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Experimental Comparison of Tig and Friction Stir Welding Processes for Aluminium 6063-T6

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ABSTRACT: The use of Aluminium-6063 is in aircraft and aerospace structures, boat building and ship building, architectural fabrication, window and door frames, pipe and tubing, and aluminium furniture, cycling frames and components. This is very crucial from the safety point of view. The joining of aluminium should be done in such a way so as to reduce the stresses produced during joining. The joining of aluminium can be done by using welding. Welding used can be of many types viz. Friction welding, Arc welding, spot welding, Tungsten inert gas welding, Metal inert gas welding, tungsten inert gas welding etc. Most advance type is Friction Stir welding, one with increasing popularity and most popular one is TIG welding. Mechanical properties as well as microstructure should be evaluated as a little alteration of these properties leads to premature failure of welding structures which is a matter of prime concern and should be evaluated from the safety point of view of welded structures. So aluminium-6063 welded by two technique, needs to be analyzed and compared for residual stresses, mechanical properties and microstructure etc. As TIG is the most widely used process for welding aluminium, so it needs to be compared with emerging welding techniques like FSW to assure best quality welds as far as possible.

I. INTRODUCTION

Aluminium is used in aircraft and aerospace structures, boat building and ship building, architectural fabrication, window and door frames, pipe and tubing, and aluminium furniture, cycling frames and components. Aluminium should be joining in such a way that so that it reduce the stresses produced during joining. The joining of aluminium can be done by using welding. Welding used can be of many types viz. Friction welding, Arc welding, spot welding, Tungsten inert gas welding, Metal inert gas welding, tungsten inert gas welding etc. Most advance type is Friction Stir welding, one with increasing popularity and most popular one is TIG welding. Mechanical properties as well as microstructure should be evaluated as a little alteration of these properties leads to premature failure of welding structures which is a matter of prime concern and should be evaluated from the safety point of view of welded structures. So aluminium-6063 welded by two technique, needs to be analyzed and compared for residual stresses, mechanical properties and microstructure etc.

As TIG is the most widely used process for welding aluminium, so it needs to be compared with emerging welding techniques like FSW to assure best quality welds as far as possible.

II. METHODOLOGY

CNC milling machine is used for welding aluminium through friction stir welding. Similarly standard TIG welding machine is used for welding aluminium through TIG welding. Electronic discharge machining is used for cutting samples from welded specimens for testing purpose. Tensile testing is done through universal testing machine followed by hardness testing which is done through Vickers hardness testing machine. Scanning electron microscopy is used for the purpose of microstructural evaluation. X-ray diffraction machine with multiple exposure technique is used for residual stress evaluation.

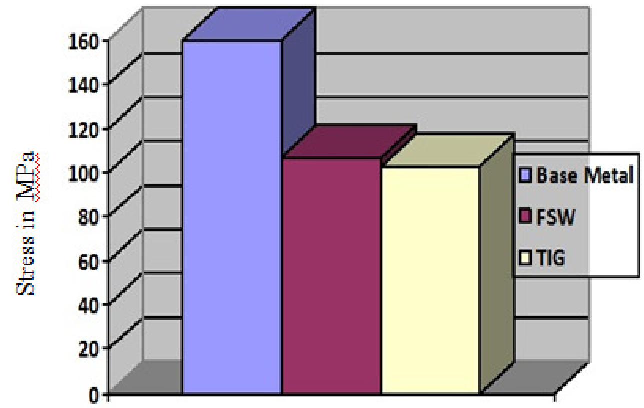
III. RESULTS AND DISCUSSION

In this chapter various results obtained from tensile testing, hardness testing, SEM microstructure, XRD testing for FSW and TIG welding is compared with the base metal as follows:

A. Tensile Testing

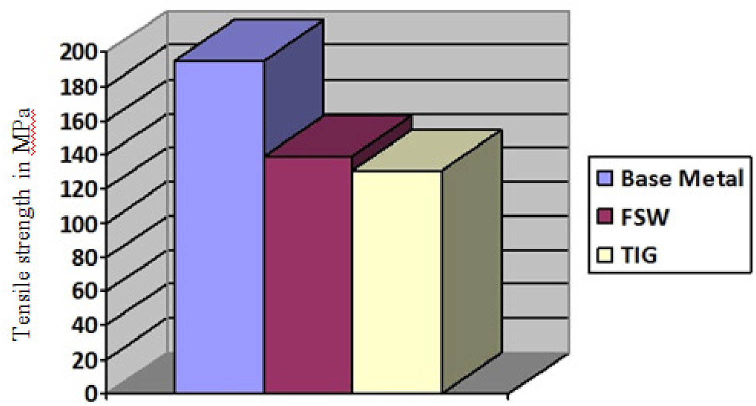
Results are shown according to their tests as given below: Proof Stress, Tensile Strength, Percentage Elongation. It has been found that the tensile properties and percentage elongation of friction stir welded aluminium 6063-T6 is lower than the parent metal but are better than conventional welding methods i.e. TIG welding. For both FSW and TIG joint the fracture location was in weld region.

