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A Review on Parametric Optimization of Aluminium Alloy 5754 for MIG Welding

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Abstract - Welding is the most practical and productive approach to join metals for all time. Almost everything we use today which we call them as necessities of modern life such as car which is our mode of transport, mobile phones, metal doors and all other stuff made of metal involve some sort of welding. It has been classified in number of processes and one of them is Metal Inert Gas welding(MIG) otherwise called Gas Metal Arc welding(GMAW) by American welding society. In MIG welding, welding takes place due to the melting of the wire electrode that is fed through a gun and its fusion with the base metal resulting in a bond. Shielding gas is supplied to protect the molten weld pool from reacting with oxygen and water vapour present in the surrounding. Various welding parameters govern the process. These parameters include welding current, welding voltage, welding speed, WFR and GFR. These parameters influence tensile strength, yield strength, weld bead geometry and microstructure of the weld. This paper focuses on the optimization of these parameters to obtain best parameter combination for the target quality. For optimization of these parameters, Taguchi method has emerged as the widely accepted method for optimization by the researchers across the globe. The previous work done have been discussed in this review.

Key Words: GFR, MIG Welding, Parametric optimization, Taguchi technique. UTS, WFR.

1.INTRODUCTION

In MIG, a fine wire acts as electrode and is feed by a spool bolstered on a gun through a conduit liner and outside the nozzle. The wire is feed continuously when the trigger on the gun I pulled. When the trigger is pulled it also switches on current and shielding gas that is provided from the high-pressurized cylinders through the nozzle. The protecting gas shields the weld pool from responding to oxygen and water vapour in the surrounding environment. An electric circular segment is shaped between the electrode & work piece & heats them above their melting point. These melt mix together and solidify to join the two pieces into a single piece. Since the electrode i.e. the wire in this case melts, therefore it is called as consumable electrode.

Its successful application relies upon proper determination of:

- Electrode – constitution, diameter and bundling
- Shielding Gas – type (constitution), immaculateness and flow rate
- Process Variables – current, voltage, method of metal transfer and travel speed
- Equipment – power source, welding torch and wire feeder

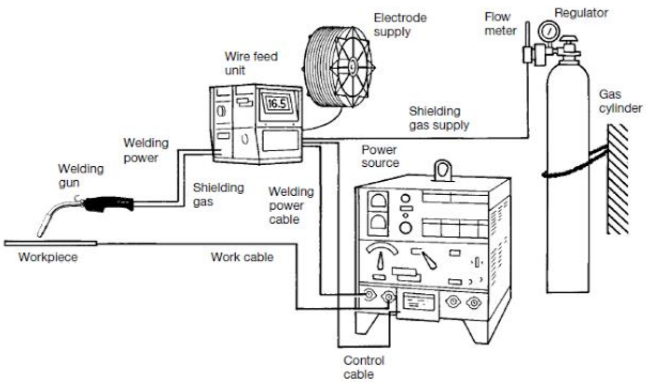

Fig -1: Diagram of MIG Welding Equipment

1.1 Advantages

- Operation can be performed in both semi-automatic as well as automatic mode.
- Welding of variety of industrial metals & alloys is achievable.
- All position welding is achievable through legitimate selection of equipment & process variables.
- Minimum after weld cleaning is needed because of the absence of a deposited slag layer over weld bead.
- Less operator expertise is required contrasted with Stick Welding.

1.2 Disadvantages

- Welding equipment is increasingly perplexing, more expensive and less convenient than that for Stick Welding.

- Welding of incredibly thin materials (<1/16") is an issue.
- The material must be free from dirt and non-corrosive.
- Welding equipment is too expensive and its complexity level is high contrasted with stick welding.

2. LITERATURE REVIEW

S. S.S. et al. [2019] carry out a comparison study of the joint of Aluminium Alloy 5052 & M.S. Plate made by MIG-brazing and Cold metal transfer with process parameters such as wire feed rate and travel speed constant. Filler wire used in the study is Al alloy BA4043 of dia. 1.3mm. Current is taken in the range 67–75 A and voltage is taken as 16.0 ± 0.2V. Torch travel velocity and WFR is 0.8 m/min and 5.8 m/min respectively, which is maintained during the process. Inert gas is used as the shielding gas with gas flow rate 20L/min. The hardness determined came out to be elevated in the toe regions when compared with CMT. In addition, zinc deposition was discovered in both the techniques. **[1]**

Vijander Kumar et al. [2018] investigates the influence of welding variables i.e. current, voltage & NPD on tensile strength of the weld. Further, the parameters are optimized using Taguchi method. The material for the study is hot die steel and copper-coated filer wire is taken as filler metal. Size of the specimen is 200*100*5mm^3. Welding is carried out in presence of inert gas. Values of current taken are 180, 190, 200A, Voltage taken is 21, 24, 27V and NPD as 12, 16, 20mm. The optimal set of parameters obtained are current as 200A, voltage as 27V and NPD is 16mm. **[2]**

