MECHANICAL AND TRIBOLOGICAL PROPERTIES OF FRICTION STIR WELDING ALUMINIUM MMC USING CYLINDRICAL TAPERED TOOL

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Abstract : Improvement of welding techniques to join aluminum metal matrix composite holds key to substitute convectional aluminium alloys in numerous applications. In the present investigation Al 6061 are reinforce with Micro titanium plus E- glass fibre. By using, stir casting Plates of six mm thickness are prepared from the casting and effectively butt joined using FSW. Cylindrical tool by incline angle of 1° used for FSW with varying constraints like tool rotational speed and traverse feed. The tool rotating speeds of 1000, 1100, 1200 rpm and traverse feed of 0.67, 0.83 and 1 mm/sec are incorporated. Tensile test specimens are prepared according to ASTM standards and the utmost ultimate tensile strength obtained for 1000 rpm speed and 0.67mm/sec feed. Wear performance of the composite was evaluated by pin-on-disc wear testing with changeable loads of 0.5, 1, 1.5kg. The minimum value of wear loss at 1kg load obtained are 1200rpm speed and 1 mm/sec feed.

Index Terms - **FSW tool, Tensile strength of FSW joints, Al MMC, FSW joints process parameters**

I. INTRODUCTION

Aluminium alloys extensively used in lot of engineering applications like transportation and manufacture. Engineering applications requires higher mechanical properties such as a very sound hardness, tensile strength etc. and better mechanical properties significantly met by using Al 6061. We require a lightweight, commercially feasible material, which exhibit better performance and strength. Aluminium and its alloys subjected to several researches. In that, Al6061 is utmost, preferable since it has better properties resistance towards corrosion, tensile strength, etc. therefore used in marine, structural, automotive and other applications.

Composites being materials composed of a combination of two or more constituents that differ in form and chemical composition have wide range of applications due to the insolubility of matrix and dispersoid and overall high strength. Metal matrix composites include metals and alloys as the matrix phase with the ability to tolerate the load and handover it to the reinforcements. E- Glass fibre, material consisting of extremely fine strands of silica-based glass having excellent dimensional stability, chemical resistance, resistance to abrasion and vibration is an excellent choice for reinforcement. Micro titanium has resistance towards corrosion and improves the fine properties of the formed composite. Friction Stir Welding do not require any filler material and it is a solid-state joining process. The energy efficiency and environmental friendliness makes FSW is a good manufacturing process to join. FSW requires a tool, which should revolve at high speed. The tool profile consist of shoulder and probe. Functions of shoulder is to apply downward pressure on the workpiece. The performance of weld quality depend on FSW parameter as well as design of the tool. The weld nugget has fine microstructures when compared with TMAZ and base material. The limitations of FSW reduced by intensive research and development. The tool rotational speed, traverse speed, tool pin profile and immersion of tool pin in base material are the important parameters that largely influence the mechanical properties and weldability. The rotational speed of the tool is the most important welding parameter as it influences the microstructure and mechanical properties of the FSW welds. The tool tilt angle is the angle of the spindle with respect to the work surface and affects the material flow around the tool. Finally, mechanical properties of the weld widely depend on the tool geometry. It also provides heating, stirs base material, and thus creates weld.

II. EXPERIMENTAL PROCEDURE

2.1 Stir Casting

The investigation is on the fabrication of Aluminium based metal matrix hybrid composites with the following composition. Aluminium 6061 metal matrix with E glass fibre and micro titanium particles as reinforcements for this work. Stir casting used to produce Al MMCs. Stirrer design; stirrer speed and stirring time are the process parameters is considered. The furnace temperature is around 750°C Al 6061 will melt at this temperature. At this point, the heated reinforcement added manually to the vortex. Then molten Al and reinforcement added stirred at 450 rpm. The mould of dimensions are 250*200 mm used to cast the composite plates. The cast composite plates cooled and then machined to 150*75*6 mm dimension by CNC machining.

