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Comparison of Properties of SA 213 T 12 Tube Weldments by GTAW, ATIG, P-GMAW and Alternating Shielding Gas GMAW

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Abstract - The composition SA 213 T 12 chrome moly alloy steel Tubes make it ideal for use in power plants, refineries, Petro-chemical plants, and oil field services where fluids and gases are transported at extremely high temperatures and pressures. These tubes offer the advantages like Consistent Workability, Preferred Fabrication and better Mechanical Properties. These tubes are often used in the water wall tubes, reheater tubes and super heater tubes of super critical and ultra-super critical boilers. Conventionally, Pulsed Gas Metal Arc Welding (P - GMAW) and Gas Tungsten Arc Welding (GTAW) processes are used to join these tubes. Activated TIG (ATIG) and Alternating Shielding Gas GMAW (A – GMAW) are the emerging processes for higher quality and productivity.

This paper compares the properties of weldments of SA 213 T 12 tubes welded by the above processes.

Keywords – T 12, P GMAW, ATIG, GMAW, Alternating Shielding Gas, Power plants.

Introduction

SA 213 T12, the ferritic and austenitic alloy steel tubes are widely used in water walls, reheaters, heat exchangers, and condensers of power plants, marine application, refineries, paper pulping, petrochemical applications, pressure vessels and general engineering applications.

For boiler applications, these tubes are welded with Pulsed GMAW (P-GMAW) and Gas Tungsten Arc Welding (GTAW) processes to meet the requirements of higher quality and productivity. Activated TIG (ATIG) and GMAW with Alternate Shielding Gas (A-GMAW) are the new high productive processes with improved quality, reduced processing time, savings in energy and consumables, reduced arc time weldment, etc.

Butt joining of the tubes were carried out with optimized parameters and the mechanical and metallurgical properties are compared.

A. Alternating Shielding Gas GMAW (A-GMAW)

The operating point in GMAW process depends on the shielding gas used; besides the wire feed speed [current] and voltage settings [1]. However, the stable operating point for each shielding gas viz. Argon and CO_2 is located differently on the parametric window. By use of alternating shielding gases wherein two different shielding gases are alternatingly supplied to the torch for effectively protecting the weld pool from the atmospheric contamination. The arc dynamics changes alternately in tune with the alternating shielding gas supply. The frequently changing arc dynamics positively influences the weld pool thereby the incidence of defects like porosity and crack are decreased. Besides, it also results in improved weld metal mechanical properties in steel. Other factors such as flat bead profile and smooth weld metal transfer are considered to be beneficial aspects of gas pulsing in GMAW process. GMAW with alternating shielding gases is characterized by the switching of the transfer mode from spray to short circuiting type, which produces reliable fusion and penetration. Gas pulsing frequency and procedures have to be established to meet the quality requirements of tube butt joints. Fig. 1 shows the Principle of operation of Alternating Shielding gases GMAW.

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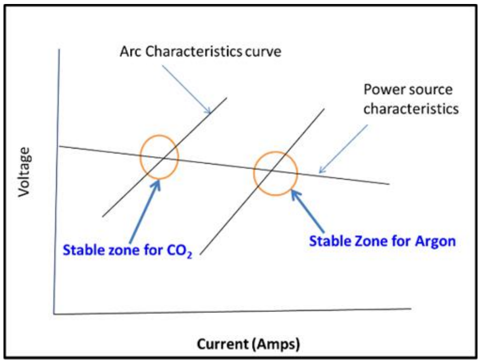

Fig. 1 Principle of Operation of Alternating Shielding gases GMAW [1]

B. Activated TIG (ATIG)

The increased weld penetration in ATIG welding is attributed to reverse Marangoni effect. Marangoni effect is one of the penetration mechanisms which refer to the convective flow within the weld pool due to the surface tension gradient on weld pool surface. During TIG welding the surface tension gradient is negative and the convection movements are centrifugal leading to shallow penetration. The addition of activated flux induces an inversion of the convection currents changing the sign of the surface tension gradient, resulting convection movements changed to centripetal. Hence, the penetration depth increases [2].

EXPERIMENTAL WORK

The SA 213 T 12 tubes have been edge prepared by the facility available as per the requirement. Square butt edge preparation was carried out for TIG process and for other processes 70º V groove.

Number of experiments to optimize the parameters and the optimized parameters were used for welding trials. Preheating has been done as per requirement using LP gas before welding. After welding, the samples were subjected to Post Weld Heat Treatment (PWHT) also as per ASME code requirement. After PWHT, the joints were subjected to Radiographic Tests (RT). Transverse tensile and impact specimens have been extracted from the welded tubes and tested as per AWS standard. Microstructural studies have been observed in the base metal and weld metals. During welding of samples, the voltage and current waveforms were also recorded by using Analysator Hannover.

