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Optimisation of influence of Tig Welding parameters on mechanical properties of aluminum 6061 alloy:A Review

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ABSTRACT

Aluminum alloys are used for many industrial applications due to their light weight and corrosion resistivity. Amongst all aluminum alloys 6061 has excellent properties, which makes it useful in aeroscope industry, aviation, marine industry and defence. Tig welding is one of the precise method which is used to weld aluminum alloys. From the literature survey it has found that Welding current, Welding voltage, Welding speed and the gas flow rate are the main input parameters which influence the mechanical properties of aluminum 6061 alloy. An attempt has made to find the conditions like how these welding parameters will set, optimization method and choice of filler rod under which aluminum 6061 plate will give optimum mechanical properties.

Keywords: Aluminum 6061 alloy, Tig welding, welding voltage, current, speed and gas flow rate, filler rod, mechanical properties.

1. INTRODUCTION

Aluminum alloys are alloys in which aluminum (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminum alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminum alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required[1]. Alloys composed mostly of aluminum have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. Aluminum-magnesium alloys are both lighter than other aluminum alloys and much less flammable than alloys that contain a very high percentage of magnesium[2]. Aluminum alloy has excellent performance so used in aerospace industry, aviation, marine industry, automobile, defence and others [3-5]. Amongst Al alloys, Al-Mg-Si (6XXX) alloys have got further preference in industrial applications as these alloys contain very fewer amount of alloying elements (0.4 to 0.9 wt.% Mg and 0.2 to 0.6wt.% Si) which makes them cheaper than other series like AlCu (2XXX) and Al-Zn (7XXX) alloys[6]. Al alloys of the 6000 seriesare known to have good formability, corrosion resistance, weldability, and high strength-to-weight ratio[7-9]. 6061 is a precipitation hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935[10]. It has good mechanical properties, exhibits good weldability, and is very commonly extruded (second in popularity only to 6063)[11]. Al-Mg-Si alloys such as AA6061 exhibit moderately high strength and excellent corrosion resistance, and have numerous applications, including welded fabrications. Due to this, AA6061 finds broad use in welded structural members such as truck and marine frames, railroad cars, and pipelines[12-13]. The good corrosion resistance of AA6061 is due to the formation of a thin, hard and compact film of adherent aluminum oxide on the surface. However, aluminum oxide may dissolve in some chemical solutions, such as strong acids and alkalis leading to a rapid corrosion of aluminum and its alloy. Furthermore, the corrosion resistance could be reduced by the presence of the weldment in the base metal[14]. It is one of the most common alloys of aluminum for general-purpose use. It is commonly available in pre-tempered grades such as 6061-O (annealed), tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

TUNGSTEN Inert Gas (TIG) welding is a welding process used for high quality welding of a variety of materials with the coalescence of heat generated by an electric arc established between a non-consumable tungsten electrode and the metal. The process of melting the work piece and filler rod to form a weld results in the formation of fumes and gases[15]. TIG welding can be wildly used in modern industries for joining either similar or dissimilar materials. Tungsten inert gas (TIG) welding is also called the gas tungsten arc welding (GTAW). TIG welding advantages like joining of similar and dissimilar metals at very high quality weld, low heat affected zone, absence of slag etc. Gas tungsten arc welding wildly uses a non-consumable tungsten electrode to produce the weld because it created a very high temperature to weld the metals. Weld zone is protected by a shielding gas (usually inert gas such as argon) from atmospheric air or gases and a filler material is normally used for fill the gap of metal[16]. Most commonly, Argon, helium and their mixture are preferred to use as a shielding gases for better welding because of does not chemically react or combine with each other. The inert gas : i) shield the welding area from air, preventing oxidation, ii) transfer the heat from electrode to metal and iii) helps to start and maintain a stable arc due to low ionization potential[17]. TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand-piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000oC and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material. Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and 150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source. The power source required to maintain the TIG arc has a drooping or constant current characteristic which provides an essentially constant current output when the arc length is varied over several millimetres. Hence, the natural variations in the arc length which occur in manual welding have little effect on welding current. The capacity to limit the current to the set value is equally crucial when the electrode is short circuited to the work piece, otherwise excessively high current will flow, damaging the electrode. Open circuit voltage of power source ranges from 60 to 80 V.

6061 is highly weldable, for example using tungsten inert gas welding (TIG) or metal inert gas welding (MIG). Typically, after welding, the properties near the weld are those of 6061-O, a loss of strength of around 80%. The material can be re-heat-treated to restore -T4 or -T6 temper for the whole piece. After welding, the material can naturally age and restore some of its strength as well. Nevertheless, the Alcoa Structural Handbook recommends the design strength of the material adjacent to the weld to be taken as 76 MPa (11,000 psi) without proper heat treatment after the weld. Still worldwide research and continuous efforts are going on to increase the weldability properties of aluminum alloys. It is well known that 46% of aluminum alloys used for various applications is in the form of sheets and plates[18].

