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TIG Welding of Al-Mg alloy: A Review

[1]Panchal Hemant, [*2]Kikani Maulik, [3]Murnal Vaibhav & [4]Desai Kirti

[1]Assistant Professor, Department of Metallurgical & Materials Engineering, Faculty of Tech & Engineering, The M S University of Baroda, Vadodara, Gujarat (India)

[2, 3, 4]UG Students, Department of Metallurgical & Materials Engineering, Faculty of Tech & Engineering, The M S University of Baroda, Vadodara, Gujarat (India)

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[*]Corresponding Author
Email:kikanimaulik2536@gmail.com

ABSTRACT

Aluminium is light in weight, yet some of its alloys have strength exceeding the mild steel. It retains good ductility at subzero temperatures, It has high resistance to corrosion and is not toxic. Due to all these properties Aluminium and its alloys are widely used in automobile industry, architectural application, aircraft and aerospace industry etc. Also, pure Aluminium melts at 660 °C and less for its alloys. It has high thermal conductivity and tendency to form oxide of high melting point around 2066 °C. Due to all these characteristics welding of Aluminium and its alloys become difficult task. So, this paper represents the reviews of different papers that are mainly focused on study of TIG Welding of Al-Mg alloy and to improve it by changing various parameters such as applied voltage, Filler wire, Shielding gas etc. It also includes the whole methods of TIG welding and its steps.

1. Introduction

The increased globalization has forced industries to increase the quality as well as the functionality of the product at minimum cost. Welding is a process of joining two or more parts by means of heat or pressure or both in such a way that there is a continuity of nature of these parts. Aluminium and its alloys play crucial and critical role in engineering material field. Aluminium and aluminium alloys are widely used in industries because they are lighter than steel, excellent formability, higher specific strength and sound damping capabilities. Aluminium and Aluminium alloys are used in aerospace industries, ship industries, automobile industries, marine industries etc

There are many types of welding processes such as Fusion welding, pressure welding; friction welding etc. fusion welding can be defined as a welding in which the metals are heated up to their melting point and joined together without applying external pressure. TIG welding is fusion type arc welding process that uses a non- consumable type electrode. The electrode is made up of Tungsten

Weld ability of a material depends on different factors like the metallurgical changes(changes in phase) that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the weld .Common fusion weld processes used for welding of Al and its alloys include Tungsten Inert Gas welding(TIG),Metal Inert Gas welding(MIG),Variable Polarity Plasma Arc(VPPA).Due to the rapid formation of aluminium oxide ,TIG is generally used with the AC power source because during the reverse polarity cycle the removal of oxide takes place.

2. TIG Welding

TIG is short form of “Tungsten inert Gas”. The proper terminology of this process is “Gas Tungsten Arc Welding” or GTAW. TIG is commonly used in welding of metals or alloys. TIG is introduced around the 1940’s during World War 2 and that time known as “Heli Arc” because the shielding gas used was helium, but now days this is no longer called Heli Arc process because in most cases Argon is used as shielding gas. The main aim of development of TIG is to welding of difficult type material such as Aluminium, Magnesium etc but now days this process is also used for welding of other material like stainless steel etc.

Gas tungsten arc welding, GTAW, uses a non-consumable electrode to produce the weld. Weld area is protected by shielding gases from the atmospheric contamination. Here in this process filler wire normally used. In this welding process Argon is used as shielding gas. The biggest advantage of this process is absences of slag. Because of this we can obtain good quality of weld.

