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Effect of Post Weld Heat Treatment on Properties of ACTIG Welded Aa6063 Aluminium Alloy Joint

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Abstract: ***AA6063 aluminium alloy joints were fabricated by alternating current tungsten inert gas (ACTIG) welding process and the effects of post weld heat treatment (PWHT) on the tensile properties, impact strength, microstructure, microhardness and fractography of the welded joints were investigated. The ACTIG welding process was adopted because it bears higher strength, more ductility and no apparent microstructure defect. The welded samples were divided into as-welded (AW) sample and PWHT sample. The PWHT method used on the samples was solution treatment (535 °C, 2h), water quenching and artificial aging (165 °C, 18h). The experimental results show that, compared with the AW samples, the microstructure characteristics and mechanical properties of the AA6063 joints after PWHT were significantly improved. The improvement of ultimate tensile strength, and impact strength are 3.72% and 22.22% respectively.***
Keywords: GTAW, PWHT, SEM, EDS.

I. INTRODUCTION

Aluminium alloys have been widely used in many fields such as the construction, transportation and aerospace owing to their excellent performance, including light weight, high strength and ductility, good corrosion resistance and abundant resources [1]. Among the various heat-treatable aluminium alloys, AA6063 aluminium alloys possess a good combination of strength and toughness with excellent weldability and extrudability, which makes this alloy an preferred choice for Automotive outer body-panels, railcars, etc. buildings (doors, windows, ladder, etc), marine(offshore structure, etc), heating(brazing sheets, etc)]. This type of aluminium alloy contains Magnesium(Mg) and Silicon(Si) as its major alloying element. Welding is one of the most common joining methods for aluminium alloys. Tungsten inert gas (TIG) process and gas metal arc welding (GMAW) are the most-used welding processes [2]. GMAW possesses advantages of high deposition rate, high welding speed and deep penetration, but excessive heat input brings particularly in welding of thin aluminium sheets. Hence, TIG welding process is preferred over gas metal arc welding so as to obtain high quality weldments [3]. The TIG welding used in this work as AC tungsten inert gas (ACTIG). Moreover, the output of pulsed current can also strengthen the molten pool stirring to produce refined grains. In terms of weldability [6], AA6063 suffers from a substantial decline in strength after welding. The loss of strength is because the rapid melting and solidification process makes all the strengthening precipitates dissolve into the aluminium matrix and complete dissolution of the precipitates can not take place in weld metal and overaging appear in HAZ and meanwhile solute segregation and grain coarsening also come up [11]. Therefore, the post weld heat treatment (PWHT) can be implemented as an effective method of minimizing the softening and improving the properties of welded joints. PWHT has been demonstrated to be a practical option to regain the strength of the joints by modifying the size, shape and distribution of the secondary strengthening particles [4]. A few research works have studied the aging impact on mechanical properties and microstructure of AA6063[9]. Hence, the present investigation is carried out to study the influence of PWHT on the properties of ACTIG welded AA6063 aluminium alloy joints.

II. EXPERIMENTAL PROCEDURE

A. Materials and Welded Specimens

Sample of AA6063 plates of 6mm thickness was cut in to the shape of smaller section having 150×70 area. Each strip was machined to obtained v-groove having an angle 60°, root face was kept 2mm as per BIS Standard no.813-1961 as shown in Fig.1. The chemical compositions and mechanical properties of the base metal are listed in Tables 1 and 2, respectively

TABLE I CHEMICAL COMPOSITION OF BASE MATERIAL

Mg	Si	Fe	Cr	Cu	Ti	Mn	Zn	Other	Al
0.45-0.90	0.20-0.60	0.0-0.35	0.0-0.10	0.0-0.10	0.0-0.10	0.0-0.10	0.0-0.10	0.0-0.15	balance

TABLE II
Mechanical properties of AA6063

Properties	Proof stress	Tensile strength	Harness Vicker	Elongation	Impact toughness
Value	170 Min MPa	215 Min MPa	75 Min	10 Min %	18 J Min

