A Review on the Optimization of Parameters of Gas Tungsten Arc Welding of Aluminium and Aluminium Alloys

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Article Info
Article history:
Received 02 January 2017
Received in revised form
20February 2017
Accepted 28 February 2017
Available online 15 March 2017

Keywords
Gas Tungsten Arc Welding, Aluminium alloy, Tensile Strength, Welding Current, Helium-Argon

Abstract
Gas Tungsten Arc Welding (GTAW) is one of the most popular welding techniques for aluminium alloys. The accuracy and efficiency of the joint largely depends upon the type of power supply(DCEP/DCEN/AC), welding speed, type of shielding gas used. This paper deals with the review of various parameters on which weld quality depends and researches carried out to analyze the weld quality obtained, defects encountered, effects of welding parameters on weld bead profile and mechanical properties etc. for TIG welding of aluminium or aluminium alloys. It consists of the amalgamation of effects of various parameters and the techniques suggested and adopted for their optimization to obtain a better-quality joint with reduced crack sensitivity, improved mechanical strengths and stronger Heat Affected Zone (HAZ).

1. Introduction

Among many globally accepted materials for industrial purposes, aluminium holds a major rank not only because of its high versatility but also because of its distinctive properties like low density, high resistivity to corrosion and great ability to bent and twist instead of breaking or splintering on applying pressure. Aluminium, because of its efficient ductility and malleability, is extensively used in the manufacturing of automobiles, aircraft bodies, trucks, railways, cars, marine vessels, bicycles, spacecraft, etc. Welding of aluminium is a difficult process because of its high affinity towards oxygen to form oxides. Fusion welding of Aluminium and its alloys is always a great challenge for designers and technologists due to the intrinsic problem of porosity in aluminium welding and its eventual strength reductions. High coefficient of thermal expansion of aluminium, solidification shrinkage, and high solubility of hydrogen during its molten state creates associated problems during fusion welding of aluminium alloys. This implies that the proper welding technique under controlled environment is necessary to obtain better weldments of aluminium material.

Gas Tungsten Arc Welding (GTAW) has been widely preferred as the most efficient welding technique.

2. Gas Tungsten Arc Welding-

TIG welding (Tungsten inert gas welding), also called as gas Tungsten Arc Welding (GTAW), uses a non-consumable electrode and a separate filler metal with an inert shielding gas. GTAW process welding set utilizes suitable power sources, a cylinder of Argon gas, welding torch having connections of cable for current supply, tubing for shielding gas supply and tubing water for cooling the torch. GTAW apparatus consists of a non- consumable electrode, a separate filler material and an environment of inert gas preferably mixture of helium and argon in welding of aluminium alloys. The welding torch has connection of cables for the current supply, tubing for shielding gas supply and for coolant water supply. The shape of the torch is characteristic, having a cap at the back end toprotect therather long tungsten electrode against accidental breakage.

Power sources used for TIG welding must deliver a constant current at a preset value. They are often called "drooping characteristic" units. Rectifier units are commonly used for DC welding although motor generators may be more suitable for site use. Combined ac/dc power sources can be used where there is a mix of work. This paper discusses various researches carried out to analyze the weld quality obtained, defects encountered, effects of welding parameters on weld bead profile and mechanical properties etc. for TIG welding of aluminium or aluminium alloys. The variables that affect weld penetration, bead geometry and overall weld quality which has been discovered in this paper are welding current, polarity(DCSP/DCRP), arc voltage or the arc length, welding speed, weld joint position, electrode diameter and shielding gas and its flow rate.

In 1999, Zhang and Zhang [1] studied the crack sensitivity of aluminium 6061 alloys under the opposing dual torch GTA welding and found that this technique is much suitable for welding without the use of filler metal and reduces crack sensitivity of the welded region. It was also found that other advantages like reduction in the number of passes were also obtained.

In January 2008, Hakem et al. [2] studied the heat treatment and effects of welding on mechanical properties and microstructure evolution of 2024 and 7075 aluminium alloys. Solutions treat the two alloys at different temperature and then quench in water. Dissimilar 2024 T3 and 7075 T6 have been produced by TIG Welding. Both the sheets measured 2mm thickness. Grains of the parent material adjacent to the fusion line showed coarsening of the re-crystallized grains and migration of the coarse and intermediate-size second-phase particles to the grain

