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## Experimental Investigation of Friction Stir Welding and TIG Welding for Al-6082

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**ABSTRACT:** An experimental investigation has been carried out, in present paper, on microstructure, Hardness and Tensile strength of weld butt joints of AA 6082. Two different welding processes have been considered: a conventional tungsten inert gas (TIG) process and an innovative solid state welding process known as friction stir welding (FSW).which the relative motion between the tool and the work piece produces heat which makes the material of the two edges being joined plastic atomic diffusion. Tungsten inert gas welding process that uses the heat produced by an electric arc created between non consumable tungsten electrode and the weld pool. In this project an attempt is made to compare and investigate the process parameters of fsw and tig on the mechanical properties of the welds. The hardness, tensile strength is considered for investigation by tool speed, tool feed and maintaining constant depth of penetration of weld. The results indicate than the microstructure of fiction weld is different from the tungsten inert gas welded joint. The weld nugget consists of small grains in friction stir welding and those are found in tungsten inert gas weld. The tensile strength of weld joint in friction stir welding is more instead of tungsten inert gas Welding. Hardness test of friction stir welding is more instead of tungsten inert gas where as in parent material also.

**KEYWORDS:** friction stir welding, tig welding, similar materials, Tensile, Hardness, microstructure.

### I. INTRODUCTION

Friction stir welding was invented by The Welding Institute (TWI) in December 1991. TWI filed successfully for patents in Europe, the U.S., Japan, and Australia. TWI then established TWI Group-Sponsored Project 5651,"Development of the New Friction Stir Technique for Welding Aluminium," in 1992 to further study this technique. The development project was conducted in three phases. Phase I proved FSW to be a realistic and practical welding technique, while at the same time addressing the welding of 6000 series aluminum alloys. Phase II successfully examined the welding of aerospace and ship aluminum alloys, 2000 and 5000 series, respectively. Process parameter tolerances, metallurgical characteristics, and mechanical properties for these materials were established. Phase III developed pertinent data for further industrialization of FSW. Since its invention, the process has received world-wide attention, and today FSW is used in research and production in many sectors, including aerospace, automotive, railway, shipbuilding, electronic housings, coolers, heat exchangers, and nuclear waste containers. TIG welding was, like MIG/MAG developed during 1940 at the start of the Second World War. TIG's development came about to help in the welding of difficult types of material, eg aluminum and magnesium. The use of TIG today has spread to a variety of metals like stainless mild and high tensile steels. GTAW is most commonly called TIG(tungsten inert gas). The development of TIG welding has added a lot in the ability to make products that before the 1940's were only thought of. Like other forms of welding, TIG power sources have, over the years, gone from basic transformer types to the highly electronic power source of the world today. TIG welding is a welding process that uses a power source, a shielding gas and a TIG hand piece . the power is fed out of the power source, down the TIG hand piece and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece. The tungsten and the welding zone is protected from the surrounding air by a gas shield (inert gas). The electric can produce temperature of upto 19,400°C and this heat can be very focused local heat. In this the material used is aluminium 6082. The chemical composition of AA 6082 is given in the table 1.

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Element	% Present
Silicon (Si)	0.70 - 1.30
Magnesium (Mg)	0.60 - 1.20
Manganese (Mn)	0.40 - 1.00
Iron (Fe)	0.0 - 0.50
Chromium (Cr)	0.0 - 0.25
Zinc (Zn)	0.0 - 0.20
Others (Total)	0.0 - 0.15
Titanium (Ti)	0.0 - 0.10
Copper (Cu)	0.0 - 0.10
Other (Each)	0.0 - 0.05
Aluminium (Al)	Balance

Table 1. Chemical Composition Of Aa6082

Experiments are conducted on similar materials and the results are obtained several trials have been made to perform different types of welding. However, with proper attachments friction welding can be performed on cnc machine and tungsten inert gas welding is performed manually. We are trying to investigate the performance of the two weldings by conducting different test on both of them.