The gas tungsten arc welding of the plates was performed at advanced welding lab SLIET longowal, Punjab. KEMPPI master TIG MCS2300ACDC is used for gas tungsten arc welding. The type of filler used for the welding process was ER5356 with a diameter of 2.4 mm. Before the welding process, the welding parts were wiped with ethanol to remove the impurities on the surface and a motor wire brush was used to remove the oxide. One-side welding was carried out on butt joint. During the process, suitable clamps were taken to avoid welding distortion. The welding condition and process parameters are presented in Tables 3

TABLE I
Parameter used for GTAW

Gas Flow Rate (lit/min)	Current (amp)	Electrode Dia. (mm)	Filler Dia. (mm)
14	230	3	2.4

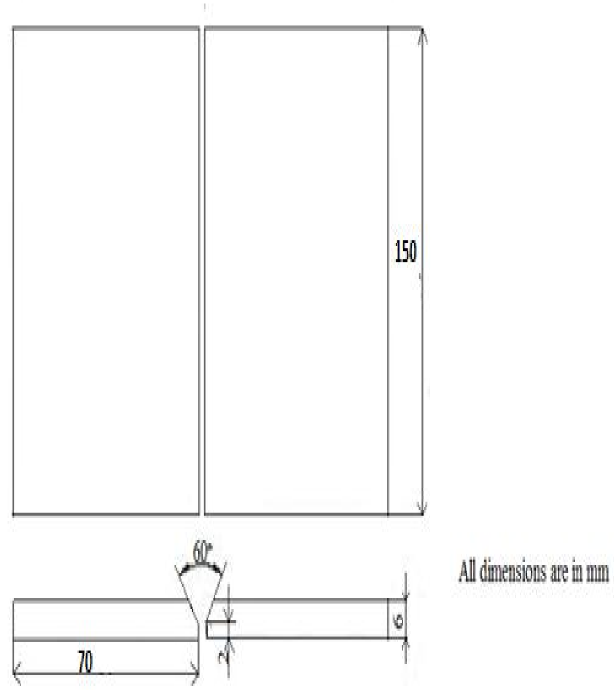

Fig. 1 Groove design for plates used for welding

B. *Post Weld Heat Treatment*

The welded samples were divided into two groups: as-welded (AW) samples and post weld heat treated (PWHT) samples. For AW joints, the tensile, microhardness, impact tests and SEM analysis of fracture surface were performed immediately after welding process. For PWHT joints, heat treatment was conducted before the latter tests. The PWHT methods were solution treatment, water quenching and artificial aging. Solution treatment was performed at 535 °C for a soaking time of 2 hour. Then, the samples were taken out of the furnace and put into a water bath for quenching. Artificial aging was carried out at 165 °C for a soaking time of 18 h. The quenched joints were heated in the furnace from room temperature to 165 °C at a rate of 10 °C/min. After the soaking time,

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the joints were slowly cooled in the furnace to room temperature and the whole PWHT process was completed [10]. PWHT of the prepared specimen was performed at chemical technology lab in SLIET, Longowal.

C. Mechanical Property Test

Tensile test specimens were sampled out from the welded plate. Dimensions of the sample were according to ASTM E08 standards. Specifications of dimensions for the tensile test specimen are shown in the Figure 2. Tensilt test is done on tensile testing machine as shown, in Welding and Metallurgy Laboratory, Mechanica Engineering Department, SLIET, Longowal

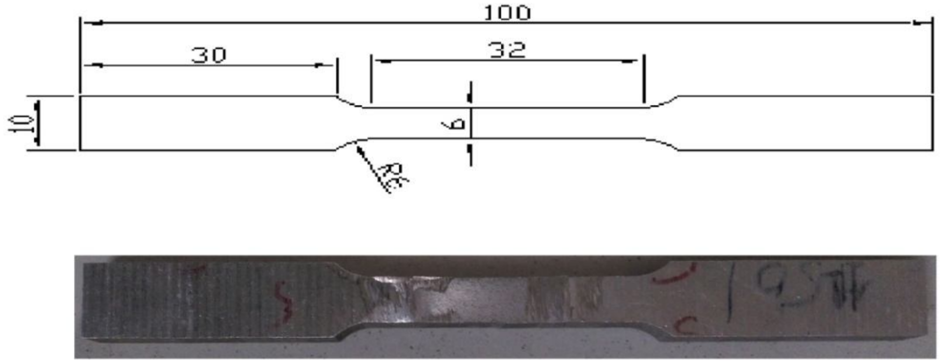

Fig. 2 Tensile test Specimen

Impact specimens were sampled out from each welded plate. Dimensions of the samples were according to ASTM E23 standards. Specification of dimensions for the charpy impact test specimen are shown in Figure 3

