

Effect of ER4043 Filler Rod on Tungsten Inert Gas Welding of AA5083-H111 and AA6061-T6 Aluminium Alloys

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ABSTRACT

The dissimilar Tungsten Inert Gas welded joints find application in many areas like ship Building, offshore constructions and transportation industries. Ship hulls made of steel plates and 5083 aluminium alloy plates were utilised in the superstructure and such constructions are plenty in the marine industry. The corrosion resistance properties of aluminium alloys are always better than steel plates. The hull and superstructure made of 5083 and 6061 aluminium alloys are gaining popularity. The joining of the two materials by using Low Silicon content Al-Si alloy filler is experimented in this paper and the observations are listed out. The softening of the weld is relatively more compared to the hardness of the cross sections.

KEY WORDS: Filler Rod ER4043, Tungsten Inert Gas Welding, AA5083-H111, AA6061-T6.

1. INTRODUCTION

In the TIG welding process, the arc and the weld are protected from atmospheric contamination by a gas shield and an electric potential is established between the electrode and the work piece causing a current flow, which generates thermal energy in the partially ionizes inert gas. Defects like porosity, loss of strain hardening in the fusion zone, as cast-coarse microstructure, hot cracking in the fusion zone due to segregation of alloying elements during solidification, result in the decrease of mechanical properties.

In the conventional properties TIG and laser welding process, dendritic structure develops in the fusion zone that leads to a drastic decrease in strength which is one of the major mechanical properties. The alloy 5083 is considered to possess good weldability in the sense it is not prone to solidification cracking and can be easily welded using all conventional welding process. However, the joint efficiencies are as low as 30-40%, mainly in thicker plate welds. This fact is of concern in aerospace application because, use of thicker plates due to low strength of the weld metal results in behaviour structures. If the yield strength of the weld metal can be increased by some means it will be of use in increasing the payload. The dissimilar TIG welding of 5083-O and 6061-T6 aluminium alloys were conducted by researchers (Mossman, 2002; Jamshidi Aval, 2012; Hakan Cetinel, 2014; Jannet, 2014; Rajesh, 2015).

2. EXPERIMENTAL PROCEDURE

Plates of 5mm in thickness were cut into strips of 300 x 150mm. 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⁻¹. 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.

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⁻¹. 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.

Table.1. Welding parameters

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

The chemical composition of the base metals AA5083-H111 and AA6061-T6 is given in Table.2. The chemical composition of filler rod ER 4043 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	Fe	Si	Cr	Cu	Zn	Ti	Al
ER4043	0.05	0.05	0.8	4.5 ~ 6	-	0.3	0.1	0.2	Rest

3. RESULTS AND DISCUSSIONS

Chemical Compositions of the 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 4.254wt% and 0.812 wt% of magnesium and 0.980wt% and 3.01 wt % of silicon. AA5083 and AA6061 contains 0.525wt% and 0.061wt% of manganese and 0.259 wt% and 0.323 wt% of iron. The aluminium silicon filler rod ER4043 contains 4.5-6 wt% of silicon and around 94 wt% of aluminium. The TIG welded joints of AA5083 and AA6061 with ER4043 contains 1.364wt% of Mg and 2.994 wt% of Si.

Table.4. TIG Welded Joints Chemical Composition

Filler Rod	Mg	Mn	Fe	Si	Cr	Cu	Zn	Ti	Al
ER4043	1.364	0.163	0.431	2.994	0.100	0.080	0.018	0.014	Rest

Optical Microstructure of TIG welded AA5083-H111 and AA6061-T6 with ER4043 Filler Rod: The optical microstructure of TIG welded dissimilar joints of AA5083-H111 and AA6061-T6 with ER4043 filler rod is 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-Al₃Mg₂ precipitates in it. This alloy also contains intermetallic compounds such as Al₆ [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 (Subbaiah, 2012).

The weld microstructures were taken at three different locations such as weld top, weld middle and weld bottom and also in Figures.3 to 5. The microstructures at the weld top are fine compared to the other two microstructures shown by Figure.4 and 5. The weld microstructure at the middle of the joint shown by Figure.4 is containing coarse dendrites compared to weld top. The weld microstructure at the bottom of the weld is shown by Figure.5. 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.6. The weld contains columnar grains at the intersection. The Grain boundaries of AA6061 side grains were not clearly visible in the HAZ. Mg₂Si precipitates are only observed. The Heat Affected Zone microstructure of the Base Metal AA6061-T6 side is shown in Figure.7. 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 Mg₂Si in AA6061-T6 aluminium alloy.

