Influence of Process Parameters on Mechanical Property of Stainless Steel 430 Plate by TIG and MIG Welding

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Abstract— Stainless steel 430 is a non hardenable steels belonging to ferritic group of steels. It has been widely used for chemical and household applications. Hence, the present work describe the 8 mm thick stainless steel 430 grade plate butt welded by TIG and MIG welding process using single pass welding procedure in single V groove design. The present research work assesses the effect of different process parameters such as welding current, voltage, speed, gas pressure and gas flow rate on different mechanical properties such as tensile strength and hardness of TIG and MIG welded stainless steel plates of 430 grade. In the present work, tensile strength and hardness of the TIG and MIG welded joints have been evaluated and results are compared. From this investigation, it is found that TIG welded joints of stainless steel 430 showed superior tensile strength compared to MIG welded joints, and this is mainly due to formation of very fine dendrite microstructure in the weld deposited due to low heat input rate. MIG welded joints have higher hardness because of higher heat input rate compared with TIG welding.

Key words: TIG welding, MIG welding, stainless steel 430, tensile strength, hardness

I. INTRODUCTION AND LITERATURE REVIEW

Welding is a fabrication process that joins the similar and non-similar metals and non-metals by causing coalescence. In the welding process the coalescence of materials is produced by heating them to the recrystallization temperature with or without the use of pressure and filler materials. The process is done by melting the work-piece and adding a filler material to form a weld pool that cools to become a strong joint [1]. Most of the products could not even be made without the use of welding process, e.g. nuclear power plant, aircraft, guided missiles, pressure vessels, transport vehicle, chemical process equipment and many others. In the welding process many of the problems are inherent that can be avoided by proper consideration of the characteristics and requirements of the process [2].TIG and MIG welding is a type of welding process and it is widely used in modern industries for joining similar and non-similar materials. TIG welding is also called gas tungsten arc welding. The main advantages of TIG welding process are that requires low heat affected zone and no slag. The quality and accuracy of joints mainly depends upon welding speed, current, voltage, type of shielding gas, power supply, gas flow rate etc. It is relatively a high strength welding technique. TIG welding process has been a most popular choice of welding process when a considerable precision welding operation or high level of weld quality is required. The current and root face effects the deposition rate very significantly. The optimal input parameters are selected to find out the best results [3]. In the TIG and MIG welding process mainly three things are require, the first things is heat which is produced by electricity passing through the tungsten electrode by creating an arc to the metal. the second things is shielding gas comes from a cylinder of gas flow to the weld area to protect from air and the last things is filler metal, it is a metal wire or rod that is added by hand into the arc in TIG welding and put by trigger in MIG welding. TIG welding uses a separate filler metal and a non-consumable electrode with an inert shielding gas. The setup of TIG and MIG welding is consists of a cylinder of argon gas, welding torch having connection of cable for current supply, a suitable power supply, tubing for shielding gas supply, and water tubing for cooling the torch, welding gun. Gurram et al. [4] investigated the ferritic stainless steel joints fabricated by the addition of 2 g Al in post-weld annealed condition resulted in better tensile properties compared to all other joints. There is a marginal improvement in the ductility of ferritic stainless steel weldments by the addition of 2 g Cu in post-weld annealed condition compared to all other joints and base metal. Arun et al. [5] reported the transverse shrinkage generated in GTAW weld joint is comparatively lower than GMAW weld joint and the tensile strength of GTAW weld joint is higher than that of the GMAW weld joint. Ahmadi et al. [6] reported the weld penetration is increased while the weld metal width decreased, among the fluxes SiO_2 flux had a significant effect on enhancing the weld penetration in A-TIG, and TIG welding can increase ultimate tensile strength of weldment because of increasing the retained delta ferrite content of stainless steel weld. Kumar A et al. [7] proposed the behaviour of the welded joints at the optimum condition of process parameters is attributed to the higher dilution of the base metal into the weld, resulting in an increased