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Cylindrical Tapered Tool Friction Stir Welding Aluminum MMC: Mechanical and Tribological Properties

Nayak Himanshu Sekhar [1*], Sanjaya Kumar Raj [2]
[1*]Associate Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India
[2]Assistant Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India
*Corresponding author e-mail: nayakhimanshu@thenalanda.com

Abstract
The key to replacing convectional aluminium alloys in many applications is improved welding processes to combine aluminium metal matrix composite. Al 6061 is strengthened in the current experiment using micro titanium and E-glass fibre. Using, stirring casting The casting is used to manufacture plates with a six mm thickness that are successfully butt connected with FSW. Using a cylindrical tool with a 1° inclination angle and various limitations, such as tool rotating speed and traverse feed Included are tool rotating speeds of 1000, 1100, and 1200 rpm and traverse feed rates of 0.67, 0.83, and 1 mm/sec. The maximum ultimate tensile strength was attained at 1000 rpm speed and 0.67mm/sec feed for tensile test specimens prepared in accordance with ASTM standards. By performing pin-on-disc wear tests with variable loads of 0.5, 1, and 1.5 kg, the wear performance of the composite was assessed. The combination of 1200 rpm speed and 1 mm/sec feed yields the lowest wear loss value at a 1 kilogramme load.

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

I. INTRODUCTION

Aluminium alloys are widely employed in many engineering applications, including manufacturing and transportation. Al 6061 considerably satisfies the higher mechanical requirements for engineering applications, including those for very sound hardness, tensile strength, etc. We need a lightweight, economically viable material that performs better and is stronger. Many studies have been conducted on aluminium and its alloys. Al6061 is the best option in this situation as it has greater tensile strength, corrosion resistance, and other qualities and is utilised in marine, structural, automotive, and other applications.

Due to the insolubility of the matrix and dispersoid and the materials' overall high strength, composites—materials made up of the combination of two or more constituents that differ non form and chemical composition—have a wide range of uses. Metals and alloys are used as the matrix phase in metal matrix composites, which have the capacity to withstand loads and transfer them to reinforcements. E- Glass fibre is a fantastic option for reinforcement since it has good dimensional stability, chemical resistance, resistance to abrasion and vibration, and is made up of incredibly tiny strands of silica-based glass. Micro titanium enhances the fine characteristics of the produced composite and is resistant to corrosion. Friction Stir Welding is a solid-state joining procedure that doesn't require any filler material. FSW is a desirable manufacturing technique to use because of its energy efficiency and environmental friendliness. FSW demands a tool that should spin quickly. Shoulder and probe make up the tool profile. Applying downward pressure on the workpiece is one of the shoulders' functions. Weld quality performance is influenced by the tool's design and the FSW parameter. Comparing the weld nugget to the base material and TMAZ, fine microstructures are evident. Through much research and development, the FSW's restrictions were lessened. The critical variables that have a significant impact on the mechanical characteristics and weldability are the tool's traverse speed, rotating speed, tool pin profile, and immersion in the base material. The most crucial welding parameter is tool rotation speed since it affects the mechanical and microstructural characteristics of FSW welds. The spindle's angle with regard to the work surface determines the tool tilt angle, which has an impact on how material flows around the tool. Finally, the tool geometry has a significant impact on the mechanical properties of the weld. Moreover, it heats the base material, stirs it, and produces a weld..

II. EXPERIMENTAL PROCEDURE

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.

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.

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.

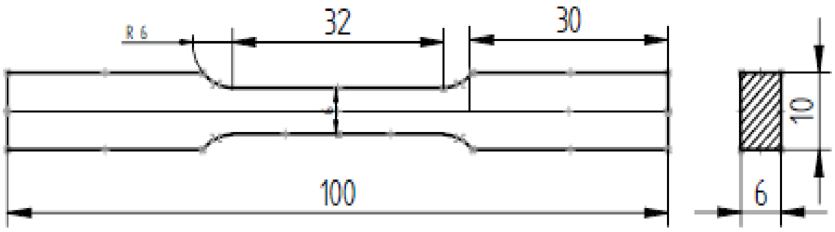


Fig 1. Dimensions of tensile test specimen (all in mm)