Proof Stress

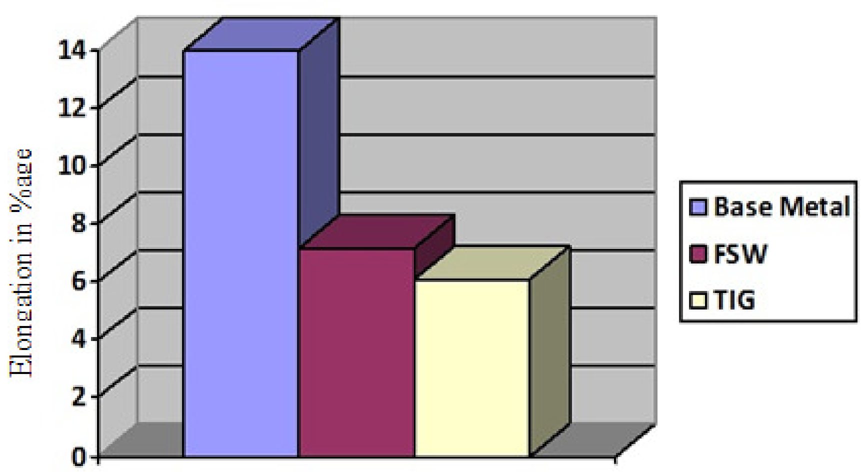


0.2% of Proof Stress

Tensile Strength



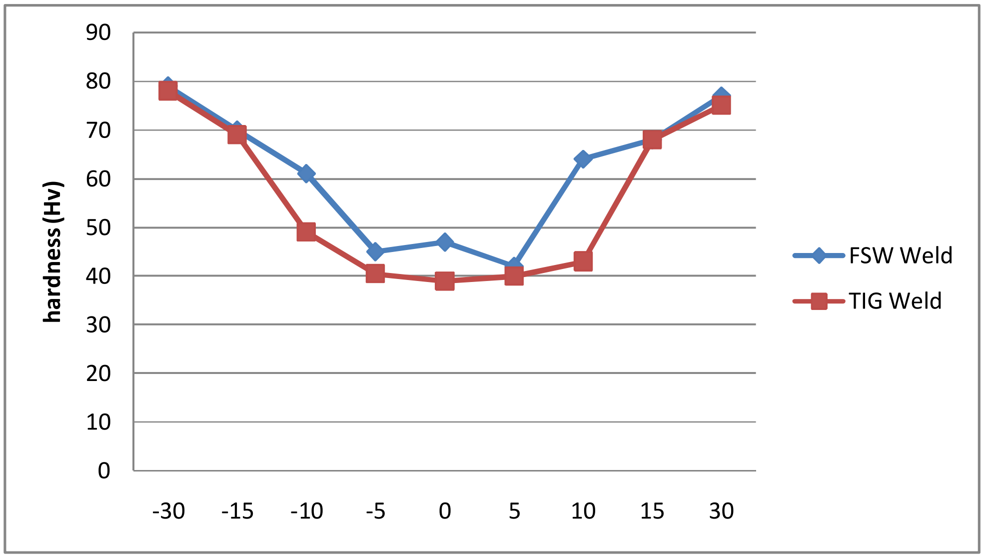
Percentage Elongation



B. Hardness Testing (Hv)

The Vickers hardness profile of the welded plates was measured at mid thickness on a cross section perpendicular to the welding direction using Vickers hardness tester with 500 gf load for 15 seconds.

Hardness points are taken at the nugget, TMAZ(for FSW), HAZ and base metal at a perpendicular direction from the weld at 0, -5,-10,-15,-30,5,10,15,30 mm respectively their distribution is shown in fig. 4.4. The Vickers hardness of the base metal was 80 Hv. The hardness of TIG joint in the weld metal region was 39 Hv. This shows that the hardness is reduced in TIG joint due to higher heat input and use of lower hardness $AlSi_5$ filler metal.