## II. EXPERIMENTAL WORK OF FRICTION STIR WELDING

Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys. Alloy 6082 is known as a structural alloy. In plate form, 6082 is the alloy most commonly used for machining. As a relatively new alloy, the higher strength of 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy. The extruded surface finish is not as smooth as other similar strength alloys in the 6000 series. In the T6 and T651 temper, alloy 6082 machines well and produce tight coils of swarf when chip breakers are used. A cnc milling machine is used for friction stir welding (FSW) of aluminum AA6082 alloy. The machine has used to maximum speed of 1000 rpm and 10-horse power. Test piece was clamped in the fixture tightly. Initially the rotating pin was inserted into a predrilled hole, which will start up of welding. Processing began at spindle speed at 1000 rpm and travel rate of 18 inch/min. the speed increased to 1200rpm and feed rate to 14 inch/min. Since tool plunge was to extent of 6.2mm and plate thickness 6mm the result was one side welded plates. The plates were then subjected to mechanical testing. In the present work the influence of speed, feed, on the performance of FSW such as hardness test, tensile strength, and microstructure. In friction stir welding (FSW) a cylindrical, shouldered tool with a profiled probe is rotated and slowly into the joint line between two pieces butted together. The parts have to be clamped onto a backing bar in a manner that prevent the abutting joint faces from being forced apart. Frictional heat is generated between the wear resistant welding tool and the material of the work pieces. This heat causes the latter to soften without reaching the melting point and allows traversing of the tool along the weld line. The maximum temperature reached is of the order of 0.8 of the melting temperature of the material. The plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged by the intimate contact of the tool shoulder and the pin profile. It leaves a solid phase bond between the two pieces. The process can be regarded as a solid phase keyhole welding technique since a hole to accommodate the probe is generated, then filled during the welding sequence.

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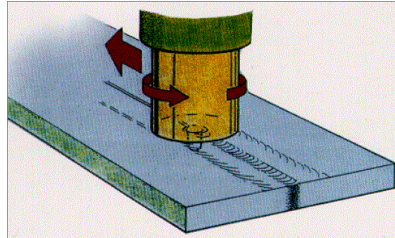


Fig 1. The process of friction stir welding

## Tungsten Inert Gas Welding

In the TIG process the arc formed between a pointed tungsten electrode and the work piece in an inert atmosphere of argon or helium. The small intense arc provided by the pointed electrode is ideal for high quality and precision welding. because the electrode is not consumed during welding, the welder does not have to balance the heat input from the arc as the metal is deposited from the melting electrode .when the filler metal is required, it must be added separately to the weld pool. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous materials such as aluminum, magnesium and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc, allowing for stronger, higher quality welds. However, GTAW comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create more focused welding arc and as result is often automated. Tungsten inert gas welding, also known by acronym as TIG welding, is a welding process that uses the heat produced by an electric arc created between non consumable tungsten electrode and the weld pool. This electric arc is produced by the passage of current trough a conductive ionized inert gas that also provides shielding of the electrode, molten weld pool and solidifying weld metal from contamination by the atmosphere.

The process may be used with or without the addition of filler metal using metal rods. Electric arc ,the process can be used with either direct or alternating current the choice is depending largely on the metal to be welded. Direct current with electrode negative offers the advantage of deep penetration and faster welding speeds. Direct current with electrode positive I highly unrecommended because uses electrode overheating and is rarely used.

## III. EXPERIMENTAL PROCEDURE

Commercial aluminum plate of thickness 6mm was selected as work piece material for the present experiment. Al plate was cut with dimension of 120mm×50mm with help of band saw and grinding done at the edge to smooth the surface to be joined. After that surfaces are polished with emery paper to remove any kind of external material. After sample preparation, aluminum plates are fixed in the working table with flexible clamp side by side and welding done so that butt joint can be formed. TIG welding with Alternating Current (AC) was used in experiments as it concentrates the heat in the welding area. Zirconated tungsten electrodes of diameter 3.4mm was taken as electrode for this experiment. The end of the electrode was prepared by reducing the tip diameter to 2/3 of the original diameter by grinding and striking an arc on a scrap material piece. This creates a ball on the end of the electrode. Generally an electrode that is too small for the welding current will form an excessively large ball, where as too large an electrode will form an satisfactory ball at all. For the first phase of experiment welding parameters selected are shown in table 2. Before performing the actual experiment a number of trial experiments have been performed to get the appropriate parameter range where welding could be possible and no observable defects like undercutting and porosity occurred.