2.2 Friction Stir Welding

In FSW, the material used for welding will be in solid state only and joining of two materials takes place well below the melting temperature therefore, a superior weld is made. The plunging of the tool results in the forging action and heat generation in the weld zone. Cylindrical tapered tool made of H13 material is used. The tool has the tool pin length, shoulder diameter and taper angle of 5.75mm, 23mm and 1° respectively. Tool rotational speeds of 1000, 1100, 1200 rpm and traverse feed of 0.67, 0.83 and 1mm/sec were used. The specimens that are fabricated through stir cast moulding are friction welded to get strong welded plates of Al 6061 hybrid composites. The tensile and wear specimens are machined by using Wire EDM to ASTM E-08 and ASTM G-99 standards.

2.3 Tensile Test

Uni-axial tensile testing was used for tension testing of the materials. Figure 1, shows the dimensions of Tensile samples. The specifications of the tensile specimen that were set according to ASTM standards were Gauge length of 25 mm, Width of 10 mm, Thickness of 6 mm and Overall length of 100 mm. The specimens were subjected to a controlled tension, until it failed. Figure 2 shows the failure sample of tensile test , failure took place almost in TMA zone.

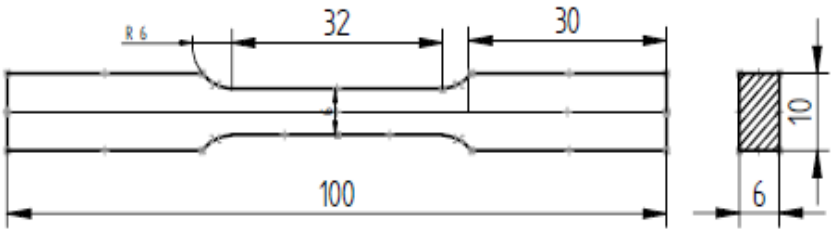


Fig 1. Dimensions of tensile test specimen (all in mm)

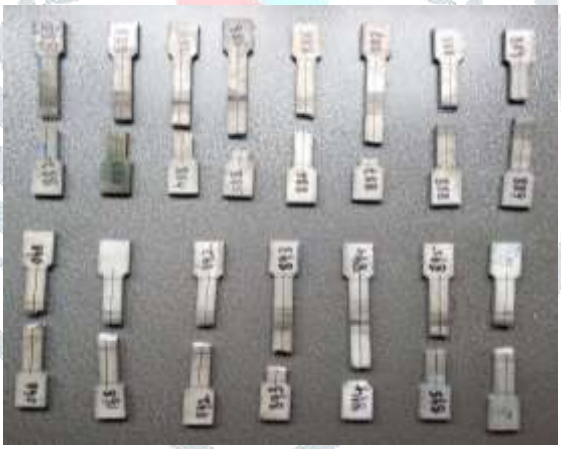


Fig 2. Failure Tensile samples

2.4 Micro Hardness

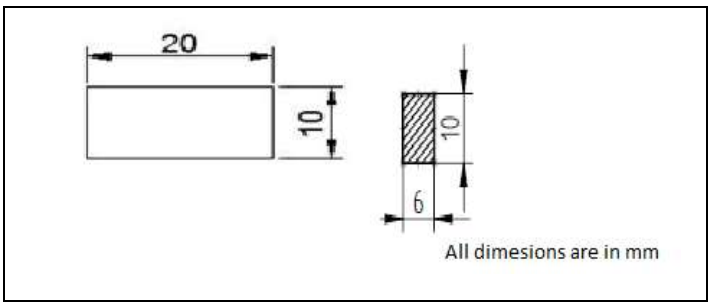


Fig 3. Hardness samples dimensions

The Vickers micro hardness samples were prepared according to ASTM Standards. The specimen was prepared in the dimensions as shown in Figure 3.

2.5 Wear Test

Wear behaviour of FSW plates in five different zones wear analysed by pin on disc apparatus. The specifications of the wear specimen that were prepared according to ASTM standards. Diameter of 10 mm, Pins were attached using fits to the specimens to carry out the test.

