. The dimensions of the work piece length 300 mm, width 25mm, thickness 5mm.The bevel heights of 5-millimetre, bevel angle is 45^0. These specimens are then welded with a root gap distance 1 millimetre. They use UTM machine with capacity 1000 KN for testing the tensile strength. All the experimental results are analysed by a power full statistical tool named Minitab software of latest version 17. After perform the experiment the conclude that the higher tensile strength is achieve at welding current (150 amp.), higher welding voltage (19 volt.) and higher wire feed rate (5m/min.).

Pawan Kumar et al [13] have objective to study the Taguchi method for parametric study of Gas Metal Arc Welding of Stainless Steel & Low Carbon Steel. They consider the process variable are welding current, welding voltage and gas flow rate. The Taguchi method is use to formulate the experimental design and Design of experiments using orthogonal array is use to develop the weldments. They perform actual practical on work piece length 100 mm, width 75mm, thickness 8mm. CO_2 is used as a shielding gas. ANOVA is to investigate which welding process parameters significantly affect the quality characteristics. After performing the experiment, they conclude that the grater hardness achieves at current (100 amp.), voltage (25 V), and gas flow rate (25 l/min).

Rakesh B Prajapati et al [14] study the different parameters of MIG welding and show the effect on the welding strength of AISI 1045 medium carbon steel. The welding current, arc voltage and welding speed and gas flow rate were chosen as variable parameters which effect on the weld strength. Taguchi technique has been used to acquire the data. They consider four factors and five level for the experiment. An Orthogonal array, signal to noise (S/N) ratio are employed to investigate the welding strength of AISI 1045 material. The dimension of the plate is 250 mm×75 mm×6mm They prepared the specimen with V Shaped groove. The groove angle, root face and root gap were 65◦, 1.5 mm and 1.5 mm, respectively. They use ER 70S-6 was selected as welding wire with a diameter of 1.2 mm was selected, shielding gas was 80% carbon and 20% argon use for experiment. After the performing the experiment they conclude that the welding current is the most effecting parameter on strength. Voltage is depending on the material and mode of metal transfer. The strength is decrease at some level of voltage but further increasing the voltage the strength is increase. Strength is parallelly increase with the increasing the value of gas flow rate.

Kapil B. Pipavat et al [15] examine the different parameters of the GMAW process and performed the experiment on AISI 316 stainless-steel plate. They take different parameters like: current, Voltage and Gas flow rate and measure the hardness and tensile strength of the weld bead. They used orthogonal array and analysis of variance for employed to investigate the welding characteristics of austenitic stainless steel AISI 316 material and optimize the welding parameters. They considered 3 parameters and each parameter have 3 levels. After performed the experiment they concluded that the 32 V, 180 I, and 300 s are optimum parameter and most effective parameter is current.

Summary of the Literature Review

- The present papers indicate that the process parameters like welding current, welding voltage, gas flow rate, and nozzle to work distance are major influence on tensile strength and micro hardness and also very with type of materials and thickness.
- After studies some research paper based on influence of process parameters on tensile strength and micro hardness, D.O.E (design of experiment) methods like TAGUCH, ANOVA, Response Surface Method (RSM) are very effectiveness to optimized process parameters of GMAW welding.

V. Objective

- Study some mechanical and metallurgical properties of gas metal arc welding (GMAW) weld on Stainless steel (100mm×100mm×10mm) using ER308L consumable electrode in this project.

- The aim of this study is to examine the effect of welding Current(I), Gas flow rate(G_f), Root Gap(R), and Different joint(J) on Ultimate Tensile Strength, Hardness and Microstructure on Stainless steel (AISI 304L) plates.

References

[1] Mohit Singhmar and Nishant Verma, "Experimental Study for Welding Aspects of Austenitic Stainless Steel (AISI 304) On Tensile Strength by Taguchi Technique", IJMERR 2015, ISSN 2278-0149, Vol. 4, No. 1.

[2] N R Anand, Vijaysingh M Chavan and Nitin K Sawant, "The Effect of Shielding Gases on Mechanical Properties and Microstructure of Austenitic Stainless-Steel Weldments", IJMERR 2013 ISSN 2278-0149, Vol. 2, No. 4.

[3] Deepak Kumar and Sandeep Jindal, "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–June 2014, ISSN: 2249-7250.

[4] Izzatul Aini Ibrahim, Syarul Asraf Mohamat, Amalina Amir, Abdul Ghalib, "The Effect of Gas Metal Arc Welding (GMAW) processes on different welding parameters", International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012), Procedia Engineering 41 (2012) 1502 – 1506.

[5] M. Aghakhani, E. Mehrdad, and E. Hayati, "Parametric Optimization of Gas Metal Arc Welding Process by Taguchi Method on Weld Dilution", International Journal of Modeling and Optimization, Vol. 1, No. 3, August 2015.

[6] Satyaduttsinh P. Chavda, Jayesh V. Desai, Tushar M. Patel, "A Review on Optimization of MIG Welding Parameters using Taguchi's DOE Method", IJMER 2014, Volume-4, ISSN No-2250-0756.

[7] R. Yilmaz and H.Uzun, "Mechanical properties of austenitic stainless steels welded by GMAW and GTAW", Journal of Marmara for Pure and Aplied Sciences, 18 (2002), pp. 97-113.

[8] Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi, "Parametric Optimization of MIG welding on 316L Austenitic Stainless Steel by Grey-Based Taguchi Method", ScienceDirect 2016, ISSN No-1038-1048.

[9] Vikash Chauhan, Dr. R. S. Jadoun, "Parametric Optimization of MIG Welding for Stainless Steel (SS-304) and Low Carbon Steel Using Taguchi Design Method", IJRSR 2015, Vol-6, Issue 2, pp.2662-2666.

[10] Mr.L. Suresh Kumar, Dr.S.M. Verma, P. Radhakrishna Prashad, P. Kiran Kumar, Dr. T. Siva Shanker, "Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Orocess of TIG & MIG Welding", IJET 2011, Vol-2, Issue 2, ISSN 2231-5381.

[11] S. Alam, Dr. M.I. Khan, "An Experimental Study on the Effect of MIG Welding parameters on the Weld-Bead Shape Characteristics", ESTIJ 2012, Volume 2, No 4, ISSN: 2250-3498.

[12] Pappu Kuma, Prof. Prakash Kumar, "Optimization of Welding Parameter (MiG Welding) Using Taguchi Method", IJSRE 2016, Volume 4, Issue 11, ISSN: 2321-7545.

[13] Pawan Kumar, Dr.B.K.Roy, Nishant, "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, Pages: 18-22.

[14] Rakesh B Prajapti, Disha B Patel and Tusha M Patel,"Experimental Investigation of GMAW for AISI 1045 Material using Taguchi Method", IJSER 2014, Volume-5, ISSN No-2229-5518.

[15] Kapil B. Pipavat, Dr. Divyang Pandya, Mr. Vivek Patel, "Optimization of MIG welding Process Parameter using Taguchi Techniques", IJAERD 2014, Volume-1, Issue-5, ISSN No:2348-6406.