# Evaluation of Strength Degradation and Microstructure in Friction Stir Welded Aluminium 6063-T6

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## Abstract

*Friction stir welding (FSW) is a new welding technology, which has been applied widely in aerospace, traffic, marine, industriesetc. because of its unique mechanical properties and metallurgic structure. It is common importance to find strength degradation and microstructure in FSW welded aluminium 6063-T6because of its applications ranging from rail road to aerospace vehicles. For this purpose an experimental investigation has been carried out on strength degradation using tensile and microstructural testing of FSW butt welded joints of 6063 T6 aluminum alloy. SEM technique is used to find out the microstructure at different points .In FSW joint, lower temperatures are involved in the process due to severe plastic deformation induced by the tool motion resulting in lower decay of mechanical properties. In the nugget zone there is a recrystallisation of very fine grain structure. Hence from industrial perspectives, FSW process is very competitive as it saves energy, has higher tensile strength and prevents the joints from fusion related defects.*

***Keywords:*** *Evaluation, Strength degradation, Microstructure, Friction Stir Welding*

## 1. Introduction

In the early 1990s a newly developed welding technique generated significant interest because of a whole range of advantages over more conventional techniques. This new technique, friction stir welding (FSW), can weld together two sheets in the solid-phase i.e. there is no melting involved. The process is relatively simple: a cylindrical tool is rotated and plunged into the joint line between the two pieces that are to be welded together. The frictional heat generated by the welding tool and the surrounding material lcauses softening and allows the tool to be moved along the joint line. The material is plasticised and is transferred from the leading edge of the tool to the trailing edge, leaving a solid-phase bond between the two pieces (see figure 1).

Friction stir welding has many benefits over conventional welding techniques, such as the ability to join materials that are difficult to fusion weld, like the high strength 2xxxaluminium alloys. Some of the other benefits include the lack of distortion, the excellent mechanical properties of the weld and the energy efficiency of the process.

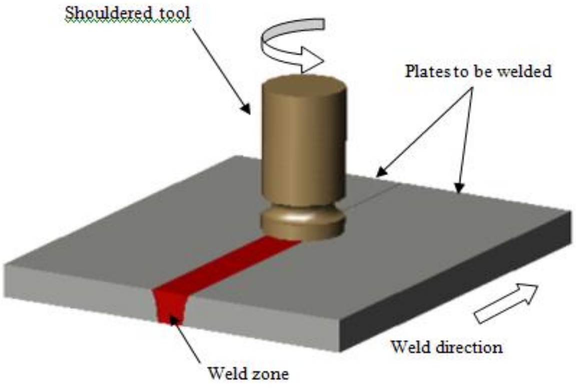


Fig. 1: Two discrete metal work pieces butted together through FSW

Today, FSW is mainly used in the aircraft, aerospace, automotive and electrical industries, considered a valuable technique for butt and lap joint welding of aluminium alloys with a range in plate thickness from 0.8 to 75 mm, with speed up to 600 cm/min. In order for the technique to be routinely applied to these applications, the mechanical properties of resultant weld must be fully understood and accurately predicted.

## 2. Materials and Methods

6 mm thick plates of aluminium 6063-T6 were machined to the required dimensions (150×75). Chemical composition of 6063-T6 is given in the table

Table 1: Al 6063-T6 composition

| 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 |

These plates of the given dimensions were friction stir welded by butting two plates together with the help of a rotating tool called Friction stir welding tool. The rotational speed of the tool was taken as 1500 rpm (anticlockwise) while the welding speed was taken as 50 mm/min. CNC machine (milling) was used to perform this experiment. The material of the friction stir welding tool was tool steel hardened to HRC 60.

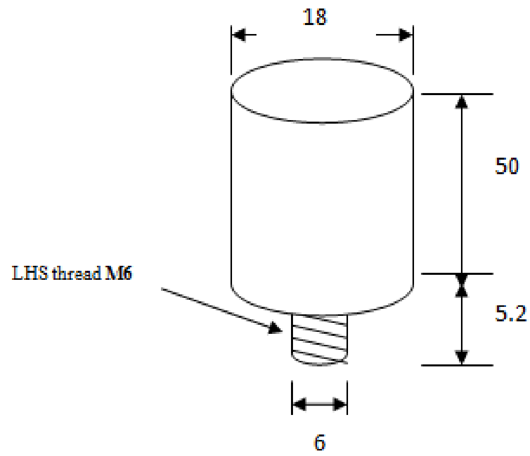


Fig. 2: Friction Stir welding tool design

Geometry of the tool is shown in fig. 2. Tool dimensions was taken as:

Shoulder diameter = 14 mm

Pin diameter = 6 mm

Height of Pin = 5.8 mm

Threads of the friction stir welding tool pin was left hand screw threaded such that the tool rotation will be anticlockwise

After the welding was accomplished different specimens were taken from the welded plates for the purpose of strength tests and microstructure tests etc. Specimen for tensile testing is shown in fig.3. tensile tests were performed on universal testing machine.