amount of Mg_2Si precipitates that are formed in the aluminium matrix. The metallographic analysis reveals a fine grain structure at the weld centre, which results in higher mechanical properties. Hussain et al. [8] reported the depth of penetration of weld bead decreases with increase in bevel height of V butt joint and tensile strength is higher with lower weld speed, the lower range of weld speed is suitable for achieving maximum tensile strength. Abdalla et al. [9] investigated the analysis of the mechanical behaviour of AISI 4130 steel after TIG and laser welding process. They reported that laser welding process easily automated and produces area phase transformation area about ten times smaller than TIG welding process. The hardness in the fusion zone is quite high for both processes, but it was reduced to about 200 HV for the laser welded steel and about 100 HV in TIG process after tempering. Peng et al. [10] investigated the effects of aging treatment and heat input on the microstructures and mechanical properties of TIG-welded 6061-T6 alloy joints. They reported that an increase in heat input results in increase in width of the HAZ and grain size of the FZ of the 6061-T6 TIG welding joints, the hardness of the FZ is lower than those of the BM and HAZ, with an increase in heat input the hardness values of the HAZ decrease whereas the hardness values of the FZ decrease initially and then increase slightly. Sathiya et al. [11] studied the comparative study on transverse shrinkage, mechanical and metallurgical properties of AA2219 aluminium weld joints prepared by gas tungsten arc and gas metal arc welding processes. They reported that the transverse shrinkage generated in GTAW weld joint is comparatively lower that in GMAW weld joint. The tensile strength of GTAW weld joint is higher than that of the GMAW wel0d joint. Zou et al. [12] investigated the mechanical properties of advanced active-TIG welded duplex stainless steel and ferrite steel. They reported that the weld oxygen content played a significant role in affecting the weld shape of both steels, which could be controlled by adjusting the oxygen content and the shielding gas of the AA-TIG welding process. They also reported that with the increase in the weld oxygen content, the weld shape became narrow and deep for both steels. The Vickers hardness of the weld metals of both steels was not affected by the oxygen content in the shielding gas. Patil and waghmare [13] investigated the optimization of MIG welding parameters for improving the strength of welded joints. They reported that the mild steel failure problems encountered by loads were successfully addressed by applying the taguchi method. The welding speed has major influence on tensile strength of welded joints. Kumar et al. [14**]** discussed the austenitic stainless steel 304 mechanical properties with dye penetrate testing welded by TIG and MIG. They reported that the TIG welding produced the less hardness value than the MIG welding. The TIG welds of stainless steel withstand the high load and produced high ultimate strength than MIG welds. Austenitic grains were presented in the microstructure and no remarkable indication from the Dye Penetrate Testing. The HAZ was increased by increased the welding current. Ghosh et al. [15] investigated the parametric optimization of MIG welding on 316L austenitic stainless steel by grey-based taguchi method. They reported that the x ray test result shows that lack of penetration and visual inspection indicate the undercut and spatter and blow holes in some samples are found. Gulenc et al. [16**]** investigated the experimental study of hydrogen in argon as a shielding gas in MIG welding of austenite stainless steel. They reported that sample welded at 240A current and with 1.5% H_2-Ar shielding media had shown good tensile property. When the amount of hydrogen in Ar is increase, then toughness of welding is increased. The hardness value is higher at base metal as compared to heat effected and weld zone.

A. Material selection

Base metal: Stainless steel 430 grade.

Many stainless steels are consider to have good weld ability. Stainless steel may be welded by many welding techniques including the TIG, MIG, laser and electron beam, resistance welding etc.in the welding of stainless steel joint surface and filler metal must be clean. The coefficient of thermal expansion for the ferritic types is less than the carbon steel and this must be assumed to minimize distortion. Stainless steel 430 grade is a non-hardenable types of steel and containing the more quantity of straight chromium (16-18%) and belong to ferritic group of steels. This type of steel used in many chemical application because of its resistance to nitric acid. It is an iron based alloy which contain chromium and a thin layer of chromium oxide film which surface of a stainless steel provides good corrosion resistance and prevent further oxidation.