Vijaya sankar et al. [2018] focusses on the effect of input variables i.e. current, GFR & potential difference on weld robustness of AISI 310 stainless steel and optimization of the variables by Taguchi method. The substrate material stainless steel AISI 310 and the filler metal AISI steel wire of dia. 0.8mm is chosen for the study. Current varies from 130-170A, voltage varies from 23-27V and GFR 13-17L/min. The optimum parameters obtained are Weld current 130A, Voltage 27V and Gas flow rate is 17L/min. The weld strength shows improvement for increasing value of voltage and GFR and decreasing value of current. **[3]**

Pavan G. Chaudhari et al. [2018] investigates the effect of single component oxide flux on the AISI 316L S.S. and MOORA technique is used for optimization. SiO_2 & Cr_2O_3 fluxes are used. Current varies from 150-180A, voltage 20-24V, welding speed is 150-180mm/min. Mixture of argon & carbon dioxide with a GFR of 15l/min is used to protect the weld pool. The technique for optimization used by them is simple, operation is carried out with lesser calculations, and overall computational time is less. **[4]**

C. Chen et al. [2018] utilized an optical magnifying lens and rapid imaging to demonstrate the impact of continuous & beat ultrasonic on weld appearance and molten metal drop movement in ultrasonic MIG. Used an optical microscope and high speed imaging to show the influence of continuous & pulsed ultrasonic on weld appearance and droplet transfer in ultrasonic assisted MIG welding. The substrate material is pure aluminium 1060 with aluminium 1003 as filler metal. Welding parameters taken are as follows: voltage-22V, WFR-5.5m/min, GFR-15l/min and welding speed -4.5m/min. Necking is observed in case of conventional MIG that is reduced in case of ultrasonic assisted MIG. The penetration of continuous ultrasonic MIG is1.68 times and of pulsed ultrasonic MIG is 1.3-1.8 times when compared to that of conventional process. **[5]**

Patil et al. [2017] shows the influence of process variables such as current, torch travel velocity & voltage on UTS of mild steel grade AISI 1030 and optimization of the variables by Taguchi method. The filler metal used is Carbon steel wire ER70S-6. Shielding gas used is argon. Current 200-240A, voltage is 23-27V and welding speed is 250-450mm/min. Argon gas is used with a flow rate of 17L/min. Ultimate tensile strength varies linearly with speed and inversely with the welding current. The parameter that has a significant influence on weld strength is welding speed. **[6]**

X. Zhan et al. [2017] discusses about the porosity formation in weld of invar alloy done by laser metal multi-layer hybrid MIG weld. Invar M93 is the filler metal. The power (laser), current and torch travel velocity are set to be 2–6 kW, 220–320 A and 0.35–1 m/s resp... The -ve clearance came out to be 0.2 mm. Gas flow rate of 20L/min is taken. Shielding gas used is argon. Conditions involving low capacity of laser in root & less current in cover pass results in porosity generation. The inner side of porosity wall has high oxygen concentration & nickel oxide, iron oxide and manganese oxide react with carbon when the weld cools to generate carbon dioxide leading to porosity. **[7]**

C. Labesh kumar et al. [2017] investigates the variation of process variables. Variables that were singled out for the study were welding current expressed in ampere, travel speed expressed in mm/min and potential difference expressed in volts. They also optimize the process variables. Optimization of these variables was carried out by DOE method. HDS steel is the test specimen and the filler metal is copper-coated mild steel wire. Inert gas is used for purpose of shielding. Three values of welding current chosen: 190, 195 and 200 amps. Three values of voltage chosen: 20, 23 and 26 V. welding speed are 0.037, 0.042, 0.048 mm/min. The optimum parameters are welding speed-0.051mm/min, voltage 26V and current 200A. **[8]**

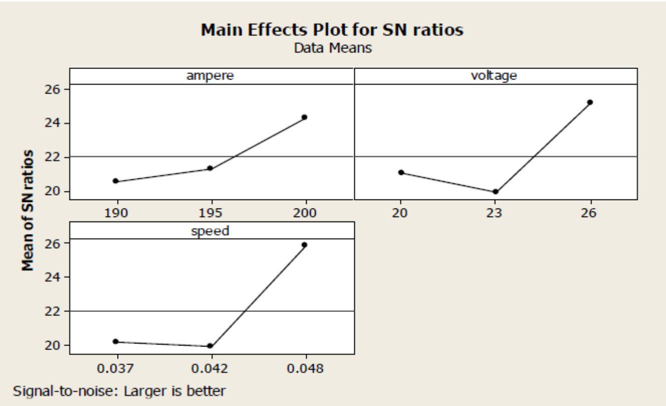

Chart -1: Plot for Parameter VS S/N ratio [8]