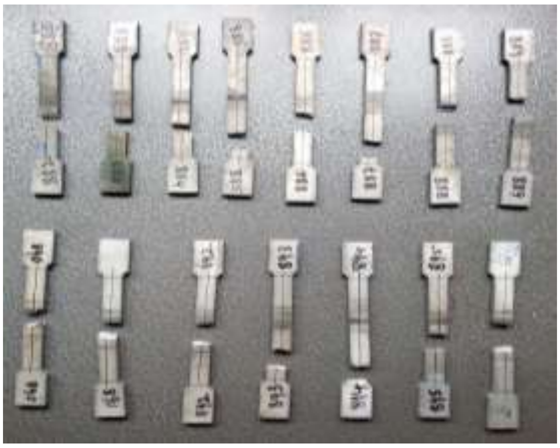


Fig 2. Failure Tensile samples *Micro Hardness*

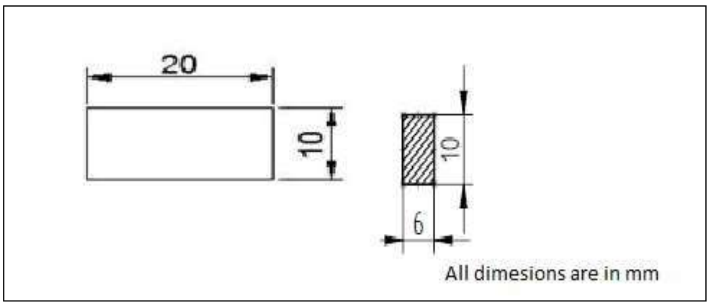


Fig 3. Hardness samples dimensions

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

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.

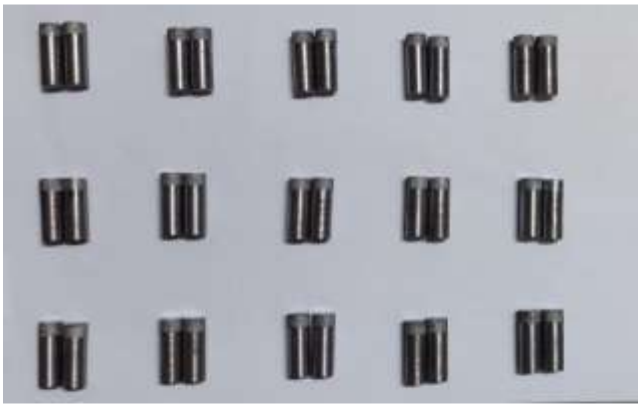


Fig 5. Wear specimens with pin

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*

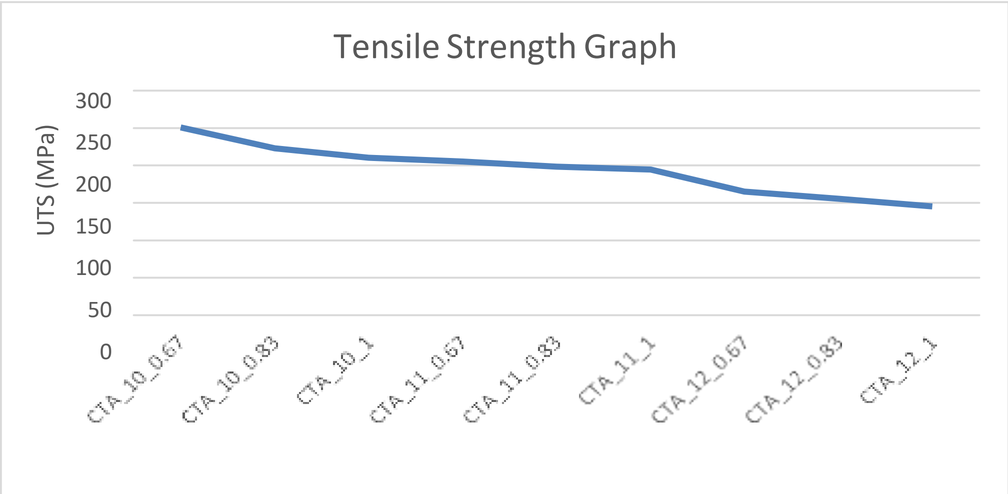


Fig 6: Variation of UTS

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.

