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Characterization And Tribological Behaviour Of Aluminium Metal Matrix Composite

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ABSTRACT
Stir casting process is an effective manufacturing technique for producing MMC. The extensively use reinforcing materials for the aluminum matrix composites are Titani diboride, aluminum oxide and graphite in the variety of particles. In this work, the effect of addition of TiB_2 as secondary particles on the microstructure, mechanical and wear properties of the Al6061-TiB_2 MMCs has been studied. Aluminum matrix composite has been prepared by adding 0, 3 wt. % TiB_2 through Stir casting process. The wear rate of the composite have been conducted using a pin on disc configuration under normal loads of 10, 20 & 30 N. The tribological behaviour was evaluated at a sliding speed of 3.14 m/s and distance of 942 m. After the wear tests, the worn out surface of test specimens have been observed with Olympus inverted optical microscope to analyse the wear mechanisms. On the conduction of Microhardness tests to measure the microhardness number (VHN) of Al 6061-TiB_2 MMCs by indenting the diamond indenter. Microstructures are observed by using Scanning electron microscopy and X-ray diffraction analysis.The Tribological properties are superior with the increasing of addition of TiB_2 particles to the aluminum matrix. The mechanical properties are enhanced with increasing the addition of wt. % of TiB_2 particles to the Al 6061 alloy.The images of scanning electron microscopy shows a uniform distribution of TiB_2 particles in the aluminium metal matrix.

Keywords: : Al-6061; TiB_2; Stir casting; Micro structure; Wear properties; Mechanical properties,Metal matrix composites (MMC)

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I. INTRODUCTION

Now a day's MMCs were the reliable source to meet the demands of developments of advanced engineering materials for various engineering applications. Stir casting is a simple and economical process is suitable for producing of composites with up to 30% volume fractions of reinforcement. A literature survey on aluminum based matrix composite has been done and acquired data as given. [1] In 2014, V. Bharath et al. studied the mechanical properties and characterization of Al-6061 MMC with Al_2O_3 as particulate reinforcement. The expansion level of reinforcement is being varied from 6 -12wt. % in steps of 3wt. %. Microstructural characterization of the composites has uncovered genuinely uniform appropriation and some measure of grain refinement in the specimens. The contrasted with unreinforced Al-6061 alloy, additionally increasing level of reinforcement hardness and wear properties are superior in case of composites when has brought about further increment in both hardness and wear resistance.

In order to give high mechanical properties of the composite, fine interfacial bonding between the dispersed phase and the liquid matrix be supposed to be obtained by the method of Stir Casting [2, 3].In 2013**,** M.Mahendra Boopathi, P. Arulshri and Iyandurai were conducted a study on valuation of Mechanical Properties of Al-2024 alloy reinforcement with Silicon Carbide and Fly Ash Hybrid Metal Matrix Composites [4]. Increment in region division of fortification in grid result in enhanced elasticity, yield strength and hardness.[5]In 2012, Kumar et al. explored the mechanical conduct of blend threw Al-6061 grid composite strengthened with Al-N particles and presumed that extreme elasticity and yield quality of the composite was superior to anything pure alloy.. The author revealed that microhardness of the composite expanded with increment in level of Al-N into the alloy matrix.. [6] In 2012, V. N. Gaitonde1, S. R. Karnik and M. S. Jayaprakash were led a few examinations on Wear and Corrosion Properties of Al/Al2O3/Graphite Hybrid Composites. The impacts of reinforcement and molecule estimate on arranged examples of composites have been considered on mechanical, wear and corrosion properties. The test comes about on Al-5083/Al2O3/Gr hybrid composites uncovered that the expansion of support enhances the hardness and diminishes corrosion and wear rates. [7] In 2010, G. B. Veeresh Kumar et al. was conducted the Studies on Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites. From that study the conclusion is SiC and Al_2O_3 results better the hardness and density of their respective composites. in the midst of all the established MMCs production techniques, stir casting is the most reasonably priced process [8, 9]. So, at present stircasting is the most accepted industrial mode of producing aluminum based composites. Manufacturing of aluminum based composite materials via stir casting is one of the well-known and inexpensive ways for processing of MMCs materials [10]. In manufacturing a composite material by stir casting, functioning parameters are playing a key role. The allocation of the particles in matrix depends on geometry,stirring parameters,position of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

The objective of this work is to examine the microstructure, mechanical and wear properties of Al 6061-TiB_2 composites. The effect of addition of 3 wt. % TiB_2 particles on the micro structure and wear properties of Al-6061 MMC processed by stir casting process has been studied.