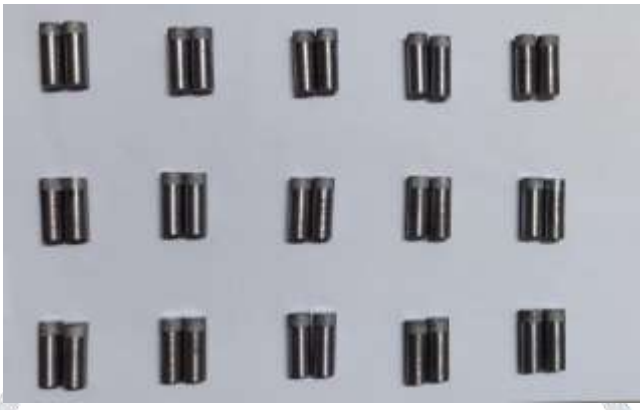


Fig 5. Wear specimens with pin

2.6 Scanning Electron Microscopy

SEM was conducted to study the microstructure of the formed composite and weld obtained by friction stir welding. Microstructural analysis through SEM helped analyse the various micro grain structures at different regions and determine the grain structure in various weld zones.

III. RESULTS AND DISCUSSION

3.1 *Tensile behavior of composites*

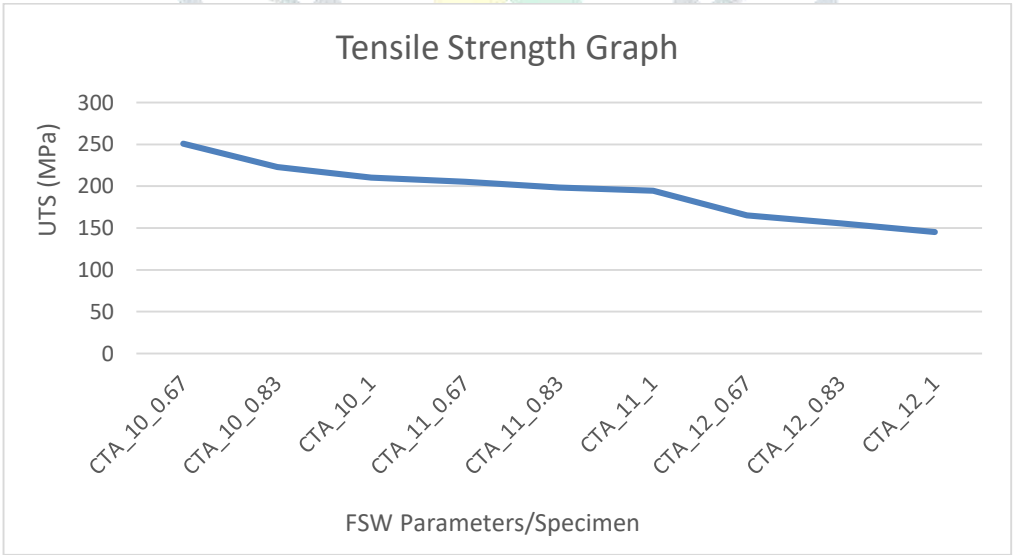


Fig 6: Variation of UTS

In figure 6, the Ultimate tensile strength of Al MMCs with varying welding parameters are indicated. Cylindrical tapered tool FSW parameters are speed 1000, 1100 and 1200 rpm. Feed rate 0.67, 0.83 and 1 mm/sec. For speed of 1000 rpm, different feed rate 0.67, 0.83 and 1 mm/s . 0.67 mm/s feed rate will give maximum tensile strength of 250.838 Mpa. For speed of 1100 rpm and varying feedrate 0.67 mm/s will give maximum tensile strength of 205.41 Mpa. For speed of 1200 rpm and varying feedrate 0.67 mm/s will give maximum tensile strength of 165.144 Mpa. The trend of Ultimate tensile strength will decrease when rotational speed has increased. Maximum Ultimate tensile strength is for speed of 1000 rpm and 0.67 mm/s.