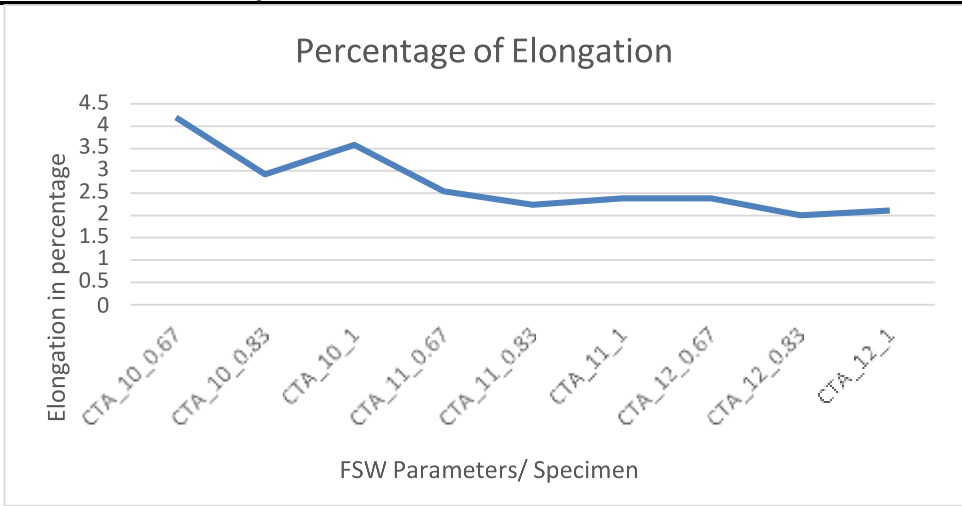


Fig 7: Variation of Percentage of elongation in tensile test

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.

Micro hardness

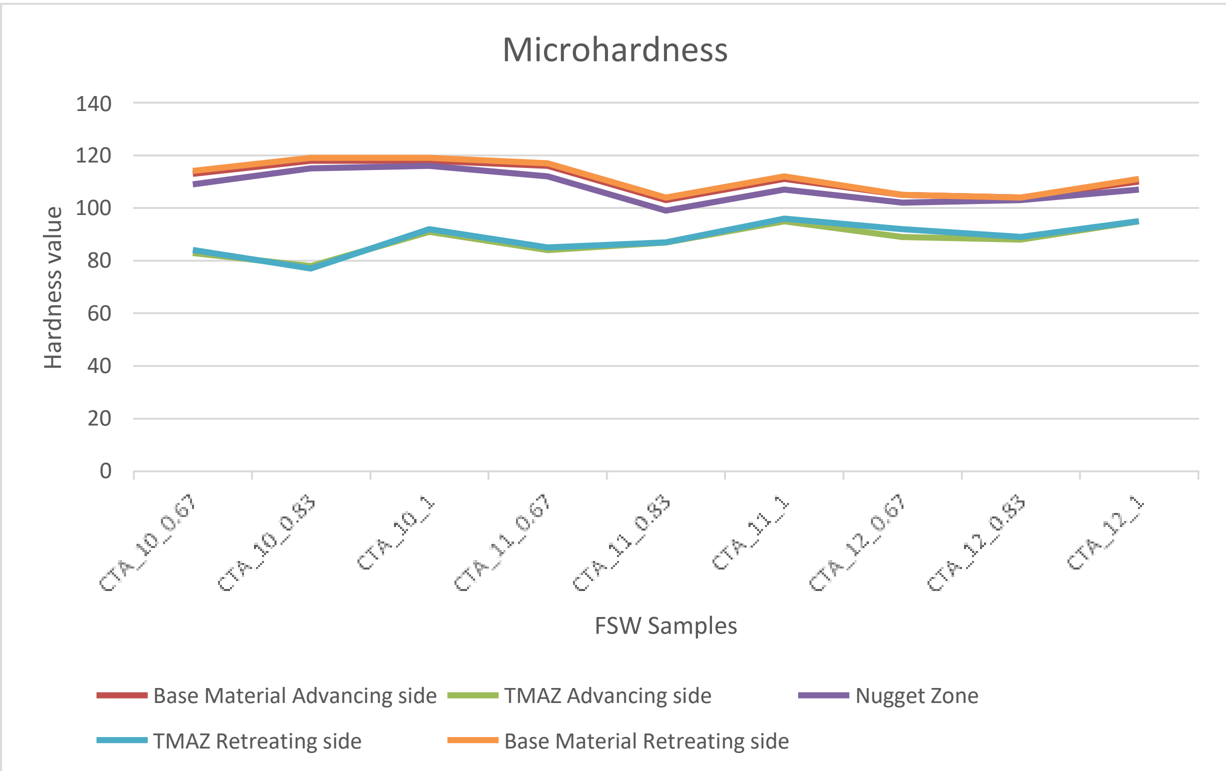


Fig 8: Vickers Micro Hardness

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. .