II. MATERIAL SELECTION

For manufacturing a composite material, the primary importance is given to the selection of Matrix and Reinforcement materials. In this work, Al-6061 alloy was selected as the matrix material and Titanium diboride was taken as secondary particles. The elemental composition of the Al-6061 alloy was shown in table. 1.

Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
0.4	0.4	0.15	0.4	0.80	0.25	0.15	Bal

Table.1:Composition (wt.%) of Al-6061 alloy

The property of having light weight is the main advantage of using aluminum as matrix material. Al-6061 alloy is highly resistant to attack by industrial chemical environment. Al-6061 was used in various applications like Structures, equipment, Automotive, Railway and Machinery applications.Al-6061 alloy was mostly used in ship building, vehicle bodies and pressure vessels. Silicon carbide is composed of carbon and silicon atoms and produces a very rigid and tough material and increases the abrasive wear resistance

II. EXPERIMENTAL PROCEDURE

The experimental procedure involves Pre heating of TiB_2 & preparation of molten Aluminum-6061, Stir casting process, mould preparation, microstructure characterization (SEM & XRD), hardness, tensile and wear tests.

3.1 Preheating of TiB_2 and preparation of molten Al-6061

The reinforcement TiB_2 particles 0,3 wt. %were preheated to a temperature of 700°C about 2 hours to remove the moisture. The required quantity of matrix material Al-6061 alloy was cut from the raw material and cleaned to remove dust particles. Al-6061 was heated to a temperature of 650°C in a resistance heated muffle furnace and degassed by using Argon gas.

3.2 Stir casting process

After complete melting of matrix material, stir casting process was carried out in muffle furnace. The muffle furnace was shown in figure 1. It consists of conical shaped graphite crucible which is used for fabrication of MMC. It withstands high temperatures more than required temperature. At first heater temperature is set to 500°C and then increased gradually. High temperature of the muffle helps to melt aluminum alloy quickly and reduces oxidation level. Time of melting argon gas was used as inert gas to create the inert atmosphere around the molten matrix. When matrix was in the fully molten condition, the reinforcement was feed into molten matrix by using hopper. Magnesium (4%) was added to the molten slurry to retain the Mg quantity in the composite material. Then stirring was carried manually by mechanical stirrer to disperse the Titanium diboride particles in the aluminum matrix material.After completion of stirring action the molten slurry was taken into semi solid form by reducing temperature of furnace.

3.3 Mould preparation

Mould is preheated at a temperature of 500°C before pouring of the molten composite slurry which is prepared in the stir casting process. The molding die was shown in figure 2. The slurry is in molten condition throughout the pouring because of the preheating of mould. While pouring the slurry in the mould the flow of the slurry is in uniform to avoid trapping of gas. Finally, mould was quick quenched in the air and produced Al-TiB_2 (0,3, wt. %) MMC with 15 mm diameter and 130 mm length. The final stir casted MMC specimens were shown in figure 3.

Fig. 1 Stir Casting Furnace

Fig. 2 Molding Die

Fig.3 Casted Composites

3.4 SEM Analysis

Scanning electron microscopy (SEM) studies were carried out to obtain higher magnification images for better visualization of microstructure of composite samples. Prior to SEM test, samples were polished using emery papers and disc polishing. The polished samples were dipped for 30 sec in an etchant solution.

3.5 XRD Analysis

X-ray diffraction is a technique primarily used for phase identification and in this the collimated x-rays are directed onto the sample. As the sample and detector rotated, the intensity of the reflected X-rays is detected.In this work, the X-ray scanning was carried in angles in between 10 and 90 degrees.The scanning speed of 2 degree/min was used in this work.

