Weldability Study of Aluminium Alloys and Composites by Gas Tungsten Arc Welding Process: A Review

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Abstract- Among the various metals used for different mechanical and fabrication work, aluminium finds wide application. This is primarily due to its light weight and high strength to weight ratio. Due to this, it is used in defense and aerospace industry where lightness is a key factor. Aluminium alloys have aluminium as primary metal with copper, magnesium, manganese, silicon, tin and zinc as alloying elements. Aluminium based metal matrix composites (MMCs) also have tremendous applications. Several researches have been conducted on this and newer composites are developed with advanced properties. Thus, fabrication of aluminium alloys and composites remains an important research area. Among them, welding is an important and interesting topic. Study of weldability of these components is an important investigative work.Although, aluminium reacts with atmospheric oxygen to form alumina as a covering which is a poor conductor of heat, however usage of Tungsten Inert Gas (TIG) welding or Gas Tungsten Arc welding provides a breakthrough solution. This paper provides an overview on the different research works related to TIG welding of aluminium based alloys and composites. Influences of welding parameters on the mechanical, thermal, micro structural properties are studied. Various methods of TIG welding and their influence on weld penetration are also indicated in this paper.

Keywords-Aluminium, Metal matrix composite, Aluminium alloy,Tungsten Inert Gas welding, Weldability

Introduction

Welding of aluminium alloys and composites by TIG welding have been an important and interesting topic of research. Several experimental investigations have been conducted to evaluate the weldability of the composites.

Luts and Sherina [1] investigated on weldability of AMg_2-TiC aluminium alloy MMC using TIG welding. Increase in hardness and strength of alloy was achieved by reinforcement of titanium carbide highly dispersed metallic phase. Study on behavior of composite material before and after weld was made. Microstructural analysis was conducted on scanning electron microscope. Hardness of samples was tested on Brinell hardness tester along with weldability tests. It was observed that weldability was satisfactory. Highly dispersed particles of reinforcing phase did not dislocate from area of base metal to weld area. Also, less porosity was obtained.

Wysocki et.al [2] investigated on fabrication of additive filler material for TIG welding aluminium-ceramic composites. The fillers were made in form of sticks containing magnesium, scandium, zirconium and aluminium. It was observed that most favorable weld structure was obtained in modification of the AlMg5 alloy by the addition of scandium. Minor dispersions of Al_3Sc became the nucleation pads of fine grains, which improved the mechanical properties of the alloy. Also, in the case of the addition of zirconium, the crystallisation shifted from dendritic tofine-grain growth. The strength of the developed filler materials were tested and most favorable one selected.

In another experimental investigation by Rao et. al [3], effect of three arc manipulation processes on weld metal grain structure and tensile properties of welded samples were studied. The three processes included pulsed current welding, magnetic arc oscillation and combination of the two. TIG welding was performed on 2219-T6 plates, whereby fine equiaxed grains resulted in weldments. Also, improvement in yield and tensile strength was obtained.

Optimization of process parameters during TIG welding of aluminium alloy was performed by Kumar et. al [4]. Aluminium alloy 6061 was TIG welded using sinusoidal AC wave with argon plus helium gas mixtures. Taguchi method was implemented as design of experiment. Improved mechanical properties were exhibited. Also, microstructural analysis of weldments was conducted to study structural property correlation with process parameters.

In another interesting experimental work by Shah et. al [5], investigation on mechanical properties of TIG Welded AA6061 alloy weldments using different aluminium fillerswere made. The two filler materials used were ER4043 and ER4047. The microstructure of base metal, weld metal and heat affected zones were analyzed using optical microscopy and scanning electron microscopy. Also, hardness of the weldments was tested along with corrosion resistance of weld beads. It was observed that properties of base metal was superior compared to weld metal and heat affected zones. It was concluded that samples of ER4043 exhibited higher mechanical properties compared to ER4047.