The proper choice of aluminum filler metal mainly depends on the base metal properties to be achieved and welding technique. Post weld cracking, corrosion resistance and behavior under elevated temperature also need to be taken into consideration. Cracking usually can be minimized by choosing a filler metal alloy of higher alloy content then the base metal.Filler wires is continuously feed into weld pool for proper filling the welding seams for good joint. Welding parameters are controlled with electronic control units[19-20]. ER4043(commonly referred to as AISi5) is a 5% silicon aluminum filler metal that is available for MIG or TIG welding processes. This alloy is recommended for welding 3003, 3004, 5052, 6061, 6063, and casing alloys 43, 355, 356, and 214.ER4043 has a melting range of 1065° to1170°F .

Taguchi‘s orthogonal design uses a special set of prede-fined arrays called orthogonal arrays (OAs) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affects the process perfor-mance (process responses). The corresponding OA is selected from the set of predefined OAs according to the number of fac-tors and their levels that will be used in the experiment.

2.LITERATURE SURVEY

TIG welding is very precise welding process to weld aluminum alloys, but the proper selection of welding parameters is very necessary. In this study, a literature review has studied and attempt has made to find out the parameters, which greately influence the mechanical properties of al 6061 alloy.

T Senthil Kumar et al.[21]studied influences of pulsed current TIG welding parameters on the tensile properties of AA 6061 aluminum alloy. Pulsed current TIG welding process utilizes arc energy more efficiently by reducing the wastage of heat energy by conduction into the adjacent parent metal. In TIG welding heat required to melt the base metal is supplied only during peak current pulses for brief intervals of time, allows the heat to dissipate leading to a narrower HAZ. The results reveal that the refinement of microstructure is due to pulsed current welding is more compared to conventional continuous current welding. It is also observed that the pulsed current welding also improves mechanical properties like tensile strength & hardness.

Prasad et al.[22] found that longitudinal cracking occurred when AA6061 was welded with Mg-rich filler metal ER5356 but not with Si-rich filler metal ER4043.

Wang et al.[23] did the experiment Using He–Ar mixed gas as shielding gas, the tungsten inert gas (TIG) welding of SiCp/6061 Al composites was investigated without and with Al–Si filler. Experiment carried out with plate dimension 60mm X 30mm X 3mm, welding was performed with gas flow rate 115 ml/s, welding speed 18 cm/min and arc length 4 mm. Welded joint with filler were submitted to tensile tests. The microstructure and fracture morphology of the joint were examined. The results show that adding 50 vol.% helium in shielding gas improves the arc stability, and seams with high-quality appearance are obtained when the Al–Si filler is added. The microstructure of the welded joint displays non-uniformity with many SiC particles distributing in the weld center. The average tensile strength of weld joints with Al–Si filler is 70% above that of the matrix composites under annealed condition.

Sanjeev Kumar et al.[24] performed TIG welding of 6 mm thick Al plate. They performed experiment in two phases in first case they used AC power supply of current (100 A, 150 A, 200 A), gas flow rate of (7 lit/min, 15 lit/min) and pulsed frequency of 4 HZ. In second case DC power supply of current (48 A, 64 A, 80 A, 96 A, 112A), gas flow rate (7 lit/min). Photomicrographs of welded specimens were taken and analyzed from the experiment it has been observed that shear strength varies with change of pulse current. This change in shear strength is due to lack of refined grain structure of weldments, responsible for poor strength. Maximum value of shear strength has been observed at pulse current of 250A, gas flow rate of 15 lit /min and base current 200 Amp.

N. Karunakaran et al.[25] did an investigation to compare the mechanical properties and welding profiles of TIG welded aluminum alloy joints. The effects of pulsed current on tensile strength, hardness, and microstructure and stress distribution were reported. The parameters were welding current (55-75) A. voltage (11-13.5) V and a constant welding speed were used. From the experiment it is found that pulsed welding current improve the tensile behavior of the weld compared with continuous current welding due to grain refinement occurring in the fusion zone.

Ahmed Khalid Hussain et al.[26] investigates the effect of welding speed on the tensile strength of the welded joint. Experiments are conducted on specimens of single v butt joint having different bevel angle and bevel heights. The material selected for preparing the test specimen is Aluminum AA6351 Alloy and found out that the depth of penetration of weld bead decreases with increase in bevel height of V butt joint. Maximum Tensile strength of 230 Mpa was observed at weld speed of 0.6 cm/sec (for 40 0 bevel and 1.5 bevel height). This indicates the strength of the weldment is weaker than the base metal. Tensile strength is higher with lower weld speed. This indicates that lower range of weld speed is suitable for achieving maximum tensile strength. Bevel angle of the weld joint has profound effect on the tensile strength of weldment. Bevel angles between 30 0 to 45 0 are suitable for maximum strength. The heat affected zone, strength increased with decreasing heat input rate.

P kumar et al.[27] demonstrated the increase of mechanical properties and effective optimization of pulsed GTAW process parameters on aluminum alloy 6061. Welding was done with input parameters as base current (80-110) Amp, pulse frequency (50-125) HZ and pulse duty cycle (30-75) %. Taguchi method was employed to calculate experimental structure and to study process optimization parameters on mechanical properties of the joints. Result of the experiment showed that pulse current, base current, pulse duty cycle and frequency plays significant role on microstructure and mechanical properties of weld, but pulse current plays the greater role i.e. 52.55 %. In this investigation, pulse current of 120A, background current of 80A, pulse frequency of 50Hz and pulse duty cycle of 75% resulted in the maximum values of mechanical properties.