**Figure.1. Base Metal****Figure.2. Heat Affected Zone and Weld****Figure.3. Weld at TOP****Figure.4. Weld at Middle**

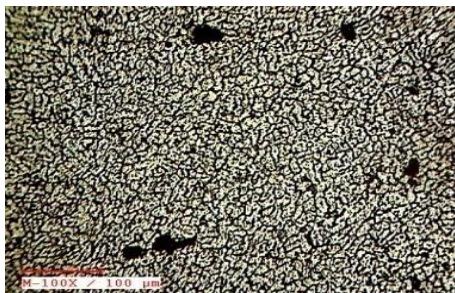


Figure.5. Weld at Bottom

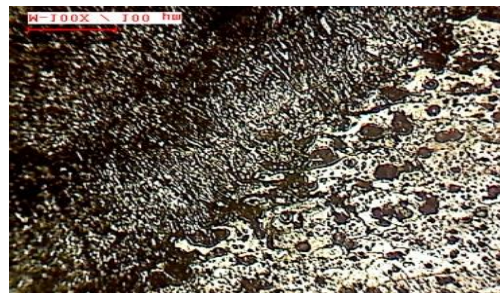


Figure.6. Weld and HAZ

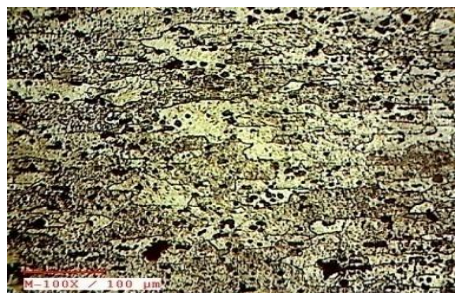


Figure.7. HAZ of 6061

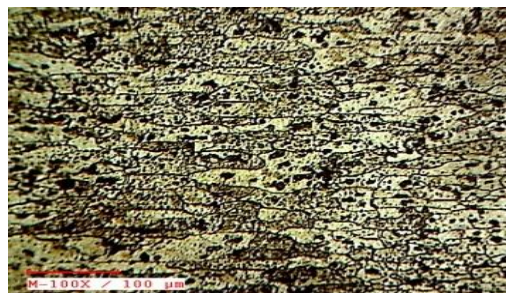


Figure.8. AA 6061-T6 Base Metal

Tensile Properties of the welded joints: The tensile properties of the AA5083-H111 and AA6061-T6 aluminium alloy plates with ER4043 filler rod was found out and listed in Table.5. The welded joint ultimate tensile strength is around 136 MPa. The percentage elongation of the welded joints in 3.09 %. The welded joint efficiency is $(136/325) \times 100 = 41.85\%$.

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	-	121.366	3.98
Weld – 2	-	142.172	5.05
Weld – 3	-	144.098	4.31
Average	-	135.879	4.45

Hardness Survey of the welded joints: The Hardness value of the welded joint on the AA5083 side is more or less equal to hardness value of AA5083 (around 80 HV1), whereas, the hardness value on the AA6061 side is more or less equal to about 110HV1. The hardness of the welded joint on the AA6061 side is more than hardness of the base metal AA6061-T6 (105HV1). This may be due to the Magnesium silicon precipitates formed on the AA6061 side.

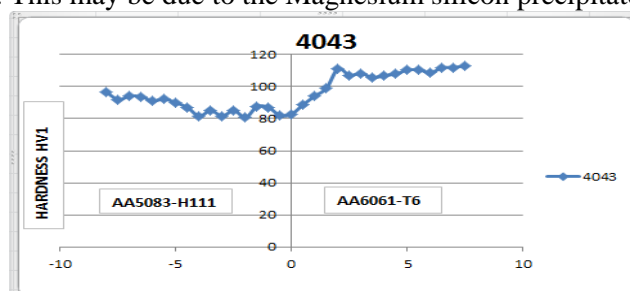


Figure.9. Hardness Survey of TIG welded joints of AA5083-H111 Aluminium Alloy

4. CONCLUSIONS

The AA5083-H111 and AA6061-T6 aluminium alloy plates were TIG welded with ER4043 filler rod. The Mechanical and Microstructural characterization of the welded joints have yielded the following conclusions.

- A 58% reduction in tensile strength was observed from the 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 5% 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.

REFERENCES

Hakan Cetinel and Mehmet Ayvaz, Microstructure and Mechanical Properties of AA 5083 and AA 6061 Welds Joined with AlSi5 and AlSi12 Wires, *Materials Testing*, 56 (10), 2014, 884-890.

Jamshidi Aval H, Serajzadeh S, Sakharova N.A, Kokabi A.H, Loureiro A, A study on microstructures and residual stress distributions in dissimilar friction-stir welding of AA5086-AA6061, *Journal of Material Science*, 47, 2012, 5428-5437.

Jannet S, Mathews P.K and Raja R, Comparative investigation of friction stir welding and fusion welding of 6061 T6 – 5083- O aluminium alloy based on mechanical properties and microstructure, *Bulletin of the Polish Academy of Sciences Technical Sciences*, 62 (4), 2014, 791-795.

Mossman M.M and Lippodo J.C, Weldability Testing of Dissimilar Combinations of 5000- and 6000- Series Aluminum Alloys, *Welding Research Journal*, 2002, 188-194.

Rajesh P Verma, Pandey KN and Yogesh Sharma, Effect of ER4043 and ER5356 filler wire on mechanical properties and microstructure of dissimilar aluminium alloys, 5083-O and 6061-T6 joint, welded by the metal inert gas welding, *J Engineering Manufacture*, 229 (6), 2015, 1021-1028.