Comparsion of Mechanical and Microstructural Behaviour of Tig Welded and Friction Stir Welded Dissimilar Aa6063 and Aa7075

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Abstract— In this study, AA7075/ AA6063 aluminum alloy plates have been welded by conventional fusion welding process tungsten inert gas (TIG) welding and friction stir welding (FSW) process. The welding process was performed with different process parameters and the joints has been investigated to find their microstructure, hardness and tensile properties. Optical microscope was used to characterize the microstructure of the weld area for both the welding process. Tensile tests were applied to weld parts to obtain the strength of the joints by UTM and Vickers hardness test was applied to obtain the hardness of the weld joint. Taking into consideration the process conditions and requirements, FSW and TIG processes were compared with each other to understand the advantages and disadvantages of the welding processes. Microstructural examination reveals that smaller grain sizes are obtained in the weld centre of FS welded specimens due to recrystallization, where as grain growth has been observed in TIG welded specimen due to severe heat input. The UTM and Vickers hardness test results show that among the two welding methods employed, FSW has yielded the best mechanical properties.

Key words**:** tungsten inert gas (TIG), friction stir welding (FS), dismillar joint, aluminium alloys AA6063 and AA7075, mechanical properties

I. INTRODUCTION.

Friction stir welding (FSW) is a solid state joining process that was developed by the TWI, UK in 1991 . FSW is a relatively new and promising welding process that can produce low-cost and high-quality weld joints of heat-treatable aluminium alloys. FSW is well suited for joining aluminium alloys, especially for those which are considered difficult to weld, such as 2xxx and 7xxx series.

FSW of aluminium alloys has been used in many field like automotive, aircraft, ship building, railway, defence industries,.The rapid development of FSW in aluminium alloys and its successful implementation into commercial applications has motivated its application to more non-ferrous materials and other metals.

In FSW as a basis a non-consumable HSS tool with a special designed pin and a shoulder is made to plunged in the abutting edges of the plates to be joined to a preset depth and moved along the weld joint. Heat is generated through the frictional contact between the rotating tool shoulder, and abutting material surface.

Literature review reveals that still there is lack of material property data regarding the comparison of FSW with TIG. Although it is observed that FSW in general yields stronger welds than fusion welds more data is required to support this fact for time being few comparisons have been made of the dissimilar material welded by different methods with different process parameters.In this paper a comparison has been made on the mechanical and microstructural behaviour of dissimilar welded AA 6063 T4 and AA7075 T6 Aluminium Alloy, by two different welding techniques FSW and TIG. The results are compared in terms of microstructural examinations, tensile properties and hardness variations across the weld joints. which find use simultaneously in several industrial sectors owing to their distinct properties.

material	mg	cu	si	fe	others	Al
AA6063	0.45	0.1	0.35	0.25	0.3	Balance
AA7075	0.18	1.2	5.1	2.1	0.3	Balance
Filler rod 4043	0.05	0.04	4.9	0.2	0.25	balance

Table 1: chemical composition of AA 6063 and AA7075(wt%) and filler rod used for TIG 4043.

II. EXPERIMENTAL WORK.

A. Material

AA 6063 is an aluminium alloy with mg and si as the alloying elements. It has generally better mechanical properties it is heat treatable and weldable. AA 7075 is an aluminium alloy, with zn as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability.

AA 6063 and AA7075 base metal sheets used in this study are T4 and T6 conditions, respectively. both plates have been manufactured by extrusion with the dimension of 120×70×5mm3(length, width, thickness). the chemical composition of both Al alloys and filler rod 4043 used in TIG welding are given in table 1.

B. friction stir welding (FSW)

The tool used in FSW process consists of a shoulder with a diameter of 20 mm and a pin with a diameter of 4 mm and a length of 3.5 mm. The FSW tool was fixed to the rotating axis of a semi milling machine and rotated clockwise. The process parameters are varied and totally six specimens are prepared (S1,S2,S3,S4,S5,S6). In this study the optimum tool rotation and welding speeds are selected as 1400rpm and100 mm min−1 respectively.
The tip of the tool i.e pin is forced into the welding plates under 5,000 to 10,000 pounds per square inch (775 to1550 pounds per square centimeter) of force. The pin continued rotating and moved forward at 100 mm min−1.