S.no	Property	Value
1	Density in Kg/m^3	7750
2	Elastic modulus in MPa	200
3	Thermal conductivity in W/Kgk	26.1
4	Specific heat in J/Kgk	460
5	Tensile strength in MPa	483
6	Yield strength in MPa	310
7	Elongation in percentage	22
8	Hardness (Rockwell)	B 85

Table 1: Property of stainless steel 430

Grade		C	Mn	Si	P	S	Cr
SS 430	Min.	-	-	-	-	-	16-
	Max.	0.12	1	1	0.04	0.030	18

Table 2: chemical composition

B. Process Parameters

In TIG and MIG welding process variables play an important role in the quality, bead geometry and weld penetration. Knowledge of process variables is important and necessary to produce weld of satisfactory quality. The process variables are changing from one range to other to produce a desired results and that are not completely independent.

The following parameters affect the quality of the weld:

1) Welding Current

When the current is high, TIG welding leads to splatter and work piece gets damaged. When the current is low, TIG welding leads to sticking of the filler wire. Fixed current mode is used to the voltage to maintain a constant arc current. Larger heat affected zone (HAZ) can be found for lower welding current.

2) Welding Voltage

Welding voltage may be fixed or adjusted. It depends upon the TIG welding equipment. A high initial voltage allows for easy arc initiation. Too high voltage, can lead to a large variable in welding quality.

3) Welding Speed

When the welding speed is increased, heat input per unit length of weld decreases and penetration of weld decreases. Welding speed controls the bead size and penetration of weld. It does not depend on current. Excessive high welding speed causes the uneven bead shapes, increase the tendency to porosity.

4) Gas Flow Rate

Gas flow rate is important factor which is affected the results and output. Flow rate range generally be 6-7 litre/min. In TIG uses a lot of shielding gas so it pays to set up the gas flow accuracy for obtain proper results.

II. EXPERIMENTAL WORK

Experimental set-up: The experimental setup used in the TIG welding process include the welding machine, shielding gas cylinder with gas regulator and pressure gauge, welding torch and a motor which carries and guide the welding gun and travel with the desired constant speeds along the plate to be welded.

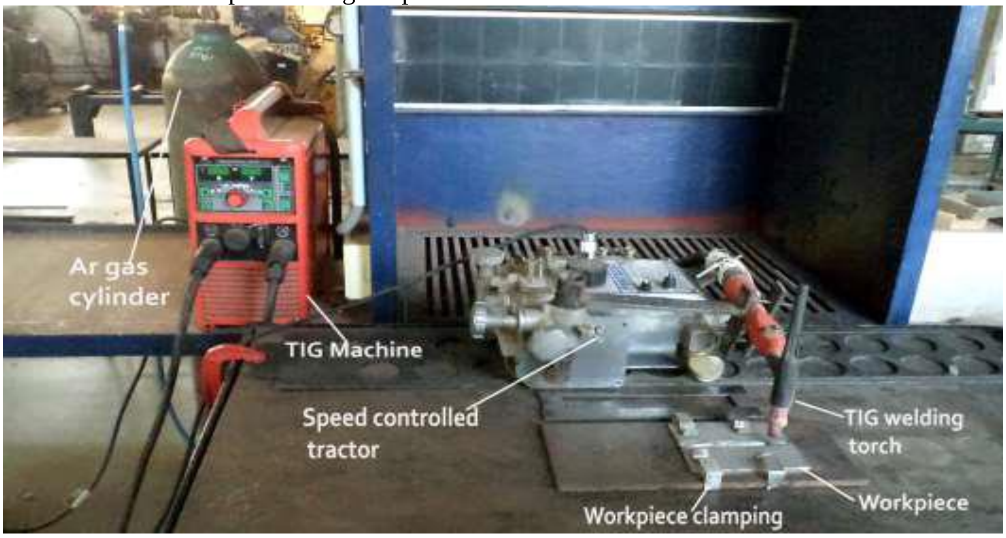

Fig. 1: GTAW setup

A. Sample Preparation

Stainless steel 430 plates with the dimensions of 100×50×8 mm were cut into the required dimension using lathe and cutting machine and grinding machine is used to smooth the joining surfaces of plates. After that emery paper is used to remove the external materials on the surfaces of plates. TIG welding was carried out using a TIG AC/DC 3000 watt welding machine. Single V butt joint was selected to prepare the joints and plates are tapered at 60^0. The selected welding parameters for this study were: current, voltage, gas flow rate, speed, gas pressure. Stainless steel grade 430 plates of thickness 8mm was selected as materials for TIG welding process.

