Effect of SiC Addition to Al-Mg-Si Alloy TIG Welded Plates

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Abstract

The Al-Mg-Si alloy plates are welded by using the Tungsten Inert Gas (TIG) welding process and another pair of Al-Mg-Si alloy plates are welded by using TIG welding process with the addition of SiC particles. The change in Microstructure, Micro hardness and Tensile strength of different zones of weld joint are observed. Better mechanical properties are observed with addition of SiC particles to weld joint. Hardness test indicated that the minimum and maximum hardness values were obtained in the Heat Affected Zone (HAZ) and Base Metal (BM) respectively.

Keywords: *TIG, Al-Mg-Si, SiC particles, Hardness, Tensile strength*

1.0 Introduction

Alloy Al-Mg-Si has a composition of Al - 1Mg - 0.6Si with 0.25% Cu and 0.2% Cr. Mn or Cr is added to most 6XXX series alloy because of their effects on promoting fine grain size and inhibiting recrystallization during solution treatment [1,2]. Specifically now-a-days particulate reinforced Aluminium matrix composites (AMC) are attracted to aerospace industry due to high stiffness and strength to weight ratio, high formability with good wear resistance and excellent fatigue resistance [3]. Aluminium matrix strengthened by reinforcing of SiC, Al_2O_3 and B_4C [3,4,5] and these reinforced particles increase strength and wear resistance.

GTAW was patented in 1890 by Coffin in a non-oxidizing gas atmosphere. This concept was modified later by Hobbert in 1920, which used helium as a shielding gas and Devers, who used argon gas for shielding. The process parameter, which effects TIG welding, is welding current, welding voltage, inert gases, welding speed. Due to the affinity of Aluminium for oxygen, it cannot successfully be arc welded in an environment. If fusion welded in a normal atmosphere, oxidization readily occurs and this results in both slag inclusion and porosity in the weld, greatly reducing its strength [4]. To overcome these problems one of the best ways of welding Aluminium has been to use the electric arc process whilst shielding the weld pool with an inert gas, so-called metal inert gas welding.

Cabello Munoz (2008) compared TIG welding and FSW on Al - 0.45Mg - 0.26Si alloy. The result found was hardening precipitates were comparatively more affected by the TIG welding than FSW process. This cause a reduction of mechanical properties for TIG welds joints, which can be overcome by a suitable post weld heat treatment [6]. Welding current, voltage, and welding speed are the most important parameters which affect the TIG welding [7].

2.0 Experimental Procedure

2.1 Al-Mg-Si Alloy:

Alloy Aluminium has a composition of (Al - 1Mg - 0.6Si) with 0.25% Cu and 0.2% Cr. Copper is added to improve the strength and chromium is added to offset any adverse effect may have on corrosion resistance. Typical composition and mechanical properties are shown below Table 1 and Table 2 respectively [1,2].

Table 1. Chemical Composition of Al - Mg - Si Alloy

Element	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Weight %	0.8-1.2	0.4-0.8	0.7	0.15-04	0.04-0.35	0.15	0.25	0.15	Balance

Table 2. Typical Mechanical Properties of Al - Mg - Si Alloy

Temper	UTS (MPa)	0.2%PS (MPa)	Elongation%
O	125	40	30
T4	240	145	21
T6	310	275	15

2.2 SiC Particles Incorporation into the Weld Zone:

Initially with the help of ACM (Abrasive Cutting Machine) samples were cut into required dimensions (300mm X 60mm X 6mm). The samples were drilled with the help of drilling machine on the lateral faces of samples as shown in Figure 1. The holes were made with a separation of 30mm, therefore a total of nine holes were drilled on each sample and 18 holes for each couple. The holes were made with approximate dimensions of 2.5mm dia and 4mm depth. Later an amount 5mg of SiC micro-sized (average 25µm) particles was carefully filled into the drilled holes. Each grade microparticles were filled into a single couple. Then the two plates were joined as shown in Figure 4 and two pairs of plates were prepared and ready for welding.

