"Experimental Investigation and optimization of AISI 1020 Mild Steel on Autogenous Tungsten Inert Gas (TIG) Welding"

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Abstract - *Tungsten Inert Gas welding is also known as Gas Tungsten Arc Welding (GTAW), is an advance arc welding process become a popular choice when a high level of weld quality or considerable precision welding is required. However, the major problems of TIG welding process are its slow welding speed and limited to lower thickness material in single pass. In this work, autogenous. TIG welding has been performed on 5 mm thick AISI 1020 mild steel plate without using any filler material. Wide range of welding current and scan speed has been tested for obtaining a full penetration welding. Activated flux has also been used to improve the weld depth. After performing welding by maintaining different gap between the plates to be welded, weld bead geometry and tensile strength of the weld has been investigated. It is observed that, by maintaining an appropriate gap full penetration welding of plate is possible which gives strength almost similar to base material.*

1. INTRODUCTION

Welding is a process of joining two similar or dissimilar metals by fusion, with or without application of pressure and with or without use of filler metal. Weldability of the material depends upon various factors like the metallurgical changes that occur due to welding, change in hardness of material, in and around the weld and the extent of cracking tendency of the joint. A range of welding processes have been developed so far using single or combination of factors like pressure, heat and filler material used.

1.1 WORKING PRINCIPLE

In TIG welding process, the terminal is non-consumable and motivation behind it just to make a circular segment. The warmth influenced zone, liquid metal and tungsten anode are completely protected room air tainting by a cover of idle gas took care of through the GTAW light. Fig. 1 shows schematic graph of the working guideline of TIG welding process. Welding light comprise of light weight handle, with arrangement for holding a fixed tungsten terminal. In the welding light, the protecting gas streams by or along the terminal through a spout into circular segment area. An electric circular segment is made among terminal and the work piece material utilizing a consistent flow welding power source to deliver vitality and led over the bend through a segment of profoundly ionized gas and metal fumes. The electric curve produce high temperature and warmth can be engaged to malt and join two unique pieces of work piece.

2. LITERATURE REVIEW

TIG welding is widely used for different types of metal & alloy and still lots of research work is going for better performance by TIG welding process.

Krishnan et al. [1] done experiment to analyze the microstructure and oxidation resistance at different regions in the mild steel weld by TIG welding. During welding process a sharp change in the microstructure due to complex thermal cycle and rapid solidification was observed.

This micro-structure change also affects the mechanical properties and oxidation resistance of the mild steel weld. Autogenous TIG welding was performed on 12 mm thick mild steel with 200 A current, 19 V voltage and 100 mm/min welding speed. Finer grain size was obtained at weld metal and heat affected zone.

Raj and Varghese [2] predict the distortion developed during TIG welding of low carbon steel. In their study, have developed three dimensional finite element model like longitudinal, angular or transverse distortion. Distortion in welding produced due to non-uniform heating and cooling. To validate the model welding was performed with welding current 150 A, electrode gap 3 mm, gas flow rate 25 l/min, electrode diameter 0.8 mm and Argon as shielding gas. They concluded that, maximum distortion occurs at surface opposite to the weld and along X direction of weld compare to other two directions.

Abhulimen and Achebo [3] performed experiments to identify the economical welding parameters using Response surface methodology (RSM) during TIG welding of mild steel pipe. Welding Parameters considered were gas flow rate 25 to 30 l/min, welding current 130 to 180 A, arc voltage 10.5 to 13.5 volt and argon as shielding gas. Results showed that, by using TIG welding of mild steel maximum tensile and yield strength of 542 MPa and 547 MPa was achieved respectively.

Mishra et al. [4] have done comparison of mechanical properties between TIG and MIG welded dissimilar joints. Mild steel and stainless steel dissimilar material joints are very common structural application. These dissimilar joints provide good combination of mechanical properties like corrosive resistance and tensile strength with lower cost.