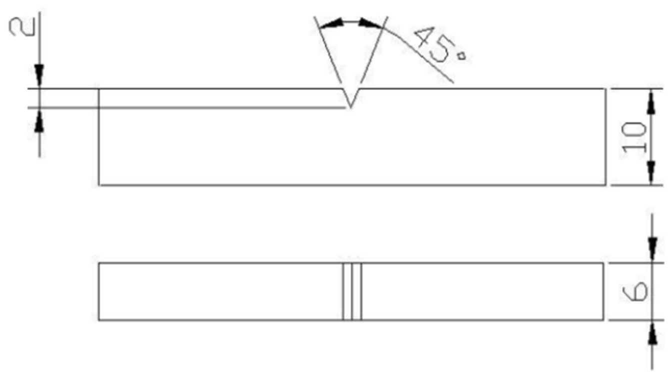

Fig. 3 Specification of impact specimen used in present work

III. RESULT

A. Tensile test

The tensile strength of the joints made using different conditions in as welded as well as in post weld heat treatment has been evaluated. In each condition the corresponding ultimate tensile strength, peak load and total elongation are mentioned in Table 4.

TABLE IV
Tensile test results of welded specimen at different conditions

Sample name	**Ultimate tensile stress (MPa)**	**Peak load (KN)**	**Total elongation (%)**
G(AW)	140	5.04	13.6
GH(PWHT)	148	4.89	15.8

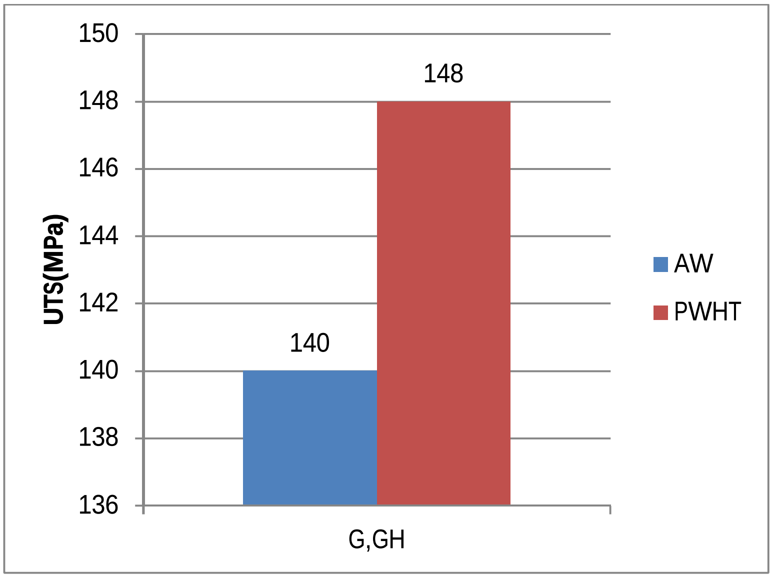

Fig 4 Graphical representation of variation in ultimate tensile strength values of welded specimen

B. *Charpy impact test*

Charpy impact strength of all the welded joints were tested by sampling the specimen across the weld joint and were evaluated. The pendulum strikes the specimen fractures it. Strength required to fracture the specimen gives the impact strength of the welded joint. Table 5 shows the results of the impact strength for joints welded by GTAW at AW and PWHT conditions.