Hardness Profile (Hv) FSW v/s TIG

C. Microstructure

Fig. 1 shows the microstructure of base metal which has a uniform structure with uniformly distributed very fine strengthening precipitates. Fig.4.6 and 4.7 shows the weld nugget zone and heat affected zone of FSW (a) and TIG (b) respectively. 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''- Mg_5Si_6. These precipitates are stable at temperatures below 200°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°C and β'' is easily dissolved. In weld nugget temperatures are higher therefore Mg_2Si precipitates goes into the solution. During cooling, precipitation time is limited due to which only a small fraction of β' precipitates are formed.

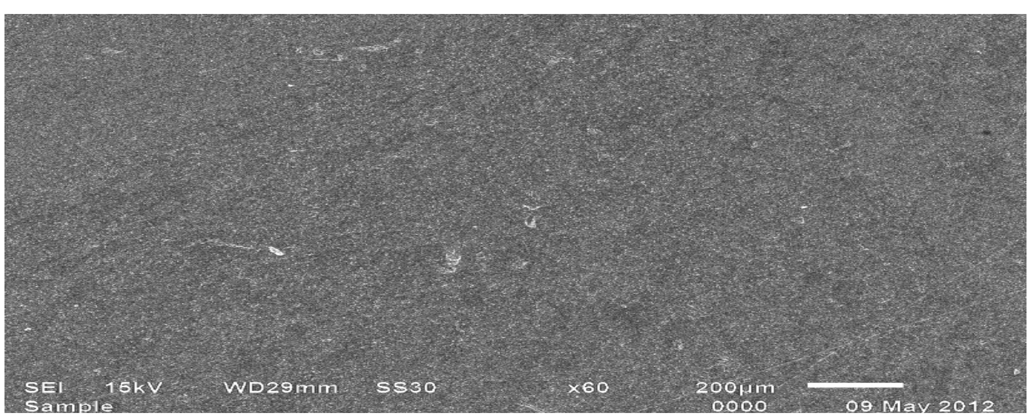


Fig. 1. SEM image of base metal.

The nugget hardness recovery is due to recrystalization of very fine grain structure and by natural aging. In FSW, friction heat softens the welded material at a temperature less than its melting point. The softened material underneath the shoulder is also subjected to extrusion by the rotating tool. It is expected that this process will inherently produce a weld with relatively few residual stress and distortion. When aluminum alloys are welded using non-heat treatable AlSi5 filler metal to avoid solidification cracking problem, the weld material is composed of fewer strengthening precipitates compared to base metal.

In fusion welding even though, large amount of silicon is available in base and filler metal (the available magnesium which is present in base metal alone) for precipitation reaction in the weld pool its content is very low. Hence, the weld region of 6063, when welded with AlSi5 filler metal usually contains lower amount of strengthening precipitates compared to the base metal region. Therefore the precipitate strengthening of Mg_2Si precipitates is weak in TIG joints. On the other hand, the weld region of FSW joint contains the alloying elements similar to the base metal.

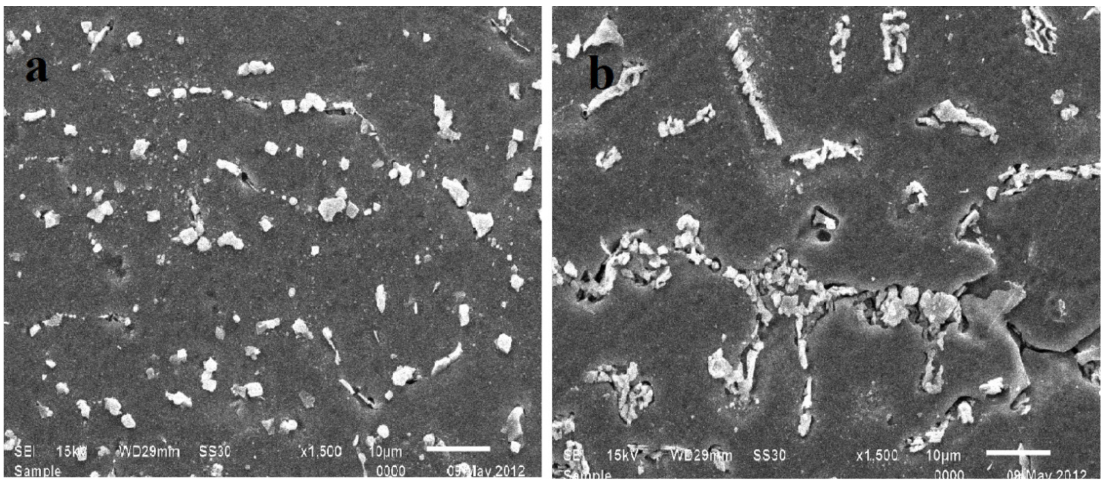


Fig. 2. SEM images of weld nugget: a) FSW, b) TIG.