Indira Rani et al.[28] investigated the mechanical properties of the weldments of AA6351 during the GTAW /TIG welding with non-pulsed and pulsed current at different frequencies. Experiment carried out with plate dimension 30 mm X 150mm X 6mm, welding was performed with current 70-74 A, arc travel speed 700-760 mm/min, and pulse frequency 3 and 7 Hz. From the experimental results it was concluded that the tensile strength and YS of the weldments is closer to base metal.

Palani PK et al.[29] investigated the effect of TIG welding process parameters on welding of Aluminum-65032. Response Surface Methodology was used to conduct the experiments. The parameters selected for controlling the process are welding speed (150-200) mm/min, current (100-120) A and gas flow rate (10-12) Lit/min. Strength of welded joints were tested by a UTM. Percent elongation was also calculated to evaluate the ductility of the welded joint. From the results of the experiments, mathematical models have been developed to study the effect of process parameters on tensile strength and percent elongation.

L.H. Shah et al.[30] investigates the effect of corrosion on the strength and microstructure of AA6061 alloy welded by TIG welding using various aluminum-based filler materials have been investigated. The results obtained from this study can be summarized as: The microstructure of the weld samples was observed. Interdendritic segregation of intermetallic phases can be seen in the weld metal as well as partially melted zone. Large intermetallic particles are visible in the base metal and intergranular segregation is not prominent in that region.Vickers hardness of ER4043 and ER4047 filler samples both show a 'weak' region in the heat affected zone. This is attributed to the recrystallization in the HAZ. The ER4043 sample shows better hardness in the HAZ and WM compared to the ER4047 sample. Corrosion analysis show that the ER4043 filler samples obtained a lower corrosion rate compared to the ER4047 filler samples. Thus it can be concluded that ER4043 filler metals are more suitable in joining AA6061 samples due to its superior mechanical and corrosion characteristics compared to samples welded with ER4047 filler.

Mallikarjun Kallimath et al.[31] conducted an experiment on aluminum alloy Al6061 Taguchi and Regression analysis methods. Finally, they conduct the test and found that Gas flow rate is the major contributing factor and also gas flow rate and current are the most influencing factor with to bead length.

Saurabh Kumar Khotiyan et al.[32] investigates the microstructure and mechanical properties of tig and mig welding using aluminum alloy and found out that the impact strength of TIG joints is higher than that of the MIG joints. It is found that hardness in weld metal region is less than that of the BM. The maximum hardness is found in TIG and the minimum hardness is found in MIG welded joint. The hardness pattern in the weld region in two welding processes is like, TIG > MIG. In case of TIG the microstructure is very fine and equiaxed, having uniformly distributed grains with strengthening precipitates as compared to MIG welding processes in which dendritic grain structures is found. Because of fine grain structure the TIG joint possesses good tensile and mechanical properties than that of the MIG welding processes. On the basis of the above discussion it can be elaborate that the TIG is the best suitable welding process to join aluminum alloy AA6061 as compared to MIG welding processes.

Gagandeep Singh et al.[33] investigates the Mechanical Properties on Tig Welding at Different Parameters with and without use of Flux and found out that hardness of weld metal decreased from with increase in current, voltage and gas flow rate. Because due to increase in current, voltage and gas flow rate the heat input and arc length increased, hence hardness decreased. It studied that hardness of weld metal increased with increase in diameter of electrode, because due to increase in diameter of electrode the heat affected zone will increase hence hardness increase. It also observed that hardness of weld metal is less in case of welding without flux as compare to welding with flux.

N.Subramani et al.[34] investigates a6061/sicp/b4c composite material by using tig welding process and found out that the microstructure of the reinforcement particles like boron carbide and silicon carbide will increase the strength of the aluminum 6061. The results indicated that the uniform distribution of SiCp particles in A6061 matrix by Tungsten inert gas welding can improve the mechanical properties of specimens. It is observed that the investigational results meet the confidence limits.

3. CONCLUSION

On the basis of Literature Survey it has found that in order to optimize the mechanical properties of aluminum 6061 alloy, it is very necessary to understand the influence of basic input parameters on mechanical properties of selected material and following points should be noted:-

A. Welding Current, Welding Voltage, Gas Flow Rate and Welding Speed are the main influencing parameters, which effect the mechanical properties of aluminum 6061 alloy.
B. Taguchi's Orthogonal array is very beneficial for optimal selection of above welding parameters.
C. For maximum strength filler rod used should be Er 4043.
D. Tig Welding machine used should be of AC Voltage type.

Through literature reviewed it has been estimated that a very little study is carried out on optimal combination of basic Tig welding input parameters such as (Welding current, Welding voltage, Gas flow rate and Welding speed) and still there is gap on optimal combination of these input parameters, which greatly influence the mechanical properties of aluminum 6061 alloy.

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