The figure 2 shows the process of the friction stir welding when performing the experiment.in this first the plates of aluminium are cleaned . then the process of welding is done carefully.

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(a)



(b)

in fig 2 (a)The plates are cut to exact equal shapes and holded tightly with clamps and cleaned by using the coolant.(b)the2 Platesare tightly held closure to each other and welding is performed

## Tensile test

Tensile test is the maximum stress where a material can withstand while being stretched or pulled before necking, which is when the specimen cross section start to significantly contract. It is an intense property. It does not depend on the size of specimen. Likely it depends upon the preparation of the specimen, surface defects, temperature of the test environment and material. Apart from this we are finding out efficiency of friction stir welded joints and tungsten inert gas welding weld specimens. It is known that the FSW process assures a great number of advantages and makes it one of the most appreciated welding procedures which could be applied in almost all industry branches. Besides ,comparing with TIG procedure, root preparation, filler metal and shielding gas are not required in materials joining by FSW procedure. For a deeper understanding of the welding process influence on the mechanical properties of the joint, a comparativeinvestigation between the tensile test results of FSW and TIG welded joints would provide more information about the thermomechanical behaviourof AA6082-T6 at welding. That's why an experimental and numerical research was conducted and showed different thermomechanical behaviourof the aluminium alloy 6082-T6 at FSW and TIGwelding.

## IV. EXPERIMENTAL RESULTS

### TENSILE TEST

Table 2 a, b Represents The Tensile Test Reports On Tig Welding And Fsw Welding

Serial no	Ultimate load (kn)	Ultimate tensile strength (n/mm <sup>2</sup> )	Elongation(%)
1	10.05	98.77	1.5
2	11.03	102.3	2.53
3	12.04	100.05	2.80
4	10.52	97.29	1.99

(a)

Table 2 , (a)Represents the values that are obtained on the tungsten inert gas welding

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Serial no	Ultimate load (kn)	Ultimate tensile strength(N/mm <sup>2</sup> )	Elongation(%)
1	3.5	30.31	1.1
2	3.9	32	1.7
3	4.32	34.45	1.40
4	3.86	31.59	1.08

(b)

Table 2 (b) Represents the tensile reports obtained for friction stir welding

### Hardness Test On Fsw And Tig Welding (Rockwell hardness)

Rockwell hardness testing is a general method for measuring the bulk hardness of metallic and polymer materials. Although hardness testing does not give a direct measurement of any performance properties, hardness of a material correlates directly with its strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation because of its simplicity and low cost relative to direct measurement of many properties. Specifically, conversion charts from Rockwell hardness to tensile strength are available for some structural alloys, including steel and aluminum. Rockwell hardness testing is an indentation testing method. The indenter is either a conical diamond (brale) or a hard steel ball. Different indenter ball diameters from 1/16 to 1/2 in. are used depending on the test scale. To start the test, the indenter is “set” into the sample at a prescribed minor load. A major load is then applied and held for a set time period. The force on the indenter is then decreased back to the minor load. The Rockwell hardness number is calculated from the depth of permanent deformation of the indenter into the sample, i.e. the difference in indenter position before and after application of the major load. The minor and major loads can be applied using dead weights or springs. The indenter position is measured using an analog dial indicator or an electronic device with digital readout. The various indenter types combined with a range of test loads form a matrix of Rockwell hardness scales that are applicable to a wide variety of materials. Each Rockwell hardness scale is identified by a letter designation indicative of the indenter type and the major and minor loads used for the test. The Rockwell hardness number is expressed as a combination of the measured numerical hardness value and the scale letter preceded by the letters.

