

Studies on Wear Behaviour of Aluminium 6061 Alloy Reinforced with Al₂O₃ & Mica Particulates Hybrid Metal Matrix Composite

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ABSTRACT: This paper constitutes the work where Aluminium Al6061 is chosen as a matrix and reinforcements like Al₂O₃ Mica were used. Such multiple high performance reinforcements introduced into Aluminium alloy tend to be a Hybrid Composites. The Hybrid composite is estimated prepared, as conventional materials lack of some qualities. To meet the ever-increasing engineering demands of modern technology, metal matrix composites are gaining importance. The basic idea is to obtain a hybrid composite by stir casting method by mixing Aluminium Al6061, Al₂O₃, and Mica in varying proportions. The wear tests were performed and evaluated.

KEYWORDS: Al6061, Al₂O₃ & Mica, Hybrid Metal Matrix composite, Stir casting, Wear.

I. INTRODUCTION

A composite material is a material system composed of a combination of two or more micro or macro constituents that differ in form chemical composition and which are essentially insoluble in each other. One constituent is called as matrix phase and the other is called reinforcing phase. The matrix holds the reinforcement to form the desired shape while the reinforcements improves the overall mechanical properties of the matrix. When these two phases like matrix and reinforcements are combined in proper proportion the new combined materials exhibit better strength than each individual materials. The most primitive man made composites materials are sand, stones, and cement mixtures to make concrete and mud, clay ash mixed to prepare a bricks for builder's constructions [1]

Aluminium Matrix

Aluminium is the most abundant metal and the third most abundant chemical element in the earth's crust. Comprising over 8% of its weight Aluminium alloys are broadly used as a main matrix element in composite materials. Aluminium alloys for its light weight has been in the net of researchers for enhancing the technology. The broad use of aluminium alloys is dictated by a very desirable combination of properties, combined with the ease with which they may be produced in a great variety of forms and shapes.

Al6061-Alloy Selection

The families of aluminium alloys are represented by 1xxx, 2xxx, 3xxx, up to 8xxx. The first digit gives basic information about the principal alloying elements as shown in table 2. The designation system also says something about the hardening of the alloys belonging to a family. Table 3 shows the nominal composition wt% of Al-6061 matrix material. The 1xxx, 3xxx, and 5xxx series are so called non heat treatable alloys; they gain their strength by

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alloying (increasing the content of Mg) and work hardening. The 1xxx series designation consists unalloyed aluminium materials which are distinguished according to their degree of purity. The 8xxx series designations are for miscellaneous types of alloys which cannot be grouped in the other families. The 2xxx, 6xxx, and 7xxx series are heat treatable alloys, which gain their strength by alloying but make use of precipitation hardening as the main mechanism among several series of aluminium alloys, heat treatable A16061 and A16707 are much explored. Among them A16061 alloy is highly corrosion resistance extricable in nature and exhibits moderate strength. It finds vast applications in the field of construction automotive aerospace marine and other allied fields they have been studied extensively because of their technological importance and their exceptional increase is obtained by precipitation hardening.[2]

Table; - 1 Chemical Analysis of the Al6061 Alloy

Element	AL%	SI%	Mg%	Pb%	Zn%	Cu%	Fe%	Ti%
AL Cube-1	97.28	1.600	0.045	0.076	0.104	0.176	0.413	0.018

Reinforcement

As for the reinforcement the material used are typically ceramics since they provide a very desirable combination of stiffness strength and relatively low density reinforcement material include SiC, Al₂O₃, B₄C, Tic cop, TiB₂, graphite and a number of other ceramics the reinforcement is added to provide increased stiffness and strength to the unreinforced matrix ceramic particles with their large elastic modulus and high strength are ideal as the reinforcing particles. Many of the ceramic particles interested are thermo dynamically unstable when they are in contact with pure metals and will react to form reaction compounds at the interface between the particles and the surrounding matrix.[2]

Aluminium Oxide

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al₂O₃. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium oxide. It is commonly called alumina, and may also be called Alexie, aloxite or alundum depending on particular forms or applications.[3]

Mica:

Mica is a generic term applied to a group of complex aluminosilicate minerals having a sheet or plate like structure with different composition and physical properties. All mica forms flat six side nonclinical crystals with a remarkable cleavage in the direction of large surface, which permits them to easily split into optically flat films. When split into thin films, they remain tough and elastic even at high temperature. Mica possesses some of the most outstanding combinations of chemical physical, electrical, thermal and mechanical properties which are not found in any other product. Mica powder in various forms is obtained by grinding breaking mica scrap which is a slow costly and extremely complicated process, because of the scrap being tough and having a plate like structure. Meticulous care and precaution has to be taken so that there is no deterioration of its natural brilliance, colour and properties.[4]

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Table; - 2 Particle size of Al₂O₃ and Mica

Reinforcement	Practical size range (µm)
Al ₂ O ₃ .	30-50
Mica	30-40

Different Methods Used To Manufacture Particulate Reinforced MMC's

MMC manufacturing can be of two type; solid and liquid.

