

# Effect of ER4047 Filler Rod on Tungsten Inert Gas Welding of AA5083-H111 and AA6061-T6 Aluminium Alloys

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## ABSTRACT

Tungsten Inert Gas Welding is one of the oldest material joining process which was invented during world war-II. The Fusion welded joints fabricated using 5000 series and 6000 series aluminium alloys had welded joint efficiencies less than one, which means that the welded joint UTS is inferior to that of the base metal UTS. The dissimilar Tungsten Inert Gas welded joints find application in many areas such as ship building, offshore constructions and transportation industries. The hull and superstructure made of 5083 and 6061 aluminium alloys are gaining popularity. The joining of the two materials by using high silicon content Al-Si alloy filler is experimented in this paper and the observations are listed out. The softening caused in the weld and subsequent hardness changes had been correlated with the chemical composition of the filler rod. The mechanical properties of the samples were evaluated by micro hardness scans and tensile test. In addition, microstructural investigations were performed by optical microscopy.

**KEY WORDS:** Filler Rod ER4047, Tungsten Inert Gas welding, AA5083-H111, AA6061-T6, Chemical composition and Properties.

## 1. INTRODUCTION

Aluminium Alloy AA5083 is commonly used in the manufacturing of pressure vessels, marine vessels, armoured vehicles, aircraft cryogenics, drilling rigs, structures and even in missile components etc. This alloy is considered as one of the best aluminium alloys for marine vessels because of its high strength and excellent corrosion resistance even in salt water and high toughness even at cryogenic temperatures to near absolute zero. The marine industry has made use of high strength magnesium base aluminium alloys such as AA 5083 to obtain the tensile strength requirements. TIG welding is widely used in aluminium and its alloy fabrications.

The preferred welding process for aluminium alloy is TIG welding due to its comparatively easier applicability and better economy. The dissimilar TIG welding of 5083-O and 6061-T6 aluminium alloys were conducted by researchers (Menzemer 2001; Leitao 2012; Subbaiah 2012; Palanivel, 2013; Sefika 2013).

## 2. EXPERIMENTAL PROCEDURE

AA 5083-H111 and AA6061-T6 plates of 5mm in thickness were cut into strips of 300x150mm. The surfaces of the plates were cleaned. TIG welds on the AA5083-H111 alloy plates were autogenously using alternating current TIG welding with a standard 2% Thoriated Tungsten electrode. The electrode tip configuration was a blunt point with a 90° included angle, the diameter of the electrode is 2mm. The argon shielding gas flow rate was 40Lmin<sup>-1</sup>.

After welding, the joints were cross-sectioned perpendicular to the welding direction for metallographic analyses and tensile test using an EDM cutting machine. Tensile properties of welds were measured in an UTM with a cross head speed of 0.03175 mms<sup>-1</sup>. In the tensile test sample, the weld was oriented perpendicular to tensile stress axis and was in the middle of the gauge length. .

Prior to the tensile tests, Vickers hardness profiles across the weld, HAZ and partial base metal were measured under the load of 1kgf for 15 Salong the centrelines of the cross-section of the tensile specimens using an automatic micro hardness tester, and the Vickers indents with a spacing of 1mm were used to determine the fracture locations of the joints. The configuration and the size of transverse tensile specimens were prepared with reference to the ASTM-E8 standard. The tensile tests were carried out at room temperatures.

Welding current and welding speed have been chosen in such a way that the heat input results in through thickness melting of the plate. The parameters used to make TIG Butt welding on 5083-H111 plates are listed out in Table.1.

**Table.1. Welding parameters**

Welding parameter			
Current, Amps	200	Travel Speed, mm/min	150
Voltage, Volt	16		

The chemical composition of the base metals AA5083-H111 and AA6061-T6 were given in Table.2. The chemical composition of filler rod ER 4047 is shown in Table.3.