Fig. 2: Filler rod ER 430

S. no .	Current (Ampere)	Voltag e (Volt)	Gas pressur e (Bar)	Gas flow Rate (Ltr/min.)	Speed (Mm/sec.)
1	145	18	0.5	10	49.23
2	150	18	0.5	10	49.23
3	150	20	1	12	44.50
4	160	23	1	15	44.50

Table 3: TIG welding process parameters

Sr. no .	Current (Ampere)	Voltag e (Volt)	Gas pressur e (bar)	Gas flow rate (Ltr/min.)	Speed (Mm/sec.)
1	120	25	0.5	25	45
2	125	26	0.5	26	43
3	140	28	1	27	43

Table 4: MIG welding process parameters

III. RESULTS

A. Heat Input Calculation

$$\text{Heat input rate} = \frac{V \times I \times \eta \times 60}{S \times 1000}$$

Sample number	Heat input rate value Kg/mm
1	2.385
2	2.468
3	3.030
4	3.721

Fig. 5: In TIG welding

Where

V = voltage in volts

I = current in ampere

Ƞ = arc efficiency (taking 0.75)

S = speed in mm

Sample number	Heat input rate value Kg/mm
1	3
2	3.40
3	4.102

Fig. 6: In MIG welding

B. Tensile Test

The ultimate tensile strength of the specimen after welding is measure in a universal testing machine (UTM) which has capacity of 400KN. This test is carried out a welding to the ASTM standard. Test is conducted at room temperature and prepared specimen dimension for tensile test. The weld sample has exhibited lower tensile strength as compared to base metal strength and the results of all specimen for TIG and MIG welding shown in the table 5 & 6. When the welding current is too small, the root of the welded joint can be unwelded, this lead to the low tensile strength welded joint. When the welding current is too high defect like undercutting and collapse appear in the layer. With the increment of welding current, the tensile strength of the welded joints go up first and then fall down. In TIG welding when current is increases and all others parameters remain constant, the tensile strength. In other hand current remain constant and all other parameters increases, the value of tensile strength decrease again. When all the parameters including welding current increases, the results shows decrease in tensile strength once again. Results show that as the process parameters such as current, voltage, gas pressure and gas flow rate are increases, the tensile strength decreases. The tensile strength decreases because in this process current, voltage, gas pressure and gas flow rate are increased gradually. From this increment the brittleness of material increased, due to this the tensile strength decreased. Results also show that as welding speed increases, the tensile strength also increases. The main reason behind this, when increasing the welding speed, the total heat supplied per unit time in welding process decreased, so brittleness decreases and tensile strength increased. In MIG welding when the process parameters like current, voltage, gas flow rate, gas pressure are increases, the tensile strength decreases. In other hand welding speed decreases, tensile strength also decreases. Results show that as the process parameters such as current, voltage, gas pressure and gas flow rate increases, the tensile strength decreases. The tensile strength decreases because in this process current, voltage, gas pressure and gas flow rate are increased gradually. From this increment the brittleness of material increased, due to this the tensile strength decreased. Results also show that as welding speed increases, the tensile strength also increases. The main reason behind this, when increasing the welding speed, the total heat supplied per unit time in welding process decreased, so brittleness decreases and tensile strength increased. From the comparative study between the TIG and MIG welding joints founded that stainless steel 430 grade TIG welded joint shows higher tensile strength in comparison with MIG welded joint. The tensile strength in TIG welded joint is higher due to formation of very fine dendritic microstructure in the weld deposit due to low heat input [Anukumar et al., 2015].