When the pin rotates with high speed, friction friction takes place and heats the surrounding material and rapidly produces a softened "plasticized" area around the pin. As the pin travels forward, the material behind the pin is forged under pressure from the tool and consolidates to form a bond. Unlike fusion welding no actual melting occurs in this process and the weld is left in the same fine-grained condition as the parent metal as shown in above figure.

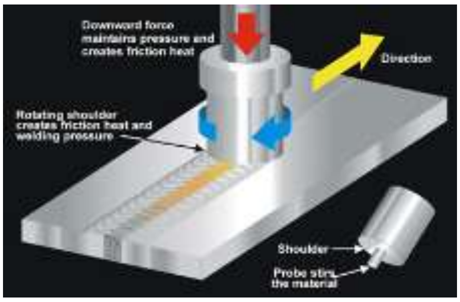


Fig. 1: schematic view of FSW process

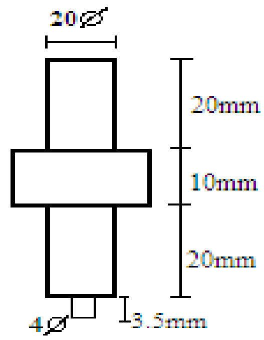


Fig. 2: geometry and dimension of stirrer tool.

Fig. 3: layout of the plates for FSW.

C. *Tungsten Inert Gas Welding(TIG)*

The longitudinal direction of the TIG weld was taken parallel to the extrusion direction of dissimilar aluminum alloys AA 6063 and AA 7075. The abutting surfaces were cleaned before welding with a steel brushing followed by light sand with 400 grit Sic paper and with acetone. The cleaning media contained no carbon. A gap of 2mm was left between the two plates being welded a V joint configuration has been prepared. A ceramic base has been kept under the plates during welding process in order to reduce heat loss, obtain a more homogeneous heat distribution and avoid warpage of the plates. two sided TIG welding has been carried out in one pass, owing to the thickness of the plates. Totally six specimens are prepared (S7,S8,S9,S10,S11,S12) the Layout of the plates during the welding is shown in Fig. 4 and the welding parameters are presented in Table 2.

After joining these two materials the 12 specimens are cut by wire cutting machine as by ASTM standard for further testings.

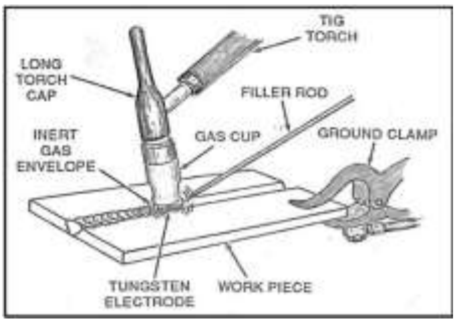


Fig. 4: schematic view of TIG welding process.

Table 2.process parameters for TIG welded dissimilar AL alloys AA6063 and AA7075

Weldig machine	Oerlikon prestotig 300
Filler rod type	Magmaweid TAL 4043
Filler rod	3mm
Diameter	100A
Current	20v
Voltage	20c
Preheating	Argon
Shield gas	5bar
Gas pressure	5min-1
Gas flow rate	