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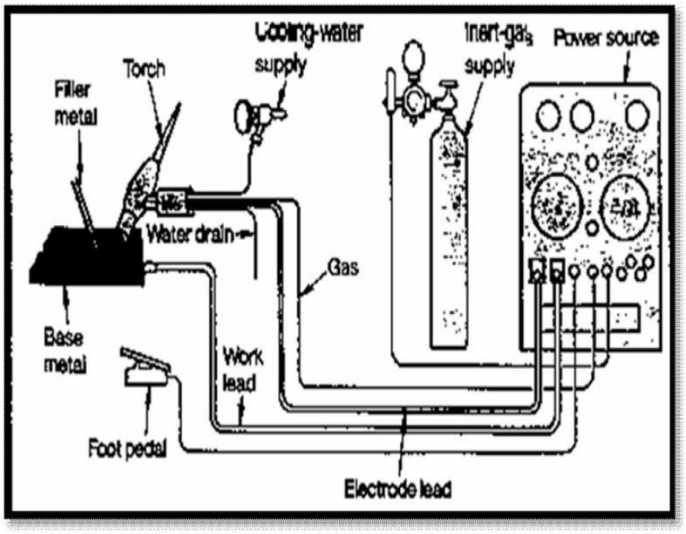

Fig. 1- Gas Tungsten Arc Welding Apparatus

Table 1- Chemical compositions of base metal (mass fraction, %)

Mg	Si	Fe	Cu
.7	1.2	.5	.1
Mn	Zn	Zr	Al
.6	.2	.05	Balance

boundaries. Coarsening of the local microstructures is attributed to the slow dissipation of heat generated during welding. Occurrence and presence of ‘‘hot-short’’ cracks near the toe of the weld is ascribed to excessive heating and melting of the segregated constituents both at and along the grain boundaries.

In 2010, Ahmed Khalid Hussain et.al. [3] conducted TIG welding on 4x50x200 mm base material of the following composition as illustrated in table 2. Filler material used is Aluminium 6063 and shielding gas used is M21 consisting 18% co2 and 82% argon. Experimental setup consisted of shielding gas regulator and quickly Motor which carries and guides the welding gun according the different speeds. It was found that a higher value of tensile strength was achieved at relatively lower speeds and nearly 30o to 45o of bevel angles. Maximum Tensile strength of 230 MPa was observed at weld speed of 0.6 cm/sec (for 40o bevel and 1.5 bevel height). This indicates that the strength of the weldment is weaker than the base metal. The depth of penetration of weld bead was found to be decreasing with increase in bevel heights. The heat affected zone, strength increased with decreasing heat input rate.

In 2011, Karunakaran and Balasubramanian [4] studied the effect of pulsed current on temperature distribution, weld bead profiles and characteristics of gas tungsten arc welded aluminium alloy joints with the base metal having following properties as shown in table 1. Plate size 150 mm ×150 mm x 4 mm thickness were used as the base materials. Single pass, autogenous welding procedure (without filler metal addition) was applied to fabricating the joints. High purity (99.99%) argon gas was used as shielding gas with a flow rate of 9 L/min. 2% thoriated tungsten electrode with 3.2 mm in diameter was used with DC straight polarity to carry out the experiments. The arc length was maintained at 2 mm. Welding was done by both the constant current (CC) and the pulsed current (PC) process. In constant current process, the highest temperature was 710 K for the higher heat input of 294 J/mm and the lowest was 586 K for 231 J/mm at the 5 mm-distance. In the pulsed current process, for the 5 mm distance the highest temperature was 707 K for the heat input of 269 J/mm and the lowest peak temperature of 589 K for a heat input of 161 J/mm. The yield strength in the constant current process was 185 MPa but in pulsed current process it was 205 MPa. The tensile strength followed the same trend as 200 and 225 MPa in the constant current and pulsed current processes respectively. The failure location for both the cases was the weld region. The efficiency of the pulsed current process was 90 % much higher than the joint efficiency of the constant current process. The micro hardness of the base metal was HV 95. It was evident that in both the cases the hardness was the least at the weld center and gradually increased at the 5-mm point and further increased at the 15 mm-point. The microstructure of the weld center reveals coarse grains in the constant current weld while in the pulsed current process the grains are fine, the dendrite spacing in the constant current is wider but the pulsed current process reveals narrower spacing. It is also seen that the area of grain boundary is much less in the constant current process compared with the pulsed current process. The value of residual stress at the weld center for the constant current process was 134 MPa while that for pulsed current one was 92 MPa. The joints fabricated by the pulsed current showed less magnitude of residual stress compared with that by constant current.

