



An Enhancement of Properties on Al7075 and Al6061 Dissimilar Materials Welded by TIG Process

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Abstract

Aluminium alloy was a predominant metal among alloys elements. The aluminum alloys like Al7075 and Al6061 which has the major elements of Zn, Mg, Cu, Si with which it will improve the hard-brittle crystalline structure and conductivity. To enhance the properties of dissimilar joint metal, TIG (Tungsten Inert Gas) welding is propagated. Mechanical properties like Tensile, Impact, Bending, micro-hardness and the study about microstructure analysis were carried out. As a result, the energy absorbed by the dissimilar joint metal is 16J and the hardness of dissimilar joint metal is 51.3HV. It revealed that, there is a high impact strength and micro-hardness properties. Consequently, the microstructure (HAZ) image exhibits good bonding strength and sufficient plastic deformation was improved due to fine distribution of grains.

Keywords: Tungsten Inert Gas Welding, HAZ, Tensile, Bending, Impact, Micro-hardness

1. Introduction

To produce a high quality welding Tungsten Inert Gas (TIG) welding was suggested by many researchers. It can also help to achieve faster welding speed, less distortion and even thin welding sheets can be easily welded with less skill required [1, 2]. However to perform precise and uniform welding some important parameters like welding speed, welding current, welding voltage, electrode diameter and gap, work piece material, shielding gas were considered. Depending upon the type of material selection of parameters was profiled along the basis of the specifications of welding machine used. By proper welding and different welding parameters welding defects can be controlled. A comparative outcome between TIG welding and base material can be investigated using Tensile, Impact test and investigation of Microstructure at different zones of the weldment [3]. Furthermore, it was observed that a failure at

welded zone over the welded specimen after conducting tensile test. A metallographic view shows the revealed grain structure at the welded zone to improve the mechanical properties [4]. The UTS is usually found by performing a tensile test and recording the stress versus strain, the highest point of the stress-strain curve is the UTS. It is an intensive property; therefore its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and the material [5, 6]. The use of Al filler also improves mechanical properties and has lower ductility. Consequently, the stress- strain curves exhibits lower plasticity but the joint with the maximum UTS had elongation and higher plasticity than the joint with the minimum UTS. The increased grain size form

re-crystallized microstructures of the partially melted zone (PMZ) of the A7075-T651 alloy were equiaxed. The HAZ was not distinguishable or might have existed along with PMZ. The melting of base material during the welding process will change the microstructure and the mechanical properties.[7, 13] Throughout, of Base Metal was distributed by an irregular distribution of coarse particles and due to increase in heat input the width of HAZ (Heat Affected Zone) increases from 335 to 690 μm .[8] A limited elongation capability for as-welded joint was due to the fact that during testing was concentrated more in the HAZ, which is the weakest part of the specimen[9, 10, 11].Thereby, reducing the strength of the

welded joint by the formation of coarse grains in HAZ was observed in the specimens of 70A and 80A [12, 13,14]. In addition, the weld area is heated and fusion occurs during the period of pulse current states that the higher current level and the impulse frequency was between 0.5 Hz and 6 HZ.[15,16] By applying pulse welding a better depth of penetration and fusion of filler material with parent metal is obtained and by this it improves strength and ductility of weldments [17, 18]. A limited literature is available, in current design standards which provide suitable residual factors for the post-fire mechanical properties of Aluminium alloys.[19] Maximum strength was suitable at bevel angles between 30° to 45° [20].

Table.1.Chemical composition of Al 6061 and Al 7075

Compositi on	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Wt % of Al6061	0.63	0.42	0.42	0.12	.19	0.05	0.02	0.08	Bal.
Wt % of Al7075	2.10-2.90	0.40	0.50	1.20-2.00	0.18-0.28	0.30	5.10-6.10	0.20	Bal.

The grain structure of the 7075 alloy was seen to be oriented in rolling direction of Aluminium sheet, a fine equiaxed dendritic network grains were observed in weld metal at the fusion zone [21]. Currently the nuggets in weld dissolution of strengthening precipitates in weld of Al alloy. The elongated grains in one direction have revealed interdendritic eutectic with light grey particles of FeAl₃ present in the Al solid solution [22]. Both similar joint and parent joint a material has superior tensile strength than the dissimilar joint

materials [23]. Excessive porosity formation and cracking was revealed in the dissimilar Al- alloy [24]. Good bonding and plastic deformation gave the fine equi-axed grains, good ductility due to the presence of manganese content which attributes high tensile strength. The coarse grain occurring condition of 7075 alloy is narrower than that of 6061 alloy. Cr or Zr addition could inhibit the grain coarsening even under the compression condition which resulted in the most possible coarse grain in the 7075 base alloy [25].

