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# Mechanical Properties of Friction Stir Welded Aluminium 6082 to Copper

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## Abstracts

The aim of present study was to analyze the influence of the microstructures and mechanical properties of friction stir welded joint of 6082 aluminium alloy and copper plates in 3 mm thickness with using filler materials. With this aim, welds were produced using High molybdenum high speed steel, with a cylindrical pin tool having 3 mm and 14 mm diameter of pin and shoulder respectively. The microstructures of weld were studied by optical microscopy and grain size in TMAZ, HAZ and NZ were analyzed. Vicker's microhardness tests were done in transverse direction of weld to check the hardness distribution in HAZ, TMAZ and weld nugget. Transverse tensile test were performed to evaluate the weakest portion of weld joints.

**Keywords**: Friction stir welding, Aluminium Alloy, copper, Hardness, Tensile testing.

## Introduction

Friction Stir Welding (FSW) is a revolutionary solid state welding technique invented at The Welding Institute (TWI) in 1991 [1]. The FSW process operates below the solidus temperature of the metals being joined. This process is a derivative of the conventional friction welding and is being used to produce continuous welded seams for plate fabrication [2].

FSW is considered to be the most significant development in metal joining in a decade. It is also a ''green'' technology due to its energy efficiency, environment friendliness, and versatility [3]. As compared to the conventional welding methods, FSW consumes considerably less energy. No shielding gas or flux is used, thereby making the process environmentally friendly [4]. The joining does not involve any use of filler metal. During initial phase of development, the process was very widely used for joining similar Al alloys. However, dissimilar aluminum alloys and composites can also be joined with equal ease. In contrast to the traditional friction welding, this is usually suitable for small axisymmetric parts which can be rotated and pushed against each other to form a joint, Friction stir welding can be applied to various types of joints like butt joints, lap joints, T butt joints and fillets [5].

## Experimental process

AA 6082 aluminum and commercially pure copper plates with the size of 150×100×3 mm were welded by using a vertical milling machine. In the present work high molybdenum high speed steel tool is used. The tool was having concave shoulder. The tool shoulder diameter was kept 14 mm with 2.7 mm pin length and 3 mm pin diameter. The tool pin was cylindrical. Welding were carried out with rotating pin in anti clock wise direction at constant 1000 rpm tool rotation speed and 28 mm/min tool feed rate with using different percentages of filler materials like Tin, Zinc, SiC and Rare earth. For microstructure analysis, welded samples are taken cross sectional. For microstructural characterization, specimens were prepared as per standard metallographic procedure. Initially intermediate polishing was done by SiC abrasive papers with 1/0, 2/0, 3/0 & 4/0 grit numbers. Subsequently polished specimens were finely polished with 5µm Alumina powder + water solutions. Finely polished specimens were etched. For Al side regions 4 ml HF + 100 ml $H_2O$ solution was applied as etchant. Pure Cu side was etched with a mixture of 0.1 L $H_2O$ + 4 ml saturated NaCl solution + 2 g Potassium dichromate + 8 ml $H_2SO_4$. Optical micrographs of weld interface were taken. Vickers microhardness of the welded joint in transverse direction was measured. A diamond indenter was used with load of 200g and a dwell time of 10 seconds. The indentations were taken in the various zones like NZ, TMAZ and HAZ. Microhardness samples were selected after tensile testing.

## Result and discussion

The friction stir welding on AA 6082 to pure copper was successfully carried out..

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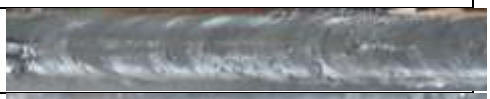
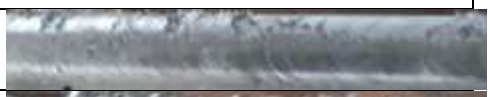
| SAMPLES | WELD JOINT |
|---|---|
| Al/Cu with Tin |  |
| Al/Cu with Zinc |  |
| Al/Cu with SiC |  |
| Al/Cu with Rare earth |  |

***Figure: 1 Friction stir welded joints of AA 6082 to copper***

The welding was carried out at constant rotation speed of 1000 rpm and constant feed rate of 28 mm/min and carried out with filler metal powders and without filler metal powders with in various amounts likes 0.5%, 1% and 1.5%. Defects free weld obtained during welding. For welding vertical milling machine used. Different welded joints were shown below fig.1

**Microstructurecharacterization**

The micrographs of the weld specimen were taken at 400X magnification. The Base metal, HAZ, TMAZ and nugget regions were studied. The characterization was done on the cross section of the specimen.

***Figure: 2 Microstructre of NZ at 400X magnification***

Fig. 2 shows different microstructure of Al/Cu at NZ. In nugget zone proper mixing of metals. Due to high temperature obtain during Zinc metal powder so, onion ring observed in the NZ.

**Tensile testing**

Tensile properties of friction stir weld joints of Al/Cu are given below.

| Material | Yield strength ($N/mm^2$) | Ultimate strength ($N/mm^2$) | % Elongation |
|---|---|---|---|
| Al/Cu Tin | 79.53 | 79.53 | 8.95 |
| Al/Cu Zinc | 108.14 | 108.14 | 3.86 |
| Al/Cu SiC | 132.55 | 182.15 | 5.26 |
| Al/Cu Rare earth | 134.65 | 193.18 | 10.53 |
| Al/cu | 59.84 | 59.84 | 5.61 |

Higher ultimate tensile strength was 218.90 MPa and higher yield strength was 135.43 MPa

**Microhardness study**

Fig.3 shows the hardness profiles of the Al/Cu FSW welds.

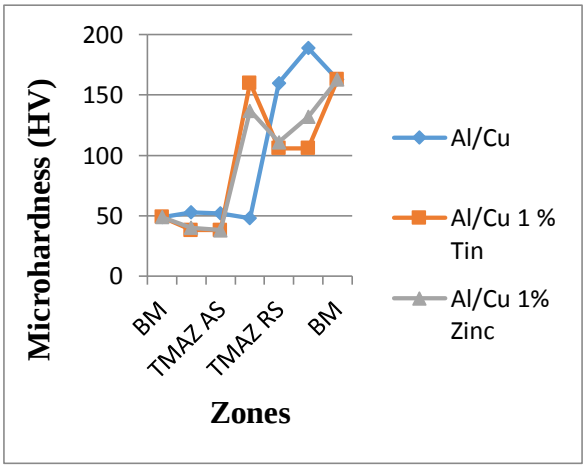



***Figure: 3 Microhardness values of Al/Cu***

Microhardness values were found to be 163 for copper base metal & 49 for aluminium base metal.

Higher microhardness was found at joining of Al/Cu with Tin Filler metal powder at Nugget zone.

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## Conclusion

All welds were defect free. Microstructures of weld were shown different regions, like TMAZ and Nugget Zone. Microharness in NZ of Al/Cu with Tin metal powder was higher than other filler metal. Tensile strength of Al/Cu with rare earth was higher than other filler metals.

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