A Review on Effect of A-TIG Welding Process Parameters on Weld Geometry of Stainless Steel 304L

Ganesh S Mudaliyar[1] J. D. Patel[2]
[1]PG Student [2]Professor
[1,2]Department of Mechanical Engineering
[1,2]Merchant Engineering College, Basna, India

Abstract— Tungsten arc welding processes are being employed widely for the precision joining of critical components which require controlled heat inputs. The small intense heat sources provided by the tungsten arc are ideally suited to the controlled melting of the material. Flux is an inorganic compound suspended in a volatile medium to increases the penetration and provide arc constriction. A variant of the TIG process by using flux called Activated-TIG process. The surface of the work piece is covered with a thin layer of the flux, which is usually a metal oxide. This layer will act as an insulation barrier to the arc current. Temperature at the centre of the weld pool will be sufficient to melt the flux so that the electric current can penetrate the flux to the weld pool and work piece.

Key words: Activated-TIG Welding, Depth of Penetration, Weld Bead, Flux, Angular Distortion, Stainless Steel 304L

I. Introduction

The study was concerned with the activating flux gas tungsten arc welding. The flux ingredient, which is inorganic compound (which can be used to produce deep penetration and arc constriction) are available in variety of range and compositions. Some of fluxes have been reported effective for particular materials. Activating fluxes contain oxides and halides (chlorides and fluorides). Oxide coating consists of iron, chromium, silicon, titanium, manganese, nickel, cobalt, molybdenum and calcium are reported to improve weld ability and increase the welding speed. The halogens, calcium fluoride and AlF_2, have claim to constrict the arc and increase weld depth of penetration activated flux is a mixture of inorganic material suspended in volatile medium (acetone, ethanol etc).

In activated flux GTAW process, a thin layer of the fine flux is applied on the surface of the base metal with brush before welding. Flux mixed with acetone to make it in a paste form as shown in the figure 1. During activated flux, welding a part or all the fluxes is molten and vaporized. There is different types of fluxes (oxides) used in welding like MnO_2, SiO_2, TiO_2, MoO_3, and Al_2O_3 etc. As a result, the penetration of the weld bead is significantly increased.

Gas tungsten arc welding (GTAW)welding has an inherent difficulty in achieving deep penetration. The depth of penetration that can be achieved in 8 mm thick S.S plate with conventional GTAW welding is approx. 2.5 mm which can be enhanced by silicon dioxide flux. The aim of the research work is to identify the effect of silicon dioxide flux on weld geometry and analyses it. Silicon dioxide flux plays a major role in influencing the various properties of stainless steel GTAW welds.

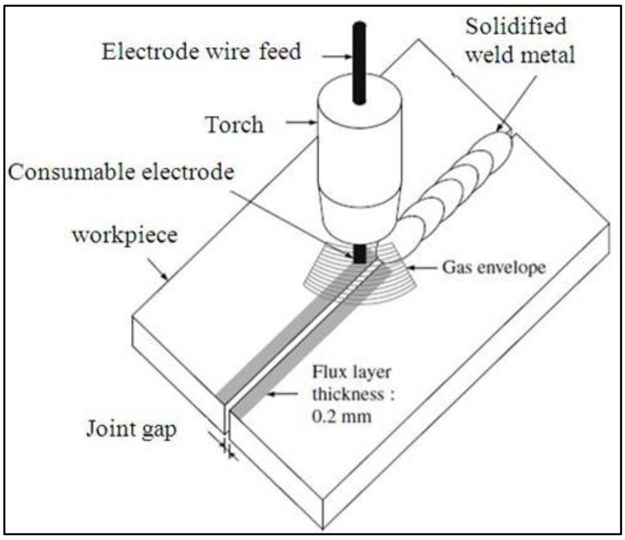

Fig. 1: Schematic of TIG welding [10]

II. Welding Set Up

A. TIG Welding

Tungsten inert gas (TIG) or gas tungsten arc (GTA) welding is the arc welding process in which the arc is generated between the non-consumable tungsten electrode and work piece. This tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium. Following is the schematic diagram of TIG welding shown in figure 2.