Solid –phase fabrication methods;

- Powder blending and consolidation; powdered metal and discontinuous reinforcements are mixed and then bonded through a process of compaction, degassing and thermo mechanical treatment.
- Foil diffusion bonding; layers of metal foil are sandwiched with long fibers, and then pressed through to form a matrix

Liquid - phase fabrication methods;

Liquid –phase fabrication method is more efficient than the solid phase fabrication methods because solid – phase processing requires a longer time.

- Electroplating/electroforming; a solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material.
- Stir casting; discontinuous reinforcement is stirred into molten metals which is allowed to solidify.
- Squeeze casting; molten metal is injected into a form with fibers preplaced inside it
- Spray deposition; molten metal is sprayed onto a continuous fibers substrate.

Methodology

In this process studies related to hybrid composites of Al6061 was reviewed Specimen were prepared using stir casting method. In this work composites of Al6061/ AL₂O₃./mica was prepared Initially only Al6061 was melted to required temperature i.e. 700⁰c and poured in to the metallic mould In preparing the composite a known quantity of Al6061 as matrix Al2O3 in varying proportions as primary reinforcement i.e. 2%, 4%, 6%, 8%by weight and fixed quantity of mica as secondary reinforcement i.e. 4% by weight was used. Further machining of the composites to ASTM standards to conduct dry sliding wear test on pin-on-disc apparatus, by applying parameters like load, speed, distance and microstructures studied under SEM.

II. EXPERIMENTALS SETUP

Composite preparations by liquid stir casting route

As shown in the figure the stir casting setup it consist of the induction furnace; stirrer assembly. The stirrer assembly consist of the mild steel stirrer which was connected to the radial drilling machine with varying speed 80-800 rpm by means of steel shaft. The stirrer consist of nine blades in curved shape as shown in the fig crucible made up of mild steel coated with graphite and the capacity of 5kg was placed inside the Furnace The graphical representation of stir casting is shown in figure 1

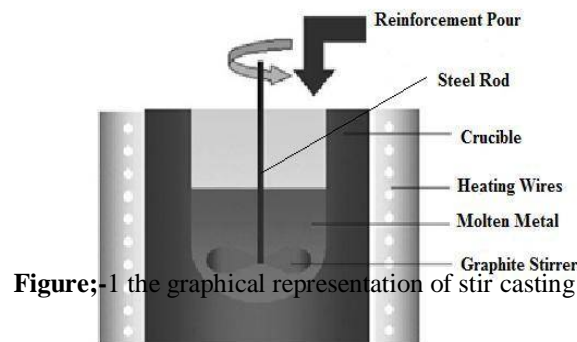
A known quality of (3kg) of Al alloys in soiled ingots was melted in the induction Furnace complete up to liquid form and slag is removed by the adding the scum powder and gas in removed by the adding hexachloro ethane tablets. After Al6061 in completely in the molten state next the reinforcement is pre heated on the surface of the Furnace to remove the moisture and to achieve good wettability of the reinforcements the stir setup was readily available for next process. The stirrer will be immersed to ¼ of the depth of molten metal stirrer will be started and stirred up to 500 rpm and the vortex will be created inside the crucible. The mixture of reinforcement like Al₂O₃ and mica by 2% &4 % (fixed) were added at the rate of 10-20gr/min in to the metal. The speed is controlled with the speedometer and temperature is

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closely monitored at this stage of reinforcement adding in the molten metal After complete addition of the reinforcement remove the stir and degassing will be done and melt poured in to the preheated mold and allowed to solidified in the atmospheric air. This will be repeated for 4%, 6%, &8% Al₂O₃



Figure;-1 the graphical representation of stir casting

Hardness's Test:-

A hardness tester model no FV 700 is used for the hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100,200,400,600 and 1000 grit size emery paper the load used on Vickers hardness tester was 1kg, 3kg and 5kg at 10x optical zoom with the dwell time 10 second for each sample The result of Vickers hardness tester for alloy Al6061 without reinforcement (sample no1) and variation of different reinforcement such as Al₂O₃ and mica in alloy Al6061 MM°C (sample NO 1-5) as shown in table below