Welding parameters considered for MIG welding were welding current 80-400 A and voltage 26-56volt. TIG welding was performed with 50-76 A current & 10-14 volt voltage.

3. EXPERIMENTAL SETUP:-

For the present project work an autogenous welding set up has been developed to perform welding with a fixed velocity without the application of filler material. A movable vehicle is used to hold TIG torch. The distance between workpiece and torch tip will remain constant the welding process. The speed of movable vehicle is controllable and can be varied according to the requirement of the welding speed and amount of heat required. Figure 3 shows experimental setup for present work.

Table -1: Welding speed on movable tractor

Sl. No.	Number on equipment	Welding speed (mm/s)
1.	1	2.30
2.	1.5	2.98
3.	2	3.6

In this phase of experiment, to study the feasibility of autogenous welding on 5 mm mild steel plate, TIG welding has been performed without using any filler rod. 5 mm thick mild steel plates were cut in 50 mm x 50 mm dimension with the help of band saw. The edges to be welded were grinded with surface grinding machine, so that proper contact is possible between the plates to be joined. Other surfaces were also polished with emery paper (silicon carbide) to remove all impurities from the surface and to provide require surface finish.

Dimension of mild steel	50mm x 50mm x 5mm
Welding speed	2.30 mm/s, 2.98 mm/s and 3.6 mm/s
Arc voltage	15 – 16V
Welding current	180 A, 200 A & 210 A
Gas flow rate	12 l/min
Current type	DC (positive work piece& negative electrode)
Distance between tip and weld center	3 mm
Shielding gas	Argon

Table -1: Experimental planning for autogenous TIG welding of mild steel

After performing the TIG welding of mild steel plate, welded specimens were cut at the perpendicular to the weld scan direction with the dimension of 20 mm x 10 mm for taking optical microscope image of the weld zone. These welded specimens were cut with the help of wire electro discharge machine. After cutting the samples, polishing & chemical etching were performed at the weld cross section, before taken the optical image. Specimens were prepared by usual metallurgical polishing method using different grit size SiC polishing paper and subsequent diamond paste polishing. Nital solution consist of ethyl alcohol (97%) and conc. HNO3 3% has been used for etching the weld cross section by dipping the polished surface in it for 10 sec. Melting depth or weld penetration was checked for each weld sample from the change in microstructure using an optical microscope.

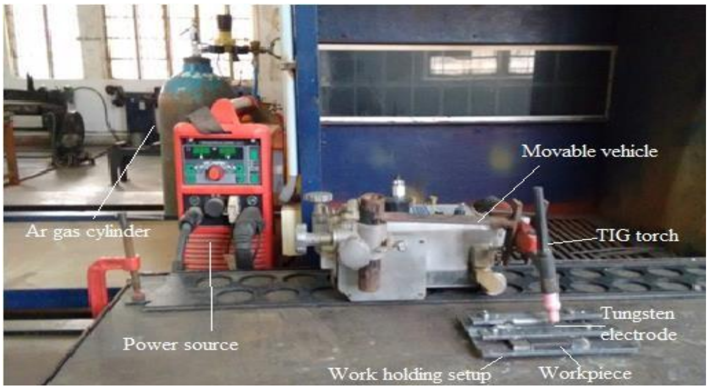


Fig -2: Experimental setup of TIG welding

1. Welding torch – TIG welding torch is capable for both automatic and manual operation. The automatic and manual torches are similar in construction. The manual torch has a handle while the automatic torch normally comes with a mounting rack. The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat effectively. The size of the welding torch nozzle depends on the amount of shielded area desired. The main purpose of TIG torch is to carry the welding current and shielding gas to the weld. For present work a manual torch has been fixed with the movable tracker using clamp arrangement to make it automated.