TABLE V

Charpy impact tests results at different conditions

Sample no.	Impact strength(J)	Sample no.	Impact strength(J)
G	10	GH	14

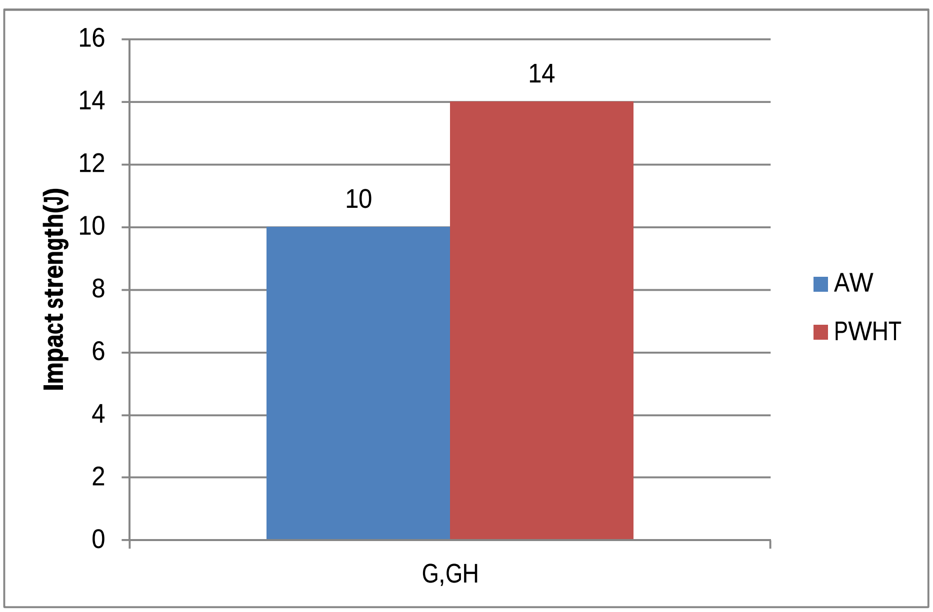

Fig 5 Graphical representation of variation in impact strength values of welded specimen.

C. Micro Hardness

Micro-indentation testing, more commonly called microhardness testing, is widely used to study fine scale changes in hardness. Microhardness examinations were carried out in a direction perpendicular to the weld bead in same plane. The comparison in the microhardness of the specimen in as welded as well as in heat treated condition shown graphically in Fig 6.