X. Zhan et al. [2016] focuses his attention to overcome the poor weld ability of the Invar 36 alloy by comparing MIG and laser-MIG welding. Current values are 250 & 200A, voltage is 22-20V and welding speed is 6-3 mm/sec. The maximum residual deformation of hybrid laser-MIG and MIG are 0.7 mm and 2.3 mm respectively. Welding of invar plates occurred in 4 passes in case of MIG and 3 passes in hybrid laser-MIG and time taken in welding for MIG is equal to 8 times of time taken by hybrid laser-MIG. **[9]**

Nabendu Ghosh et al. [2016] focusses on process variable variation and their effect on weld quality measured in respect of yield strength, UTS and % elongation of 316L stainless steel. Filler metal taken is 316L S.S. Current values are 100,112,124A, GFR is 10, 15, 20L/min and NPD is 9-12-15mm. The best weld quality is achieved when current is 100 A, GFR is 20 l/min and NPD 15mm and worst for sample with settings equal to 124 A as current, 10 l/min GFR and NPD 15mm. The significance of current on strength of joint is found to be more when compared to remaining variables. Optimum set of parameters obtained are welding current-100A, GFR-20L/min & NPD-15mm. **[10]**

Pappu kumar et al. [2016] focusses on the consequence of variation of process variables i.e. current (A), welding voltage expressed in volt & WFR expressed in m/min on Tensile strength of mild steel and optimization of these variables done by Taguchi method. Carbon dioxide is used for shielding the weld. The values of welding current chosen are 50, 100 and 150 amps. Three values of arc voltage chosen: 15, 19 and 23 V & wire feed rate is 3, 4, 5 m/min. Among the set of process variables, the variables that has larger influence on tensile strength are voltage and current. Optimum set of variables determined are 150A (current), 19V (voltage) & WFR-5m/min corresponds to maximum value of tensile strength. **[11]**

Prasenjit Mondal et al. [2015] emphasises on optimisation of process variables such as welding current, voltage & welding speed for maximum value of hardness and tensile strength and their effect on them. The substrate material is S.S. AISI-304 & Mild steel plate IS 1079. Current values taken are 130-135-140A, voltage is 22-24-26V and welding speed is 25-30-35cm/min. Optimum values of welding current, voltage & welding speed are 135A, 22V & 35 cm/min respectively. The effect of parameters on the MRPI is as follows: voltage > current >speed. **[12]**

K. Sivasakthivel et al. [2015] investigates the variation of process variables. The selected variables are welding current expressed in ampere, voltage expressed in volts & travel speed expressed in cm/min and their consequence on material properties of titanium i.e. tensile strength, impact strength, hardness and to optimise the above parameters by ANOVA. Shielding gas is argon. Three values of welding current are chosen: 250, 280 and 300 amps. Three values of arc voltage are chosen : 20, 25 and 30 V. welding speed are 55, 60, 65 cm/min. Acc. to S/N ratio analysis and ANOVA, the process variables affecting the Tensile Strength were speed, current and Voltage. The effect of parameters on penetration is as follows: voltage> current>speed. **[13]**

Vikas Mukhraiya et al. [2014] studies the influence of process variables on torsional rigidity of welded rod of steel ST-37 of 20mm dia. Argon and carbon dioxide concoction was used to shield the weld pool combined in ratio 4:1 respectively. Three values of welding current are chosen: 340, 350 and 360 amps. Three values of arc voltage are chosen: 350, 360 and 370 V. wire feed rate are 80, 100, 120 m/min. The welding voltage shows greater effect than wire feed rate on torsional rigidity. An optimum parameter combination is obtained by Taguchi method for maximum torsional rigidity. **[14]**

Mohd. Shoeb et al. [2013] worked to determine the consequence of variation of input variables (singled out are welding speed (mm/sec), voltage (volts) and GFR (l/min)) on weld bead geometry i.e. penetration, width & height of HSLA steel IS 304. The filler metal is OK Autrod 13.14 Cu based alloy. Mixture of 80% Argon, 18%, CO_2 & 2% O_2 is used for shielding the weld pool. Voltage is varying from 26-32V, GFR is varying from 20-25L/min and welding speed varies 2.7-3.6mm/sec. No effect of welding speed has been observed on penetration. Also for any value of current, bead width varies inversely to the welding speed. No significant effect of gas flow rate variation on penetration has been observed. The penetration is proportional to increase in voltage and the height varies inversely with voltage. **[15]**

