International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

Comparative Study Of Friction Stir And Tig Welding For Aluminium 6063-T6

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Abstract:
An experimental investigation has been carried out on microstructure, hardness distribution and tensile properties of weld butt joints of 6063 T6 aluminum alloy. 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) process. In this study it has been found that heat affected zone of FSW is narrower than TIG welding and mechanical properties like tensile strength etc. are within comfort zone and are better than TIG welding method. Microstructure results also favour FSW. Results showed a general decay of mechanical properties of TIG joints, mainly due to high temperature experienced by the material. Instead, in FSW joint, lower temperatures are involved in the process due to severe plastic deformation induced by the tool motion and lower decay of mechanical properties. Hence from industrial perspectives, FSW process is very competitive as it saves energy, has higher tensile strength, lower residual stress values and prevents the joints from fusion related defects.

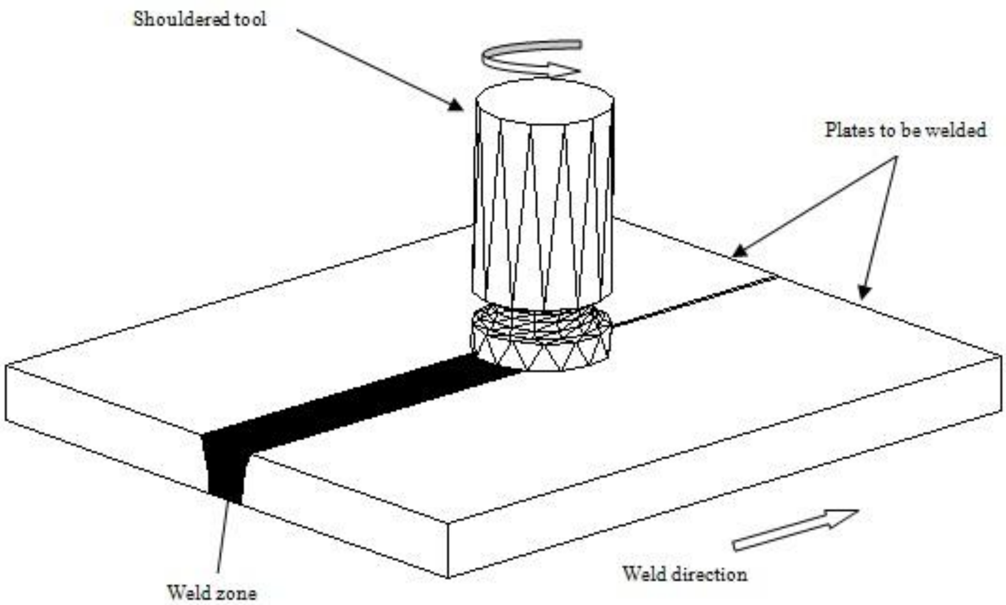
Keywords: Comparative Study;Friction Stir Welding; TIG Welding.

1. Introduction

1.1 *Friction stir welding*

Friction-stir welding (FSW) is a solid-state joining process (meaning the metal is not melted during the process) and is used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminum, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics. It was invented and experimentally proven by Wayne Thomas and a team of his colleagues at The Welding Institute UK in December 1991.

In FSW, a cylindrical-shouldered tool, with a profiled threaded/unthreaded probe (nib or pin) is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together. The parts have to be clamped rigidly onto a backing bar in a manner that prevents the abutting joint faces from being forced apart. The length of the nib is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work surface. The nib is then moved against the work, or vice versa.



1.2 *TIG welding*

Tungsten inert gas (TIG) or gas tungsten arc welding (GTAW) welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

2. Materials and Methods

Two plates of aluminium 6063-T6 of the dimensions 150×75 were taken for each welding. The composition of aluminium 6063-T6 is given in table:

Table 1. Aluminium 6063-T6 compostion

Element	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Ti**	**Cr**	**Al**
% Present	**0.2 - 0.6**	**0.35**	**0.1**	**0.1**	**0.45 - 0.9**	**0.1**	**0.1**	**0.1**	**BAL**