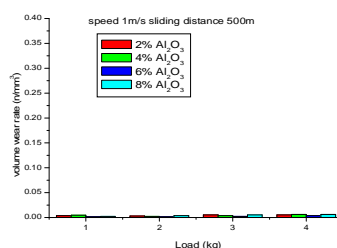
Table no 3: hardness measurement

Sample no	Sample name (Al6061+)	Mean hardness no(VHN)
1	Pure(base Alloy)	52.0
2	2% Al ₂ O ₃ +4%Mica	87.45
3	4% Al ₂ O ₃ +4%Mica	95.40
4	6% Al ₂ O ₃ +4%Mica	105.69
5	8% Al ₂ O ₃ +4%Mica	115.56

Results and Discussion:-

Graphs Showing the Wear Performance of Al6061, Al₂O₃, mica Sliding Distance 500, 1000, 1500m with constant Speed 1m/s

The pin on disc apparatus was used to perform the wear experiment the wear track alloy and composite specimens cleaned through with acetone prior to each test after that the specimen is mounted on the pin holder of the trybometre reedy for wear test, For all the experiment track diameter is 60mm and load 1kg 2kg 3kg &4kg speed 1m/s, 2m/s, &3m/s sliding distance 500m, 1000m, &1500m.

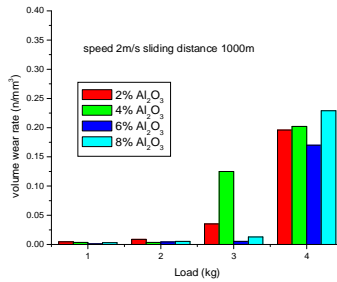


(a)

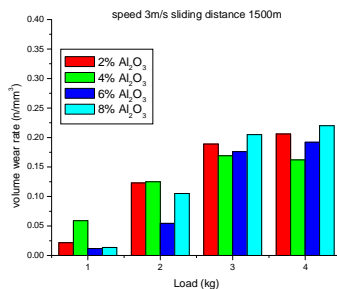
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(b)

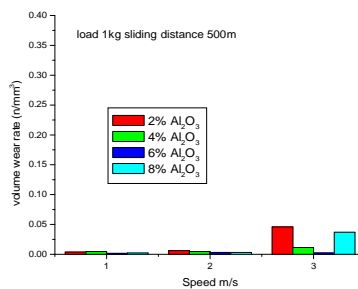


(c)

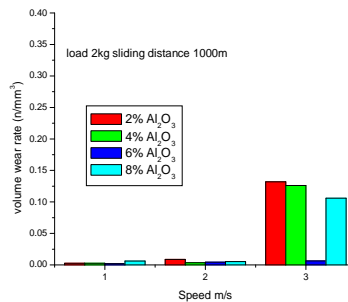
Figure:-2 Variation of volume wear rate against load

a) at sliding distance of 500m; b) at sliding distance of 1000m c) at sliding distance of 1500m
 From the fig2 (a) show that the wear rate is increased with increasing in load the maximum wear rate is at 8% reinforcement of Al₂O₃ and minimum wear rate is 6% reinforcement of Al₂O₃ irrespective of load applied due to increasing contact between disc and pin leads
 From the figure 2 (b) show that with an increasing load on Al₂O₃/mica oxides coexisted with inter metallic phase that volume wear rate wear mild low loads and increased gradually until they material experienced transient from mild to severe load
 From the figure 3(c) it is evident from the experiment that at low applied load and 2m/s speed the warm pin surface predominantly raises fine and shoal grooves in the slide rate

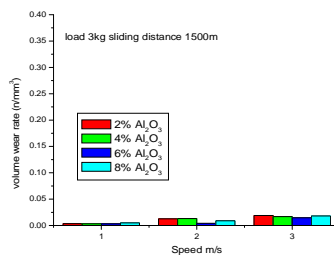
Graphs showing the Wear Performance of Different Sliding Speed with Constant sliding distance 500m, 1000m, 1500m



(a)



(b)



(c)

Figure:-4 Variation of volume wear rate against speed

a) At load 1kg b) at load 2kg c) at load 3kg

b)

From the graph plotted on volumetric loss vs. speed and volumetric loss vs load it is found that at 4 kg load, speed 3m/sec and 6%Al₂O₃ and 4% mica as reinforcement wear loss is found to be optimum. As observed from the microstructure it is because uniform distribution of Al₂O₃ and mica particles

SEM analysis

The specimen will be prepared by the etching different grits size of emery paper like 400, 600, 800 and 1000 the surface will be nearly mirror image the specimen will be mounted on specially designed holder after that specimen with holder kept in to the machine HICATHI S-3400N under 20kv voltage figures shows that the SEM micro graphs of the different aluminium matrix composite at different magnification 500x, 1000x, 1500x.