Weldability study of unreinforced aluminium alloy (AA6082) and an AA6092/SiC/25p composite using Al–5Mg (ER5356) and Al–5Si (ER4043) filler metals was attempted by Lean et. al [6]. Heat input was reduced to obtain interfacial reaction between molten aluminium matrix and SiC particles. There was formation of aluminium carbide (Al_4C_3) in the weld pool. Tensile test of weld beads revealed similar results raging approximately 223 MPa. Heat affected zone of unreinforced alloy exhibited failure.

TIG welding machine setup and welding process is shown in figure 1 and typical weld bead profile on aluminium alloy AA6063 is depicted in figure 2.

Figure 1: TIG welding machine setup and welding process

Figure 2: Typical TIG welded bead profile on Aluminium AA6063 alloy

Microstructure study of aluminium alloys and composites

Various metal composites have been developed which exhibit different and improved properties. Zhang et. al [7] investigated effects of mischmetal (MM), a mixture of rare-earth elements addition on the microstructural development of in situ Al–15wt.%Mg_2Si composite. It was observed that addition of MM in composite reduced the size of primary Mg_2Si particles and the pseudo-eutectic Mg_2Si transformed from fibrous structure to flake like structure. Also, small amount of rare earth element was formed as $Al_{11}RE_3$due to addition of mischmetal.

In some research work, MMCs with various ranges of matrix materials including aluminium, titanium, copper, nickel and iron and second-phase particles such as borides, carbides, nitrides were produced. The composites exhibited excellent mechanical properties. Tjong and Ma [8] attempted to study the microstructure and mechanical properties of composites reinforced with in situ ceramic phases.

Jayashree PK et. al [9] investigated on microstructure and mechanical properties of SiC reinforced aluminium metal matrix composites using tungsten inert gas welding as shown in figure 3. The welded composites were aged to peak age-hardening conditions. Aged and non-aged hardened composites exhibited difference in microstructure w.r.t. misorientation, grain boundary fraction and stored energy. After ageing, microstructure displayed refined gain size and orientation. Hardness and tensile strength increased with increase in SiC content. Increased tensile strength with decreased misorientation showed that effect of annihilation of dislocations was less pronounced and precipitation strengthening was dominant.

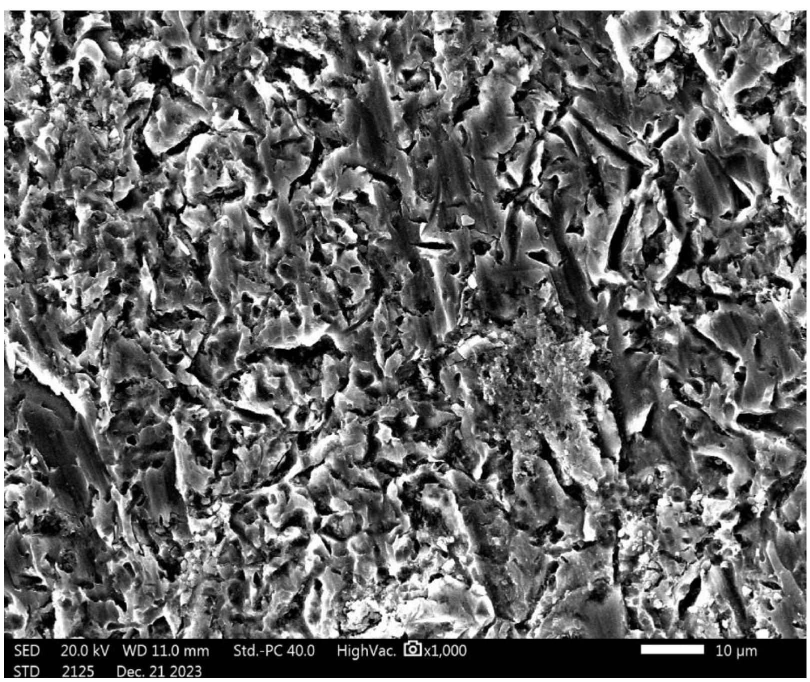

Figure 3: Typical microstructure of SiC reinforced Aluminium Metal Matrix Composite

Influence of Parameters on GTAW

Influence of welding parameters on the effect and quality of weld plays an important role. The degree of influence of each parameter on the weld quality depends on the range of each factor.