Wear Results

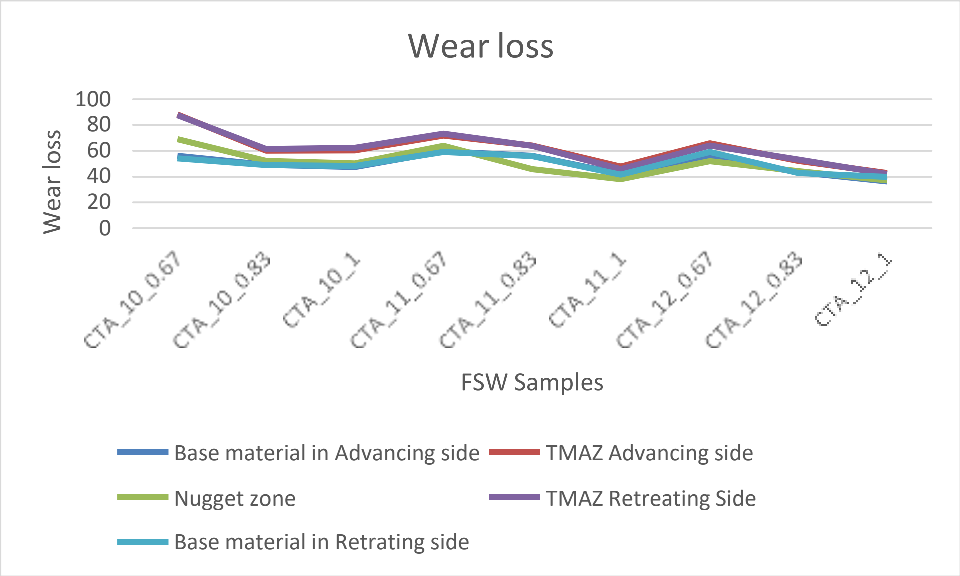


Fig 9. Wear loss graph for 1.5 Kg load

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.

Microstructural Study

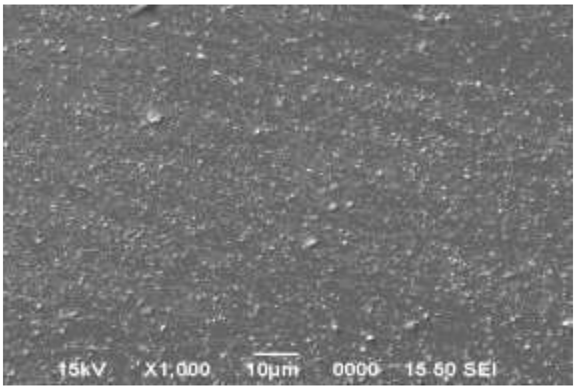
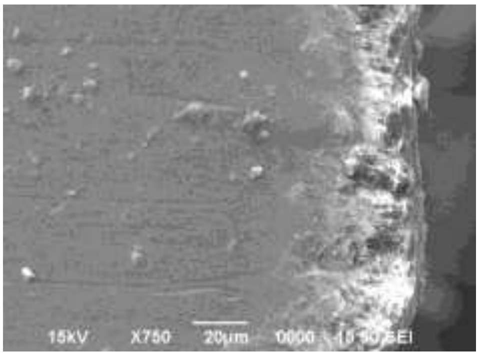
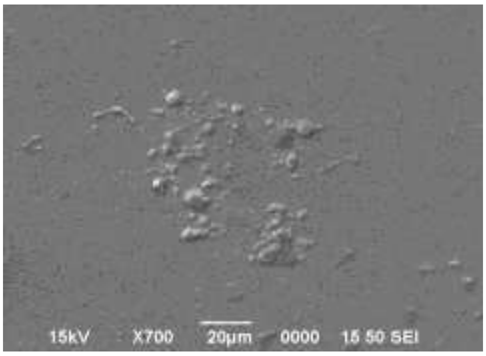


Fig 10. FSW Nugget Zone





(b)

MAZ zone at 20 micrometer (b) Microstructure of retracting side TMAZ zone at 20micro 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 bothadvancing and retracting side.

IV. CONCLUSIONS

Stir casting was used to successfully manufacture the hybrid metal matrix composite of Al6061 reinforced with micro Ti and E glass fibre.The FSW parameters for cylindrical tapered tools are 1000, 1100, and 1200 rpm. Feed rates range from 0.67 to 1 mm/sec.For FSW Parameter 1000 rpm and 0.67 mm/s feed rate, the highest ultimate tensile strength is achieved.The maximum percentage of elongation at 1000 rpm and 0.67 mm/s feed rate for the FSW parameter. Maximum Vickers micro hardness was attained at a 1000 rpm feed rate. SEM investigation will show the nugget zone's fine microstructure and the TMAZ's coarse microstructure.

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