Figure 1 TIG welding equipment

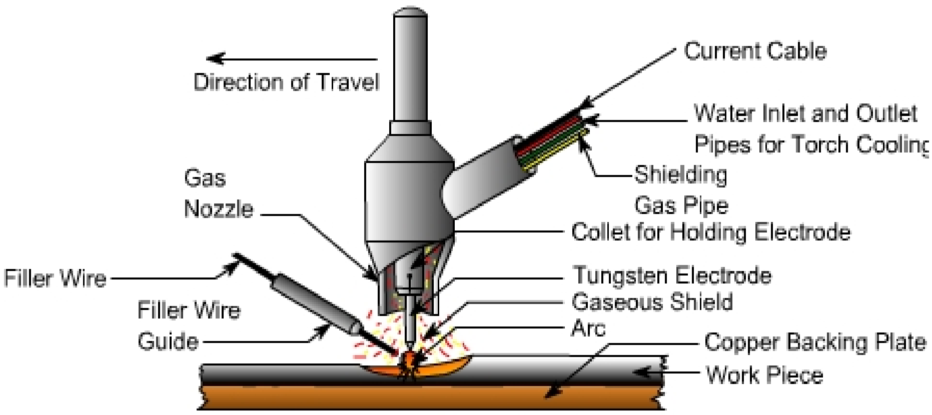

Figure 2 Schematic diagram of TIG welding torch

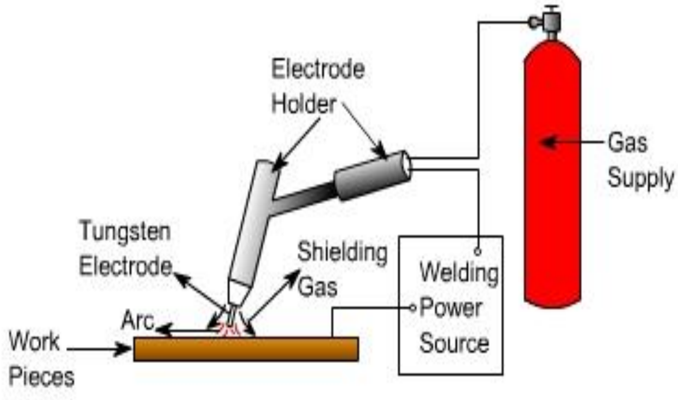

Figure 3 Schematic diagram of TIG welding

3. Process variables of TIG

The process variable of TIG welding process is listed below,

3.1. Material

The most influential parameter can be grouped under base metals properties such as composition and also other properties like its reactivity with oxygen, thermal conductivity, coefficient of thermal expansion etc.

3.2. Shielding Gas (lit/min)

It provides protective gas to prevent the atmospheric contamination. Use of proper shielding gas enhances the weld quality. The shielding gas flow rate is also important as it has effect on weld bead shape which affect the Heat affected zone, residual stress, mechanical properties of weld joint.

3.3. Weld Geometry

There can be various joints such as butt joint, lap joint, fillet joint. Also, bevel may be single-V, double-V or U shape. Weld geometry has direct influence on weld quality. There are various welding positions such as flat, horizontal, vertical, overhead etc. If the welding position is difficult, then it is difficult to obtain good weld quality. So, weld joint and welding position is very important.

3.4. Welding Speed (cm/sec)

It changes with weld penetration and width of beads. As the welding speed decreases, the heat input per length increases and penetration and bead width increase. If travel speed is too high then it results into undercut and porosity and weld obtain with poor quality.

3.5. Material thickness

This plays an important role in process selection and deciding parameter. It decides the heat input and controls cooling rate. Higher thickness means higher cooling rate and also high HAZ (Heat Affected Zone).

3.6. Welding current (Amp)

Welding current is the most significant parameter which directly affects the penetration and lack of fusion by affecting the welding speed. If the welding current is too high then the depth of fusion will also be high. And also, it leads to excessive melting of filler wire. And if current is too low, then it may lead to lack of fusion.

3.7. Welding Voltage (V)

It may be defined as potential difference between the tip of welding wire and surface of the molten weld pool. It decides the shape of fusion zone and weld reinforcement. It also affects the weld composition. As increase in the arc voltage results in longer arc length and less penetration is obtained. If voltage is too high then it gives s hat shaped concave weld with low crack resistance and also there is higher tendency to undercut. Lower voltage reduces the arc length and result in increase in penetration. With excessively low voltage unstable arc obtain and crowned bead.

4. Application of TIG welding

TIG welding is most commonly used in welding of thin section of stainless steel and non-ferrous metals such as aluminium, magnesium, copper and its alloys.