3.6 Microhardness test

The microhardness tests were carried on Vickers hardness testing machine. The Vickers hardness test was performed by applying a load of 500 gm for 10 sec. The diamond indenter was pressed into the material surface with a penetrator.

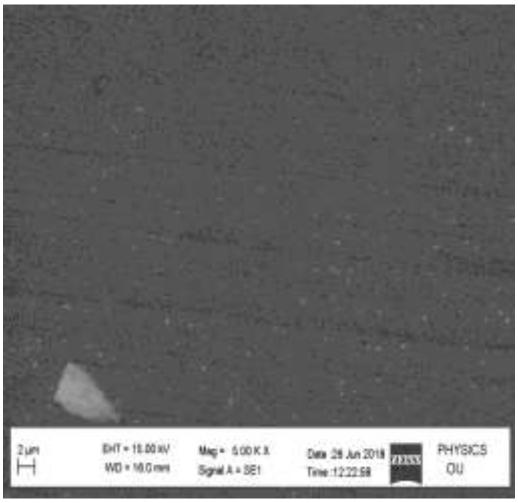
3.8 Wear test

Tribological properties are evaluated by conducting tests on Pin on disc tribometer. The wear tests were carried out on specimens with 10 mm diameter and 20 mm length. Prior to each test, the samples and disc were cleaned in acetone. Wear tests were performed with normal loads of 10, 20 and 30 N. The sliding velocity and distance are of 3.14 m/sec ,942 m respectively used throughout the experiment. The wear rate and coefficient of friction between samples and rotating disc was recorded using a device connected to the computer.

III. RESULT AND DISCUSSION

4.1 SEM Analysis

The microstructure of the Al 6061-TiB_2 (0,3 wt. %) composites was observed by scanning electron microscope at 500X magnification.The micrographs of the composites revealed the uniform dispersal of TiB_2 particles in the Al 6061 matrix. This was attributed to the effective and uniform stirring action. The SEM images of Al 6061-TiB_2 (0,3,wt.%) composites were shown in fig4



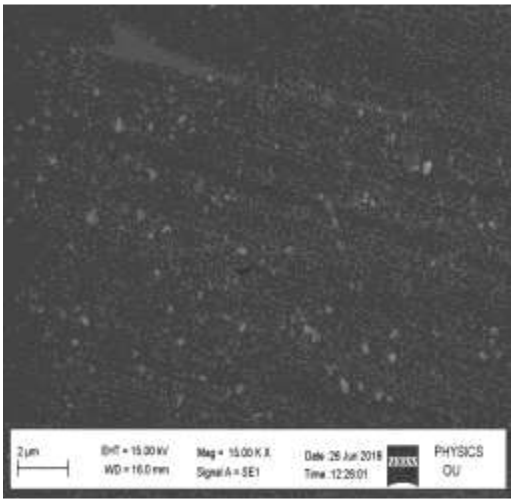


Fig 4: SEM Micrographs; (A) Al 6061-0% MMC, (B) Al 6061-3% MMC

In SEM images, the white regions shows the SiC particles and black regions shows inter metallic Mg_2Si phases.Agglome matrix. The SiC particles were homogeneously distributed due to the uniform stirring action. The uniform dispersion of SiC particles was increased by increasing the addition of SiC to the aluminum matrix.

4.2 XRD Analysis

Figure 5 shows the XRD profile of Al5083-3% SiC composite material. The major high intensity peaks of Aluminum and SiC particles were observed in the Al5083-3% SiC MMC. Weak peaks of Mg_2Si were observed in the composite material.

