

# Effect of Heat Transfer in Tungsten Inert Gas Welding of 5000 Series Aluminium Alloys

A. Ramarajan and K.Subbaiah\*

Department of Mechanical Engineering, SSN College of Engineering, Chennai.

\*Corresponding author: E-Mail: subbaiahk@ssn.edu.in

## ABSTRACT

The aluminium alloys are widely used in the transportation sectors nowadays due to their light weight, high specific strength, recyclability and corrosion resistance. The 5000 series aluminium alloys, which falls under the Non-Heat-Treatable category, is a medium strength alloy. The fusion welded joints fabricated using 5000 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. To produce such a joint, careful selection of welding parameters is important in order to supply the required amount of heat to the plates to be connected. The approximate heat supplied to the joints and their effect in formation of the joints is discussed in this paper.

**KEY WORDS:** Aluminium Alloys, Heat Transfer, Joint Properties, and Tungsten Inert Gas Welding.

## 1. INTRODUCTION

The U.S automotive industry is currently facing increased demands to simultaneously increase its fleet average fuel economy and reduce greenhouse gas emissions. In order to meet these new standards, the industry is increasingly moving toward decreasing the weight of the vehicles through the use of new materials, especially lightweight aluminium alloys.

For the reduction in CO<sub>2</sub> emission produced by vehicles, the application of Al alloy to the structural components of vehicles is increasingly becoming important due to the high specific strength of this alloy. Currently, Al alloy ranks the second metal in terms of consumption around the world, and hence its recycling is an important technology for materials circulation.

Yao Liu (2012) have investigated that the mechanical properties and microstructural features of aluminium 5083 weldment processed by gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW). Weldments processed by both methods are mechanically softer than the parent material Al 5083, and could be potential sites for plastic localization. It is revealed that Al5083 weldments processed by GTAW are mechanical more reliable than those by GMAW. The former bears higher strength, more ductility and no apparent microstructure defects. Perceivable porosity in weldments by GMAW is found, which could account for the distinct mechanical properties between weldments processed by GTAW and GMAW. It is suggested that caution should be exercised when using GMAW for Al5083 in the high-speed-train industry where such light weight metal is broadly used.

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 its 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 (Birol, 2006; Christian, 2006; Yazdipour, 2011).

## 2. EXPERIMENTAL PROCEDURE

AA 5083-H111 plates of 5mm in thickness were cut into strips of 300 X 150 mm. 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 90degree 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 the tensile stress axis and was in the middle of the gauge length. The sample has an overall length of 25mm and a width of 10mm.

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     | 140 | Travel Speed, mm/min | 150 |
| Voltage, Volt     | 16  |                      |     |

The chemical composition of the base metals AA5083-H111 is given in Table.2. The Base metal AA5083 contains 4.254 wt. % of magnesium and 0.980 wt. % of silicon. AA5083 contains 0.525 wt. % of manganese and 0.259 wt. % of iron.

**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 |

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

| Design | Mg        | Mn         | Fe   | Si      | Cr    | Cu   | Zn   | Ti   | Al   |
|--------|-----------|------------|------|---------|-------|------|------|------|------|
| ER4043 | 0.05      | 0.05       | 0.8  | 4.5 ~ 6 | -     | 0.3  | 0.1  | 0.2  | Rest |
| ER4047 | <0.10     | <0.15      | <0.8 | 11 ~ 13 | -     | <0.3 | <0.2 | -    | Rest |
| ER5356 | 4.5 ~ 5.5 | 0.05 ~ 0.2 | 0.4  | 0.25    | 0.14  | 0.1  | 0.1  | 0.13 | Rest |
| ER5183 | 4.3 ~ 5.2 | 0.5 ~ 1.0  | 0.4  | 0.4     | <0.25 | 0.1  | 0.25 | 0.15 | Rest |