Microstructural changes were examined with scanning electron microscope (SEM) operating at 15kv. For the microstructure images the cross-section of the weld was polished and then etched with keller's reagent.

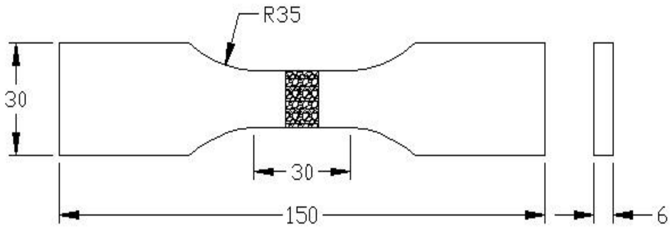


Fig. 3: Specimen for tensile testing

## 3. Results and Discussions

### Mechanical Properties

Results of tensile testing are shown in fig.4, fig.5 and fig.6 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 far better than other conventional welding methods like TIG welding. The joint efficiency which is

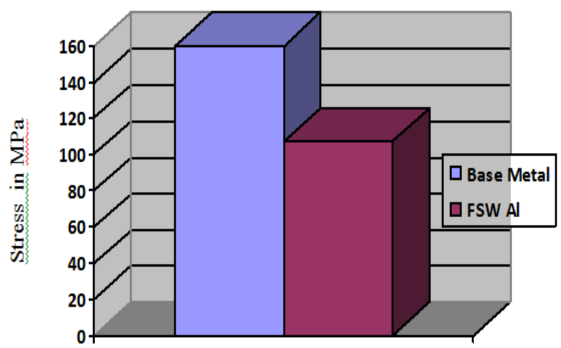


Fig. 4: Proof Stress (0.2%)

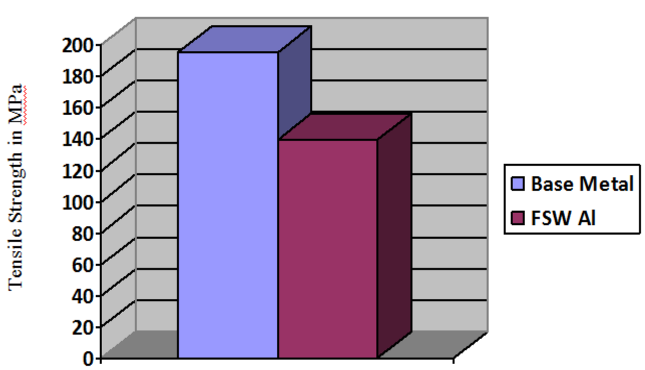


Fig. 5: Tensile Strength

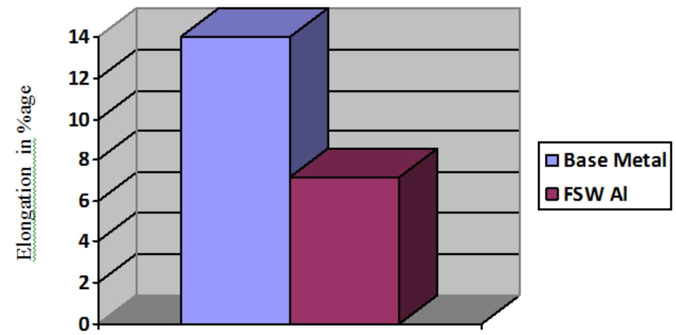


Fig. 6: Percentage Elongation

the ratio of tensile strength of welded joint to the tensile strength of base metal is 69% for friction stir welding in this case . Degradation of 0.2% proof stress and percentage elongation is 36% and 52% respectively.