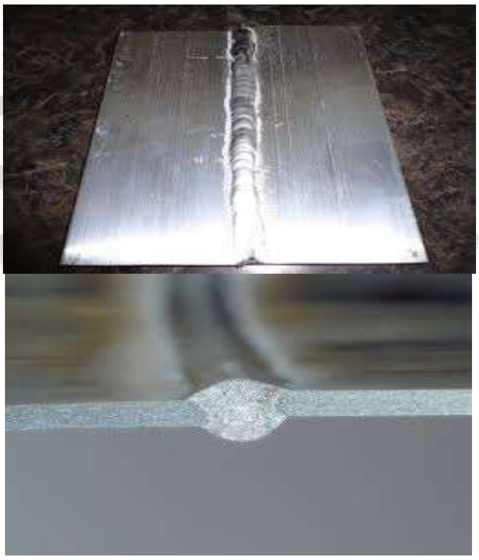
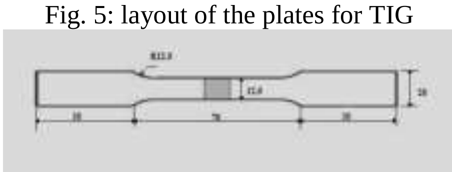


Fig. 5: layout of the plates for TIG



III. Result and Discussion

A. *Microstructure*

In this present study dissimilar AA6063 and AA7075 have been successfully joined using the FSW and TIG process. after welding with both methods the cut surface of the specimens were polished with alumina suspension. The polished specimen has been etched for 100s in 50ml methyl alcohol, 25ml hydrochloric acid,20ml nitric acid and one drop hydrofloric acid solution to reveal the microstructure variation. the microstructure result of FSW process revealed the the classical formation of the whirlpool rings in the weld area.

Microstructure examinations are conducted at the middle section of the specimens. in FSW totally four distinct regions are observed ,namely the nugget zone[NZ], thermo mechanical affected zone [TMAZ], heat affected zone[HAZ] and the base metal [BM]. nugget zone is the region that experience the highest strain and undergoes recrystallization. TMAZ is the region surrounding the nugget on either side where there is less heat generation compared to the centre and therefore may exhibit partial recrystallization.

The HAZ zone is the zone where material progressively tends to remains uneffected. The BM has long equiaxed grains structure, where as the weld nugget is composed of fine-equiaxel grains, approximately 6-9µm in diameter, due to recrystallization, which is formed under high temperature and plastic deformation in the weld centre due to the stirr process. the microstructure view for all four regions are as shown below fig 6.

TIG welding on the other hand reveals three zones, namely weld centre, HAZ and the base metal which are typically in any fusion welding. In TIG welds grains shows a tendency of having greater diameters in the HAZ and weld region compared to the base metal due to high heat input to the material. In the HAZ the grains becomes less equiaxed and in the weld region there is a non homogeneous and unequiaxed grain distribution. grain sizes are measured about 20µm in diameter in the weld centre. When the grain structure is compared at the weld centers of FSW and TIG it revealed that grain sizes have reduced in FSW due to recrystallization, where as there is grain size increase in TIG due to severe heat input. The microstructure view for TIG welding is as shown below in fig7.