Effect of different weld parameters like weld current (amps), weld speed (mm/min) and gas flow rate (l/min) were examined by A. Daniel Das[10-11] during TIG welding of aluminium six-series Al 6063 alloy welded samples using zirconated tungsten electrode. Weld strength was measured by tensile strength.

In a review work by Thakur and Chapgaon [12], effect of various TIG welding process parameters on weld quality was examined. Increased weld current resulted in increased deposition rate and reduced hardness. Deeper weld penetration is accomplished by direct current electrode negative (DCEN) compared to direct current electrode positive (DCEP) and alternating current (AC) polarity.Increasedweld speed results in decrease in bead width and depth of penetration. Increased weld voltage resulted in decreased depth of penetration and deposition rate. Different combinations ofshielded gasexhibited different effect on arc plasma which depended upon gas properties such as electrical conductivity,molecular weight, ionization temperature etc. Arc velocity, current density and heat flux decreased with increase in tip angle of electrode.

In another investigative work by Singh et. al [13], effect of current on microstructure and hardness of butt welded aluminium AA6082 samples by TIG welding was examined. This alloy has excellent corrosive resistance property and possesses the highest strength amongst 6000 series aluminium alloys. Optimization of weld current was performed by trial experiments. Also microstructure and hardness were analyzed.

Optimization of process variables for TIG welded aluminium alloy AA 8006 samples were performed by Satish et. al [14] using Taguchi L_9 orthogonal array as design of experiment. Input factors considered were welding speed, base current, and peak current with three levels each. Surface hardness and tensile strength of welded samples were examined. 3D profilometric images of tensile-tested specimens were examined and they suggested optimized process parameters based on the results.

In an experimental work by Kumar et. al [15], an attempt to investigate improvement of mechanical properties and optimization of pulsed current GTAW process parameters on aluminium AA6061 alloy using sinusoidal AC wave was performed. Argon mixed with helium was used as shielding gas. Modified Taguchi method was used as design of experiment. Microstructure study of the weld beads was made.

Manti et. al [16] experimented to study the effect of pulsed TIG welding process parameters e.g. pulse duration, peak current, and pulse frequency on Al-Mg-Si alloy. Microstructure and microhardness of weld beads were investigated. It was observed that pulsed TIG welding produced finer grain structure compared to conventional TIG welding. With an increase in pulse frequency, there was refinement in aluminium eutectic grain structure for short pulses. Pulse duration determined the effect of pulse frequency on grain structure.

Conclusion

This paper attempted to studyresults and inferences on TIG weldability of various aluminium based alloys and composites.It was observed that during TIG welding of AMg_2-TiC aluminium alloy MMC, hardness and strength of alloy was increased due to reinforcement of titanium carbide. Also, less porosity was obtained.Effect of using different filler materials on mechanical properties of aluminium based welded samples were investigated. Study was also made on fabrication of filler materials for TIG welding of aluminium composites. Addition of zirconium transformed the dendritic tofine-grain growth.Also, effect of arc manipulation process on weld metal grain structure and tensile properties of welded samples was investigated. The types of processes were pulsed current welding, magnetic arc oscillation and mixture of the two.Several researches on optimization of TIG welding parameters were attempted. Microstructure study of various aluminium based alloys and composites were made. Addition of mischmetal (MM), a mixture of rare-earth elements addition on the microstructural development of in situ Al–15wt.%Mg_2Si composite was made. It was observed that addition of MM in composite reduced the size of primary Mg_2Si particles and the pseudo-eutectic Mg_2Si transformed from fibrous structure to flake like structure. In another investigation, MMCs with various ranges of matrix materials including aluminium, titanium, copper, nickel and iron and second-phase particles such as borides, carbides, nitrides were produced. The composites exhibited excellent mechanical properties.Finally, the influence of welding parameters on the effect and quality of weld were studied. Influence of different welding parameters like weld current, weld speed and gas flow on responses like depth of penetration and bead width were examined.

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