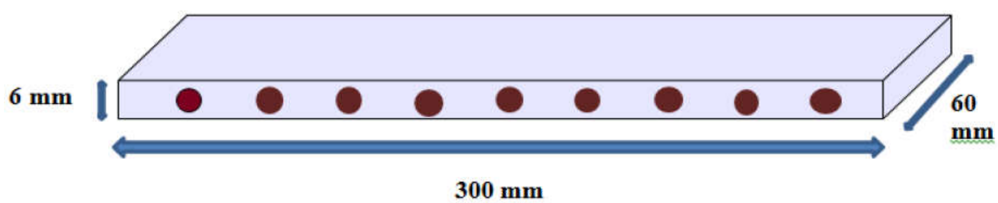


Figure 1. Schematic Diagram Showing the Drilled Holes in the Sample

2.3 Process Parameters For TIG:

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from the atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used [8]. 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 handpiece.

An electric arc is then created between the tungsten electrode and the workpiece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapors [9]. The tungsten electrode and the welding zone are protected from the surrounding air by an inert gas. The electric arc can produce temperatures of up to 20,000°C and this heat can be focused to melt and join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding are shown in Figure 2 and Figure 3 respectively.

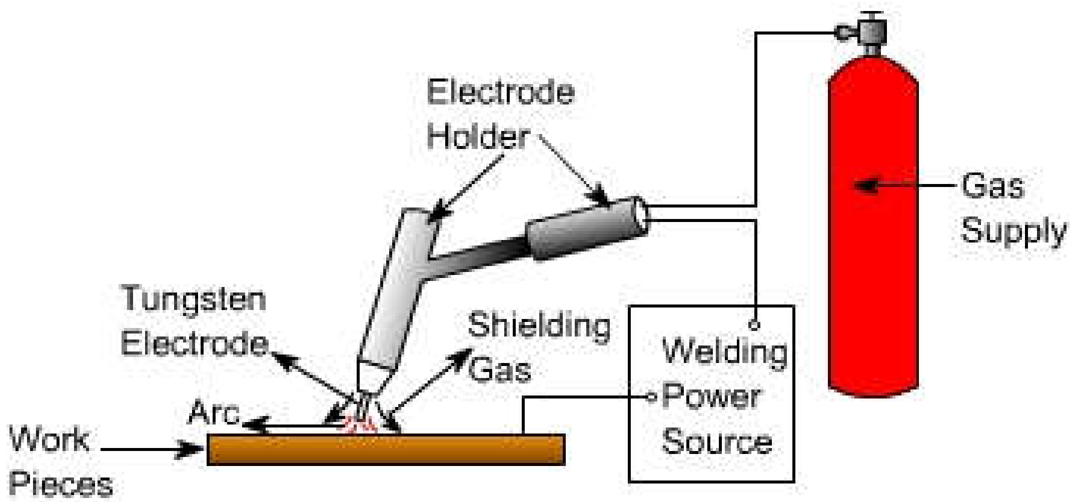


Figure 2. Schematic Diagram of TIG Welding System [10]