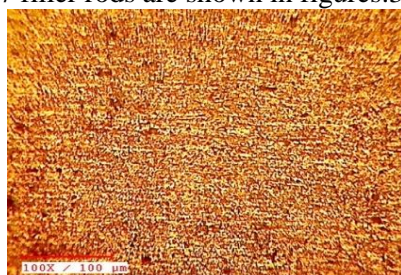
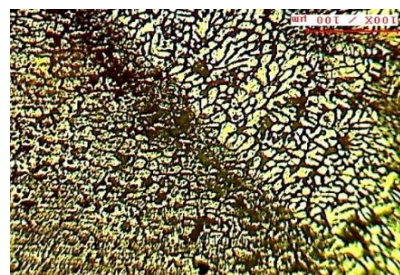
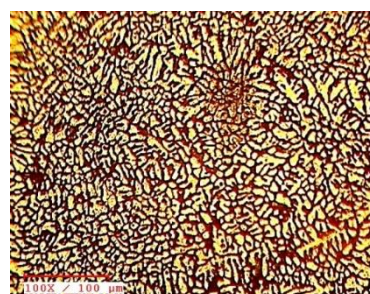
### 3. RESULTS AND DISCUSSIONS

**Chemical Compositions of the TIG welded joints:** The chemical composition of the TIG welded joints of AA5083-H111 aluminium alloy 5mm plates were given in Table.4. The TIG welded joints of AA5083 with ER4043 contains 1.499 wt. % of Mg and 3.516 wt. % of Si. The TIG welded joints of AA5083 with ER4047 contains 1.795 wt. % of Mg and 5.175 wt. % of Si. The TIG welded joints of AA5083 with ER5183 contains 5.992 wt. % of Mg and 0.142 wt. % of Si. The TIG welded joints of AA5083 with ER5356 contains 6.178 wt. % of Mg and 0.116 wt. % of Si.

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

| Design | Mg    | Mn    | Fe    | Si    | Cr    | Cu     | Zn    | Ti    | Al   |
|--------|-------|-------|-------|-------|-------|--------|-------|-------|------|
| ER4043 | 1.499 | 0.131 | 1.79  | 3.516 | 0.032 | <0.001 | 0.190 | 0.016 | Rest |
| ER4047 | 1.795 | 0.184 | 0.38  | 5.175 | 0.042 | <0.001 | 0.465 | 0.021 | Rest |
| ER5356 | 5.992 | 0.129 | 0.157 | 0.142 | 0.018 | <0.001 | 0.018 | 0.067 | Rest |
| ER5183 | 6.178 | 0.530 | 0.127 | 0.116 | 0.104 | <0.001 | 0.026 | 0.069 | Rest |

**Optical Microstructure of TIG welded AA5083-H111 with Four Filler Rods:** The optical microstructure of TIG welded joints of AA5083-H111 with ER4043 and ER4047 filler rods are shown in figures.1 to 4. The AA5083-H111 base metal microstructure is shown in Fig.1. The heat affected zone and weld intersection microstructure of TIG welded joint with ER4047 filler rod is shown in Fig.2. The weld microstructures of the TIG welded joints of ER4043 and ER4047 filler rods are shown in figures.3 and 4 respectively.

**Figure.1. AA5083-H111 Base Metal****Figure.2. HAZ and Weld Intersection****Figure.3. Weld Microstructure of ER4043 Weld****Figure.4. weld Microstructure of ER4047 Weld**

The optical microstructure of TIG welded joints of AA5083-H111 with ER5183 and ER5356 filler rods are shown in figures 5 to 8. The heat affected zone and weld intersection microstructure of TIG welded joint with ER5356 filler rod is shown in Fig.6. The weld microstructures of the TIG welded joints of ER5183 and ER5356 filler rods are shown in figures.7 and 8 respectively.

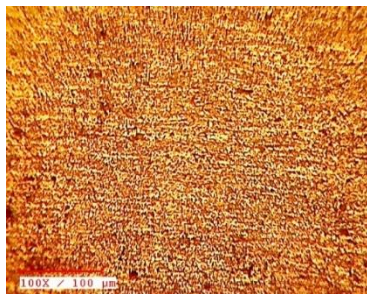


Figure.5. AA5083-H111 base Metal



Figure.6. Heat Affected Zone



Figure.7. Weld Microstructure of ER5183 Weld

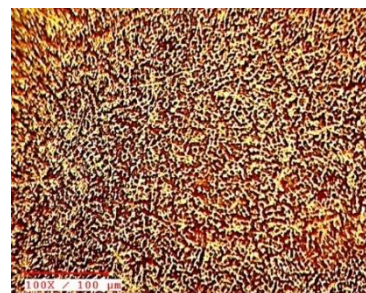


Figure.8. weld Microstructure of ER5356 Weld

**Tensile Properties of the AA5083-H111 alloy plates with Four Filler Rods:** The tensile properties of the AA5083-H111 aluminium alloy plates with four different filler rods were found out and listed in Table.5. The tensile properties of Al-Si filler rod (ER4043 and ER4047) welded joints are less than the tensile properties of the base metal AA5083-H111 aluminium alloy. Similarly the tensile properties of Al-Mg filler rod (ER5182 and ER5356) welded joints are less than the tensile properties of the base metal AA5083-H111 aluminium alloy. The welded joint with ER5356 filler rod has produced better joint strength compared to the welded joint with ER5182 filler rod. Out of the four welded joints of AA5083-H111 aluminium alloy plate with four filler rods, the welded joint fabricated using ER5356 filler rod has produced the best tensile properties.