B. Microstructure of FSW:

Fig .6: Microstructure of FSW

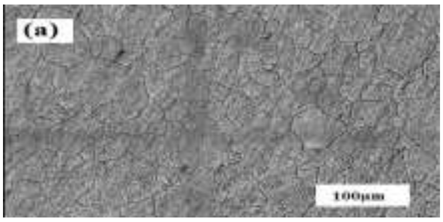


Fig .6(a): Base metal AA 6063

Fig. 6(b): TMAZ & HAZ AA6063

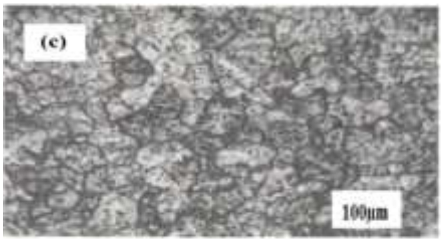


Fig. 6(c): NZ AA6063 & AA7075**.**

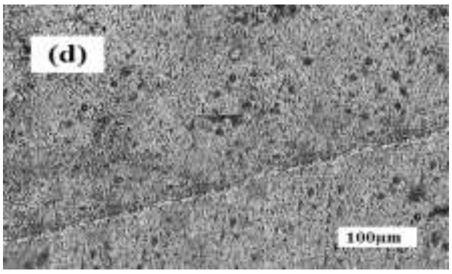


Fig. 6: (d) TMAZ & HAZ AA7075

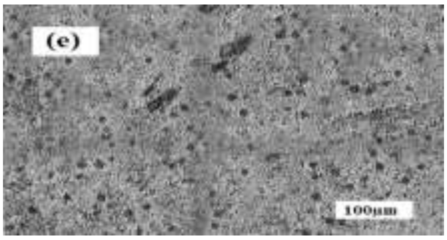


Fig. 6: (e) Base metal AA7075

C. Microstructure of TIG

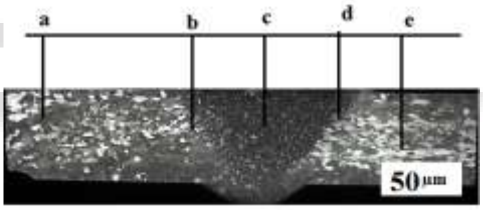
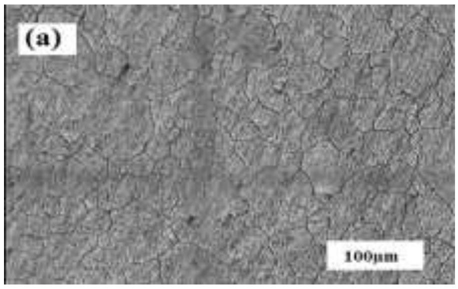