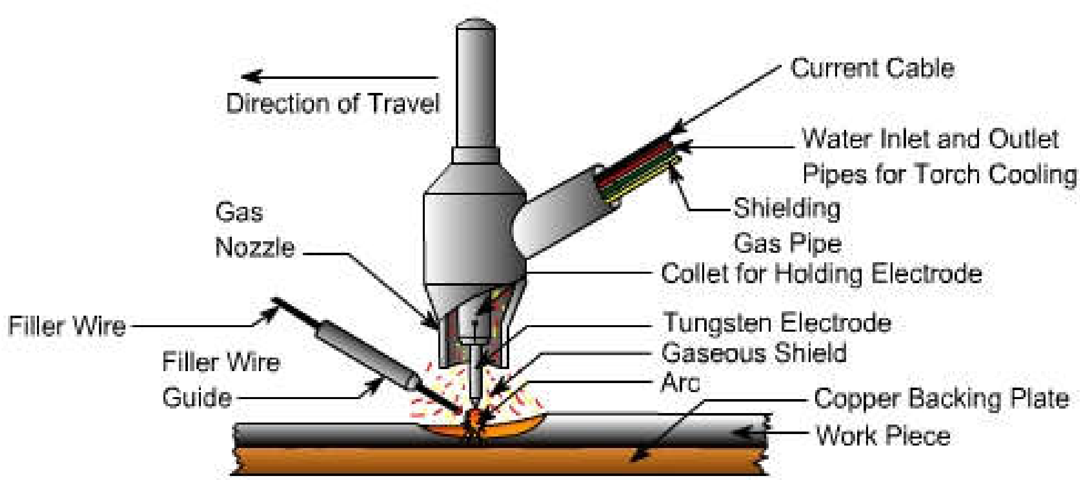


Figure 3. Principle of TIG Welding Process [10]

Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and 150-200 mm length as given in Table 3. The current carrying capacity of each grain size of the electrode depends on whether it is connected to the negative or positive terminal of DC power source.

The working electrodes were kept in the open-circuit condition for 1 hour prior to conducting the potentiodynamic scan at a rate of 1 mV/s. A saturated calomel electrode (potassium chloride) was used as the reference electrode and a platinum mesh was used as the counter electrode and welding is performed as per Table 4.

Table 3. Chemical Composition of Filler Wire 4043 Al - Mg - Si Alloy

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Balance
Weight %	4.5-6.0	0.8	0.3	0.05	0.05	0.0	0.10	0.20	Al

Table 4. TIG Welding Parameters

Parameter	Value
Welding current (Amp)	120
Welding speed (mm/sec)	4.2
Arc length (mm)	2
Shielding gas	Helium
Gas flow (l/mm)	15

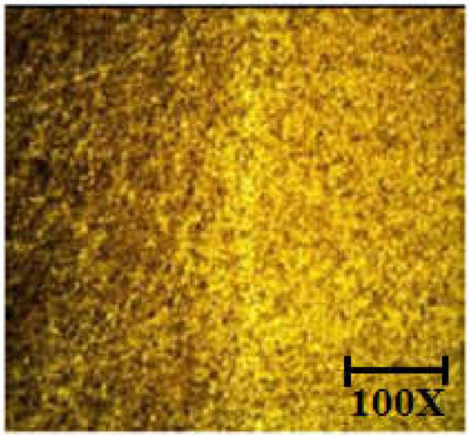
Figure 4. TIG Welded Sample

3.0 Results & Discussions

3.1 Microstructure Analysis:

The parent aluminium alloy, TIG welded samples were observed under a microscope (Leica microscope) for the microstructural analysis. Later, the microstructures of the weld zone with metal SiC were observed. The microstructures of parent alloy, parent weld without SiC and with SiC particles is shown in the following Figure 5. Figure. 5 is showing optical micrographs of TIG welded samples. The NZ has shown fine equiaxed grains due to dynamic recrystallization in T IG welded samples. The grain size of the HAZ was almost similar to that of the Base metal. At low magnesium contents, elemental silicon may be present as second-phase particles. As magnesium increases, both silicon particles and equilibrium hexagonal Mg_2Si constituents may be present. At higher magnesium contents, only Mg_2Si is present. The NZ consists of fine equiaxed grains due to dynamic recrystallization. The grains in NZ are much smaller than those in other regions. The phases present are Al as the matrix and Mg_2Si with fine equiaxed grains in the NZ as shown in figure. 8. The average grain size in the four zones is the order:

BM > HAZ > TMAZ > NZ



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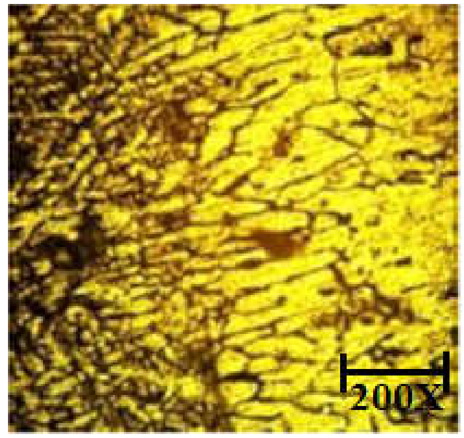
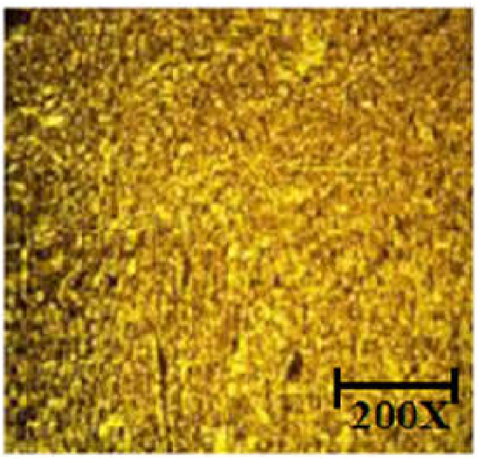


b

a. Microstructure of base metal showing Al matrix, Mg_2Si precipitates

b. Microstructure of weld zone showing elongated grains

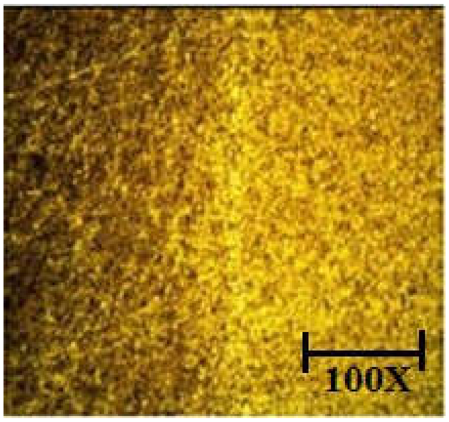
c



c. Microstructure of HAZ showing fine equiaxed grains near base metal and coarse grains near weld zone

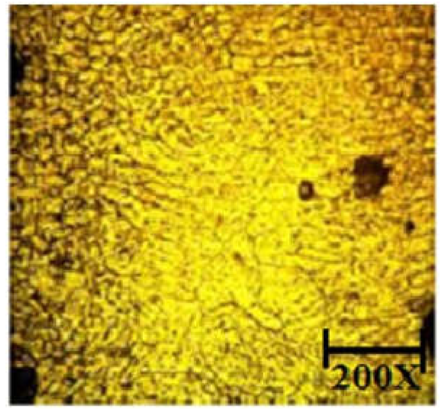
Figure 5. Microstructures of TIG Welded Samples

In the TMAZ, which is adjacent to the NZ, the strain and the temperature was lower than in the NZ and the effect of welding on the microstructure was correspondingly smaller. The grain size of the HAZ was similar to that of the BM. The HAZ was common to all welding processes subjected to a thermal cycle, but it was not deformed during welding. By adding SiC particles grain size was decreased because of it acts as a grain refiner.



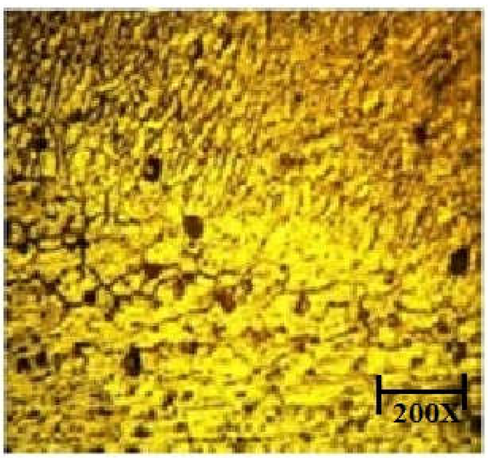
a

a. Microstructure of Base metal showing Al matrix, Mg_2Si and SiC particles



b

b. Microstructure of weld zone showing completely dissolved SiC and elongated grains



c

c. Microstructure of HAZ showing fine equiaxed grains near base metal and coarse grains near weld zone

Figure 6. Microstructures of TIG Welded Samples With SiC

The optical micrographs of Aluminium alloy 6061 and AA-6061 with SiC were observed. From above Fig. 5 and Fig. 6, 6061 and 6061 SiC micrographs of TIG welded joints showing Base metal, HAZ and weld regions. Welded region contains dendrite grains due to slower cooling rates and higher heat input. HAZ region next to weld zone has coarse grains and next to base metal has fine grains. In weld zone dendrite grains were formed. In fusion zone, equiaxed grains appear. The addition of SiC resulted in the reduction of grain size by acting as grain refiner and pinned the grain boundaries to improve mechanical properties.