FSW is modern welding process used for lower thickness of sheet with higher quality. By processing and comparing the friction stir welding (FSW) & Tungsten inert gas welding (TIG) processes. The final result shows optimal condition. Efficiency of welding on FSW & TIG are 81.6% & 68% respectively that clearly shows that FSW is relatively better process for 3 mm thick plate of Al alloy (5052). In FSW process fatigue endurance limit is increase and reduction percentages are also in favor of FSW process. Here in FSW process the filler metal doesn't required, so chemical component of weld metal doesn't change relative to base metal and this could lead to lower down fracture of tensile test specimens that is welded. [1]

With using modern TIG welding process with improved and satisfactory development of processes higher thickness as well as very lower thickness plate can be easily welded in ferrous and non-ferrous both metals. Here flux is not used during the process, so doesn't appears any slag formation during or after welding process only shielding gas are used for inert atmosphere and because of that there is no spatters and fumes. Al is highly reactive metal so to reach its melting point and make weld is difficult. During welding process like arc welding oxide layer is form that can cause stress concentration on the surface but it could completely ignore by using TIG process with argon inert atmosphere that stops an oxidation layer of Al on the surface. [2]

Al and its alloy are highly electronegative materials so generally attracted with oxygen because of that TIG process is very limited in use and by changing the various parameter of process for Al alloy 6063 can be effectively welded with optimum result. To achieve that, welding current should be 120 A, gas flow should be 12 LPM & preheating of metal should be 100°C that can make maximum tensile strength 202.69 MPa. Changing diffent parameters can cause change in microstructure with elongation and fine grains have higher tensile strength than others. [3]

Aluminium and its alloys which have different heat treatments can be used in aerospace industries. The microstructure of metal is change with respect to heat treatments that also change the hardness of the metal. Microhardness values from middle layer to the top layer in the PMZ of CYS side were the increased.in the three layers of TIG weld different layer of WZ has different distribution pattern of eutectoid structure. Here on each side the regions of microhardness values from the minimum to maximum were WZ, OAZ, PMA and HAZ, respectively. Deformation on joints only accrues in WZ and OAZ region. Where stress concentration is higher at that place fracture gradually evolved from brittle to ductile with the extension of the crack. [4]

In modern day, aluminum and its alloy are most widely used in automobile industry because of its high strength to weight ratio. So, it is important to study the strength of aluminum alloy welded component. It maybe differs in different load in condition. If crack propagate in welded component in working condition, then the component failed which is undesirable. Experiment conduct on the welded 6061 aluminum alloy and it is found that, at a higher strain rate there is considerable increased in yield strength and ultimate and tensile strength. This is because of there is insufficient time for elastic recovery at a higher strain rate. The tensile test performed on 100KN universal testing machine under uniaxial static loading.[5]

AA 6061-T6 Aluminum alloy is medium strength, heat treatable material which is used in aerospace industry because of good corrosion resistance and good workability. Welding is thermal process; residual stresses wheel induced into the welded part and alter the properties. Here in this residual stress is evaluated using X-ray diffraction method. *Sin2θ* method is used for measuring the strain TIG joint of AA 6061-T6 across and along the weld melts both on crown and root sites. Residual stresses are generated due to weld preparation like chemical cleaning, mechanical scraping etc. from this experiment found out that surface stresses are considerably changed while preparing surface for welding. Bead width also affects the residual stresses. The residual stresses are reduced by lowering the bed width. Also, by reducing weld heat inputs residual stresses are reduced. [6]

Intermetallic compound (Al_2CuMg) is formed in aluminum, copper, magnesium containing metals when subjected to TIG welding, in which desire temperature is maintain to melt this material and then manual stirring is carried out for 5 minutes to form intermetallic compound. Then the results are analyzed by using XRD techniques and 55.5% of intermetallic compound obtained. Also by XRF 44.87% Al_2O_3, 35.21% CuO and 19.24% MgO obtained. Heat treatment is carried out to enhance the properties of 5 wt% proportion with aluminum metal at 140°C for five hours. By this experiment it is found that tensile strength improved 1307% Mpa and hardness improved 34%. This new material has improved tensile strength and hardness. [7]

Here in this, observation of the microstructure and mechanical properties of 2219 Aluminium alloy joints, welded by variable polarity TIG welding in four different heat treatments with/without pre/post heat treatment is carried out. Form this research it is found that,

(a) Without any pre and post weld heat treatments, in this precipitation of weld metal dissolve into matrix and overaging occur at heat affected zone. This result in hardness of joint decrease to 68.8% base metal and tensile strength decrease to 58% of base metal.
(b) With post weld artificial aging treatment, it causes fine dispersed precipitates separate out of weld metal and result in hardness increased by 20%.