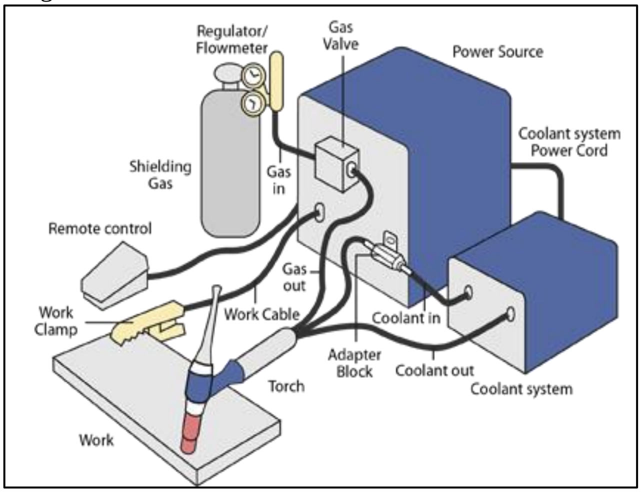

Fig. 2: Schematic of TIG welding

B. Mechanism of A-TIG Welding

Available literatures show that some of the mechanisms, which play major role in increase weld quality are Marangoni Effect, Buoyancy force, Electromagnetic force, Arc constriction due to active flux, Arc constriction due to negative ions. Arc concentration effect is explained in

Figure 3 As the surface flux evaporates and surrounded by a region of arc as atoms which forms under the high temperature of weld arc. Evaporated atoms seize electrons and shape into the negative ion in the region due to lower temperature inside. Arc conductivity decreased the automatic contraction and the heat concentrated. This concentrated arc permits control of heat input to the work piece resulting in a narrow heat affected zone. This is an advantage because while this process is ongoing, the base metal faces change due to superheating of arc and fast cooling rate.

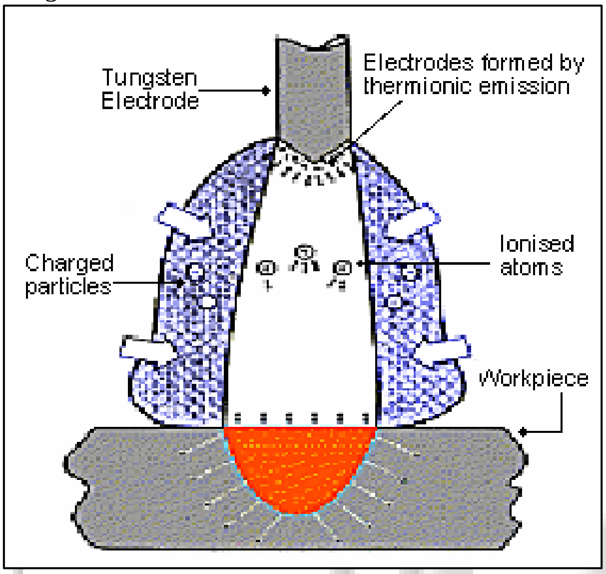

Fig. 3: Mechanism of Arc Constriction Due To Vaporized Molecules [2]

III. EFFECT OF A-TIG WELDING PROCESS PARAMETERS

A. *Welding Current*

As the electrode feed speed is varied, the welding current varies in a like manner when a constant voltage power source is used. This occurs because the current output of the power source varies dramatically with the slight changes in the arc voltage (arc length) that result when changes are made in the electrode feed speed. When all other variables are held constant, an increase in welding current results in an increase in the depth and width of penetration, deposition rate, and weld bead size.

B. *Arc Voltage and Arc Length*

Arc voltage and arc length are related terms that are often used interchangeably. However, they are different. Arc voltage is an approximate means of stating the physical arc length in electrical terms. The same physical arc length, however, could yield different arc voltage readings, depending on factors such as shielding gas, current, and electrode extension. When all variables are held constant, a reliable relationship exists between the two: an increase in voltage setting will result in longer arc length. Although the arc length is the variable of interest and the one that should be controlled, arc voltage is more easily monitored. Because of this fact, and because the arc voltage is normally required to be specified in welding procedures, it is the term that is more commonly used. From any specific value of arc voltage, an increase tends to flatten the weld bead and increase the width of the fusion zone. Excessively high voltage can cause porosity, spatter, and undercut. A reduction in voltage results in a narrower weld bead with a higher crown.