2. Electrode – A non-consumable tungsten electrode is used in TIG welding process. The tungsten electrode held firmly in the center of the torch and around the electrode a constant flow of shielding gas. The electrode used in GTAW is made of tungsten or tungsten alloy due to its highest melting temperature among the pure metals. Tungsten electrode is surrounded by a gas nozzle. This gas nozzle is generally made of ceramic material. For present experiment 2.4 mm diameter tungsten electrode has been used.

3. Power source – A constant current power source is used for TIG welding process. Direct current with straight polarity is used for welding of mild steel plate. Work material is connected to the positive terminal of DC welding machine and negative terminal to an electrode holder, this welding condition is said Direct Current with straight polarity. The DC power supply used for TIG can be steady or pulsed. For present work DC power supply in steady condition has been used where current is fixed and consequently voltage can vary to maintain a stable arc.

4. Inert gas supply unit – A gas cylinder is used to supply Argon gas to the welding torch. Argon gas is supplied from gas cylinder with a suitable gas flow rate. Gas flow is controlled by regulator and valve. The purpose of supplying inert gas is to shield the weld zone in order to protect it from atmospheric contamination which leads to welding defects. For present experiment gas flow in the range 12-15 l/min has been flown.

5. Movable vehicle – A movable setup is used to provide constant welding speed for TIG welding operation. This movable tractor is used to hold the welding torch. It also helps in maintaining a proper gap between tip of the tungsten electrode and welded area of the work-piece. Manually it is difficult to maintain a constant weld speed and gap between electrode and work-piece. So with the help of a portable moving tractor welding speed and gap between work-piece and electrode can be easily controlled.

6. Work holding setup – It is used to hold the work-piece material. Proper clamping is required to hold the work-piece during welding process, so that during heating and cooling work-piece should not bend. Further if welding done by keeping the work-piece directly on metal plate heat will flow by conduction method and does not concentrate in the welding zone. Therefore work holding device designed in such a way that just below the weld zone of plate some gap is maintained.

3.1 WELDING PARAMETERS FOR AUTOGENOUS TIG WELDING OF MILD STEEL

Dimension of mild steel	50mm x 50mm x 5mm
Welding speed	2.30 mm/s, 2.98 mm/s and 3.6 mm/s
Arc voltage	15 – 16V
Welding current	180 A, 200 A & 210 A
Gas flow rate	12 l/min
Current type	DC (positive work piece& negative electrode)
Distance between tip and weld center	3 mm
Shielding gas	Argon

3.2. WELDING PARAMETERS FOR TIG WELDING OF TIO2FLUX COATED MILD STEEL

Dimension of mild steel	50mm x 50mm x 5mm
Welding speed	2.30 mm/s, 2.98 mm/s and 3.6 mm/s
Welding current	210 A
Arc voltage	14 – 15 volt
Current type	DC (positive work piece& negative electrode)
Distance between tip & weld center	3 mm
Gas flow rate	12 l/min
Shielding gas	Argon
Activated flux	TiO2
Electrode diameter	2.4 mm

4. RESULTS AND DISCUSSION

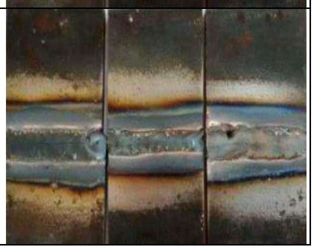
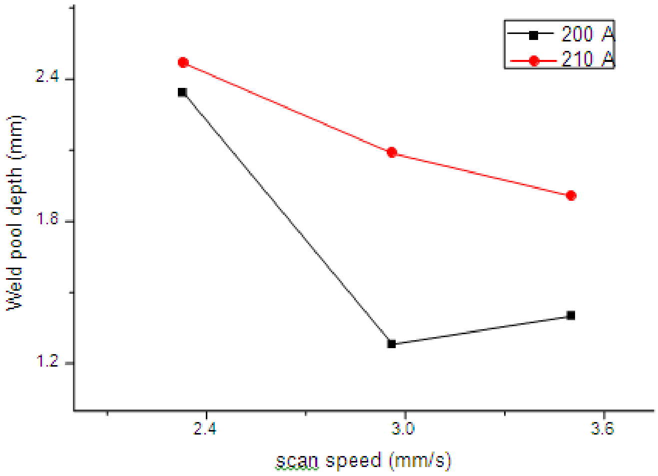
Sl. No.	Welding current	Welded sample at different speed
1	180 A	
2	200 A	
3	210 A	