TIG welding joints Tensile Strength result					
Process parameters					Result
Current (Ampere)	Voltage (Volt)	Gas flow rate (Ltr/min)	Gas pressure (Bar)	Speed (Mm/sec.)	Tensile strength (MPa)
145	18	10	0.5	49.23	389
150	18	10	0.5	49.23	385
150	20	12	1.0	44.50	377
160	23	15	1.0	44.50	370

Table 5: TIG welding mechanical results

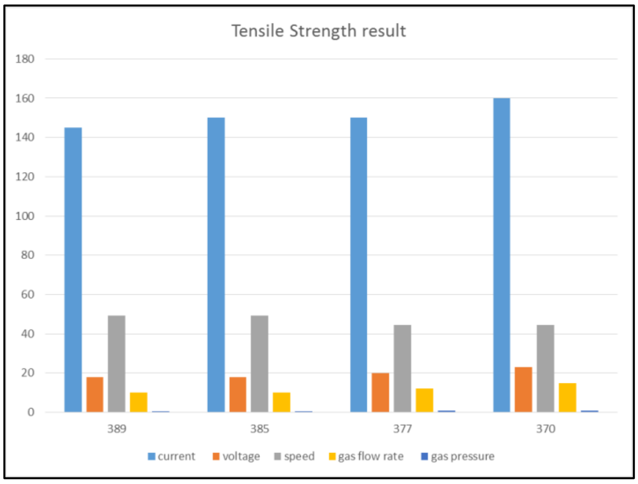

Fig. 3: Tensile Strength result

MIG welding joints Tensile Strength result					
Process parameters					Result
Current (Ampere)	Voltage (Volt)	Gas flow rate (Ltr/min)	Gas pressure (Bar)	Speed (Mm/sec.)	Tensile strength (MPa)
120	25	25	0.5	45	358
125	26	26	0.5	43	350
140	28	27	1.0	43	343

Table 6: MIG welding mechanical results

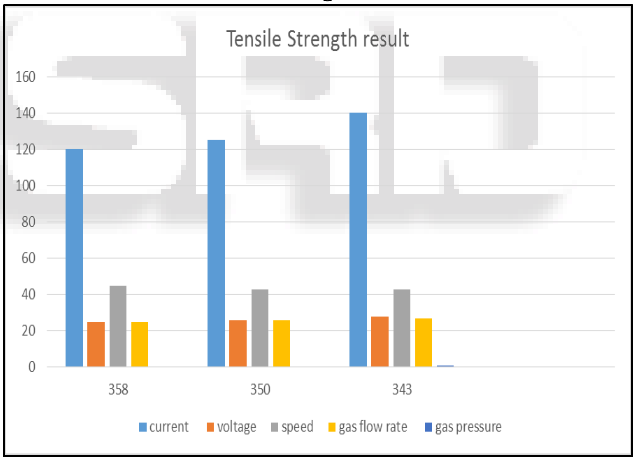

Fig. 4:

C. *Hardness*

TIG and MIG welded sample were examined for the Rockwell hardness measurement across the weld zone with 100 kgf load and a steel ball tool with B scale is used. The experimental study shows that higher hardness at base metal as compared to weld zone and heat effected zone. The main reason of increase or decrease hardness in the weld zone/base metal/ heat effected zone hardness was attribute to the repeated thermal process experienced during the multipass procedure with melting and solidification of the filler metal. The hardness values of all specimen shown in table 7 & 8 for both the sample at HAZ, BM and WZ. In TIG welding when current is increases and all others parameters remain constant, the hardness decreases. In other hand current remain constant and all other parameters increases, the value of hardness increases. When all the parameters including welding current increases, the results shows increase in hardness values again. Results show that as the process parameters such as current, voltage, gas pressure and gas flow rate increase, hardness at base metal, heat effected zone as well as weld zone increases. The main reason behind this hardness is mainly depend on the heat input rate when increasing the values of current, voltage, gas pressure and gas flow rate, the heat input rate is increased. From this increment the brittleness of material increased so hardness value is also increased. Results also show that as welding speed increase, hardness at base metal, heat effected zone as well as weld zone decreases. The main reason behind this the welding speed is inversely proportional to the heat input rate. When welding speed is increased, the heat input rate is decreased and thus, brittleness of material decreases. So the value of hardness also decreases. In MIG welding when the process parameters like current, voltage, gas flow rate, gas pressure are increases, the hardness increases. In other hand welding speed decreases, hardness values increase again. The result and reason also same in the case of MIG welding process. From the comparative study between the TIG and MIG welding joints founded that stainless steel 430 grade MIG welded joint shows higher hardness in comparison with TIG welded joint. The main reason behind this MIG welded joints have higher hardness because of higher heat input rate compared with TIG welding. As the heat input rate increases, brittleness of material increases. Thus, hardness increases.