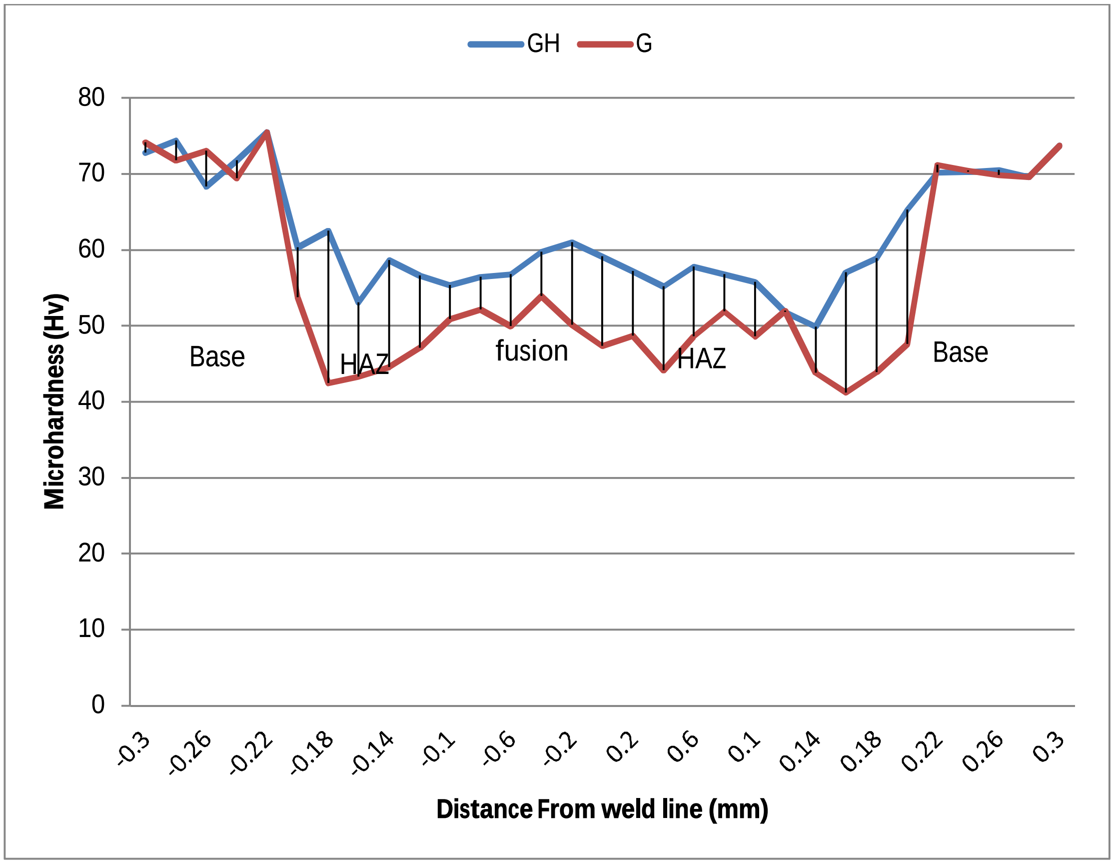

Fig. 6 Microhardness variation

D. Microstructure

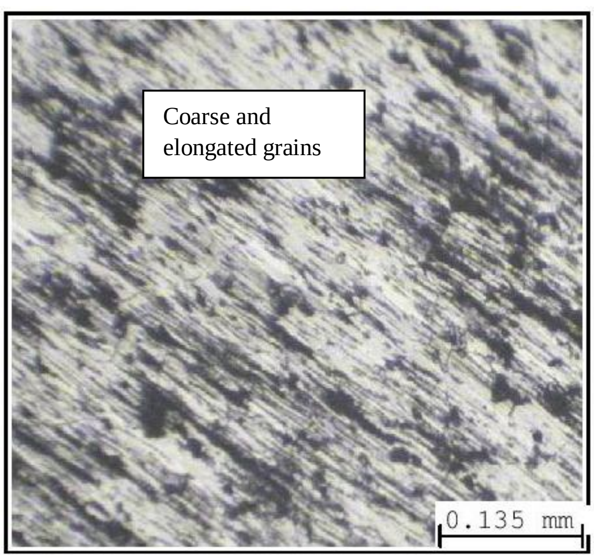

Fig.7 (a) shows microstructure of base metal

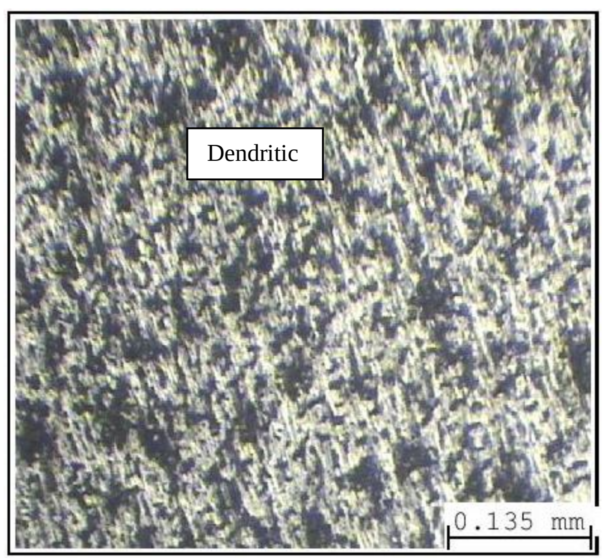

Fig.7 (b) shows the microstructure of specimen G

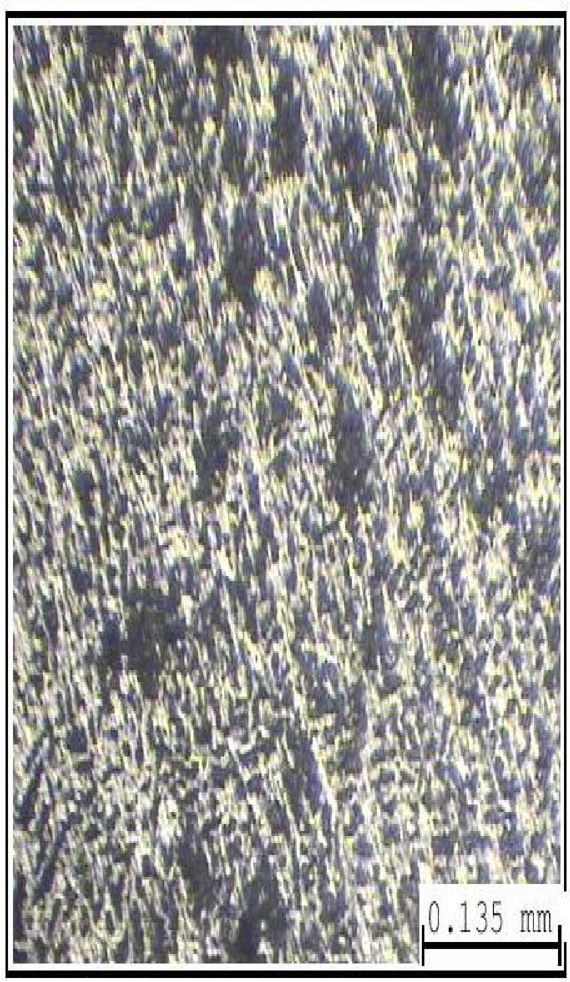

Fig. 7(c) shows fusion zone of specimen Gh

E. Scanning Electron Microscope (SEM) and Energy Dispersive X-Spectroscopy (EDS) Analysis