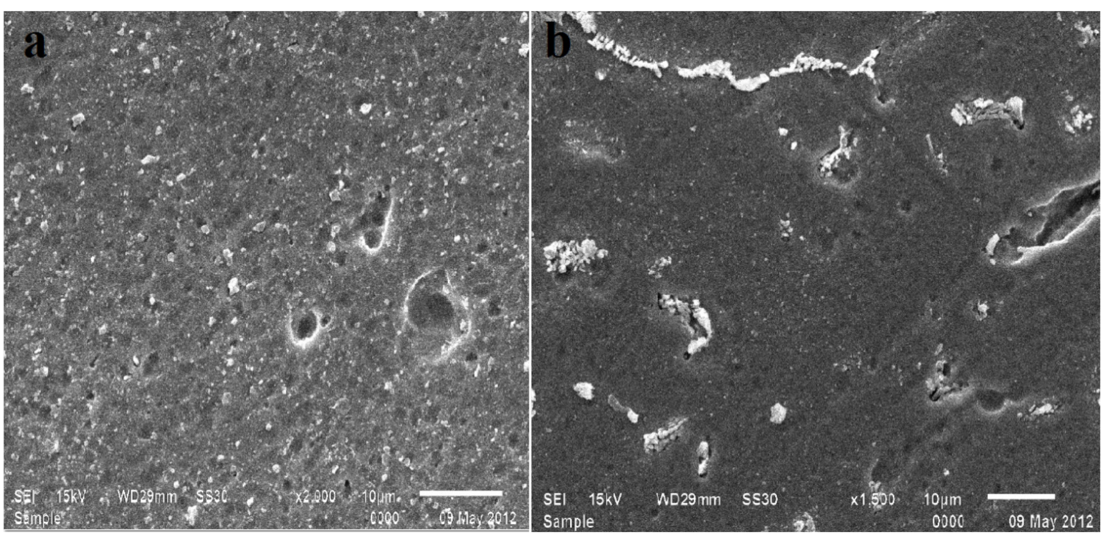


Fig. 3. SEM images of HAZ: a) FSW b) TIG.

D. Residual Stresses

The surface residual stresses for TIG and FSW were quantified at different locations across the weld. Specimens were cut from the welded plates using a wire EDM. The measurements were collected using the XRD in both longitudinal and transverse directions. The dimensions of the specimens and residual stress measurement locations are illustrated in Fig. 4. A summary of the surface residual stress measurements per location for FSW and TIG welding is provided.