Because of SiC particle grain size was reduced. It has shown Al as the matrix and Mg_2Si precipitates. The TIG welded metal contains coarse and elongated grains. The weld region of TIG welded joints shows coarse and elongated grains normal to the welding direction.

3.2. Micro hardness:

Microhardness test is carried out by using of Vickers hardness test for all the specimens under 500gms load with dwell time 15Sec. All the hardness values are tabulated in Table 4.

Table 5. Hardness Values of TIG Welded AA-6061 and AA6061 With SiC Particles

Sl. No.	**TIG welded AA-6061**		**TIG welded AA-6061 with SiC particles**	
	Distance (cm)	**Hardness HV**	**Distance (cm)**	**Hardness HV**
1	-1.5	68.1	-1.2	71
2	-1.3	53.7	-1	76.1
3	-1.1	50.6	-0.8	72.9
4	-0.9	60	-0.6	61.5
5	-0.3	58	-0.4	58
6	-0.1	56.3`	-0.2	56.8
7	0.1	56.6	0	59.6
8	0.3	55.7	0.2	59.7
9	0.5	55.6	0.4	56.8
10	0.7	64.5	0.6	57.2
11	0.9	69.1	0.8	65

12	1.1	63.6	1	63
13	1.3	71.7	1.2	68.4

From Table 5, it is clearly showing the difference between welding technique and incorporation of SiC particles with parent metal. It is showing hardness values of different weld zones. The hardness of the sample was decreased at weld zone due to its structure. In all joints of TIG welded samples Heat Affected Zone (HAZ) area adjacent to weld zone was coarse-grained which posse's low hardness whereas HAZ area adjacent to base metal was fine-grained which posse's high hardness is. The reason for this trend of micro-hardness in HAZ of joint was that the area adjacent to weld zone experiences relatively slow cooling rate and hence has a coarse-grained microstructure, whereas the area adjoining the base metal undergoes high cooling rate due to steeper thermal gradient and consequently has fine-grained microstructure. Al-6061 incorporated with SiC particles graph showing higher hardness than Al-6061 alloy. This increasing hardness due to SiC particles are migrated towards weld metal region these are impeded to dislocation motion and also Mg_2Si fine precipitates formed in weld zone these are creating coherency with Aluminium matrix.

3.3. Tensile Properties:

The average tensile strength of base metal is 200MPa.The base metal is rich in all properties yield strength is 187MPa and elongation is 14.5% as given in Table 6. In TIG weld tensile strength is decreased, this due to formation dendrite structure in Fusion zone. The same trend is shown by the alloy and with SiC addition to the base alloy. However there is some improvement with SiC addition though it is lesser than the base metal.

Table 6. Tensile Properties of Base Metal, TIG Welded AA 6061 and AA6061 With SiC Particles

Tensile Properties	Base metal (AA-6061)	TIG (AA-6061)	TIG (AA-6061-SiC)
YS (MPa)	178	48	57
TS (MPa)	200	80	98
% Elongation	13	5	3

4.0 Conclusion

1. TIG welding has coarser and dendrite grains due to slower cooling rates.
2. By adding SiC particles to base alloy minimizes the grain size, here SiC act as grain refiners.
3. Micro-hardness of the BM is more compared to the HAZ and NZ (AA6061, AA6061-SiC).
4. TIG has lower tensile properties (yield strength and tensile strength).
5. By adding SiC particles tensile properties increases. Higher tensile properties were observed in TIG of AA-6061 with SiC particles.

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