The plates were friction stir welded with the help of a rotating tool called FSW tool by holding the two plates together in a fixture as to withstand the high vertical downward force exerted by the tool. Material for FSW tool was tool steel hardened to HRC 60 and thread was left hand screw threads. Rotational speed of tool and welding speed was taken as 1500rpm (anti-clockwise) and 50mm/min respectively. CNC milling machine was used to perform the welding operation. Tool dimensions were taken as:

- Shoulder diameter = 14 mm
- Pin diameter = 6 mm
- Height of Pin = 5.8 mm

For TIG welding double pass was used with the combined bevel angle of 60^o for both the upper and lower surface. $AlSi_5$ was used as a filler rod for TIG welding. Other parameters for TIG welding were:

- AC welding with straight polarity
- welding current 90 amperes
- welding speed 120mm/min
- gas inflow 20ltr/min
- filler rod diameter 3mm

After the completion of welding a no. of specimens were taken from the welded plates for the purpose of tensile testing, microstrucural evaluation and hardness testing. Tensile testing specimen is shown in fig. 2. Universal testing machine was used for tensile testing. For the purpose of microstructural evaluation Scanning Electron Microscope (SEM) operating at 15Kv was used. For microstructure images small specimens were taken from different areas of the plate i.e. welded as well as non welded, polished and then etched with a keller's reagent.

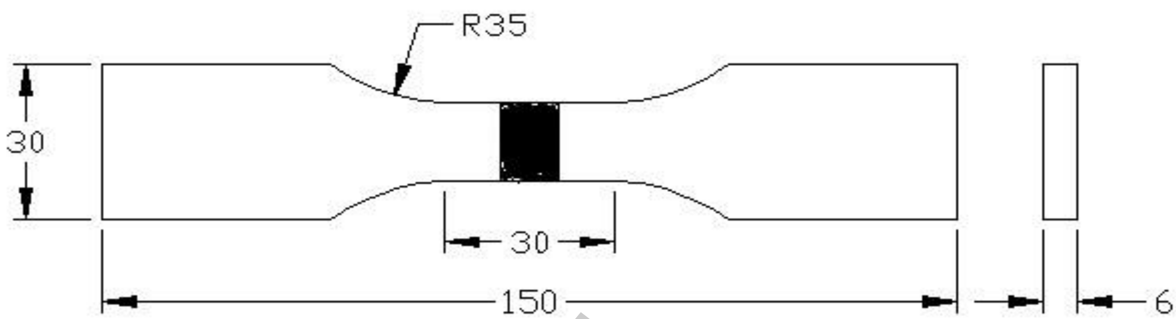


Fig. 2. Specimen for tensile testing.