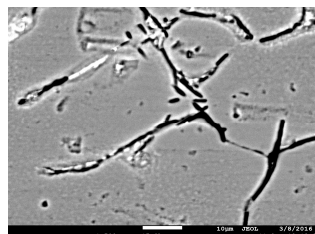


Figure: - 5 SEM of MMC'S with 2% Al₂O₃ & 4% mica at a) 1500x

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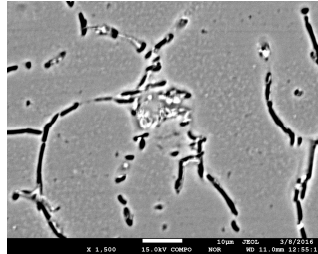


Figure:-6 SEM of MMC'S with 4% Al₂O₃ & 4 % mica at b) 1500x

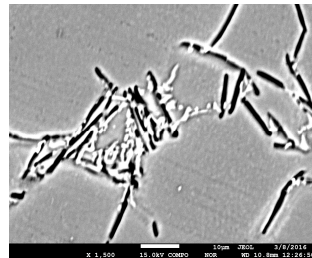


Figure:-7 SEM of MMC'S with 6% Al₂O₃ & 4% mica at c) 1500x

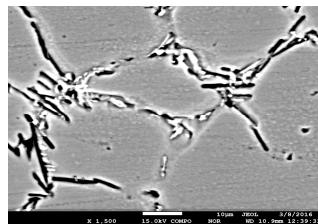


Figure:-8 SEM of MMC'S with 8% Al₂O₃ & 4% mica at d) 1500x

Figure 8 shows the homogenous distribution of Al₂O₃, mica reinforced particle in alloy matrix homogenous distribution of particle is desired for achieving better wear behaviour and mechanical properties homogenous distribution of particle in a molten alloy is achieved due to the higher shear rate caused by stirring which also minimize the particle setting. However agglomeration of particle in some regions is clearly visible in all cases there is due to the presence of porosity associated to it presence of entrapped air and moisture in the reinforcement particle result in the void/porosity after casting. Poor bonding between the Al6061 alloy matrixes.

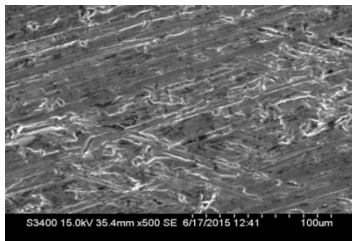
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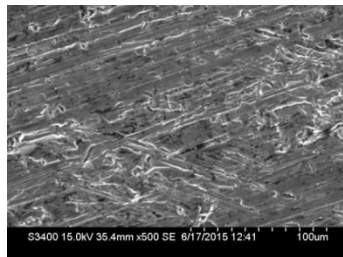
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Micro structure observations of worn surfaces

The worn out surface of some selected /typical specimen (6% and 8% of reinforcement) after the wear test were observed under SEM at 250x, 500 xs.



(a)



b)

Figure:-9 micrographs shows that a) 6% of Al_2O_3 , b) 8% of Al_2O_3 in Al6061

The structure of the worn surface generally depends on load, speed, sliding distance and hardness of particle. Comparing their figure it can be visualized that one of the common features observed in all this MMC'S i.e. the formation of grooves and roughness running parallel to the sliding distance on further analysis it has been found that grooves are fine on the worn surface of Al6061 with 8% Al_2O_3

III. CONCLUSIONS

The conclusion given from the present investigation is as follows

- Al based metal matrix composite have been successfully fabricated by stir casting technique with fairly uniform distribution of Al6061 with Al_2O_3 , mica, particulates.
- For synthesizing of composite by stir casting process stirrer design, stirrer position, stirrer speed and time particles preheating temperature are the important process parameters
- The results confirmed that in the base alloy the hardness increases with increasing the reinforcement
- The SEM images revealed that Al_2O_3 particulates are fairly distribution in aluminium alloy matrix.
- And it is also revealed from the SEM images that at some places void has been occurred before wearing after wear grooves running slide marks observed

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