Izzatul Aini Ibrahim et al. [2012] discusses the consequence of welding parameter variation. Welding current (A), voltage (V) and torch travel (cm/min) are singled out to carry out the research. By varying these variables, influence of these variables on properties of the weld of mild steel material is determined. Filler metal used is ER 70S-6. Shielding gas is carbon dioxide. Three values chosen for the welding voltage are 22, 26 and 30 V. Three values of welding current chosen are 90A, 150A and 210 A respectively. The welding speed values selected for the research are 20cm/min, 40cm/min and 60 cm/min. The value of hardness is higher at 90A and decreased a little at 150A and at 210A it increased by a little than 150A and maximum value is obtained when voltage corresponds to 26 V, current corresponds to 90 ampere & welding speed corresponds to 60 cm/min. The grain boundary size is affected when process variables are varied as per DOE. The penetration increases with increasing value of welding current and is maximum for welding speed 60 cm/min, voltage 26 V & welding current 210 A. **[16]**

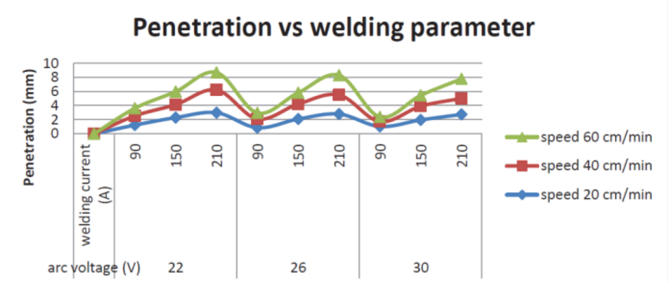

Chart -2: Penetration VS process parameters [16]

Ajit Hooda et al. [2012] determines the consequence of process parameters variation such as welding current, voltage, wire feed rate & gas flow rate on tensile strength of AISI 1040 medium carbon steel joint and an optimum set of parameters is obtained using Taguchi technique. Filler metal used is ER 70S-6. Values of Welding Voltage (V), Current (A), Wire Speed (m/min), and Gas Flow Rate (l/min) Values taken are 23-25V, 200-220A, 2.4-3.2m/min, and 12-16l/min respectively. Optimum values of process variables i.e. welding voltage- 22.5V, current- 190A for transverse & 210A for longitudinal, wire feed rate- 2.4m/min and gas flow rate- 12l/min corresponds to maximum yield strength of AISI 1040 medium carbon steel joint. **[17]**

S. V. Sapakal et al. [2012] shows the effect of various process variables such as welding current, voltage and welding speed on penetration depth in MS C20 material. Shielding gas used is carbon dioxide. Three values of welding current chosen: 60, 90 and 120 amps. Three values of arc voltage chosen: 15, 22.5 and 30 V. welding speed are 2, 4, 6 m/min. The value that has been obtained experimentally from optimum parameters is 5.25mm for penetration and 14.4 as S/N ratio. **[18]**

H.T. Zhang, J.Q. Song [2011] discusses of the welding of two dissimilar metals AZ31 Magnesium & 2B50 Aluminium using MIG with layer of zinc foil between the two metal layers. The filler metal taken for the welding is ER4043 Al-Si wire. Welding is done on CLOOS GLC403/603 QUINTO Welding machine. Welding current is 20A, voltage is 22.5V, WFR is 3.1m/min and welding speed is 185cm/min. Use of zinc foil as the inter layer between the metals made the welding of these metals possible without burn through and cracking. An Al–Si hypoeutectic structure and an Al–Zn eutectic structure is observed in the fusion zone of the weld. **[19]**

BAI Yan, et al. [2010] uses an orthogonal experimental design to study the influence of plasma-MIG welding parameters on the weld porosity of 5A06 aluminium alloy. Argon serves the purpose of shielding gas. Values of wire feed rate (m·min−1) are 9.0-10.1-11.2-12.3. MIG welding Voltages are 26.4-28.5-30.2-32.0V. Shielding gas flow rate (L·min−1) 20.0 & 25.0. Welding speed (mm·min−1) 400.0 & 600.0. Plasma current is 95-110-125-140A and Plasma gas flow rate (L·min−1) 8.0 &10.0. The effect of plasma gas flow rate is more dominant than other factors. The secondary factors are welding voltage, welding speed, wire feed rate and plasma current. Optimum parameters obtained are wire feed rate as 10.1 m/min, voltage as 28.5V, welding speed as 400 mm/min and current is ranging from95A to 140A with GFR corresponding to 20-25l/min. From this hybrid method joint with great mechanical performance were acquired, which achieved excellent rigidity of 92%.**20]**

3. CONCLUSIONS

From this review, it has been concluded that very less research has been done on Aluminium alloy 5754 that offers excellent weld ability and machinability among 5*** series of aluminium alloys. It has a wide range of applications that includes shipbuilding, vehicle bodies, rivets, nuclear structure and food processing industry. It has excellent corrosion resistance.

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