The surfaces of the tubes to be joined are cleaned to remove oxide films, oil coatings, etc. prior to welding. Día 0.8 mm ER 80 S B2 filler wire was used for all welding trials.

Welded joints with GTAW process were carried out in orbital GTAW machines using Dia. 54 x 4 mm SA 213 T 12 tubes with 100% argon as shielding gas. The welding was completed in 3 passes.

Welding trials with P-GMAW process were carried out in the automated tube butt welding machines using Dia. 57.15 x 14.3 mm tubes with 95% argon and 5% CO_2 mixed gas, as shielding gas. The welding was completed in 5 passes.

C. ATIG Processes

After ensuring, right fit up of the square edge prepared tube joints, the activated flux paste (mixture prepared with flux powder and acetone) was applied on the joint area by using a smooth brush. The flux that was applied had major elements such as Silica, Titanium, Al, Fe, Calcium, Manganese, Nickel, Chromium and Copper. On applying the flux on the joint area, shielding gas, suitable welding current, welding voltage, welding speed, wire feed rate, gas flow rate, torch angle, torch position, polarity were set appropriate so that full penetration is obtained in a single pass.

D. Alternating Shielding Gas GMAW (A-GMAW)

Dia. 57.15 x 14.3 mm SA 213 tubes were welded by using alternating shield gas GMAW process. The shielding gases argon and CO_2 are alternatingly fed into the weld pool through the gas alternator at the frequency of 0.02 sec and 0.04 sec respectively.

Fig. 2 shows the welding set up for ATIG and A-GMAW processes.

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Fig. 2 Set up & Weld Joint for A-GMAW process and ATIG processes

RESULTS AND DISCUSSIONS

The mechanical properties of welds deposited by all the four types have been studied and compared.

E. Radiography Test (RT)

The welded samples were subjected to Radiography (RT) test to ensure the soundness of the joint. All the joints met the RT requirement as per ASME.

F. Tensile Test

The tensile strength of the welds were determined by using UTM 600 kN. The transverse tensile test specimen is prepared as per the standard AWS B 4.0.

Table I shows the transverse tensile test results for SA 213 T12 tube welds and compared with parent / base Material.

TABLE I
TENSILE TEST RESULTS

Description	UTS MPa	Position of Fracture
GTAW	474, 481	Base Metal
ATIG	491, 511	Base Metal
P-GMAW	467, 470	Base Metal
A-GMAW	470, 473	Base Metal
Parent Material	415	As per Literature

From Table I it could be observed that the UTS values of all the four methods are above the minimum value of base material i.e., 415 MPa. The UTS values of ATIG welds are much higher than other processes. The A-GMAW also results in better UTS value than P-GMAW.

G. Guided Bend Test

The welds were subjected to guided bend tests and test coupons were prepared as per AWS B 4.0. Both transverse face and root bend tests were carried out for GTAW and ATIG and side bend test for P-GMAW and A-GMAW, to evaluate both the ductility and soundness of the weldments. 180° bend tests with mandrel diameter equal to 4t were carried out on all welded samples. Both the specifications were tested and the results are tabulated in Table II. All samples passed the test without any discontinuity which ensures the ductility of the weld.

TABLE II
GUIDED BEND TEST RESULTS

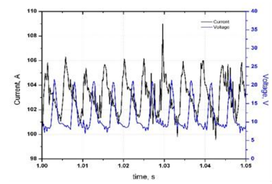
Description	Face	Root	Side
GTAW	Passed	Passed	-
ATIG	Passed	Passed	-
P-GMAW	-	-	Passed
A-GMAW	-	-	Passed

H. Macrograph & HAZ

The macrograph of the joints and with of Heat Affected Zone (HAZ) are compared as

detailed below.

A
B
C
D
Fig. 3 Macrographs



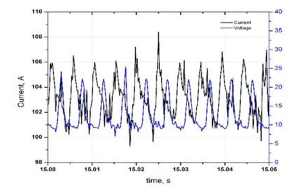
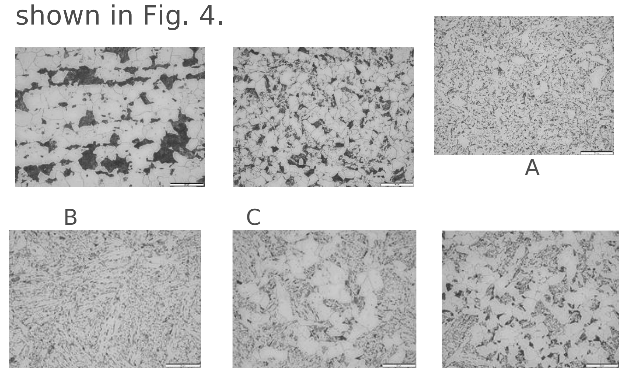