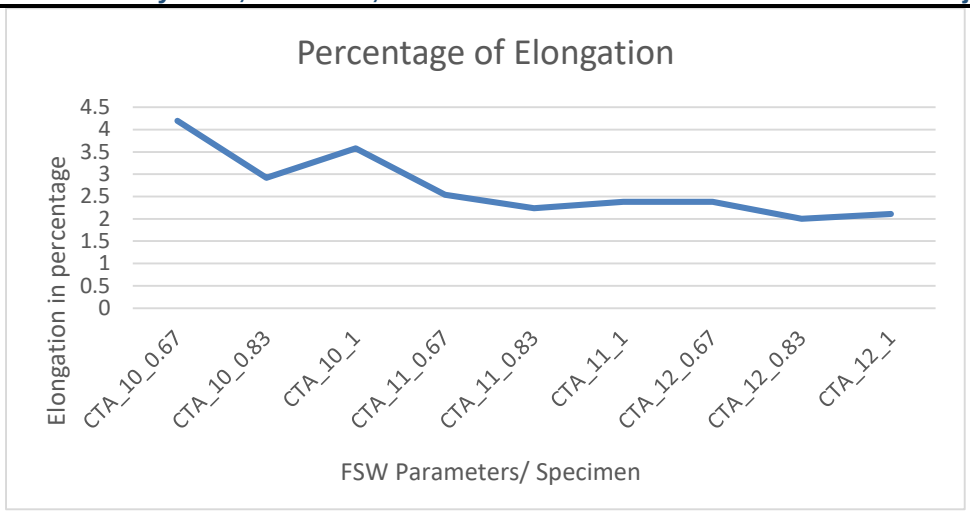


Fig 7: Variation of Percentage of elongation in tensile test

Fique 7 indicate the percentage of elongation of Al MMCs with different FSW parameters. Will analyze percentage of elongation with fixed speed 1000, 1100 and 1200rpm and varying feed rate. Firstly the percentage of elongation when working at a speed of 1000 rpm and 0.67 mm/s feed rate, 4.2 percentage of elongation were obtained. This is the maximum percentage of elongation when compared with 0.83 and 1 mm/s feed rate for 1000 rpm. When working at a speed of 1100 rpm and 0.67 mm/s feed rate, 2.54 percentage of elongation were obtained. This is the maximum percentage of elongation when compared with 0.83 and 1 mm/s feed rate for 1100 rpm. When working at a speed of 1200 rpm and 0.67 mm/s feed rate, 2.38 percentage of elongation were obtained. This is the maximum percentage of elongation when compared with 0.83 and 1 mm/s feed rate for 1200 rpm. Finally, the Maximum percentage of elongation for cylindrical tapered tool is 4.2 Percentage and this is obtained for 1000 rpm and 0.67 mm/s feed rate.