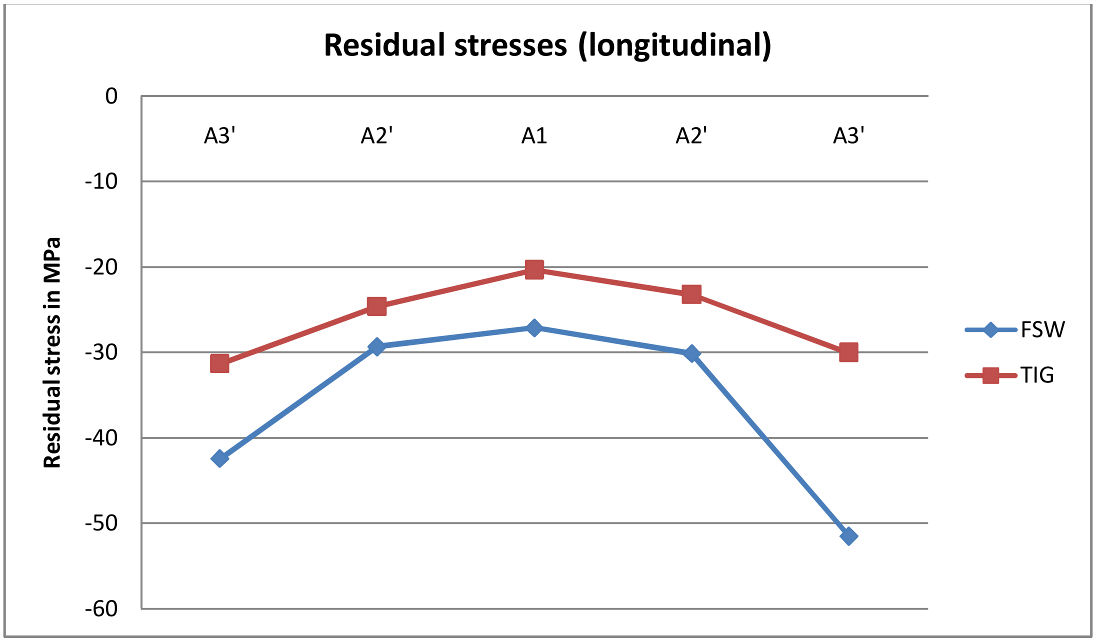


Fig. 4. Residual stress distribution for FSW v/s TIG welding (Longitudinal direction).

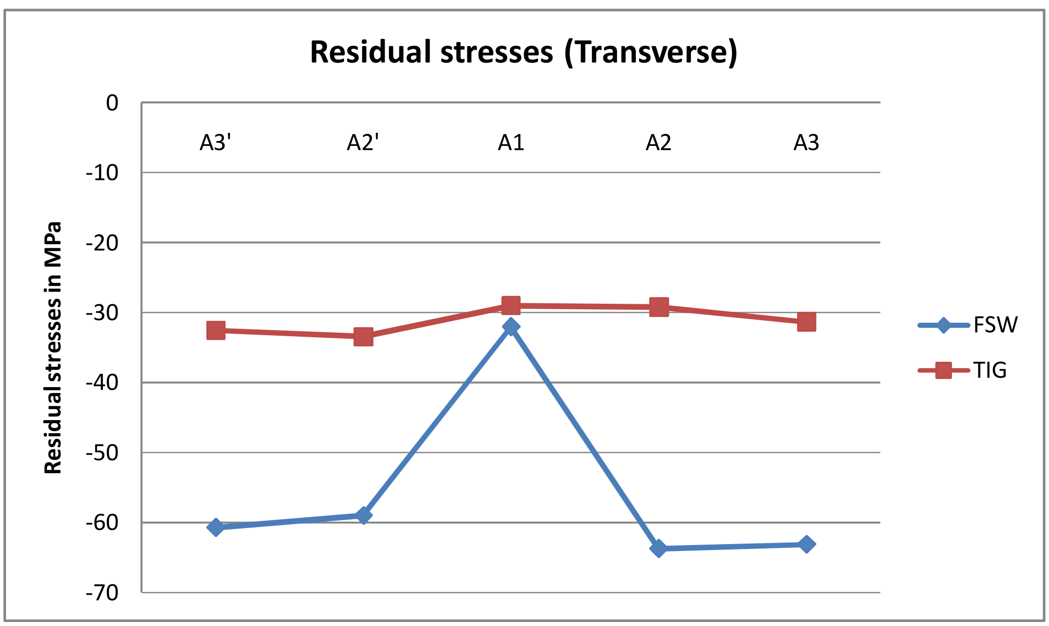


Fig. 5. Residual stress distribution for FSW v/s TIG welding (Transverse direction).

Results have shown that Residual stresses both in transverse as well as longitudinal direction are compressive in nature. These results indicate that sectioning did cause significant residual stress changes in the samples which becomes more compressive. There is 60-80% reduction in residual stresses after sectioning. It should be noted that all these measurements were taken at the surface; subsurface measurements may exhibit different values. Measurement taken at other locations at the surface are also expected to increase or decrease depending on the location relative to the weld centreline and direction of the residual stresses being measured. Measurements indicate that residual stresses were not uniform along the welded plate, and large variation in stress magnitude could be exhibited at various locations along the FSW plate as well as in TIG. As shown in results, it has been found that residual stresses are more compressive in case of FSW as compared to TIG with a highest value of -63.7 in longitudinal direction.

IV. CONCLUSION

On the basis of experimental investigation carried out on FSW and TIG welded joints of AA 6063-T6, the following conclusions are drawn:

- 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. 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.
- Hardness tests confirm the general decay of mechanical properties induced by higher temperature experienced by material in case of TIG joint.
- Hardness tests performed in case of FSW joint shows great differences among four different zones: nugget zone, TMAZ, HAZ (Heat affected zone) and base metal. The first two zones are characteristized by a general drop of mechanical properties, even though nugget zone showed a slight recovery due to fine grain structure.
- Sectioning did cause significant residual stress changes in the samples which becomes more compressive after sectioning. Measurements indicate that residual stresses were not uniform along the welded plate, and large variation in stress magnitude could be exhibited at various locations along the FSW plate as well as in TIG welded plate.

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