Evaluation of mechanical properties on welded 5052 and 2014 aluminium alloys by heat treatment process using TIG welding

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Abstract- Aluminium alloys are the king in aircraft construction materials for aircraft industry since 1930.in the aerospace industry,5052-Aluminium alloy after 2014-aluminium alloy is the second most popular of the 2000-series.it is commonly forged and extruded. TIG welding can be a potential tool which is superior to the joining techniques, resulting in weight reduction with high strength in order to find out the mechanical properties at before heat treatment and after heat treatment by TIG welding, the quality of the weld is depending upon the various welding parameters and these parameters can effect on the tensile and hardness properties of the weld material. To investigating the quality of the welding of aluminium alloys (Al-2014 and Al-5052) using TIG welding process and after by evaluating mechanical properties by comparison of before heat treatment and after heat treatment. Effect of welding parameters (current and argon gas flow rate) on the tensile strength and hardness of the TIG welded joints in Al alloys has been investigated. Optical microscope analysis and Micro hardness testing done on the welded zone and identified the changes in mechanical properties of welded zone from the experimentation.

*Index terms-***Aluminium alloys, mechanical properties, heat treatment, TIG welding, Microstructure.**

1. INTRODUCTION

The TIG welding process is used to get the good welding appearance and a high quality of the weld is required.in this welding process an electric arc is formed between a tungsten electrode and the base metal. Inert gas is used to protect the arc region.

Generally in TIG welding of aluminium alloys with argon shielding full perception welding is restricted to joints of maximum thickness of 3mm and to relatively low welding speed at constant current and power supply produces electrical energy, which is conducted using a column of highly ionized gas and metal vapors, together form called plasma arc.

TIG welding is well suited for welding of thin sections of both ferrous (steels) and nonferrous metals (aluminium, copper and magnesium alloys).

Vinay Kumar Yadav, et.al. Discussed the effect of post-weld heat treatment on mechanical properties and fatigue crack growth rate in welded AA-2024[1].Urena, et.al.Investigated the influence of the interfacial reaction between aluminium alloy matrix and SiC particle reinforcement on the fracture behavior in TIG welding. This welding is carried out on 4mm thick AA2014/SiC/X_p sheets using current setting in the range of 37-155 A and voltage of 14-167V.from experimental results it was found that the failure occurred in the weld metal with a tensile strength lower than 50% of the parent metal [2]. Lakshminarayanan, et.al. Investigated the mechanical properties of AA6061 aluminium alloy joints welded by gas tungsten arc welding, in this pure argon shielding gas and AA4043 filler wire is used [3]. Lateef, et.al, the arc is covered by an inert gas protecting the base metal from contact with oxygen, nitrogen [4]. Narang et.al., The ultimate tensile strength increase with increase in weld speed in the test range.in case if high thickness plates are welded then weld deposits are form co-axial dendrite micro structure towards the fusion line and tensile fracture occur near to fusion line weld deposit [5]. Indirarani et.al, concluded that the tensile strength of weldments is closer to base metal, failure location of weldments occurred at HAZ and from this we said that weldments have better weld joint strength [6].
Karunakaran et.al. Strength of weld zone is less than the base metal and tensile strength increases with

reduction of welding speed in case aluminium plates are 4 mm thickness [7].

Tseng, K. H et.al. To join 6mm thickness plates it was found that the use of SiO_2 flux improves the joint penetration [8]. Raveendra, A et.al. Lower magnitude of residual stresses was found in pulsed current compared to constant current welding. Tensile and hardness properties of the joints strengthen due to formation of fine grains and breaking of dendrites for the use of pulsed current. Non pulsed current were more than the parent metal and pulsed current weldments. Single pass activated TIG welding process increase the creep rupture life of the steel weld joint over multi pass TIG weld joints.in high cycle fatigue tests the ratio of fatigue strength to tensile strength of the weld metal is lower than that of base metal, in low cycle fatigue tests weld metals slightly shorter than the base metals [9]. Sakthivel, T et.al, the fine microstructure was observed at the center of the weld which was form due to higher cooling rate at the weld center compared to the fusion boundary, it means that the welding speed increases the cooling rate at the center of the weld also increases, producing smaller size dendrite structure [10]. Yuri, T et.al, the heat input increases with increase of welding current and decrease of welding speed. Successfully joined dissimilar metals like Al alloy and AISI 321 stainless steel with different filler materials. Addition of Si preventing the IMC layer minimizing its thickness. Microstructure of all the welds were studied and correlated with the mechanical properties observed due to redistribution of internal stresses and residual stresses in the weld. Hardness of weld metal is lower than that of HAZ and base metal. Penetration depth, weld bead width and mean grain size in the weld metal increases with increasing hydrogen content. The highest tensile strength was obtained for the sample welded under shielding gas of 1.5%H_2-Ar [11]. Norman, A. F.et.al., The plate thickness and welding heat input have great effect on the dynamic process and residual distortion of out of plane. In case double shielded TIG method to improve weld penetration and welding parameters are directly impact the oxygen concentration in the weld pool and temperature distribution under various welding parameters used gas flow rate 10m^3/min, welding speed (100-300) mm/min, current (100-200)A and thickness of work piece 10mm [12]. Song, J. L.et.al., Addition of helium in shielding gas improves the arc stability and quality of welding when Al-Si filler is added and the microstructure of the welded joint shows Non-uniformity with Sic particles distributing in the center of the weld [13]. Huang, B.et.al. The micro hardness near fusion zone at Mo-Cu composite side increased from weld metal to fusion zone and peak value appeared near the boundary between fusion zone and Mo-Cu composite. Effect of welding speeds and nitrogen contents in argon shielding gas on pulse currents were study to achieve an acceptable weld bead profile with complete penetration [14].

From the literature review, it is found that welding of aluminum is a big challenge by conventional arc welding process. In this welding of 6mm Aluminium plate and an automated TIG welding setup was made. Welding of aluminum plate was done by changing the welding current and welding speed to get a high strength joint. Effect of welding speed and applied current on the impact strength of weld joint, micro hardness of the weld pool and microstructure of the joint was analyzed.

Experimental procedure:

5052 and 2014 Aluminium alloys are found to be widely used in aircraft industries because Copper content in AA alloy is 2-10% and for AA alloy 5052 is 0.1% which increases strength and hardness by reducing ductility which is best fit for aerospace applications due to good machining characteristics and increased corrosion resistance.

Al-2014 and Al-5052 plates of thickness 5mm was selected as work piece material for the experiment. Both plates are cut into 150mm X 85mmX 5mm edge formation of V-groove at an angle 45^0 and grinding done at the edges to get smooth surface to be joined. Dust and any kind of external material removed by 200grit emery paper. Al plates are fixed in working table with flexible clamp and welding process done to form the butt joint. Zirconated tungsten electrodes of diameter 3.4mm was taken as electrode for this experiment.

Before using GTAW primary steps are very crucial to achieve best quality of weld. The electrode made of tungsten and weld joint surfaces must be clean and free from oxides and oils. Fixturing the weldment properly during the welding.

Experimentation was done in single phase and Butt welding of Al-5052 and Al-2014 similar plates of

5mm thickness done with current setting and with AA 5356 filler material. The electrode was prepared by reducing the tip diameter to 2/3rd of the original diameter. This creates a ball on the electrode. Generally an electrode is too small for the welding current will form an excessively large ball, whereas too large an electrode will not form a satisfactory ball at all.

Figure1: Butt joint

For the first stage of experiment the welding parameters Voltage 50v,speed 3.5 to 4mm/s, distance of tip from weld center is 3mm and current type is AC are selected.

Heat treatment: Normalizing process is utilized to achieve an anticipated microstructure and assurance of better mechanical properties like hardness and microstructure.

Firstly take the Al-2014 and Al-5052 specimens and put into muffle furnace. Turn on the power supply and adjust the furnace temperature up to 600^{o}C.hold it for one hour then specimens are completes the heat treatment process. Then remove from the furnace apply air cooling and then conducted the tests.

Further a 10mm X 5mm X 3mm specimen were cut at the cross section and polished with 220,600 and 1200 grit size polishing paper sequentially for microstructural study.

Rockwell hardness testing machine is used for hardness measurements and performed to determine the strength and tests are mostly based on resistance to penetration by a spherical steel indenter pressed under a constant load and hardness was measured from the penetration depth shown in tables.

S.NO	Load (Kgf)	Weld zone	Heat effected zone	Base
1	100	82	79	61

Table 1: Al-5052 before heat treatment

S.NO	Load (Kgf)	Weld zone	Heat effected zone	Base
1	100	41	70	64

Table 2: Al-5052 after heat treatment

From the tables we can understand that after heat treatment the hardness at the weld zone area decreases so ductility will be increases.

S.NO	Load (Kgf)	Weld zone	Heat effected zone	Base
1	100	91	85	81

Table 3: Al-2014 before heat treatment

S.NO	Load (Kgf)	Weld zone	Heat effected zone	Base
1	100	70	83	87

Table 4: Al-2014 after heat treatment

From the tables hardness at the weld zone area decreases so that ductility will increase and also hardness is equivalent at both heat affected zone and base.

Microstructure:

Microstructure examination was conducted using a light optical microscope (OLYMPUSGX51). The specimens for metallographic examination were prepared by sectioning from the weld joint it includes weld metal and base metal adjoins regions. After sectioning process polished using various grades of abrasive papers. Specimens were done using diamond compound etched with Keller’s reagent to reveal microstructure with scanning electron microscope.

Microstructure of the base metal and of the welded specimens was observed. The zooming range of the microscope was 50-400 µm for the study of microstructure evaluation. Welded base material piece was cut in the flat form having size as 50mmX 10mmX 6mm and grinded. The specimens for metallographic observation were sectioned to the desired size. The weld joint regions and polished using different grades of emery papers to achieve smooth surface. On the surfaces of the specimens with the help of grit size rough emery papers. For the polishing purpose 180,220,320,400,600,800 and 1200 are grades were used. After polishing the specimens were passed through the etching process. Final polishing was done on the disc polishing machine.

The etching process was done with the help of etching liquid solustion. The etching process was the final process after polishing during etching process Brasso-Liquid mixture were used having HF(hydro-fluidic acid) as 0.5%.After etching microstructure of the specimens was captured on microscope at 200X magnification with the help of a camera along the weld.

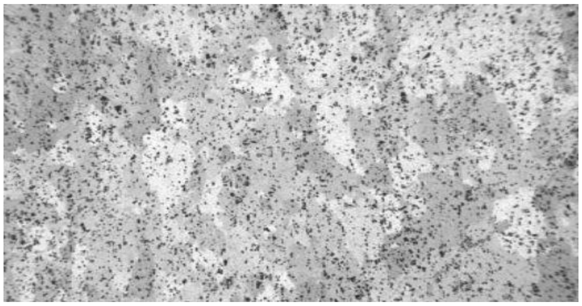

Fig 2: Microstructure of AL-5052 before heat treatment

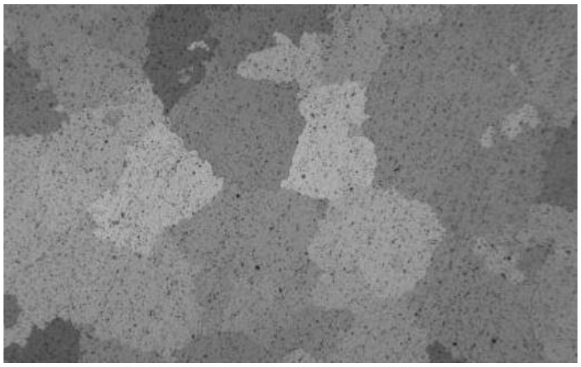

Fig 3: Microstructure of AL-5052 after heat treatment

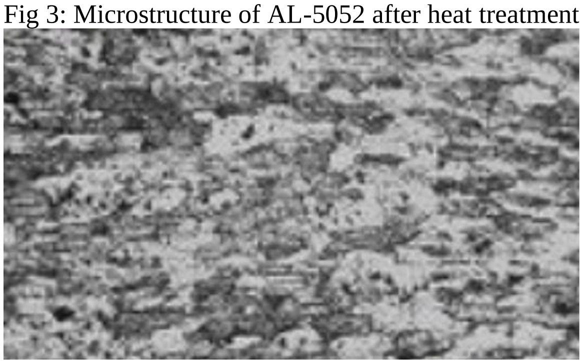

Fig 4: Microstructure of AL-2014 before heat treatment

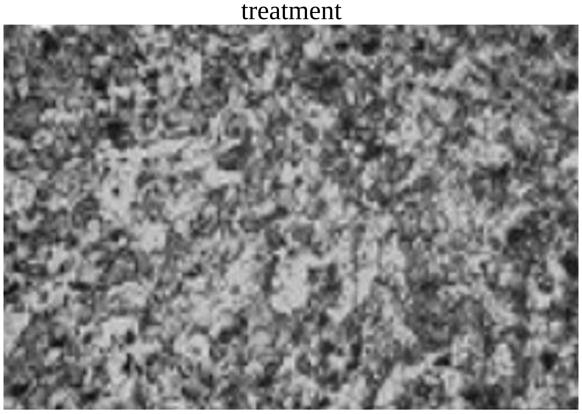

Fig5: Microstructure of AL-2014 after heat treatment

From the observations we have clear that the microstructure of heat treatment alloys are changed to fine grain size to coarse grain size.

CONCLUSIONS:

From the experiment of TIG Welding of Al-2024 and Al-5052 alloys following conclusions can be made:

1) After the heat treatment, microstructure shows relatively coarse and closely spaced precipitates along the grain boundaries and the fine properties within the grains.

2) After heat treatment process the hardness values are decreases which further increases the ductility and weld zone as well as HAZ (Heat affected zone).

3) After heat treatment process hardness of the Al-2014 of the heat affected zones and base are equivalent

4) For the welding strength and welding profile is widely influenced by the selection of welding material and specifications of the welded machine used.

5) AC power is mostly preferred for better and cleaning action, weld appearance and heat distribution in TIG welding of Aluminium alloys.

6) Automation of TIG welding process can make it more useful and precise to achieve fast welding speed, less distortion and even thin welding sheets can also be welded.

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