**Table. 2. Chemical Composition of Base metals**

Base Metal	Mg	Mn	Fe	Si	Cu	Cr	Zn	Ti	Zr	Al
AA5083-H111	4.254	0.525	0.259	0.980	0.346	0.113	0.103	0.019	0.002	93.31
AA6061-T6	0.812	0.061	0.323	3.01	1.142	0.184	0.072	0.02		94.31

**Table.3. Filler Rod Chemical Composition**

Filler Rod	Mg	Mn	Si	Fe	Cu	Zn	Ti	Zr	Al
ER4047	<0.10	<0.15	11~ 13	0.8	<0.30	-	<0.2	-	Rest

### 3. RESULTS AND DISCUSSIONS

**Chemical Compositions of the TIG welded joints:** The chemical composition of the TIG welded joints of AA5083-H111 and AA6061-T6 aluminium alloy 5mm plates were given in Table.4. The Base metals AA5083 and AA6061 contains 4.254% and 0.812% wt. of magnesium and 0.980 and 3.01 wt. percent of silicon. AA5083 and AA6061 contains 0.525 and 0.061% of manganese and 0.259 and 0.323 wt. percent of iron. The aluminium silicon filler rod ER4047 contains 11-13 wt. percent of silicon and around 86 percent of aluminium. The TIG welded joints of AA5083 and AA6061 with ER4047 contains 0.489 wt. percent of Mg and 6.503 wt. percent of Si.

**Table.4. TIG Welded Joints Chemical Composition**

Filler Rod	Mg	Mn	Fe	Si	Cr	Cu	Zn	Ti	Al
ER4047	0.489	0.074	0.482	6.503	0.044	0.040	0.394	0.019	Rest

**Optical Microstructure of TIG welded AA5083-H111 and AA6061-T6 with ER4047 Filler Rod:** The optical microstructure of TIG welded dissimilar joints of AA5083-H111 and AA6061-T6 with ER4047 filler rod are shown in Figures.1 to 8. The AA5083-H111 base metal micro structure is shown in Figure.1. The grains are elongated in the rolling direction. This alloy contains alpha-Al matrix and beta-Al<sub>3</sub>Mg<sub>2</sub> precipitates in it. This alloy also contains intermetallic compounds such as Al<sub>6</sub>[Fe, Mn]. The Grains are not seen clearly in this picture. The Intersection between Base metal and Heat affected zone is shown in Figure.2 on the AA5083 side. The columnar grains at the intersection of BM and HAZ are clearly shown in this picture. The presence of the columnar grains normally reduces the ductility of the welded joints. Some micro pores and cavities were observed along the intersection. The reduction in the ductility of the welded joint due to the presence of columnar grains is because of their anisotropic nature.

The intersection of the HAZ and the weld of the TIG welded joint is shown in Figure.3. The weld microstructures were taken at three different locations such as weld top, weld middle and weld bottom and also shown in Figures.4 to 6. The microstructures at the weld top is fine compared to the other two microstructures shown by Figure.5 and 6. The weld microstructure at the middle of the joint shown by Figure.5 is containing coarse dendrites compared to weld top. The weld microstructure at the bottom of the weld is shown by Figure.6. This microstructure is a relatively coarser than the other two. This microstructure also contains weld defects such as cavities and pores.

The intersection between the weld and HAZ on the 6061 side is shown in Figure.7. The weld contains columnar grains at the intersection. The Grain boundaries of AA6061 side grains were not clearly visible in the HAZ. Mg<sub>2</sub>Si precipitates are only observed. The AA6061-T6 base metal micro structure is shown in Figure.8. The grains and grain boundaries are visible in this picture. The black spots indicate the presence of the strengthening precipitate Mg<sub>2</sub>Si in AA6061-T6 aluminium alloy.

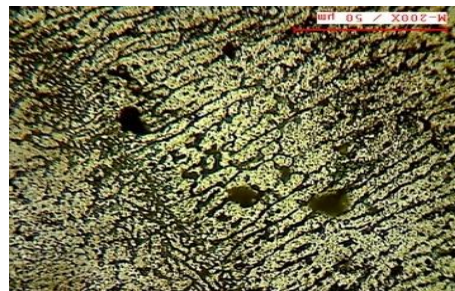
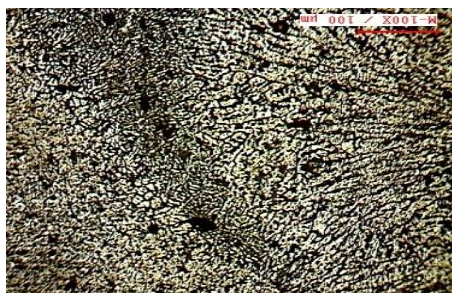
**Figure.1. Base Metal****Figure.2. Junction at 5083 side****Figure.3. Junction on 5083****Figure.4. Weld at Top**