In November 2014, Mohammad W. Dewan [5] studied the influence of Weld Defects and Post-Weld Heat Treatment (PWHT) of Gas Tungsten Arc Welded (GTAW) AA6061-T651 Aluminium Alloy. Rolled plates of AA-6061-T651 aluminium alloy with 300 mm × 76 mm × 6.35 mm dimensions are GTA welded utilizing ER- 4043 Aluminium alloy GTA welding filler rod. An inert gas mixture of Argon/Helium (50/50) was used as shielding gas as it helps in the constriction of arc and concentrates the heat within a restricted weld nugget area, thereby reducing the size of the heat- affected -zone (HAZ). Lack of fusion (LOF) is generally caused due to low welding voltage and low welding speed. Post-weld heat treatment (PWHT) was performed to improve tensile properties of welded specimens. The ultimate strength for the six defect-free tensile specimens ranged from 170 MPa to 182 MPa, averaging 177 MPa. Specimens with voids had an average tensile strength of 162 MPa while their toughness was 8.3 MJ/m3. About 7% improvements in ultimate tensile strength (UTS) and 16% improvement in yield strength (YS) observed in the age-hardened (AH-10h) specimens.

In 2011, Pawan Kumar, et.al. [6] did the process parameters optimization of an Aluminium Alloy with Pulsed Gas Tungsten Arc Welding (GTAW) using Gas Mixtures. The material under investigation is 5.00 mm thick Al alloy 6061. Non-consumable tungsten electrode of 2.4 mm Φ and filler rods (31.5 mm Φ) of Aluminium alloy 5183 used for this alloy for getting maximum strength and elongation. Sample plates of size 300 × 150 × 5 mm were used. Welding of the samples was carried out on Automatic Pulse GTAW Tri-ton 220 V AC/DC. In Al alloy 6061 pulse current plays the maximum role i.e. 29.31%. In this investigation, pulse current of 165 A, background current of 135 A, pulse frequency of 125 Hz, pulse duty cycle of 45% and 30% of Helium with Argon affects the maximum to the mechanical properties. UTS of 389.31MPa, Micro hardness of 121.4 and percentage elongation of 12.98 was observed as optimum response.

In 2012 Peasura and Watanapa [7] conducted GTA welding on plates of aluminium alloy AA 5083 of 6 mm thickness and 50x50 mm. The Alloy 5083 samples were welded by using GTA welding without filler metal addition. Welding current was set constant 100 Amps alternating current (AC). The welding travel speeds was at 12 mm/sec. Tungsten electrode (EWP) diameter of 2.4 mm. was used in this study. Argon and helium was selected as a shielding gas with the flow rate of 6, 10 and 14 liters / minute. The result showed that types of shielding gas and gas flow rate interaction hardness at HAZ and fusion zone with a P–value < .05. The factor which was the most effective to the hardness HAZ and fusion zone was argon with a flow rate of 14L per minute at HAZ with 74.27 HV and fusion zone with 68.97 HV. The helium was responsible for high thermal conductivity, resulting in a large amount of heat. This helium environment provided much larger grains in size with reduced hardness. Experimental results showed that the argon condition provided small grains with high hardness value comparatively both in weld metal and heat affected zone (HAZ).

In 2013 Lakshman Singh et al [9] conducted GTA welding on AA5083 aluminium alloy of 5 mm thickness. It was observed that maximum tensile strength of 129 MPa was obtained at welding current of 240 amps, gas flow rate of 7 Lt/min and welding speed of 98 mm/min. The value of tensile strength increased up to the optimum limit then it started to decrease with the increase of welding speed and welding current. The observed effects of welding speed and current on tensile strength is shown in figure 2 and figure 3.

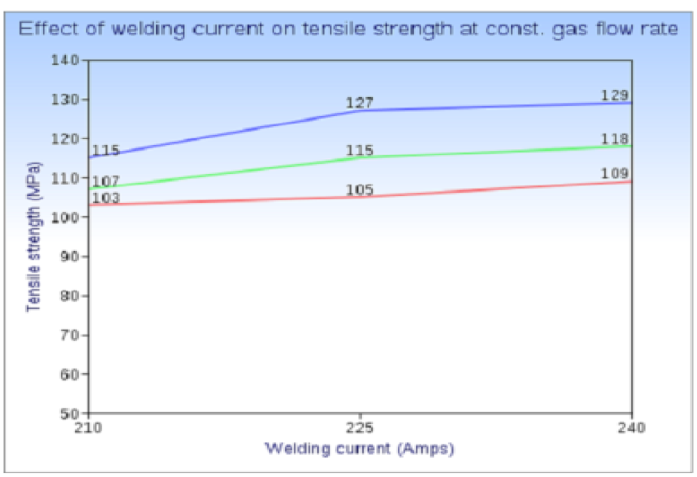

Fig.2- Effect of welding current on tensile strength

In November 2014, Mohammad W. Dewan [9] studied the influence of Weld Defects and Post-Weld Heat Treatment (PWHT) of Gas Tungsten Arc Welded (GTAW) AA6061-T651 Aluminium Alloy. Rolled plates of AA-6061-T651 aluminium alloy with 300 mm × 76 mm × 6.35 mm dimensions are GTA welded utilizing ER- 4043