Fig. 3A shows the bead profile of GTAW, B shows the ATIG profile, C the P-GMAW and D the A-GMAW. Comparing the bead profiles ATIG produces deeper penetration and lesser bead width in single pass. The bead width of gas alternator is also uniform and lesser comparing with P-GMAW and A-GMAW. Further, it could be observed that the width of HAZ is 5.29 mm is for the weld with A-GMAW against 5.56 mm for P-GMAW and this may be due to the low heat input in A-GMAW to the weld pool.

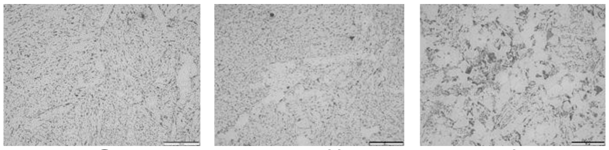
I. Microstructure

The microstructural study was done under the optical microscope under proper illumination condition in the desired region, under 500X magnification for P-GMAW and A-GMAW joints.

The microstructure of base materials, HAZ and weld metal for SA 213 T12 tube are shown in Fig. 4.



A
B C
D E F



G H I

A: Base Metal B: P-GMAW HAZ C: A- GMAW HAZ

D: P-GMAW Weld Top E: P-GMAW Weld Middle C: P-GMAW Weld Bottom G: A-GMAW Weld Top H: A-GMAW Weld Middle I: A-GMAW Weld Bottom

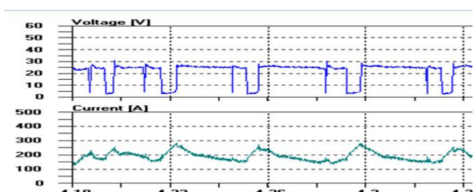
Fig. 4 Micrographs of Welds

Equal amount of polygonal ferrite and bainite was seen in base metal. Hard martensitic phase was observed at the HAZ; also prior austenite grain boundary is seen.

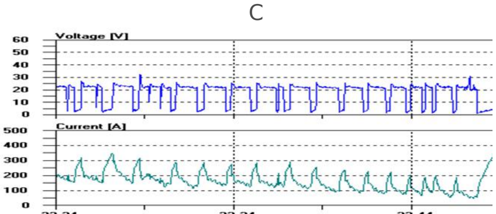
It can be seen that the bainite structure is formed at the weld metal region in both gas mixer and gas alternator The coarse polygonal ferrite was noticed together with bainitic phase at middle and bottom of the weld metal of gas mixer when compared to gas alternator.

J. Arc Characteristics

During the welding trials, the current and voltage signatures were captured using the Analysator Hannover system, developed by Late Prof. Dr. Ing. Rehfeldt of Germany. The current and voltage transient signatures are shown in Fig. 5 and analyzed.



C



D

A: GTAW B: ATIG C: P-GMAW D: A-GMAW

Fig. 5 Current & Voltage Characteristics

From Fig. 5 A and B, It will be interesting to note that comparing to GTAW, in ATIG process, the arc voltage increases significantly. Further, the arc voltage is much more stable comparatively.

While comparing Fig. 5 C and D it can be observed that Combination of argon and CO_2 in A-GMAW for a shorter duration generate more pulses which enhance the metal deposition with reduced heat input, also enables to increase the welding speed during welding.

In the case of P-GMAW the occurrence of lesser peak current for a longer duration will drastically increase the instantaneous heat input.

CONCLUSIONS

The weld metal deposited by all the methods is found to meet all mechanical properties viz. tensile and bend, as per ASME standards. ATIG and A-GMAW produces much better results than conventional processes.

- In ATIG process, the welding has been completed in single pass, whereas in other process it is multipass welds.
- The productivity of tube joints is increased by three times per shift in ATIG welding compared to GTAW method.
- The consumption of power, shielding gas, consumable wire came down to approx. 50% for ATIG.
- The gas consumption in A-GMAW is lesser comparing to P-GMAW.
- The current and voltage signature analysis proves that ATIG process results in more stable voltage.
- The A-GMAW produces more pulses and higher peak current which enable the process to increase the speed as well with reduced heat input.
- The bead profile of ATIG and A-GMAW are better than GTAW and P-GMAW.
- The microstructure of A-GMAW is better than P-GMAW.

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