Fig: - 3 Welded Specimen performed with 3 different speed And current seating by conventional autogenous TIG welding

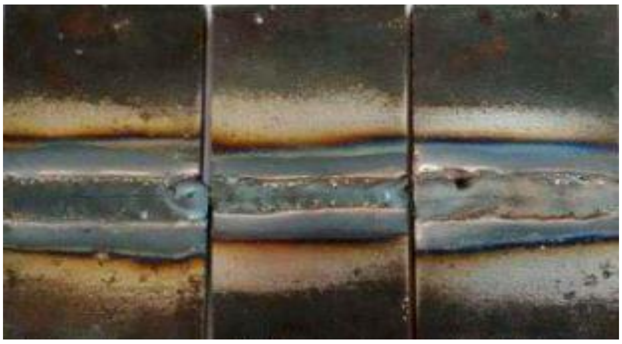
4.1 OPICAL MICROSCOPICE IMAGE AT CROSS SECTION OF WELD BY CONVENTIONAL AUTOGENOUS TIG WELDING PROCESS



4.2 WELD BEAD GEOMETRY AT CROSS SECTION OF WELD ZONE BY CONVENTIONAL AUTOGENOUS TIG WELDING

Sl. No.	Current (A)	Speed (mm/s)	Width (mm)	Depth (mm)
1	200	2.30	6.4	2.33
2	200	2.98	5.76	1.26
3	200	3.6	5.85	1.55
4	210	2.30	6.9	2.45
5	210	2.98	5.82	2.07
6	210	3.6	6.15	1.90

4.3 WELDED SPECIMENS PERFORMED BY ATIG WELDING PROCESS



4.4 OPTICAL IMAGE AT WELD ZONE OF SPECIMEN ATIG WELDING PROCESS

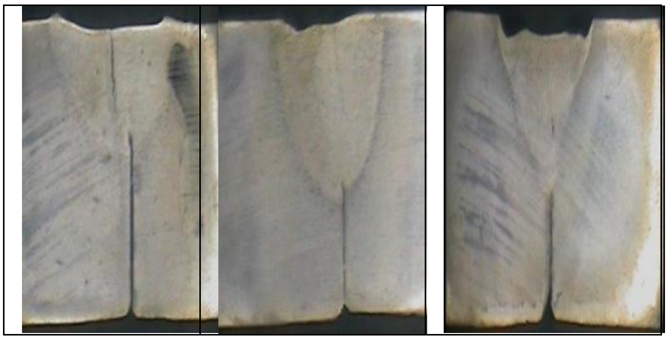


Fig :- Optical Image at Weld Zone of Specimen ATIG welding process

4.5 WELD BEAD GEOMETRY AT CROSS SECTION OF WELD ZONE BY TIG WELDING WITH TIO2 FLUX

Sl. no.	Current (A)	Speed (mm/s)	Width (mm)	Depth (mm)
1	210	2.30	7.16	2.65
2	210	2.98	5.52	3.09
3	210	3.6	6.28	2.95

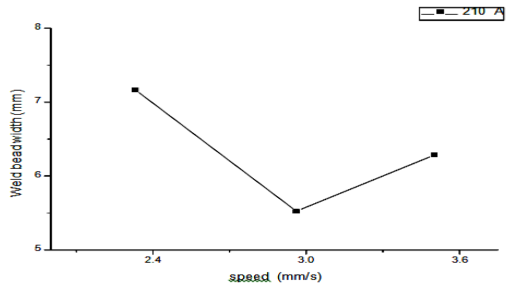


Fig. 17 Variation of weld bead width against scan speed for 210 A welding current