Table.2. Filler wire composition

Material	Cu	Si	Mn	Mg	Fe	Cr	Al
Wt % of Al4043 filler wire	0.17	4.5-6.0	0.24	0.05	0.05	0.05	Bal.

2. Experimental Setup

A. Specimen Preparation

A material used for this study was 7075 Aluminum alloy and 6061 Aluminium alloy, and its chemical composition is shown in Table 1. Test specimens were prepared in the dimension of

200×150×12 mm, using power hack saw and milling machine. Double Edge Chamfering was prepared using vertical milling machine with semi right angle (45°) in both directions shown in Fig. 1. For a high quality weld the rate of deposition was slow and it limits the range of application in terms of thickness was produced by Lincoln

Electrical Precision TIG 375 GTAW machine, whereas Al4043 filler wire is used join specimens the composition elements were shown in *table. 2*. Electrode holder is available in size that range from 150 to 500 Amps to weld dissimilar materials. The specification of efficiency, Arc voltage, A.C voltage, Current range was 0.6, 20V to 80V, 30 V to 80 V, 125 A to 600 A respectively.

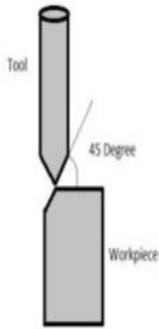


Fig.1. Edge preparation

B. Mechanical Properties Test

After the welding, the welded plates are cut into ASTM standard for tensile, impact, bending and micro hardness test by using CNC cutting machine. Tensile test was done on computerized INSTRON Universal testing machine. The gauge thickness and length of tensile test according to ASTM E8 standard load applied about 400 KN. The material to be tested, also known as a specimen, is machined to standardized dimensions. A typical specimen has a diameter of 12.5mm and a gauge length of 50 mm. The crystal structures are collapsed in various load condition, in this case applied load range is randomly applied upto 1-2 Kgf . The specimens were prepared as per ASTM standard E407 metallographic procedure. Modified Keller reagent and Wecks reagent were used to reveal the microstructure. The material flow, grain

size and grain orientations were carried out using an optical microscope.

3. Results and Discussion

A. Tensile Test

From the values of UTS obtained for Al7075-Al6061, it is observed that dissimilar weldment shown in Fig. 2 (a) depicted maximum ultimate tensile strength when compared to similar weldment materials. But, there was a significant change in the value of percentage in elongation 4.68% which is shown in table 3.

Table. 3 Tensile test result for dissimilar weld material

Details of Sample	Tensile strength (Mpa)	Yield strength (Mpa)	Elongation (%)
Al 7075 – Al 6061	51.53	30.91	4.68

Un-welded parent metal achieved about 537 MPa and 570 MPa, with respect to the yield strength and the tensile strength for TIG welding. Consequently, 110 MPa and 118 MPa the yield and tensile strength of GMAW joint were observed [20]. The tensile strength of the dissimilar joint is lower the value is shown in Table 3. The yield strength and tensile strength of GMAW joints are 141 MPa and 163 MPa, respectively. However, the yield strength and tensile strength of unwelded parent metal are 302 MPa and 335 MPa, respectively. Similarly, the yield strength and tensile strength of GTAW joints are 188 MPa and 211 MPa, respectively which are 37% lower compared to parent metal [25]. For, a lower tensile strength a brittle fracture and as well as higher ductility AA6061-T6 failure occurred [23]. Nevertheless, the bending properties were improved upto 3.82KN, the tested material was shown in Fig.2 (b).

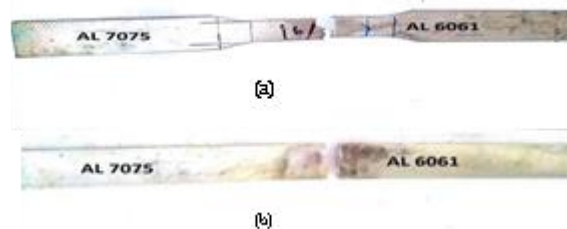


Fig.2.After (a) tensile and (b) bending test specimen

B. Impact test

A weld can absorb only 4J in GMAW and 6J in GTAW as compared to 12 J absorbed by the base metal [23]. Table 4. shows the dissimilar material Al7075-Al6061 TIG weld achieved 16J while impact.

4. Energy absorbed Level for Aluminum weld.

Details of sample	Impact in joules
Al7075-Al6061	16

C. Microhardness Test

The resulting depth of impression was measured by the help of a microscope as shown in Fig. 3. Using hardened steel ball indenter of 10mm diameter was fixed on the BHN machine demonstrated in the experimental set up. Under this condition, the literatures reported that the hardness of Al6061 alloy increased from 3875 HV to 10475 HV, whereas, the 7075 alloy increased from 13575 HV to 21075 HV. The micro hardness of similar and dissimilar RSW weld joints, the lowest hardness was on Al6661 base metal. Currently, the dissolution of strengthening precipitates in welds of Al alloy attributes the decrease in micro hardness [21].Consequently; the filler metal used in TIG welding is 5356 electrode which contains Magnesium, Manganese and chromium as principal alloying elements. These alloying elements may precipitate carbides which may contribute to the higher hardness levels [23].