Figure.5. Weld at Middle



Figure.6. Weld at Bottom

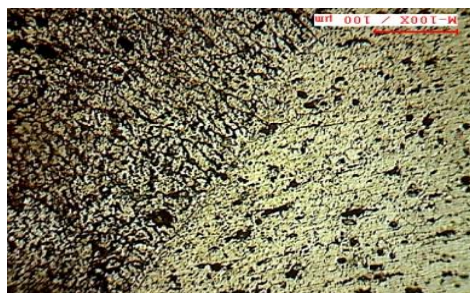


Figure.7. Weld &amp; HAZ 6061 side

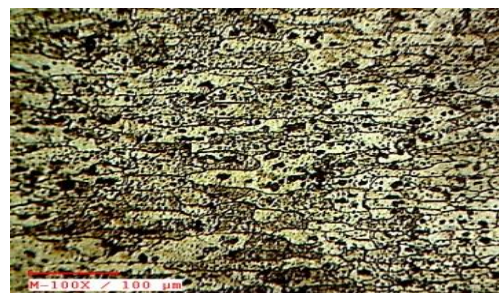


Figure.8. AA6061 BM

**Tensile Properties of the AA5083-H111 and AA6061-T6 aluminium alloy plates with ER4047 filler rod:** The tensile properties of the AA5083-H111 and AA6061-T6 aluminium alloy plates with ER4047 filler rod was found out and listed in Table.5. The welded joint ultimate tensile strength is around 115MPa. The percentage elongation of the welded joints is 3.09 %. The welded joint efficiency is  $(115/325) \times 100 = 35.38\%$ .

Table. 5 Tensile Properties of AA5083-H111 welded joints

Material	Yield Stress, MPa	Tensile Strength, MPa	Elongation, %
Base Metal- AA5083-H111	197.39	321.34	22.26
Base Metal-AA6061-T6	265.99	325.08	15.93
Weld – 1	-	133.405	4.00
Weld – 2	-	87.615	2.21
Weld – 3	-	125.863	3.05
<b>Average</b>	-	<b>115.628</b>	<b>3.09</b>

**Hardness Survey of the welded joints:** The Hardness graph of the TIG welded AA5083-H111 and AA6061-T6 with ER4047 filler rod is shown in Figure.9. The hardness value of the welded joint on the AA5083 side is more or less equal to hardness value of AA5083, whereas, the hardness value on the AA6061 is above 120HV1. The hardness of the welded joint on the AA6061 side is more than hardness of the base metal AA6061-T6. This may be due to the Magnesium silicon precipitates formed on the AA6061 side.

HARDNESS SURVEY OF TIG WELDED JOINTS WITH ER 4047 FILLER ROD

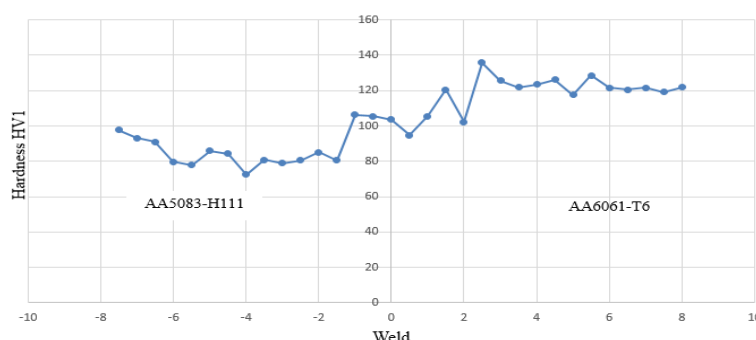


Figure.9. Hardness Survey of TIG welded joints of AA5083-H111 Aluminium Alloy

#### 4. CONCLUSIONS

The AA5083-H111 and AA6061-T6 aluminium alloy plates were TIG welded with ER 4047 filler rod. The Mechanical and Microstructural characterization of the welded joints have yielded the following conclusions.

- A 64% reduction in tensile strength was observed in our experiment.
- The Hardness values along the AA5083 side is more and less the same as the base metal values, whereas, the hardness values on the AA6061-T6 side is 10% above the AA6061 base metal values.
- The Increase in the hardness on the AA6061 side may be due to formation of large number of  $Mg_2Si$  precipitates.

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