3.2 Micro hardness

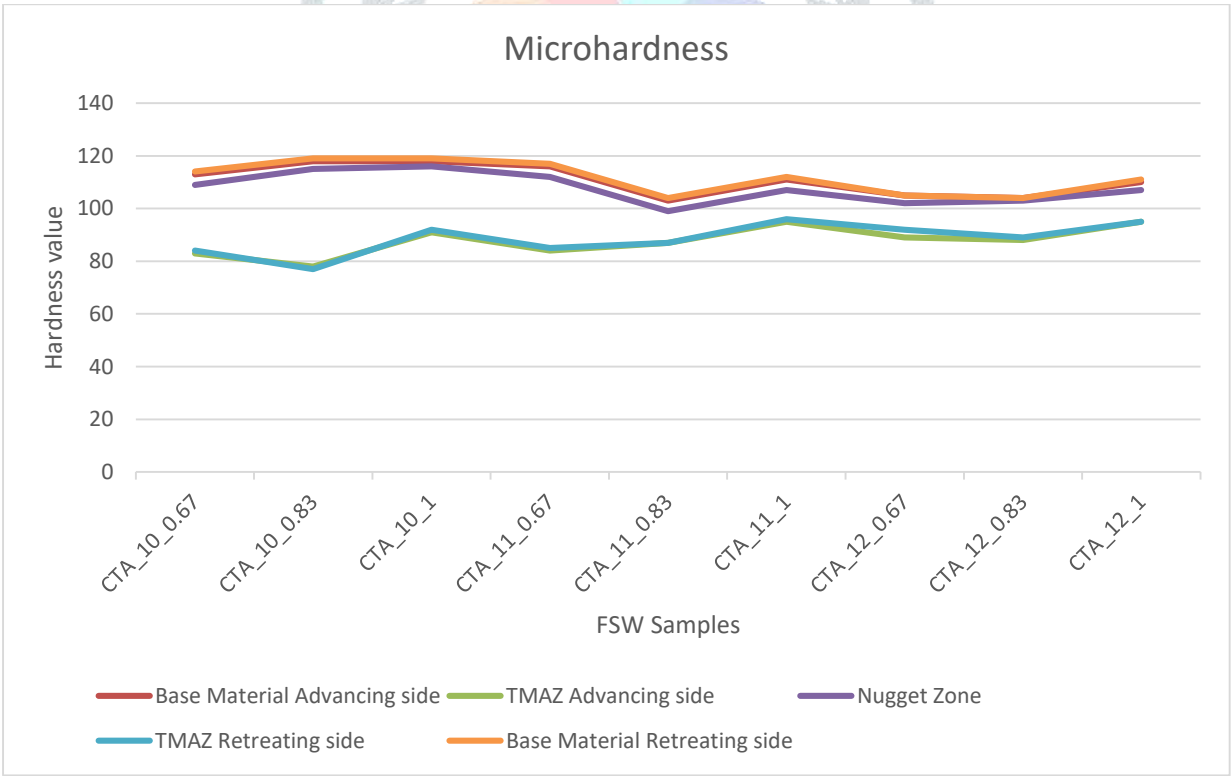


Fig 8: Vickers Micro Hardness

Figure 8 represents the variation of micro hardness of Al MMCs. Micro hardness obtained on top surface for all nine samples in five different zones. Different zones such as Nugget zone, Base material with advancing and retreating side and TMAZ zone with advancing and retreating side. At nugget zone, maximum hardness obtained when working at 1000 rpm and 1 mm/sec. When compared with different speed 1000, 1100 and 1200 rpm for all these speed working at 1 mm/s had given the good result with hardness. This trend continues in Base material as well as in TMAZ. .

3.3 Wear Results

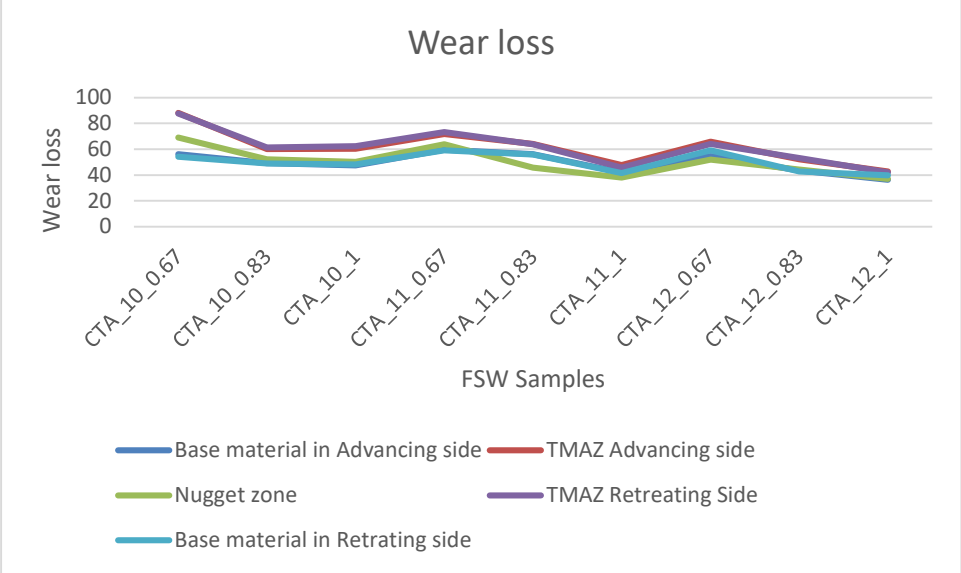


Fig 9. Wear loss graph for 1.5 Kg load

Figure 9 shows the Wear loss in microns for five different zones in FSW plate using taper tool at 1.5 kg loading condition. Five samples selected for wear loss analysis are weld zone, Base material in advancing and retreating side and TMAZ in advancing and retreating side. Wear loss found to be minimum in weld zone compared with TMAZ. Base material wear loss is also minimum compared with TMAZ zone. Wear analysis done with three different loading condition 0.5 kg, 1 kg and 1.5 kg. The least value of wear loss found for the specimen with parameters 1200-rpm rotational speed and 1 mm/sec feed for cylindrical tapered tool.