Fig. 7: Microstructure of TIG**.**



Fig, 7(a): Base metal AA 6063

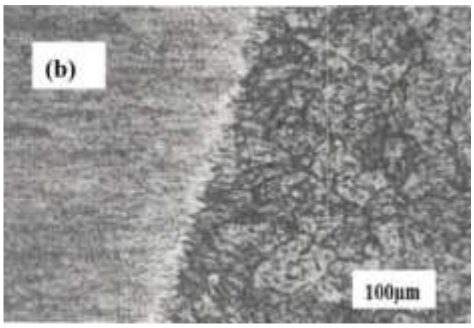


Fig. 7(b): HAZ AA6063

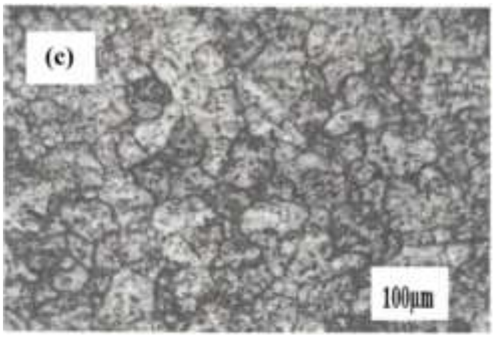


Fig. 7(c): weld centre AA6063 & AA7075

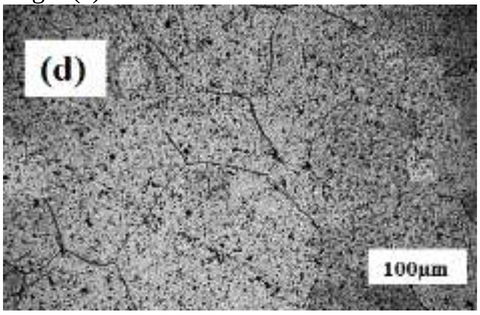


Fig. 7(d): HAZ AA7075

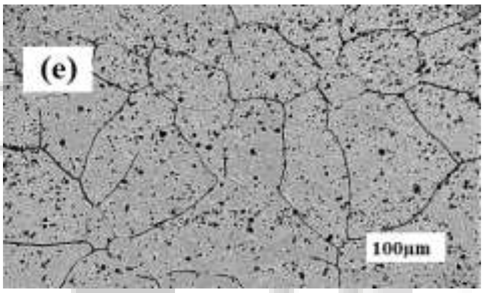


Fig. 7(e): Base metal AA7075

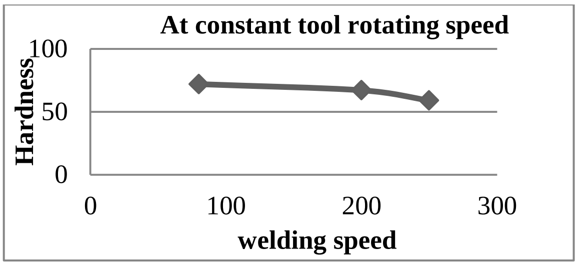
D. Hardness

Microhardness measurements (HV) has been carried throughtout the weld region for FSW and TIG welded dissimilar alluminium alloys AA6063 and AA7075 to determine the hardness of different regions across the weld region. the middle section of weld region has been chosen for the hardness measurement. Base metal hardness values are around 150 HV for AA7075 and 83 HV for AA6063. In FSW it is found that as tool rotating speed increases hardness also increases the optimum speed has been found at 1400rpm and 100mm/min welding speed. In TIG welds hardness decrease has been observed in both HAZ and the weld centre due to softening and large grain size diameter compared to base metal. Figure 8 shows the microhardness distribution over the weld cross section of FSW and TIG welded dissmilar AL alloys AA6063 and AA7075.

1) For FSW:

When tool rotation speed is constant:

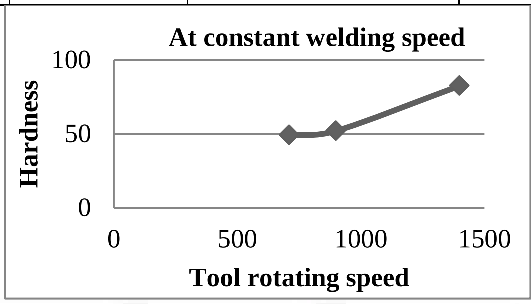
SL.NO	Tool rotating speed(rpm)	Welding speed(mm/min)	Hardness
S1	900	80	72.03
S2	900	200	67.13
S3	900	250	59



As welding speed increases temperature at the joint decreases by that hardness value also varies.

When welding speed is constant:

Sl no	Welding speed (mm/min)	Toolrotating speed (rpm)	Hardness
S4	100	710	49
S5	100	900	52.03
S6	100	1400	82.5

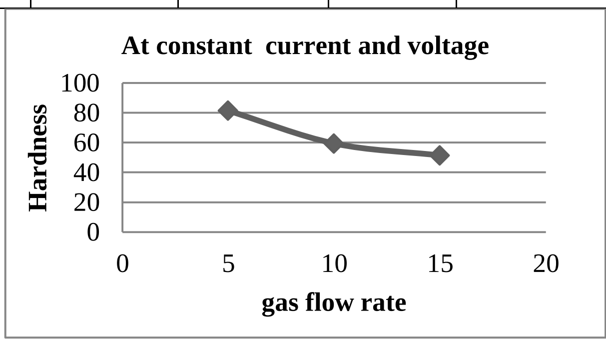


Above graph reveals that as RPM increases hardness also increases.

2) For TIG Welding:

When current and voltage are constant:

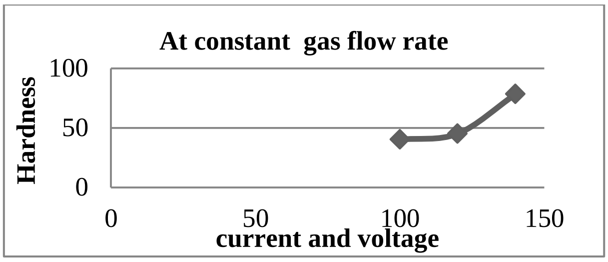
Sl no	Current(A)	Voltage(V)	Gas flow rate(min-1)	Vickers Hardness(HV)
S7	100	20	5	71.5
S8	100	20	10	59.4
S9	100	20	15	51.4



As welding gas flow rate increases temperature at the joint decreases by that hardness value also varies

When gas flow rate is constant:

Sl no	Current(A)	Voltag(V)	Gasflow rate(min-1)	Vickers Hardness(HV)
S10	100	10	5	40.2
S11	120	14	5	45.13
S12	140	16	5	78.23



Above fig reveals that as gas flow rate increases hardness also increases.