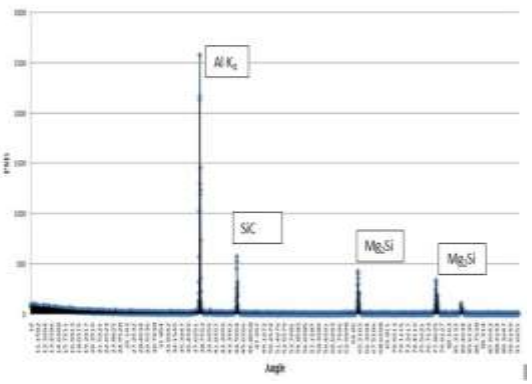


Fig 5. XRD image of Al 6061-3%SiC MMC

The formation of inter metallic compounds Mg_2Si in aluminum alloy composites can be attributed to its alloying elements and the presence of SiC particle. The high peak of aluminum was observed at 37.49 degrees and SiCat $44.51^0$of diffraction angles.The weak peaks of inter metallic compound Mg_2Si was observed at 64.06^0 and 77.85^0.The X-ray diffraction analysis revealed that the distribution of SiC particles and Mg_2Si inter metallic compound in the aluminum matrix.

4.3 Mechanical Properties

4.3.1 Microhardness test

The microhardness was improved on comparisition of addition of weight percentage of SiC particles to the aluminum matrix and addition of TiB_2 particles .The microhardness was gradually improved 51.9 to 79.3 HV by adding 3 wt. % TiB_2 particles to the Al 6061 alloy. The maximum value of microhardness was 79.3 HV, and it was observed for Al 6061-3% TiB_2 MMC. The TiB_2 particles were highly stiffer and stronger than Al 6061 alloy and gave better mechanical properties to the Al 6061-TiB_2 composite materia

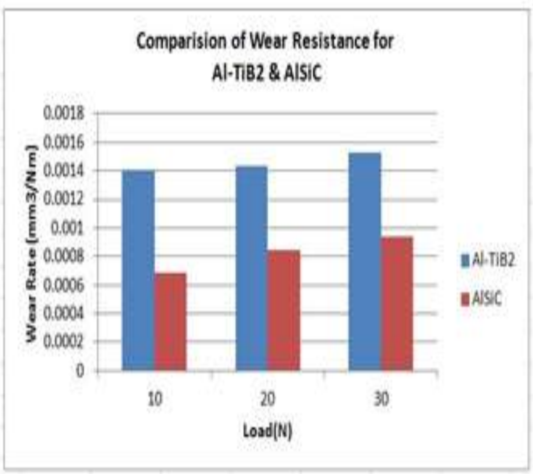


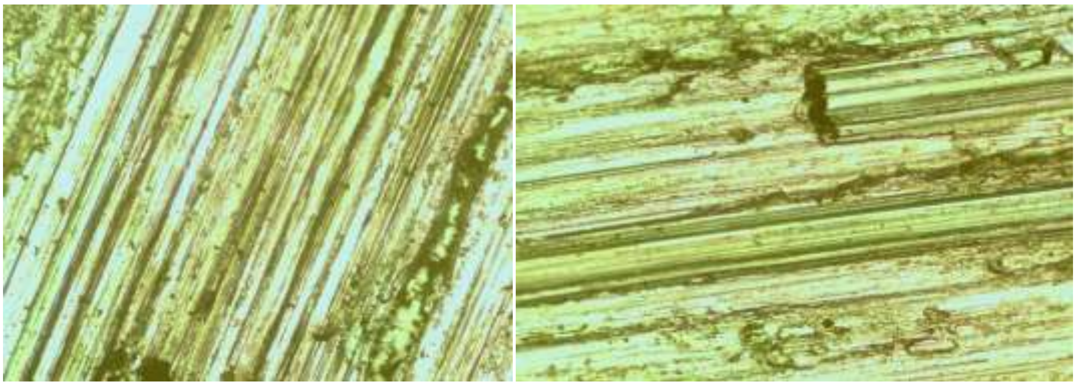
Fig.8: comparisition of Wear rate with applied load for Al 6061-SiC to Al 6061-TiB_2(3 wt. %) MMC