C. *Travel Speed*

Travel speed is the linear rate at which the arc is moved along the weld joint. When all other conditions are held constant, weld penetration is a maximum at an intermediate travel speed. When travel speed is decreased, the filler metal deposition per unit length increases. At very slow speeds, the welding arc impinges on the molten weld pool, rather than the base metal, thereby reducing the effective penetration. As the travel speed is increased, the thermal energy transmitted to the base metal from the arc increases, because the arc acts more directly on the base metal. However, further increases in travel speed impart less thermal energy to the base metal. Thus, melting of the base metal first increases and then decreases with increasing travel speed. As travel speed is increased further, there is tendency toward undercutting along the edges of the weld bead, because there is insufficient deposition of filler metal to fill the path melted by the arc.

D. *Shielding Gas Composition and its Flow Rate*

The primary function of the shielding gas in most of the welding processes is to protect the surrounding atmosphere from contact with molten metal. In the GTAW process, this gas plays an additional role in that it has a pronounced effect on arc characteristics, mode of metal transfer, and depth of fusion, weld bead profile, welding speed, and cleaning action. Inert gases, such as argon and helium, are commonly used, as is the inert gas, argon. It is also common to use mixtures of these gases and to employ small additions of oxygen. A mixture Ar-He is suitable for all carbon steel and is recommended with low alloy steel electrodes. Weld metal toughness is improved often, when one of these mixtures is used.

E. *Arc Pulsing*

Pulse TIG welding is used when the current output (amperage) changes between high and low current. Electronics within the welding machine create the pulse cycle. Welding is done during the high-amperage period within the cycle. DC Pulse TIG welding allows faster welding speeds with better control of the heat input to the job, reducing the heat input minimizing distortion and warping of the work and is of particular advantage for the welding of thin stainless steel and carbon steel applications. The high pulse frequency capability of the advanced inverter agitates the weld puddle and allows you to move quickly without transferring too much heat to the surrounding metal. Pulsing also constricts and focuses the arc thus increasing arc stability, penetration and travel speeds.

Welding parameters	Main effects on weldment	
Current in excess of optimum	Excess spatter and flat wide bead deposit	Deep penetration and electrode overheat

Current less than optimum	Metal piles up and Poor penetration	Poor bead shape
Voltage in excess of optimum	Arc wander, deposit irregular and flat bead	Spattering occurs
Voltage less than optimum	Irregular piling of weld metal and arc extinction	Little penetration
Travel speed in excess of optimum	Narrow thin weld bead	Undercut
Travel speed less than optimum	Wide thick deposit of metal	Reduces penetration
Coating of Activated Flux	Deep penetration and improve weldability	Constrict the arc and reduce number of passes
Excessive electrode extension	Poor penetration	Unstable arc
Shielding gas (Ar)	Protect the weld pool and easy arc initiation	Enhance speed and penetration

Table 1: Welding Parameters and its Effect on Weldment

IV. APPLICATION OF A-TIG WELDING

- Fillet TIG Welding of Structural Steel Tubing.
- It can weld aluminium, copper, nickel, magnesium and their alloys, stainless steel.
- It can weld high temperature and hard surfacing alloys like zirconium, titanium etc.

V. EXISTING LITERATURE REVIEW

Agrawal N et al. (2017) has undertaken the research and progress in tungsten inert gas (TIG) and metal insert gas (MIG) welding of different materials are critically reviewed from different perspectives. Input parameters are current, welding speed and gas flow rate. By considering several aspects of corrosion resistance properties, microstructure, dissimilar metal welding and optimization of different welding process using experimental and numerical approaches. Using higher welding speed with higher current enhance the mechanical properties of the weld metal. Welding speed adversely affects the bead geometry of welded joints. The size of heat effected zone is less when low heat input is used while welding stainless steel using GTAW process.