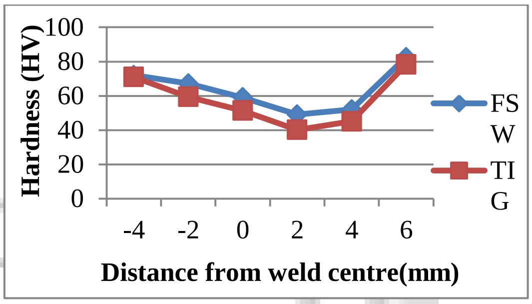


Fig 4:hardness profiles of dissimilar Al alloy AA6063 and AA7075 welded by FSW and TIG.

E. Tensile Test.

The tensile test has been carried out for all 12 specimen . FS welded specimens have fractured in the weld region the tensile value of the weld region is lower than BM values. While tungsten inert gas welded specimens have been fractured on the AA 6063 HAZ base metal interface the tensile value for these specimens are lower than the base metal values base metal value for AA6063 is around 210Mpa and for AA7075 around 430Mpa. tensile values of FSW specimens are obtained higher than the TIG welded specimens. The tensile strength for both the welding metdods is shown in the below graph.

1) For FSW

When toll rotation speed is constant:

SL.NO	Tool rotating speed (rpm)	Welding speed (mm/min)	Tensile strength
S1	900	80	72.21
S2	900	200	85.68
S3	900	250	96.22

When welding speed is constant:

Sl no	Welding speed (mm/min)	Tool rotating speed (rpm)	Tensile strength
S4	100	710	84
S5	100	900	93.552
S6	100	1400	99.522

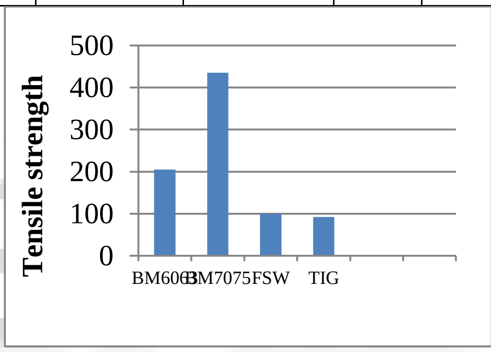
2) FOR TIG WELDING:

When current and voltage are constant

Sl no	Current(A)	Voltage(V)	Gas flow rate (min-1)	Tensile strength (MPa)
S7	100	20	5	68
S8	100	20	10	80
S9	100	20	15	92

When gas flow rate is constant

Sl no	Current(A)	Voltage(V)	Gas flow rate (min-1)	Tensile strength (MPa)
S10	100	10	5	81.10
S11	120	14	5	85.56
S12	140	16	5	91.1



The optimum tensile strength obtained from FS welded specimens is 99.522N/mm2 and from TIG welded specimens is 92N/mm2. The above graph revels that friction stir welding gives better tensile result when compared to tungsten inert gas welding.

IV. CONCLUSION

The following conclusion can be derived from this study:

1) 1.FSW and TIG welding have applied successfully to dissimilar AA 6063 and AA 7075 with no visible macroscopic defects or porosity across the weld region.
2) 2.In FS welding it is observed that nugget zone possessed with fine-equiaxed grains due to recrystallization where as in TIG welding grain size increased due to several heat input.
3) 3.Hardness graph reveal that FS welding gives better hardness when compared to TIG welding.
4) 4.Tensile strength values for both welds were lower compared to both base metal values. tensile strength reveals that dissimilar Al alloys are better suited to be welded with FSW process compared to TIG welding.

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