3.4 Microstructural Study

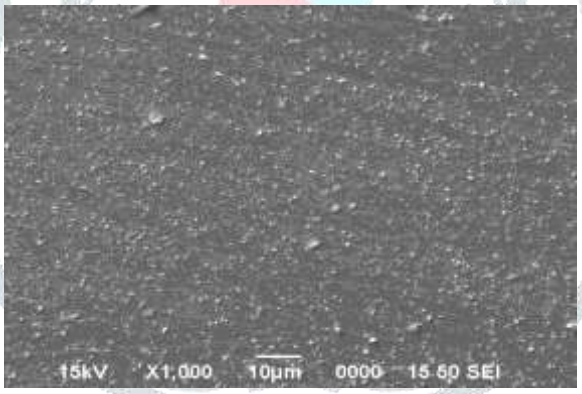
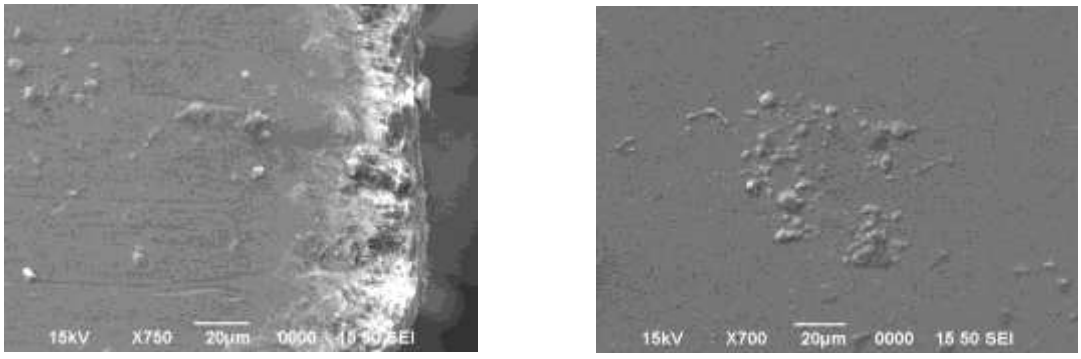


Fig 10. FSW Nugget Zone



(a) (b)

Fig 11. (a) Microstructure of advance side TMAZ zone at 20 micrometer (b) Microstructure of retracting side TMAZ zone at 20 micro meter

Figure 10 show the SEM image of FSW plate in nugget zone, the FSW parameter for this plate is 1200 rpm and 0.67 mm/s feed rate using taper tool. The grain structure found to be finest compared TMAZ. Figure 11 show the SEM image of FSW plate in TMAZ zone. The grain structure found to be disturbed in the TMAZ zone. Hence, the TMAZ zone shows the coarse grain structure in both advancing and retracting side.

IV. CONCLUSIONS

- The hybrid metal matrix composite of Al6061 reinforced with micro Ti and E glass fibre were prepared successfully by Stir casting.
- For Cylindrical tapered tool FSW parameter are speed 1000, 1100 and 1200 rpm. Feed rate are 0.67, 0.83 and 1 mm/sec.
- The Ultimate tensile strength is maximum for FSW Parameter 1000 rpm and 0.67 mm/s feed rate.
- The maximum Percentage of Elongation obtained for FSW Parameter 1000 rpm and 0.67 mm/s feed rate.
- Maximum Vickers micro hardness obtained for 1000 rpm and 1 mm/s feed rate.
- SEM analysis will indicate the fine microstructure in nugget zone and coarse microstructure in TMAZ.

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