Fig.3. Microhardness testing setup

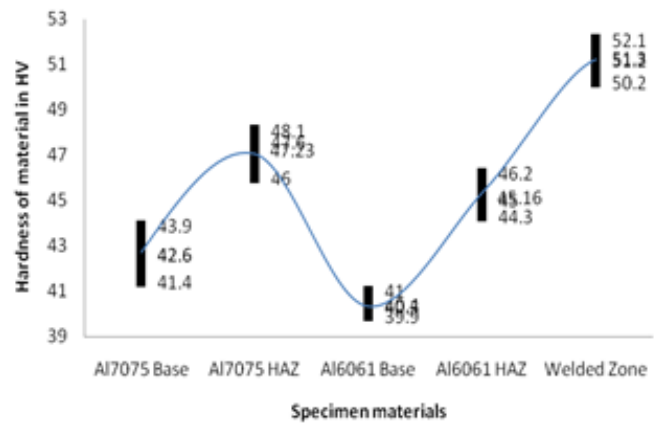


Chart. 1. Comparison of different specimen materials vs. HV

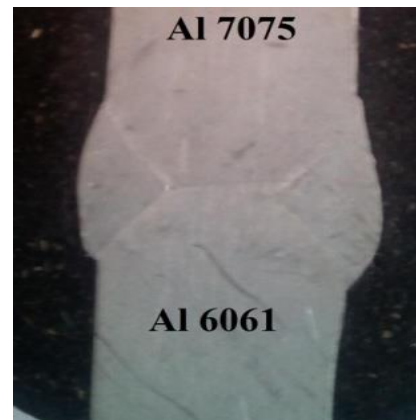


Fig.4. Specimen used for both microhardness and microstructure

The base material hardness of AA6061 alloy is reduced towards the stir zone to HV 68 in D65 joints and further decreased to HV 65 towards AA5086 alloy side [24]. Since the hardness in the base material is scattered between 50 to 53 HV. And the GMAW process the HAZ having maximum hardness and away from weld zone the hardness is gradually reducing. GTAW process welding center zone hardness varies from 69.8 to 59.9 gradually decreasing to base material hardness [24]. In Chart no. 1. It is clearly evident that there is a larger variance in the hardness values in the Al7075 and Al6061 dissimilar joint (weld zone) with the maximum hardness value of 51.3HV.

D. Microstructure analysis

The welded joint is composed of a fusion zone (FZ), a wide HAZ, and a BM area. Irregular distribution of coarse particles throughout the BM is observed clearly. An equiaxed dendritic network is formed in the FZ. Generally, the fine

microstructure of the FZ is attributed to the high cooling rate associated with the TIG welding [8]. The 6061-T6 Al alloy has co-axial grains while, the 7075-T651 alloy has longitudinally oriented grain structure. The grain structure of the 7075 alloy was seen to be oriented in rolling direction of Aluminium sheet. Some second phase particles were revealed among the rolling microstructure. Fine equiaxed dendritic network grains were observed in weld metal at the fusion boundary. A dendritic structure was formed in weld fusion zone and caused alloying element segregation. HAZ is formed in different grain sizes and widths at 6061 and 7075 alloy portions of dissimilar RSW joints. The HAZ for 6061 alloy plate was narrower in comparison to the HAZ at the 7075 alloy plate, due to the different properties of the alloys. Hot cracking is normal in the alloys with wide solidification range, such as, Al-Mn, Al-Si, Al-Cu, Al-Mg alloys. Hot cracks usually occur above the solidus curve and in the solidification range [21]. Microstructure evolution in the base material is normally elongated grains due to rolling process. There is a coarsened dendritic grain structure in the WC zone. Grain size is quit variable in these areas, and is much longer than the original BM grains. The lamellar grains are the welding regions, BM region quite lamellar to coarsened grains are forms. The grain size is fine at welding region in FSW. The FSW welding region grains are compared to BM it is more or less similar. The fine grain size would affect increasing mechanical properties [24]. Due to the heat input the welding zone and HAZ is affected by the tensile properties. GMAW process the fracture occurred in the HAZ. The tensile properties would not affect the weld zone due to the high welding strength [24]. Microstructure of the parent metal has revealed spheroidal particles of MgZn (black precipitates) and light grey particles of FeAl₃ present in the Aluminium solid solution. We can also see the grains elongated along one direction. Microstructure of the weld metal has revealed interdendritic eutectic with light grey particles of FeAl₃ present in the solid solution. The microstructure of the HAZ has revealed elongated grains with grain boundary eutectic and light grey particles of Fe₃Al present in the Aluminium solid solution [23]. Microstructure of all the joints was examined at different locations, but most of the