3. Results and Discussions

3.1. *Mechanical Properties*

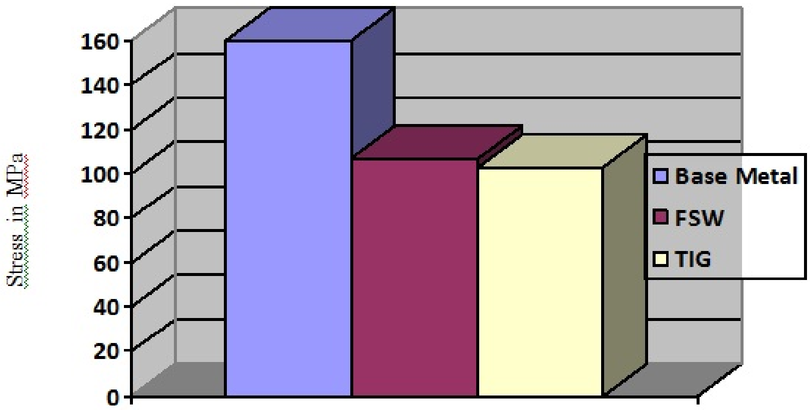


Fig. 3. Proof stress

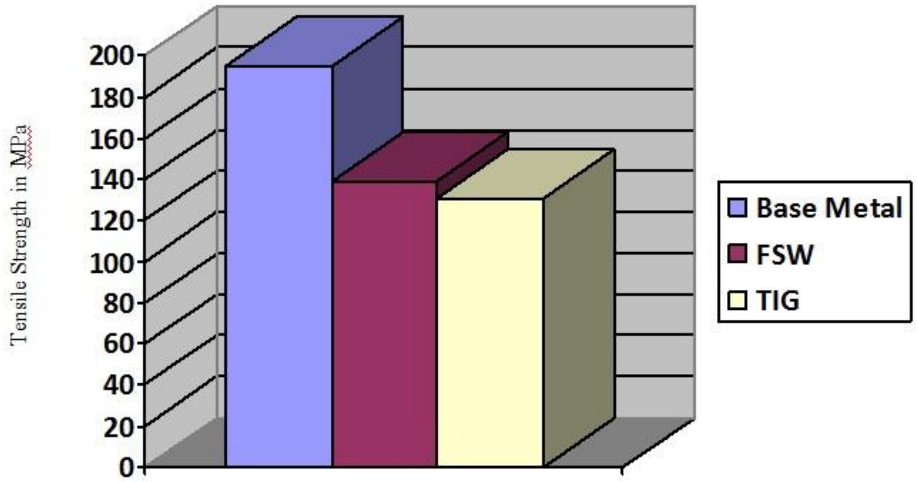


Fig. 4. Tensile strength

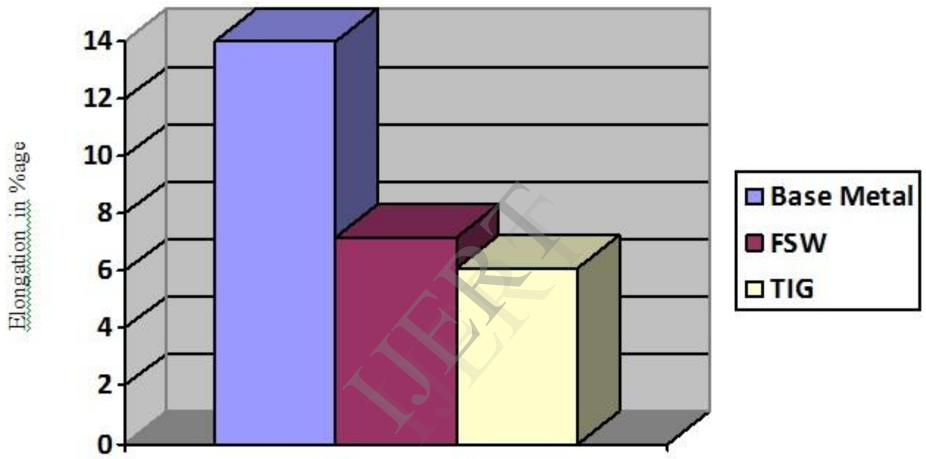


Fig. 5. Percentage elongation

Results of tensile testing are shown in fig.3, fig.4 and fig.5 respectively. It has been found that the tensile properties and percentage elongation of friction stir welded aluminium 6063-T6 is lower than the parent metal but are better than conventional welding methods i.e. TIG welding. The joint efficiency which is the ratio of tensile strength of welded joint to the tensile strength of base metal is near about 70% for friction stir welding as compared to 67% in TIG welding. Degradation of 0.2% proof stress and percentage elongation is 33% and 48% respectively for FSW. For TIG welding degradation of 0.2% proof stress and percentage elongation is 36% and 56% respectively.

3.2 Microstructure

Fig. 6 shows the microstructure of base metal which has a uniform structure with uniformly distributed very fine strengthening precipitates. Fig.7 shows the weld nugget zone of FSW (a) and TIG (b) at 1500X. The weld zone of FSW joint contains equiaxed grains and it is due to the dynamic recraystallisation during FSW process. The fusion zone (weld nugget) of TIG joint contains dendritic structure and it may be due to fast heating of base metal. Strength of base metal is due to alloying elements such as silicon and magnesium. These elements combine to form strengthening precipitates β”- Mg5Si6. These precipitates are stable at temperatures below 200^{o}C. In TIG HAZ and Weld nugget strengthening precipitates are lower than the base metal due to higher temperatures. In FSW temperatures are over 200-250^{o}C and β” is easily dissolved. In weld nugget temperatures are higher therefore Mg2Si precipitates goes into the solution. During cooling, precipititation time is limited due to which only a small fraction of β' precipitates are formed.