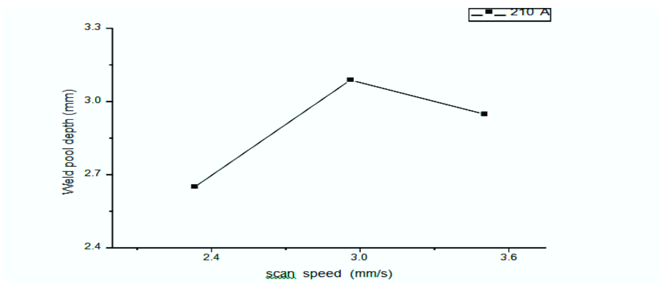


Fig. 18 Variation of weld pool depth against scan speed for 210 A welding current

4.6 COMPARISON OF DEPTH OF PENETRATION BETWEEN WITHOUT FLUX WELD AND WITH FLUX WELD SAMPLE

Table:-4.6.1 Comparison between without flux welds and with flux weld sample

Sl. No.	Current (A)	Speed (mm/s)	Depth (mm) without flux	Depth (mm) with flux
1	210	2.30	2.45	2.65
2	210	2.98	2.07	3.09
3	210	3.6	1.90	2.95

4.7 MEASUREMENT OF WIDTH, DEPTH AND CRATER OF WELDED SAMPLE AT WELD ZONE FOR DIFFERENT CURRENT AND GAP MAINTAIN BETWEEN WORK PIECE

Sl. no.	Current (A)	Gap (mm)	Width (mm)	Depth (mm)	Crater (mm)
1	160	0.5	5.85	2.26	0.29
2	160	0.75	6.05	2.83	0.4
3	160	1	6.2	4.21	0.51
4	180	0.5	6.37	2.47	0.42
5	180	0.75	6.13	3.05	0.76
6	180	1	6.5	4.88	0.9
7	200	0.5	6.52	3.46	0.71
8	200	0.75	6.34	4.61	0.86
9	200	1	6.94	4.98	0.98

Table:-4.7.1 Measurement value of width, depth and crater

5. TENSILE TESTING

Fig. 5.1 Tensile testing specimen

Sl. No.	Welding current (A)	Gap between workpiece (mm)	Tensile strength (MPa)
1	160	0.5	115.95
2	160	0.75	225.21
3	160	1	264.54
4	180	0.5	319.10
5	180	0.75	346.38
6	180	1	501.173
7	200	0.5	442.98
8	200	0.75	395.45
9	200	1	617.22

Table:-5.1 Tensile testing with gap between work piece

6. HARDNESS VALUE FOR SAMPLE

Table:-6.1 Hardness Valve test of material

Sample No.	Welding current (A)	Welding speed (mm/s)	Gap between work piece (mm)	Hardness value at molten metal zone	Hardness value at heat affected zone	Hardness value at base material zone
1	180	2.30	0.5	192.6 HV	158.5 HV	149 HV
2	200	2.30	0.75	198.5 HV	176.8 HV	146.4 HV

7. CONCLUSIONS

- The after effects of the customary TIG welding process performed show that, most extreme profundity of infiltration was gotten with parametric blend of least welding rate and greatest current.
- When a similar technique is rehashed with extra use of TiO2 motion, profundity of entrance increments in contrast with the traditional welding, however some break on the weld zone was watched for utilizing motion.
- With consistent welding speed, another arrangement of tests were finished by keeping up a hole between work piece to be welded. It is seen that, with a hole of 1 mm, imperfection free welding with appropriate material stream got all through the joint for higher welding current.
- Comparing the three techniques for TIG welding, profundity of entrance and elasticity of weld joint is most extreme when satisfactory hole is kept up between the parts to be welded.
- From the diagrams plotted, it very well may be surmised that welding width and profundity increments with increment in welding current and hole kept up between the parts to be welded.

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