Kurtulmus M et al. (2017) had studied the parameters are welding current, welding speed and flow rate on depth of penetration. In this review paper, A-TIG welding of austenitic stainless steels is examined. The welding flux, the shielding gas and the welding parameters affect the weld penetration in A-TIG welds. The effects of the activated flux welding mechanisms, the flux chemical composition, thickness of the flux, flux powder size welding current, the arc voltage, the arc length, the welding speed and composition of the shielding gas on weld geometry of austenitic stainless-steel a-TIG welds are explained in detail. When the oxygen concentration in the weld metal is over 70 wt. ppm, the Marangoni convection in the weld pool changes from outward to inward. Consequently, a deep and narrow weld shape forms. A-TIG welding process leads to less welding distortions and higher weld strengths. Deep welds give distinguished savings in welding time and weld costs.

Babu A. V. Santhana et al. (2016) had examined penetration capability of tungsten inert gas (TIG) process, flux bounded TIG (FBTIG in aluminium alloy aa 2219 t87. Input parameters involved in this process are peak current: 160–240A, speed: 160 to 200mm/min, pulse duration: 20% to 80%, pulse frequency: 2 to 10 Hz, arc length: 2mm, shielding gas: Ar, 30 l/min, electrode tip angle: 35◦, tungsten electrode diameter: 3.2mm and base current: 100A. The bead depth is also observed as 1.91mm in conventional TIG process where as the depth significantly improved to 4.61mm in FBTIG process. When peak pulse current is varied from 160 to 240A, the bead depth increases steadily from 1.04 to 3.04mm. The depth to width ratio increases from 0.24 to 0.34 as the peak current increases from 160 to 220A. When current increases further to 240 A, the ratio slightly decreases to 0.33. This is because along with depth, bead width also increases at current levels above 220A. When speed is varied from 160 to 200mm/min, the depth to width ratio decreases from 0.36 to 0.31. The bead depth also decreases steadily from 2.5 to 1.65 mm. This is caused by lesser heat input at higher speeds.

Kumar V et al. (2016) had presented research on effect of TIG welding parameters such as welding current, gas flow rate, welding speed, weld torch angle that are influences on responsive output parameters such as weld penetration, width, fusion area, micro hardness, and tensile strength of welding using taguchi method. In taguchi method, L9 orthogonal array is used for experimentation. Surface plots and perturbation plot are generated by using mathematical models developed for penetration, weld width, fusion area and UTS these plots may be useful for prediction of the responses like UTS, penetration, width and fusion area the response can also be estimated from these plots. Hardness value increased from base region to HAZ and HAZ to weld region.

Kumar G et al. (2016) had studied bead-on-plate welds were made on 10-mm-thick 304b plates using gas tungsten arc welding with Ar and Ar+2% nitrogen as the shielding gases, activated-flux GTA and electron-beam welding processes. Full-penetration welds were obtained in a single pass using activated-flux GTA and EB welding. By using variable input parameters defect-free welds of 304b4 borated stainless steels can be easily made using GTA, activated-flux GTA, nitrogen-added GTA and EB welding processes. Low-heat-input EBW inhibits the formation of PMZ. A significant loss in the hardness occurs in the PMZS Of the GTA and nitrogen-added GTA welds, which is mainly due to the slow cooling rates associated with high heat inputs.

Vasudevan M et al. (2016) had developed flux for enhancing the penetration performance of TIG welding process for autogenous welding of type 304L and 316L stainless steels. Multi-component activated flux was developed which was found to increase penetration of 10-12 mm in single-pass TIG welding of type 304L and 316L S.S.

Improvement in toughness. Values were observed in 316L stainless steel produced by A-TIG welding due to refinement in the weld microstructure in the region close to the weld center. This research also compares 304L (10-mm-thick) stainless steel weld joints made by TIG and A-TIG welding processes.

Duhan et al. (2014) used Fe_2O_3, $MgCl_2$, MnO_2 And ZnO as an activating flux to investigate the effect of activated tungsten inert gas (activated TIG) process on microstructure and hardness of grade 304 stainless steels.MnO_2 Flux can only led to increase in the hardness (306hv) in weld zone except the other flux used. $MgCl_2$, which shows unidirectional self- cooled mixed grain structure of austenite and ferrite in the weld zone. All the fluxes show fully austenitic ferrite grain structure at the base metal and non-uniformly cooled unidirectional grains with size varying from fine to coarse in the weld zone of the metal except $MgCl_2$.