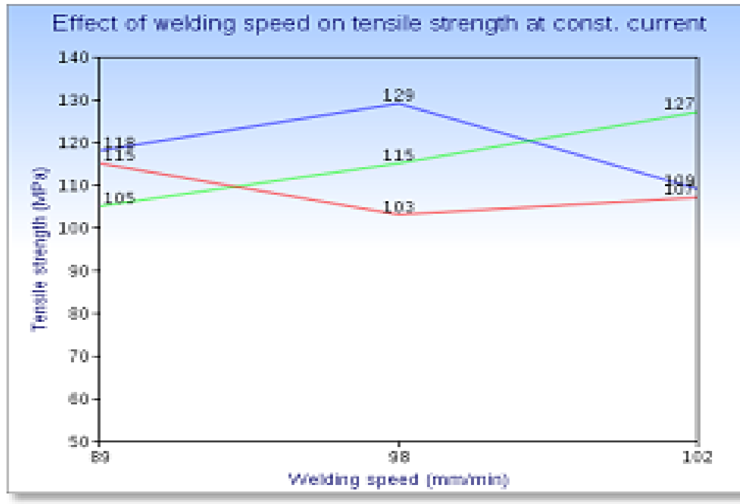

Fig. 3- Effect of welding speed on tensile strength

Aluminium alloy GTA welding filler rod. An inert gas mixture of Argon/Helium (50/50) was used as shielding gas as it helps in the constriction of arc and concentrates the heat within a restricted weld nugget area, thereby reducing the size of the heat- affected -zone (HAZ). Lack of fusion (LOF) is generally caused due to low welding voltage and low welding speed. Post-weld heat treatment (PWHT) was performed to improve tensile properties of welded specimens. The ultimate strength for the six defect-free tensile specimens ranged from 170 MPa to 182 MPa, averaging 177 MPa. Specimens with voids had an average tensile strength of 162 MPa while their toughness was 8.3 MJ/m3. About 7% improvements in ultimate tensile strength (UTS) and 16% improvement in yield strength (YS) observed in the age-hardened (AH-10h) specimens.

In June 2015, M. Ishak, N.F.M. Noordin, A.S.K. Razali, L.H.A. Shah and F.R.M. Romlay [10] studied the effect of filler on weld metal structure of AA6061 aluminium alloy by tungsten mm X 2 mm were taken. Butt welds were prepared using AC-TIG welding sources subjected to welding currents of 60 A and 70 A and preheating temperatures of 80ºC and 120ºC. The highest tensile value for filler ER5356 is of specimen at 70A and 80°C preheating temperature with heat input given as 812.90 J. For filler ER4043, specimen 8 produced the highest tensile strength value using parameters of 70A and 120°C preheating temperature with heat inert gas welding.AA6061 plates of 150 mm × 150 input applied at 482.05 J. For filler ER4047, specimen 10 produced the highest tensile strength value at 60A and 120°C preheat temperature with heat input applied at 593.18 J. The grain size observed at the FZ for welds with ER5356 is 25.69 µm, while the welds with fillers ER4043 and ER4047 have larger grain sizes of 52.75 µm and 76.78 µm, respectively. The highest average hardness value was obtained at 67.07 HV using the ER5356 filler at a current of 70A and 120°C preheating temperature. The average hardness value at the FZ for the other two samples using fillers ER4043 and ER4047 were 60.05 HV and 56.9 HV, respectively. Joining strength using ER5356 yields the highest value of 171.53 MPa compared to joining using fillers ER4043 and ER5356 which yield 167.34 MPa. It can be concluded that TIG welding using ER5356 filler yields better joints compared to ER4043 and ER4047.

3. Conclusions

It is observed that TIG welding is one of the best welding techniques for aluminium alloys. The primary factors which influence the weld quality of aluminium are voltage, current, welding speed and filler material. It is observed that welding done with pulsed current gives a better yield strength, tensile strength and efficiency to the joint instead of constant current welding. While on the other hand, low welding voltage and low welding current causes lack of fusion. Opposing dual torch welding technique is much better since it reduces the crack sensitivity of the weld joint and it also reduces the number of passes of the welding torch required to generate the required weld joint. A rather observation was found that mechanical properties of the joint started to decrease with the large increment in the welding current.

Filler material also plays a very important role in determining the yield strength as it was obtained that larger yield strength of joint was obtained with filler material ER 5356 than the filler materials ER 4043 and ER 4047. Helium, on being used as the shielding gas, provides high thermal conductivity with the larger grain size while Argon provides smaller grain size with much higher values of hardness provided all other parameters remains constant. Lower speeds of welding process are much better for obtaining higher values of tensile strength. These observations clearly state that GTAW technique for aluminium is much efficient when lower speeds are used with optimum values of current along with the mixture of Helium and Argon gas used as the shielding gas.

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