### Microstructure

Microstructures taken by SEM operating at 15kv are shown in fig.7 and 8 respectively. Fig.7 shows the microstructures of base metal, friction stir welded weld nugget and thermo mechanically affected zone at 200X whereas fig.8 shows microstructures of weld nugget, TMAZ and HAZ at 1500X respectively.

Base metal has equiaxed grains with uniformly distributed very fine strengthening precipitates denoted as β”. Base metal has a very high strength due to the presence of alloying elements like silicon and magnesium and iron. These high strengthening precipitates are stable at temperatures below 200$^0$C

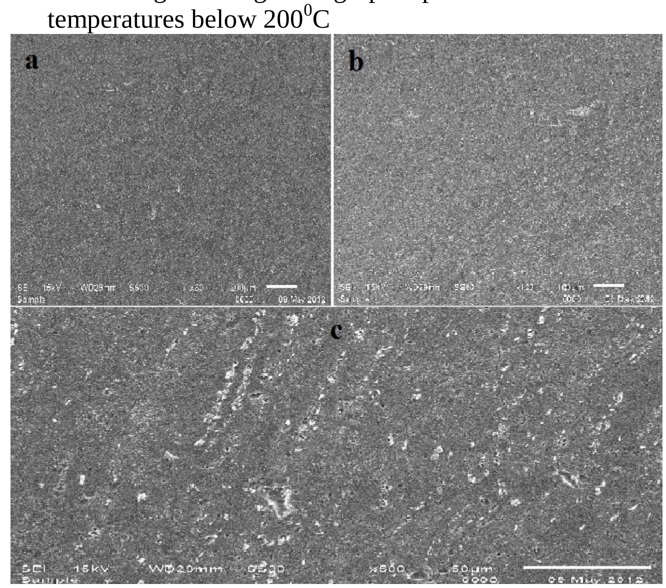


Fig. 7: SEM images of base metal (a), FSW weld nugget (b), and FSW TMAZ (C) respectively

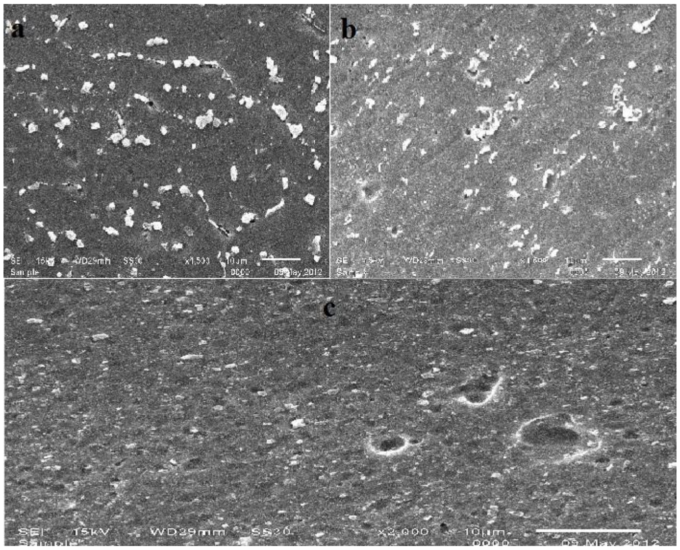


Fig. 8: SEM images weld nugget (a), TMAZ (b) and HAZ (c)

B" precipitates are absent in weld nugget and heat affected zone as the temperature are over 200$^o$C in these regions. So these precipitates are dissolved. In HAZ precipitate β' exist i.e. there is a transition from β" to β' ($Mg_2Si$) at elevated temperatures by dissolution. Weld nugget has a fine recrystallized structure In the weld nugget temperature is high, so β'' precipitates goes into the solution. Only a small fraction of β' are formed due to the limited time of precipitation .

Thermo- mechanically affected has coarse bent recovered grains. This region is characterized by recrystallization arising from frictional heating and plastic flow during the welding. Interface between weld nugget and HAZ is a weaker region that's why joint is fractured at this region.

## 4. Conclusions

- Tensile strength, proof strength and percentage elongation is within comfort region
- Heat –affected zone of friction stir welding is narrower than other welding processes
- The friction-stir process produced precipitate distributions differing from those in the base material, which contains a high density of needle shaped precipitates
- The density of needle-shaped precipitates decreases at the region between 8.5 and 10 mm from the weld center. All precipitates dissolved at the regions within 8.5 mm of the weld
- The required pre operations before welding are very limited in FSW
- FSW saves consumable material time cost and improves the quality of the welds

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