With pre-weld solution treatment and post-weld artificial aging treatment together, there is hardness increased 20% of weld zone and 11.5% of hardness of heat affected zone. Also 20.3% increased tensile strength of the joint. [8]

Here in this, TIG welding process with continuous wire feeding system is used for join to dissimilar aluminium alloy

5083 and 6061 plates of 6.35 mm with pulse TIG welding. To check the lack of penetration and porosity radiography is used also microstructure of base metal. Heat affected zones are examined by optical microscopes. From this trial run experiments it is found that acceptable weld obtained by 175 A peak current, 105 A base current, 2 Hz pulse frequency with welding speed (155 mm /min). This was resulted into 213 MPa of tensile strength, 176 MPa of yield strength and 12 % elongation. Also, micro hardness of fusion zone increased by low heat input due to finer structure but this result in decreased in ductility and toughness. [9]

AA 5052 and AA 6061 are used to made welded blank by using TIG welding process and heat affected zone examined by using finite element techniques and experimental methods. This blank is also investigated by thermo simulations test. Also, further analysis of heat affected zone made by scanning electron microscopy and micro hardness test to predict the mechanical properties. From this analysis it is found that heat affected zone narrower at the AA 5052 then at the AA 6061 alloy. While hardness of heat affected zone is lower in AA 5052. Heat affected zone for all welding process mainly depended upon amount of heat which is given during welding.[10]

This experiment of TIG welding optimization was taken under consideration for aluminium alloy 8011. For the effective optimization Taguchi method is very useful. Essential requirements for all welding processes are higher tensile strength with lower elongation. This study refers to the application of Taguchi method coupled with grey relation analysis for solving multi-criteria optimization problem in the field of welding process. Now from the grey relation analysis it is found that the largest value of grey relational grade for the pulse current of 145 A, base current of 80A and pulse width of 60%. [11]

Hot cracking is the most frequently observed defect during welding. To study the cracking phenomenon, process parameters, mechanical factor a hot cracking test was performed. For welding conditions, microstructure is always composed of a central enquire zone and a peripheral columnar zone where crack generates. For the study of cracking, the process map which represents the cracking zone according to welding parameters can be very useful. [12]

The experiment was carried out to select the suitable gas for TIG welding. Various tests were performed. The addition of oxygen-argon or argon-helium mixture has a significant effect on welding speed or penetration. The drawback is the formation of black surface oxides around the weld bead. These gases are generally not employed for TIG processes. [13]

To investigate and optimize the welding parameter the experiment was carried performed on aluminum alloy 6061 using firefly algorithm. For these experiments the input parameters are welding current, gas flow rate and current polarity. The output parameter is ultimate tensile strength. If specimens were welded according to the parameters given by RSM [Response Surface Methodology] and their tensile strength was measured by using UTM [Universal Tensile Machine]. Various contours and surfaces are plotted in order to understand the relationship between input and output parameters. Optimization is carried out using firefly algorithm. [14]

Al and Al alloys plays an important role in the field because of good formability. For the welding of Al and Al alloys TIG method is usually employed due to its better control. By using TIG welding the uniform welding is possible. The speed and current plays an important role. For the better performance, pre and post welding precautions must be taken. By controlling the welding precautions, the defects can be avoided. [15]

The experiment was carried out on the Al Alloy A110 with a thickness of 3 mm. The metal was treated with 400 grid number sand paper before the test. The joint used in this process is butt joint. The results show that good welding can be performed by producing a constant weld bead width. The performance can be increased at the welding current of 160 A and welding speed of 1.1 mm/sec. [16]

5. Summary

From above review, we can summarise as follows:

- By using TIG welding process uniform welding of aluminium alloys are possible.
- The important parameters affecting the output responses have been identified as speed and current.
- Selection and preparation of welding joint are greatly affect the welding strength and microstructure etc.
- To improve welding quality of aluminium pre-welding and post-welding precaution must be taken during welding process.
- By optimizing and controlling welding parameters (like welding current, gas flow rate, welding speed, etc.) welding defects can avoid totally.

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