Table 3: a,b,c,d represents the hardness test reports on tungsten inert gas welding and friction stir welding. This also shows the reports of the parent metal on tig and fsw

Serial no	Location	Impression1	Impression2	Impression3	average
1	On weld	42	41	43	42

(a)

Hardness Test Report On Tungsten Inert Gas Welding

Serial no	Location	Impression1	Impression2	Impression3	average
1	On weld	46	45	44	45

(b)

Hardness Test Report On Friction Stir Welding

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Serial no	Location	Impression1	Impression2	Impression3	average
1	On weld	48	42	44	43.3

(c)

Hardness Test Report On Parent Metal Friction Stir Welding

Serial no	Location	Impression1	Impression2	Impression3	average
1	On weld	40	42	41	41

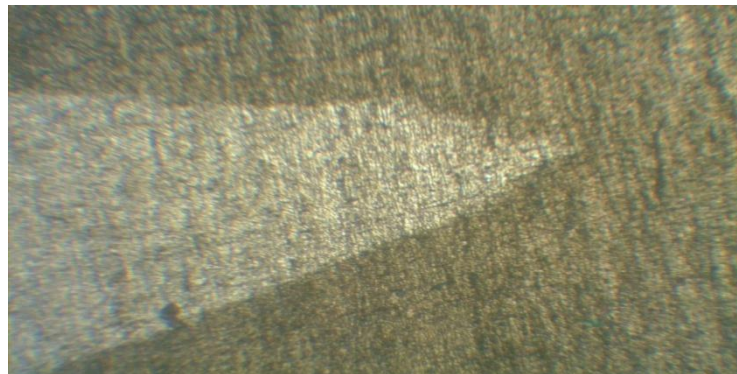
(d)

Hardness Test Report On Parent Metal Tungsten Inert Gas Welding

### Microstructure Properties Of Friction Stir Welding And Tungsten Inert Gas Welding

#### Microstructure Of Friction Stir Welding

Fig 3 the microstructure of friction stir welding on the heat affected zone of the aluminium 6082. We can see the variation when we observe the microstructure of the heat affected zone of tungsten inert gas welding .



(a)

Fig 3 : (a)Microstructures of friction stir welding

The microstructure consist of dendritic network of Al, Si, Mg in the matrix. HAZ :HAZ is well fused and free from non metallic defectsThe parent metal shows fine grains of the eutectic particles that are precipitated uniformly in the aluminum solid solution. The microstructure shows the dense grain flow along the direction of the force. The heat of the process made the eutectic particles completely precipitated. The precipitated particles are Cu-Al<sub>2</sub>, Mg<sub>2</sub>Si with some inter metallic.The microstructure is studied and observed that the heat affected zone is well fused and free from non-metallic defects.

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## Microstructure Of Tungsten Inert Gas Welding



(b)

Fig 3: (b)Microstructures of tungsten inert gas welding

The microstructure consist of dendritic network of Al, Si, Mg in the matrix. HAZ :HAZ is well fused and free from non metallic defects.The microstructure shows the dense grain flow along the direction of the force. The heat of the process made the eutectic particles completely precipitated. The precipitated particles are Cu-Al<sub>2</sub>, Mg<sub>2</sub>Si with some inter metallic. The weld zone shows the fine precipitated and fragmented eutectic particles from both the bars, and also shows the thermo mechanical transformed zone. The point is just fraction of mm from the weld zone. This can also be called heat affected zone.

## V. CONCLUSION

From the observations in the project it is concluded that:

Smooth surface finish can be obtained by using Friction stir welding with a tool having a smooth pin.

The microstructure is studied and observed that the heat affected zone (HAZ) is well fused and free from non metallic defects.

Here in the Friction stir welding the breaking point is outside the weld on tensile test whereas in TIG welding the breaking point is exactly on the weld.

Here in the hardness test on the weld. Friction stir welding is more better than TIG weldingNo cracking occurred in the heat affected zone

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