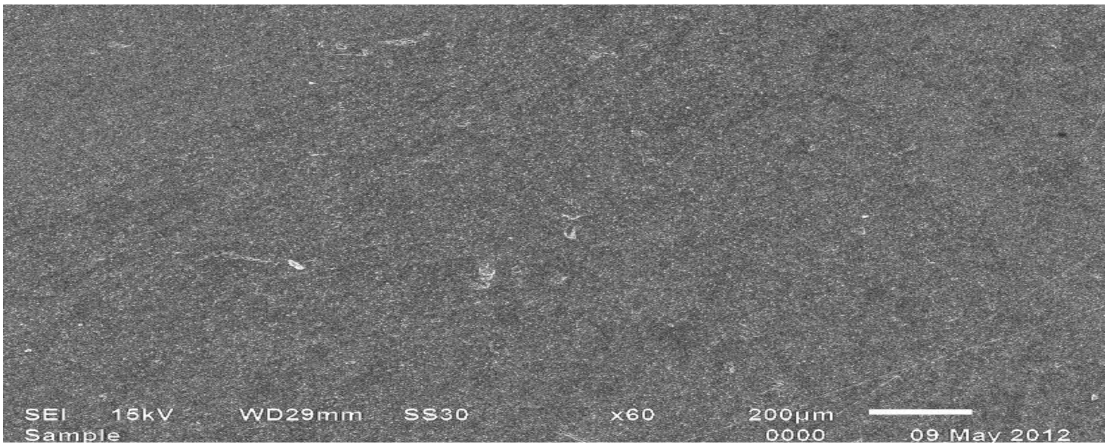


Fig. 6. SEM image of base metal

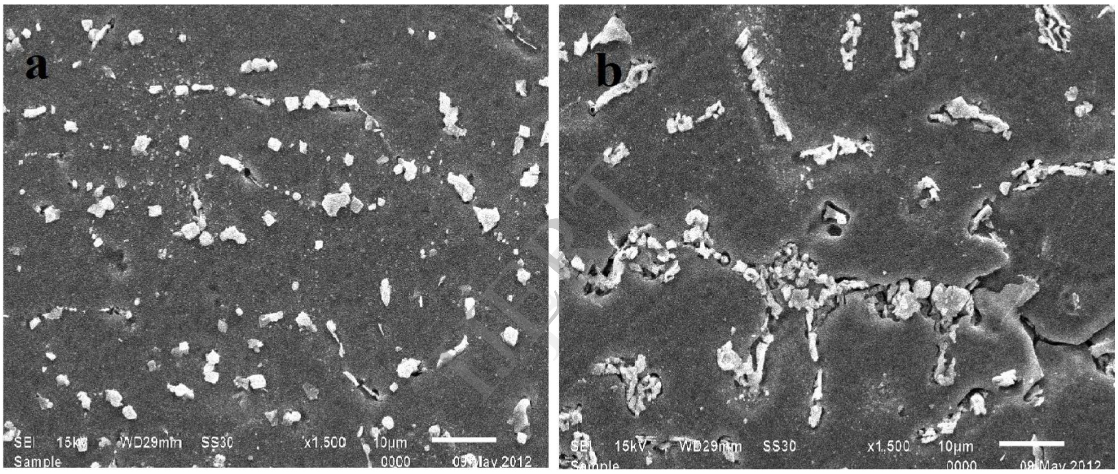


Fig. 7. SEM images of weld nugget: a) FSW, b) TIG

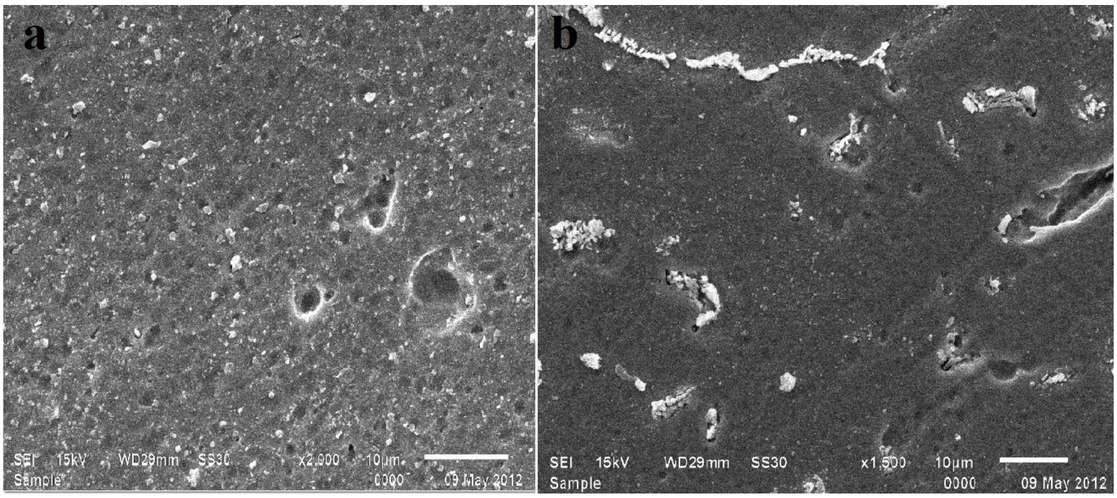


Fig. 8. SEM images of HAZ: a) FSW b)TIG

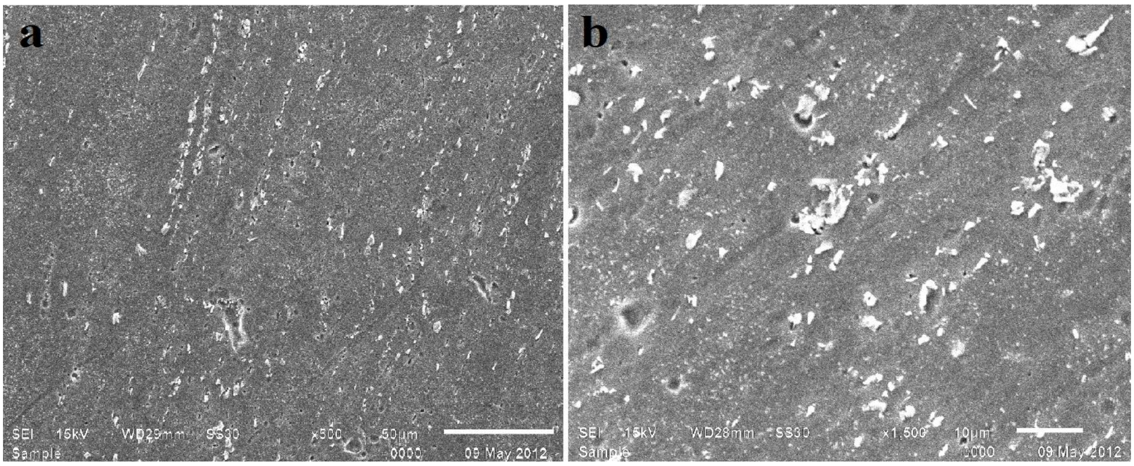


Fig. 9. SEM images of TMAZ of FSW at a) 500X b) 1500X

The friction-stir process produced precipitate differing from those in the base material, which has a high density of needle shaped precipitates with a low density of b8 precipitates. Between 12.5 and 10 mm from the weld center the density of needle shaped precipitates decreases. All precipitates are dissolved within a region of 8.5mm from the weld. all these combindly results in softening of weld.

Fig. 9 shows the images for thermo-mechanically affected zone whose properties lies in between those of base metal and heat affected zone. It is a zone which has recovered grains.

4. Conclusions

- The formation of fine, equiaxed grains and uniformly distributed very fine strengthening precipitates in the weld region is the reason for superior tensile properties of FSW joints compared to TIG joints.
- Tensile test results shows that FSW joints have higher strength and higher ductility compared to TIG joints. FSW joint exhibited higher strength values compared to TIG joint.
- Heat –affected zone of friction stir welding is narrower than TIG welding process.
- FSW requires less pre-operations than that of TIG.
- From industrial perspectives, FSW is very competitive because it saves energy due to less heat input, prevents joints from fusion related defects, is cost effective and has better strength than TIG joint.

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