4.3.3 Wear Test

Tribological properties are evaluated by conducting tests on Pin on disc tribometer. The Wear tests were conducted with normal loads of 10, 20 and 30 N. The sliding velocity of 3.14 m/sec and sliding distance of 942 m were used throughout the experiment. The value of Wear rate with applied load for Al 6061-TiB_2 (0, 3 wt. %) composites was shown in figure 8. The casted Al-SiC has high wear rate than Al 6061-TiB_2 MMCs. By adding TiB_2 particles to the Aluminum matrix the wear rate has been reducedCasted Al 6061-SiC alloy has wear rate of 0.000685, 0.000849 and 0.000941 mm^3/Nm at the normal loads of 10, 20 and 30 N respectively. The wear rate was drastically reduced by adding 3 wt. % of TiB_2 to the Aluminum matrix. The wear rate was increased by increasing the applied load. The minimum wear rate of 0.00141mm^3/Nm was observed for Al6061-3% TiB_2 composite material at 10 N applied load.The wear resistance of the composite material was enhanced by increasing the addition of wt. % TiB_2 to matrix due to the self lubricating property of TiB_2 particles. TiB_2 itself acts as a lubricant. Al6061-3% SiC composite has minimum wear rate and high wear resistance.

4.3.5 Worn surfaces & Wear morphology

The wear mechanism of samples was easily understood by studying the worn surfaces and wear debris. The optical microscopy was used to analyze the wear surfaces of specimens. The worn surfaces of the Al6061-TiB_2 (0,3 wt. %) composite specimens was shown in figure 10 The casted Al5083-3% SiC composite has low resistance in wear than other two composite materials. High wear rate was observed during the test. Wear surface revealed that small cracks and grooves were takes place on surface of sample.



(A) (B)

Figure 10: Wear surfaces of (A) Al6061-3% TiB_2 at 3kg Normal load, (B) Al6061-SiC at 3kg Normal load

The strained surface of Al 6061-3% TiB_2 was exhibited scratches with and parallel grids in plastically deformed regions.The abrasive contact between the steel disc and Al MMC specimen pin was resulting the abrasive wear due to the parallel grooves and scratches on the strained surface. The strained surface of Al6061-3% TiB_2 was showed less wear than other materials.Because of inter metallic phases the Al6061-SiC composite showed high wear rate and low wear resistance.The presence of inter metallic phase was reduced and TiB_2 particles were uniformly distributed in Al6061-3%TiB_2 composite materials.Because of the uniform dispersal of TiB_2 and presence of low inter metallic phases Al6061-TiB_2 composite wear resistance enhanced and low abrasive wear.

IV. CONCLUSSIONS

In this work metal matrix composite preparation done by using aluminium-6061 alloy as matrix and SiC as reinforcement. The microstructure of specimen was studied by SEM and X-ray diffraction techniques. The wear tests were conducted on pin on disc equipment at different normal loads and worn out surfaces were studied by using optical microscope. From the experimentation work we concluded the following results:

The SEM Images of the specimen reveales that uniform dispersal of TiB_2 particles in the Al matrix. This was due to the effective and uniform stirring action.Agglomeration of particles was observed in some regions and this is because of porosity presence to it.The X-ray diffraction analysis revealed the distpersal of SiC particles and Mg_2Si inter metallic compound phases in the aluminum matrix.The microhardness improved after addition of TiB_2 particles to the Al 6061 alloy. The maximum hardness value of 79.5 HV was observed for Al 6061-3% TiB_2 MMC material.By adding 3 wt. % of TiB_2 particles to the aluminum alloy matrix, the microhardness of the Al 6061- 3% TiB_2 MMC has been improved.By adding TiB_2 reinforcement particles to the Aluminium matrix, the resistance of wear to composite specimens has been increased.The Tribological properties were improved by increment in the addition of wt. % TiB_2 particles to Al matrix because of self-lubricating property of TiB_2 particles.It was found that resistance of wear was inversion with the applied load because of more volume loss has been taken place on contact surface between specimen and disc.The Olympus inverted micrographs revealed, the abrasive contact between the steel disc and Al6061-TiB_2 composite specimen pin was result the abrasive wear due to the parallel grids and and scratches on the strained surface.The Al6061-3% TiB_2 MMC material has better properties of wear and mechanical due to fairly uniform dispersal of TiB_2 particles in the aluminum matrix.

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