Table.5. Tensile Properties of AA5083-H111 welded joints

| Material   | Yield Stress, MPa | Tensile Strength, MPa | Elongation, % |
|------------|-------------------|-----------------------|---------------|
| Base Metal | 197.39            | 321.34                | 22.26         |
| ER4043     | -----             | 138                   | 2.47          |
| ER4047     | 162               | 168                   | -             |
| ER5182     | 166               | 176                   | 3.00          |
| ER5356     | 147               | 187                   | 4.13          |

**Hardness Survey of the welded joints:** Hardness measurement was taken in the transverse direction, i.e. parallel to the base plate surface. The hardness distribution for the AA5083-H111 alloy and its TIG weld is shown in figures.9 to 12. It is observed that the hardness curve is symmetrical with respect to the weld centreline. The main reason for this fact is that the melt flow field on the both sides of weld centre is uniform. The hardness distribution of TIG welded joints with Al-Si filler rods are shown in figures.9 and 10, whereas the hardness distribution of TIG welded joints with Al-Mg filler rods are shown in figures.11 and 12 respectively. The hardness along the welds in figures.9 and 10 are greater than the hardness of the base metal AA5083H-111aluminium alloy. The hardness along the welds in figures.11 and 12 are more or less equal to the hardness of the base metal AA5083H-111aluminium alloy.

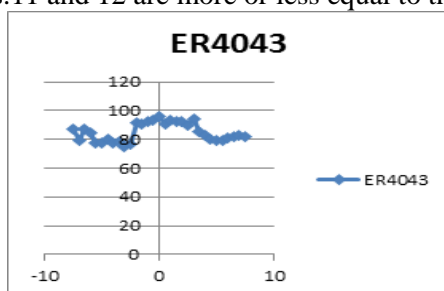


Figure.9. Hardness of TIG joints For ER4043 filler

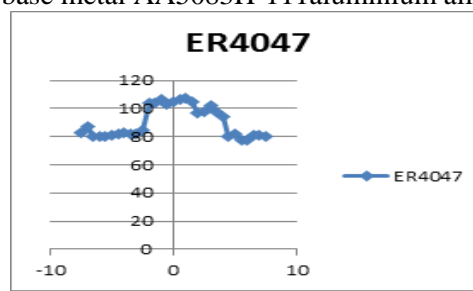


Figure.10. Hardness of TIG joints for ER4047 filler



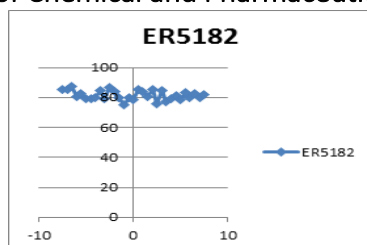


Figure.11. Hardness of TIG joints for ER4047 filler

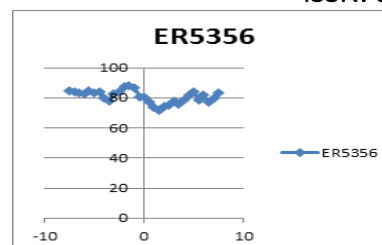


Figure.12. Hardness of TIG joints for ER5356 filler

#### 4. CONCLUSIONS

The AA5083-H111 aluminium alloy plates were TIG welded with four filler rods, Viz., ER4043, ER4047, ER5356, and ER 5183. The Mechanical and Microstructure characterization of the welded joints have yielded the following conclusions.

The ER5356 Filler rod produced best tensile properties compared to the other filler rods, such as ER4043, ER4047 and ER5182.

The Al-Si Filler rods, Viz., ER4043 and ER4047 have produced higher hardness values in the TIG weld compared to the other Filler rods such as, ER5183 and ER5356.

The ER4047 Filler rod welded joints produced best Hardness properties compared to the other filler rods, such as ER4043, ER5182 and ER5356.

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