Patel et al. (2014) conducted the tests on sheets with the dimensions of 100×70×6 mm were prepared and tests were conducted. Optimal parameters of welding process were determined using taguchi method with L9 orthogonal array. Optimal parameters of the process are welding current 110 A, gas flow rate 13 l/min, at constant TiO_2 flux. And for SiO_2 flux the optimal parameter of the process are welding Current 110 A, gas flow rate 7 l/min, for using the proportion flux the optimal process parameter are welding current 110 A, gas flow rate 7 l/min and flux proportion are 60 % SiO_2 AND 40% TiO_2 flux. Weld penetration depth is increased in due to the increase in the current and it was also determined that decrease the weld width which is important term of welding distorting.

Alsabti et al. (2014) concluded that mainly arc temperature and arc force contributed to the deeper weld penetration using two designed flux-cored tubular wires containing cryolite (Na_3AlF_6) and MgF_2. Immersion corrosion test results on the ATIG weld specimens in separate 3.5% sodium chloride and 0.1% phosphoric acid solutions for 800 h, particularly in terms of mass loss, compared favourably with the autogenous welds. Wires 45 and 15 produced welds with much better corrosion resistance than TI-CP G2. As the cryolite content in the flux increases, the weld penetration, arc force, and arc temperature increase as well.

Tseng et al. (2010) had used input parameters as activated flux(MnO_2, TiO_2,MoO_3, and Al_2O_3),weld current-200A, travel speed-150mm/min, diameter of electrode-3.2mm, tip angle of electrode 45◦, electrode gap-2mm,shielding gas-pure argon and gas flowrate -10 l/min which is used to analyse impact on weld morphology, angular distortion, delta-ferrite content, and hardness of type 316l stainless steels using optical microscope. When using oxide fluxes, the delta-ferrite content in activated TIG weld metal slightly increased to 7.0–7.6 FN. This result showed that type 316l stainless steel TIG welding with SiO_2 flux produced a substantial increase in the weld depth and weld depth-to-width ratio of about 7.25mm and 1.02. Constricted arc plasma as a mechanism in increasing activated TIG penetration.

Qing-ming et al. (2007) had investigated that the SiO_2 flux can increase the arc voltage. While TiO_2 has no effect on arc voltage compared with conventional tungsten inert gas welding (C-TIG). It is found that the arc shape of A-TIG welding used with the SiO_2 Flux has changed obviously. Weld beads were achieved by a TIG welding process using welding currents between 80 a and 180 a. Straight polarity and mounted torch with a standard 2% thoriated tungsten electrode were used in this welding process and 99.99% argon was used as shielding.

VI. CONCLUSIONS

Based on literature survey we can conclude that the there will be significant Influence of process parameters such as Welding current, welding speed, Arc pulsing, Arc length and types of shielding gas along with their flow rate on efficiency and output of TIG welding we can conclude that TIG welding is the most widely used arc welding process due to its vast range of advantages over other welding process. It has been observed that TIG welding can be approach to its best output when the above listed parameters are set to its most suitable atmosphere for the specified work. Welding current depends upon the selection on heat dissipation required either on work piece or electrode. Mostly DCEN or DCSP is used. Tungsten electrode Tip is also shaped accordingly. Welding speed depends upon the types of shielding gas used and thickness of material. When it comes to weld Stainless Steel TIG is best joining process. Flow rate of shielding gas in both pre-weld stage and post weld stage plays a major role into the contribution of weld quality. Arc pulsing of TIG welding allows faster welding speeds with better control of the heat input to the job, reducing the heat input minimizing distortion and warping of the work and is of particular advantage for the welding of thin stainless steel and carbon steel applications

VII. FUTURE SCOPE

Effect of TIG welding parameters on the weld joint of stainless steel is explained in this paper which further useful to understand and chose the proper welding parameters to suit best on the optimum working condition. Behaviour of angular distortion of the workpiece regarding to specific input parameter needed to be research. Effect of the quantity of the particular parameters on the weld pool and weld geometry can be more precisely forecast for the best output.

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