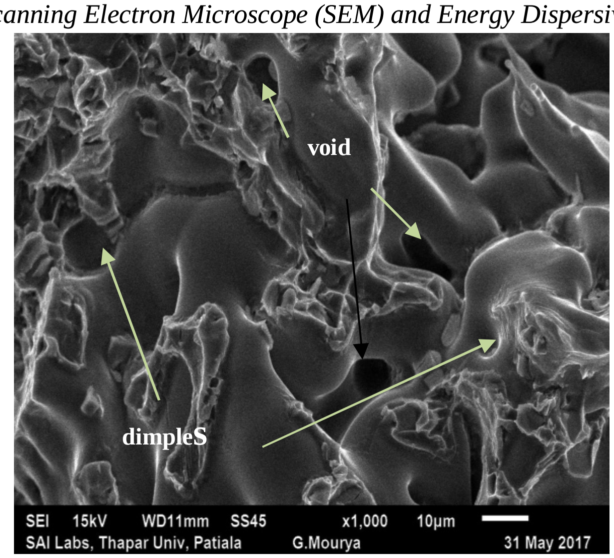

Fig. 8(a) shows SEM image of specimen G at 1000x

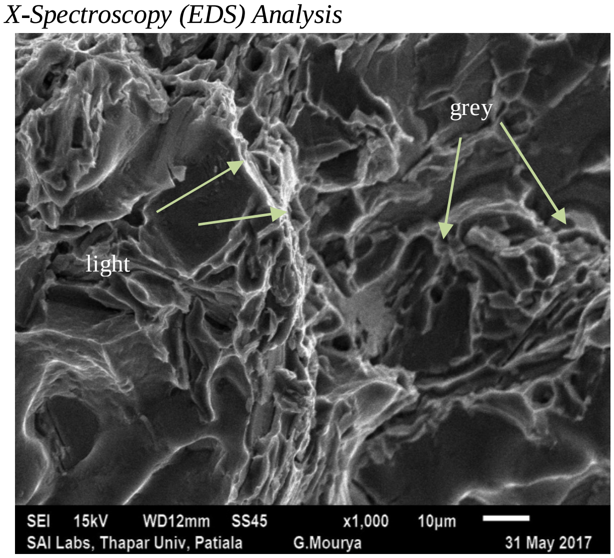

Fig. 8(b) shows SEM image of specimen GH at 1000x

TABLE VI
EDS spectrum shows percentage of alloying element in G

Spectrum	In stats.	C	Al	Si	Ti	Fe	Ni	Cu	Zn	Total
Spectrum 3 (%)	Yes	10.99	81.88	4.21	0.33	0.89	0.14	0.46	1.10	100

TABLE VII
EDS spectrum shows percentage of alloying element in GH

Spectrum	In stats.	Zn	Al	Si	Mn	Fe	Ni	Cu	S	Total
Spectrum 1 (%)	Yes	0.40	81.36	11.49	0.41	0.96	1.15	0.86	0.34	100

IV. DISCUSSION

Fig. 7a, 7b and 7c shows the microstructure of base metal, fusion zone of specimen G (as welded) and GH (PWHT) welded by GTAW. The base metal contains coarse and elongated grains with uniformly distributed very fine strengthening precipitates.The fusion zone of TIG welded joint contain dendritic structure and this may be due to fast heating of base metal and fast cooling of molten metal due to welding heat [5]. The higher strength of the base material is mainly attributed due to presence of alloying elements such as silicon and magnesium. These two elements combine and undergo precipitation reaction and form strengthening precipitates β”- Mg_5Si_6 as shown by darken particles in base metal by Fig. 7a. These precipitates are stable at temperatures lower than 200°C. Fine and uniform distribution of these precipitates throughout the aluminium matrix provides higher strength and hardness to the joints. This precipitate exists in the unaffected base material but is absent in the weld zone and in the HAZ. In HAZ and weld zone strengthening precipitates are lower than the base metal due to higher temperature. Therefore the precipitate strengthening of Mg_2Si precipitates is weak in GTAW joints.

From SEM and EDS anlysisThe effect of the pwht has been clearly shown by sem images as in Fig.8 and eds analysis shows the recovery of the alloying element after PWHT. Scanning electron microscope was used to characterize the micro fracture surfaces of the impact tested specimen to understand the failure patterns. SEM photographs of as welded and heat treated joints were taken for whole joint surface of the fractured specimen as shown in Fig.8 a and 8b. All of the fractured surfaces invariably consist of dimples of varying size and shape, which is an indication that most of the failure is the result of ductile fracture. Impact testing of ductile material, voids generally form prior to necking. However, if a neck is formed relatively earlier, the void formation becomes much more prominent, coarse and elongated dimples are seen.The SEM micrographs of heat treated fractured surface of the impact specimen contains a large population of shallow and small dimples while fracture surface of as welded joints have small population of deep and elongated dimples as shows in Fig b and Fig a respectively. The heat treated specimen have more ductile failure pattern than as welded specimen which is evident from their tensile test result with higher percentage elongation.

From EDS analysis it can be seen that precipitated inter metallic particles are present in the Aluminium matrix. These are visible as grey and light areas. EDS analysis of these areas shows that grey eutectic regions consists of significant amount of Al and Si. The inter metallic compounds (light areas) consist of Al-Si-Fe having small quantity of Mg. High iron concentration in these particles could be due to the composition of the filler metal. Comparing Fig 8a and 8b, it can be seen that post weld heat treatment process have reduced the total area of eutectic zone due to diffusion phenomenon [Nikseresht, 2010].

V. CONCLUSION

Mechanical and metallurgical properties shown by the joint welded by GTAW (as welded and post weld heat treated) proved to be sound enough, however the following conclusion can be drawn on the basis of present work

A. However the effect of post weld heat treatment seem to be very significant as indicated by tensile test results of GH2 which shows 68.83% of the ultimate tensile strength of base metal. 3.72% more than as welded condition

B. As the best possible result obtained after PWHT higher impact strength values (77.77% of base metal) compared to as welded.

C. The fractography of specimen GH joint revealed fine dimples which shows that GH joints have higher ductility compared to TIG joints.

D. Micro hardness tests confirm the general decay of mechanical properties induced by higher temperature experienced by material in case of TIG joint but post weld heat treated specimen (GH) much harder than as welded specimen (G).

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