Sample number	Base metal	Heat effected zone	Weld zone
1	B88	B87	B82
2	B89	B88	B82
3	B90	B90	B84
4	B93	B91	B86

Table 8: TIG welding hardness values

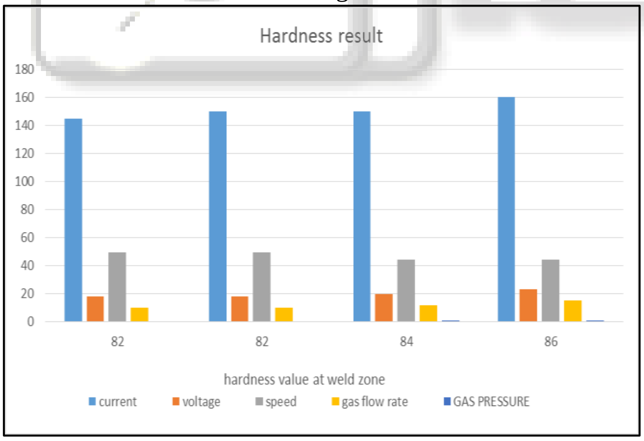

Fig. 5:

Sample number	Base metal	Heat effected zone	Weld zone
1	B94	B91	B88
2	B95	B91	B89
3	B96	B93	B91

Table 7: MIG welding hardness values

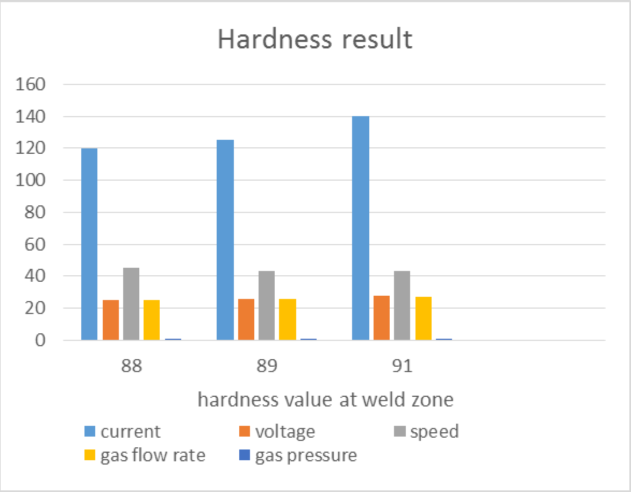

Fig. 6:

IV. CONCLUSIONS

The 8mm thick stainless steel 430 plates were welded by TIG welding process. Full penetration joints without any defects were produced by TIG welding. The mechanical property of TIG and MIG welding joints are investigated. The following conclusion are derived from the experimental results and discussions-

- The joints fabricated by TIG process exhibited higher tensile strength as compared with MIG joints. The superior tensile properties of TIG joints are due to formation of very fine dendritic microstructure in the weld deposit due to low heat input [Anukumar et al., 2015]. When the welding speed is high, the tensile strength is lowered in both cases. TIG welding specimen can bear higher elongation and yield strength. When the welding current or heat input rate is increased the tensile strength of weld zone decreased but yield strength and elongation is increased. Tensile strength is higher with lower welding speed. This indicates that lower range of weld speed is suitable for achieving maximum tensile strength.
- Heat input rate is higher in MIG welding so hardness of MIG welding is greater than TIG welding. Hardness of TIG and MIG welds are lesser than the base metal. When the welding current and voltage is high the hardness value is also high. Hardness is increased with increased heat input rate but decrease on heat effected zone.
- TIG welding is better than MIG welding and it's suitable for steels.

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