tensile specimens failed in the weld metal region, and the optical micrographs taken at the weld metal region alone. The base metal contains coarse and elongated grains with uniformly distributed very fine precipitates. The fusion zone of GMAW and GTAW joints contain dendritic structure and this may be due to the fast heating of base metal and fast cooling of molten metal due to welding heat. The only difference between these two dendritic structures is the dendrite arm spacing. The spacing is marginally wider in GMAW joint and narrower in GTAW joint. However, the weld region of FSW joint contains very fine, equiaxed grains and this may be due to the dynamic recrystallization that occurred during FSW process [25]. The microstructure of base metal consists of very fine insoluble second phase precipitates dispersed in various locations. The base metal grains are elongated in the rolling direction. In the TMAZ region the bending of the grains is observed which is due to the plastic deformation resulting by the stirring action. From the micro structural study it has been observed that the larger is the shoulder diameter, the wider is the TMAZ due to increased contact area between the tool and the work piece. The microstructure shows poor weld metal consolidation is the stir region resulting into the lowest joint efficiency.

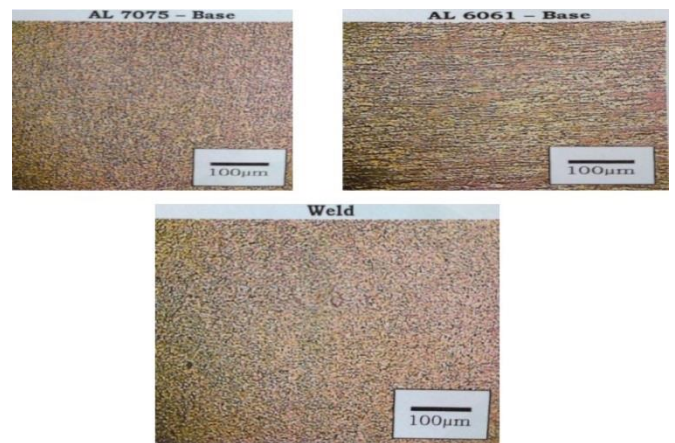


Fig.5. Microstructure of Al7075, Al6061 and welded zone

Mg alloys possess lower melting temperatures than Al, and they are highly reactive at elevated temperatures. Al and Mg alloys also possess low solubility in each other. The grains in the microstructure of the PMZ of the A7075-T651 alloy recrystallized; thus, the grains increased in size. The grain boundary became shaggy compared

with that of the parent alloy because of the effects of welding heat. The microstructure showed that the grains in the PMZ of the A7075-T651 alloy were equiaxed [7]. The second-phase undissolved particles, such as Al_2Cu Fe or Al_2Cu Fe₄, are identified in the base metal. The BM of AA6061-T6 consists of elongated grains of the parent metal with fine precipitated particles of Mg₂Si eutectics, which are evenly present. The microstructure shows elongated grains of Aluminum solid solution with finely precipitated eutectics of the strengthening phases. The various precipitated eutectics are Zn-Al₂, Mg₂Si, MgAl₂, and CuAl₂. In the thermo-mechanical heat affected zone AA7075-T6, the direction of flow patterns of grains was changed to the raw material flow due to severe plastic deformation. The elongated grains of the parent metal were changed perpendicularly, the presence eutectics were also observed and these particles were of considerable quantity having fine dispersive nature. The heat affected zone AA7075-T6 shows elongated coarse grains with inter-metallic particles which are agglomerated in an irregular pattern towards the flow. This might be due to the lower temperature difference when compared with interface and thermo mechanical zones. The microstructure shows Fig. 5. the interface zone which dynamically recrystallized, that there is sufficient plastic deformation and good bonding between these alloys which gave high brittle strength due to the fine uniformly distributed grains. All the dissolved eutectics of the alloy have re-appeared due to heat. The grain of the eutectic has fragmented and present as agglomeration with fine grains. This zone contains the eutectic particles of both Al7075 and Al6061. However the same was contributed as very fine particles, mostly AA7075-T6 diffused in AA6061-T6, are observed [20].

CONCLUSION

The tensile properties of welded region is low where else, the energy absorbed by the specimen is about 16 joules, which possess high impact strength under TIG welding process. From the experiment the microhardness (51.3HV) appeared in welded zone is higher than parent materials, it attributes that due to low ductility properties. However, with high impact strength the Al7075 and Al6061 welded specimen the brittle

strength has improved. The microstructure (HAZ) image shows, that there is sufficient plastic deformation and good bonding strength between the dissimilar alloys which give high brittle strength due to the fine uniformly distributed grains.

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