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ANALYSIS OF WEAR BEHAVIOUR OF ALUMINIUM COMPOSITE WITH SILICON CARBIDE AND TITANIUM REINFORCEMENT

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ABSTRACT

In the field of material science and engineering, composites are nonlinear metallic materials with rounded stress–strain curves that are not well represented by the simplified elastic-perfectly plastic material model used in most existing design specifications. Aluminum (Al) have been the primary material for the structural parts of aircraft for more than 80 years. Here, we fabricate aluminum matrix composite with silicon carbide (SiC) and Titanium (Ti) by stir casting method. The wear characteristics are found out by carrying out "Pin on Disk" test. In this project, aluminium is taken as base metal and reinforced with Silicon Carbide and Titanium particulates by stir casting method. The aluminum scrap is to be studied using Edox test and followed by stir casting in which Titanium and Silicon Carbide is added as reinforcements. Later, "Pin on disk" test is carried out to find out wear properties of the composite. SEM test is carried out finally to study the grain structure.

Keywords: Aluminium composite; Silicon carbide; Titanium; Microstructure; Wear behaviour.

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1. INTRODUCTION

In an advanced society like ours we all depend on composite materials in some aspect of our lives. Aluminium composites are mostly used in grills and screens due to its light weight and durable properties. A unique combination of properties puts aluminium and its composites among our most versatile engineering and construction materials. All composites are light in weight, yet some have strengths greater than that of structural steel. The majority of alloys are highly durable under the majority of service conditions and no colored salts are formed to stain adjacent surfaces or discolor products with which they come in contact, such as fabrics in the textile industry and solutions in chemical equipment. They have no toxic reaction. Aluminium and most of its composites have good electrical and thermal conductivities and high reflectivity to both heat and light. Aluminium and most of its alloys can easily be worked into any form and readily accept a wide variety of surface finishes. Light weight is perhaps the best known characteristic of aluminium, with density of approximately 2.73 x 103 kilograms per cubic meter at 200°C as compared with 8.89 x 103 for copper and 7.86 x 103 for carbon steel.

1.1. Composites

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, racing car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

1.2. METAL MATRIX COMPOSITES (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-toweight ratios of resulting composites can be higher than most alloys. The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

2. LITERATURE REVIEW

[1] Anuj Kumar et al (2017) fabricated and found out the wear characterization of the aluminium matrix composite by reinforcing copper and silicon carbide. Wear behavior of Al-SiC-Cu MMC is analyzed for different reinforcement content, load, sliding speed and distance. [2] