

Comparison between tungsten inert gas and friction stir welding in commercial aluminium alloy plates

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ABSTRACT

An experiment was done on Commercial aluminium alloys for investigation of the mechanical properties by using two different welding processes such as tungsten inert gas (TIG) welding and friction stir welding (FSW). Tested mechanical properties are tensile strength and hardness of welded joint. Results shows that FSW posses higher tensile strength (157.33Mpa) and hardness (49.03Hv) than TIG welding (140.8Mpa, 45.56 Hv) respectively. Maximum hardness for TIG welding observed at nugget zone where as heat affected zone (HAZ) posses higher hardness for FSW.

KEY WORDS: TIG welding, FSW, Tensile strength, Hardness.

1. INTRODUCTION

Aluminium alloys are widely used now days in automobile industry, aircraft, building and construction industry due to its high strength to weight ratio, low density, and high resistance against corrosion. Aluminium is introduced as a welded structural material with the introduction of inert gas welding in 1940. This welding process used an inert gas to protect the molten aluminium from atmospheric contamination and oxidation during welding, so that a high quality, high strength welds at high speeds in all positions is possible with minimizing defects. GTAW was patented in 1890 by Coffin in a non-oxidizing gas atmosphere. This concept was modified later by Hobbart in 1920, who used helium as a shielding gas and Devers, who used argon gas for shielding. The process parameter which affects TIG welding are welding current, welding voltage, inert gases, welding speed.

Friction stir welding (FSW) was invented and experimentally proven at The Welding Institute of UK in December 1991. Friction stir welding is a solid state joining process where a metallic tool is used to join two facing surfaces of work piece. The friction between the tool and material generates the heat which forms a very soft region near the FSW tool shoulder due to plastic deformation in that region. It then mechanically intermixes the two pieces of metal at the place of the joint, and then the softened metal is joined with the help of axial force given by the tool shoulder. Firstly this method was popular for welding aluminium, and mostly on extruded aluminium alloys which cannot be heat treated, and on structures which needs superior weld strength without any post weld heat treatment and which face difficulty to weld by fusion welding. The parameters which affect FSW process is rotational speed of the tool, traverse speed, tilt angle of the tool, axial force, tool profile and tool hardness.

Literature Review: Juan zhao (2010), compared microstructure, tensile strength, and hardness of Al-Mg-Sc alloy welded by TIG welding and FSW. The result shows that tensile strength, yield strength and hardness of FSW joints are much better than TIG welded joints; the strength coefficient of FSW joints is up to 94%. Yield strength and Tensile strength of friction stir welding joints are 31% and 13% higher than that of TIG welded joints, respectively.

Ericsson (2003), experimented how the welding speed affect the fatigue properties of friction stir weld, and compare it with MIG and TIG welding on Al-Mg-Si alloys. According to the result they get extreme low and high welding speed has major influence on the fatigue properties of Friction stir welding joints. The friction stir welds showed higher static and dynamic strength than MIG-pulse welds and TIG welds.

Fahimpour (2013), investigated on corrosion behaviour of aluminium 6061 alloy joined by FSW and gas tungsten arc welding. They found the grain size of FS weld joint have finer and equiaxed than GTAW weld joints. So that resistance against corrosion is greater for FSW grains than the GTAW grains. In both cases, chances to corrosion attack were greater at the joint region than the base metal. FSW resulted in equiaxed grains of about 1-2 μm , while GTAW caused dendritic structure.

Squillace (2004), compared between FSW and TIG welding and investigated the modification of microstructure and pitting corrosion resistance in AA2024-T3 butt joints aluminium alloy. According to the conclusion a gradual decrease in mechanical properties in TIG welding is due to the heat subjected on the material. However in friction stir welding, the material experienced less heat compared to TIG and the joining occurs due to severe plastic deformations induced by the tool motion; a slight decay in mechanical properties was found out in nugget zone, flow arm, TMAZ while in HAZ mechanical properties were slightly improved.

Cabello Munoz (2008), compared TIG welding and FSW on Al- 4.5Mg- 0.26Sc alloy. The result found was hardening precipitates were comparatively more affected by the TIG welding than FSW process. This cause a reduction of mechanical properties for TIG welds joints which can be overcome by a suitable post weld heat treatment.

Guo (2014), experimented FSW process by taking dissimilar aluminium alloy AA6061 and AA7075 and investigated the effect of process parameters such as material position and welding speed on microstructure, hardness and tensile properties. It was found that a good mixing of materials was found out when AA6061 placed on advancing side. Tensile strength increases with increase in welding speed and when AA6061 placed on advancing side.

Gibson (2014), presented automation and control of FSW. Here they discussed the process, latest research, and modern application of FSW used now days.

Krasnowski (2015), find the influence of tool shape and different welding conditions on mechanical and microstructural properties of AA6082 aluminium alloy using FSW. It was experimentally proved that conventional and triflute tool provides the best tensile property than other tool profiles.

Atul Suri (2014), experimented FSW on commercial aluminium alloy plate taking 6.5mm thickness. The result obtained was a flat pin tool gives better tensile strength than straight threaded pin tool. But for both tools refined microstructure can be noticed at welded zone.

Summary: Number of experiments has been done on friction stir welding and TIG welding methods on aluminium alloy till date. There are number of factors which affect the material properties after welding. Welding current, voltage, and welding speed are the most important parameters which affect the TIG welding whereas tool profile, tool rotational speed, and tool traverse speed affects FSW. Investigations done by various researchers will help in predicting strength of the welded aluminium alloy and outline the best and suitable method for aluminium welding.

Need and significance of proposed work: One important factor in welding aluminium is the stress induced during welding need to be addressed. Many welding techniques have been used for welding aluminium like FSW, arc welding, spot welding TIG welding, metal inert gas welding etc. Out of these FSW is gaining popularity in comparison to other process. Mechanical properties needs to be carefully evaluated as little change in these properties may leads to pre mature failure of welded structures. TIG welding has been chosen for comparison since it is the mostly used method for aluminium welding.

2. MATERIALS AND METHODS

Commercial aluminium alloy of thickness 3mm was taken. It was cut into 150 × 40 × 3 mm pieces for the experiment. Every piece was hammered for making flat surfaces. After that edges were polished by using different grades of emery paper for removing oxide layer from the surface and cleaned by using acetone prior to welding. Composition of aluminium alloy was given below:

Table.1. Material composition

Elements	Si	Fe	Mn	Cu	Zn	Ni	Cr	Ti	Al
Weight (%)	0.7	1.07	0.15	0.3	0.004	0.005	0.24	0.015	bal



Fig.1. Polished Work piece

TIG welding: In this research, two type of experiment was conducted. The first type of welding was butt joint of Al plate welded at one side and the second type of welding was butt joint of Al plate welded at both side of joint one after one with different current setting such as 70, 80, 90, 100, 110 amp. TIG welding was done without using any filler material. All other parameters such as argon gas flow rate, electrode and work piece distance, speed remains constant throughout the process such as 10 ltr/min, 3mm, 4mm/sec respectively.

FSW: FSW was done by using conventional vertical milling machine. Mild steel tool was used for the experiment. Tool material and specification are given below:

Table.2. Tool profile dimension

Tool material	Shoulder diameter(mm)	Pin Diameter(mm)	Pin length(mm)
Mild steel	12	4	2.5

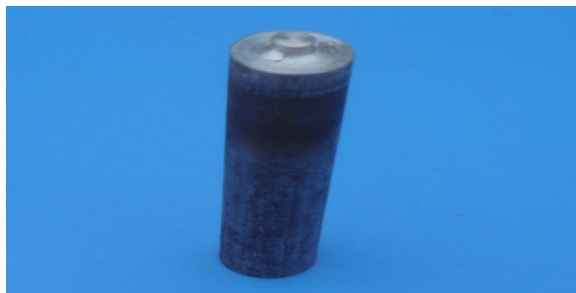


Fig.2. FSW Tool

Joining of two metals occurs by frictional heating generated by the rubbing action of the rotating shoulder of the tool with the contact surface of work piece. The rotating pin deforms and stirs the material which comes in contact to the tool pin. So that metal below the shoulder and surrounding the pin deforms plastically and gets soften. Also the axial force given by the tool shoulder helps to generate heat due to friction. Accordingly, when the tool moves to the next position the softer material below the shoulder gets solidified.

In this paper three values of rotational speed of tool was taken for comparison such as 910 rpm, 1000rpm, 1400 rpm. The mechanical properties observed were compared with TIG welding observations.

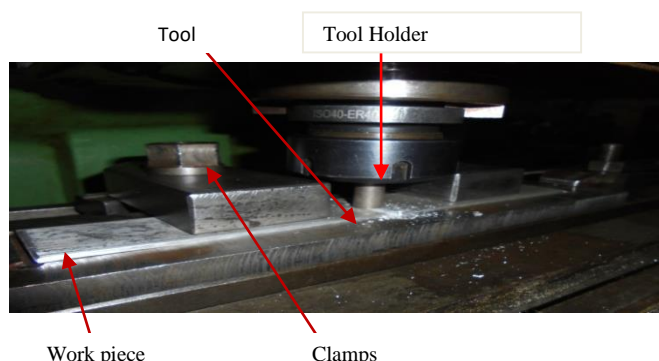


Fig. 3 Vertical milling machine performing Friction stir welding operation

3. RESULTS AND DISCUSSION

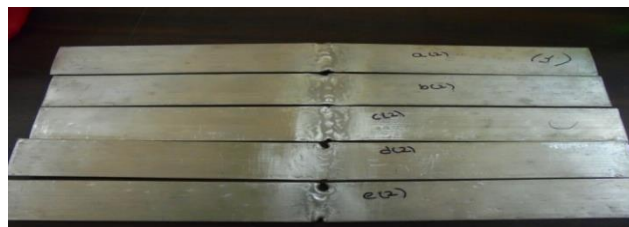
Visual inspection:

TIG welding: For single sided welding at low current value such as at 70A and 80A, incomplete fusion and small cracks are found at starting point of welding but towards the end comparatively good welding was found. This is because of high thermal conductive of aluminium. At starting due to less heat, improper fusion occurs but due to thermal conduction temperature of the end reason increases and comparatively good welding occurs. With increase in current heat input increases and proper melting of base metal happens. so molten metal properly penetrates throughout the thickness and joint occurs in larger area. With high current value such as at 110A maximum penetration was found out.

For double sided welding at lower value of current such as at 70A and 80A no visible cracks, very less porosity, as well as no overheating was found on both side of welding. With increase in current visible cracks are found on the front side immediately when back side welding was processed. Crack size increases with increase in current and with high current value such as at 110A large groove was found on the welded reason because of over melting.



a



b

Fig.4 TIG welding a) single sided welding, b) Double sided welding at different current values

FSW: It was found that at lower value of rotational speed incomplete fusion of material occurs at welding zone. This is due to less amount of heat generated due to low rotational speed. When rotational speed increases results in increase in stirring intensity and materials get mixed well. Excessive higher tool rotational speed results in higher heat generation and this helps in excessive release of stirred material to the upper surface and accordingly results in decrease in strength at the joint.



Fig.5. Visual inspection of FSW (a) at 910 rpm (b) at 1400 rpm (c) at 1000 rpm respectively

Tensile testing: An universal testing machine (Instron) was used for tensile strength testing of the welded specimen with maximum load capacity 600KN. Load was given with a speed of 1mm/min. Prior to tensile test sample was prepared according to ASTM specification.



Fig.6. Tensile specimen



Fig.7. Universal tensile testing Machine performing operation

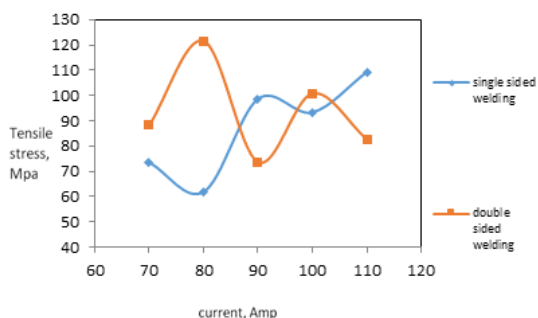


Fig.8. Tensile stress Vs current for TIG welding

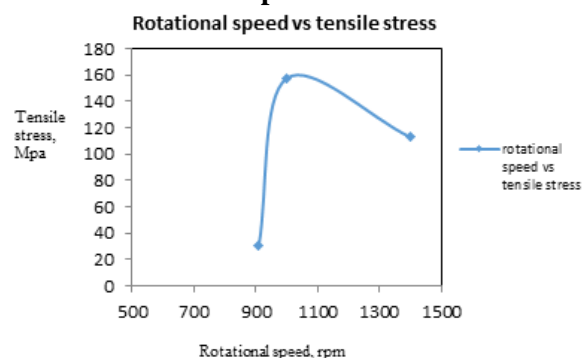


Fig.9. Tensile stress Vs rotational speed of FSW

From the experiment it was observed that tensile stress of double sided welding was higher than that of single sided welding. This may be because of during double sided welding melting occurs in larger area and both side joint takes place. During single sided joint melting occurs in one side and incomplete fusion occurs. Molten material could not reach on the opposite side of single sided joint which may be the reason of early failure.

For double sided joint tensile strength increased with increase in current at starting and then started decreasing. This decreasing behaviour due to heavy crack formation in higher current values. Highest tensile stress value 121.6 Mpa was found at 80A current.

For single sided welding higher tensile stress of 109.33 Mpa was found at high current value of 110 A. This is because of larger joint area. At high current value melting rate of parent metal is higher so that proper penetration occurs towards the opposite side.

When we compare FSW with TIG welding, FSW possessed higher strength than TIG welded joint. At 910 rpm (30.93 Mpa) failure occurs due to incomplete fusion where as at 1400 rpm (112.8 Mpa) failure occurs due to tunnelling defect. High value of tensile stress was found out at 1000rpm (157.33 Mpa).

Hardness testing: Hardness test was done by using Vicker's hardness testing machine under 10kgf load. Testing was done from the centre of weld zone towards the both side of the base metal. Prior to testing, samples were polished by using different grades of emery papers such as 400, 600, 800, 1000, 1200 grades for clear view of indentation. Result showed that all most all cases of TIG welding, hardness value of base metal is higher than the welding zone.

Hardness value starts decreasing towards the HAZ and again increases in welding reason. Low hardness value was observed for single sided welding. Base metal had hardness value of 49.10Hv. For Single sided welding lower hardness value (28.61Hv) found at 80A and higher value (42.57Hv) found at 110A. Similarly for double sided welding lower (37.88Hv) and higher (43.50Hv) found at 70A and 110A respectively.

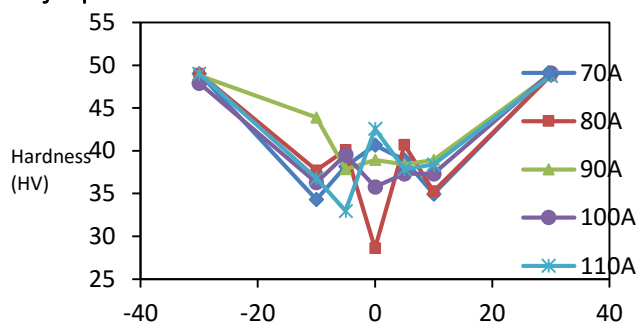


Fig.10. Hardness profile of single sided TIG welding

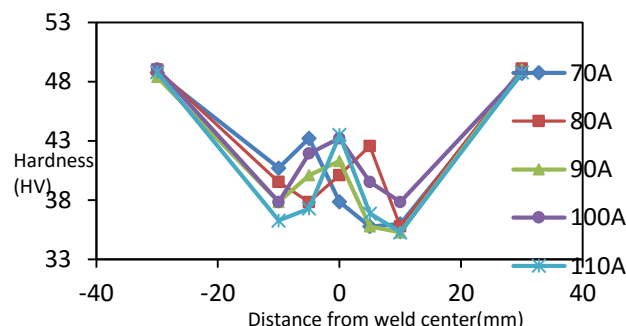


Fig.11. Hardness profile of double sided TIG welding

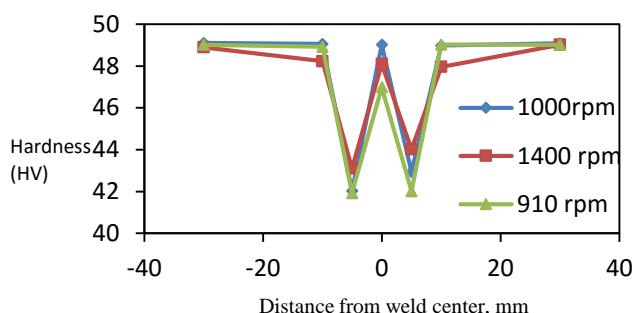


Fig.12. Hardness profile for FSW

In case of FSW, hardness drops at the HAZ may be because of coarsening of the grain structure. Hardness value decreases with increase in rotational speed. HAZ of advancing side had higher hardness than retreating side. TMAZ zone possess smaller hardness compared to other zones. Advancing side TMAZ had lower hardness than retreating side. At welded zone higher hardness (49.02HV) and lower hardness (46.98HV) found at 1000rpm and 910rpm respectively. When we compare FSW with TIG welding, we get FSW has higher hardness value at welded reason.

4. CONCLUSION

The conventional TIG welding process and FSW process were successively applied to join commercial aluminium alloy plates. After studying its mechanical properties such as tensile strength and hardness of both type joints, it was found that for commercial aluminium alloy TIG welding without filler material is not suitable because of its high alloy percentages of aluminium alloy. High percentage of iron present in this aluminium alloy leads to crack formation when it exposed to excessive high heat. From the present work following conclusions can be drawn:

- Double sided welding of commercial aluminium alloy of 3mm thickness using TIG is given better weld quality than single sided welding.
- For TIG welding in all most all cases hardness value decreases towards the HAZ from base metal and then it increases towards the welded reason. With increase in current hardness value increases.
- At low and extreme high rotational speed of the tool in FSW leads to defects in welding.
- From the tensile test it was found out FSW joints possesses higher strength and higher ductility in comparison of TIG joints.
- A great difference in hardness among four different zones such as nugget, TMAZ, HAZ and base metal was found out in case of FSW joint. From base metal towards the HAZ a decrease of hardness was found out, but towards nugget zone after TMAZ, FSW showed an improved higher hardness value.

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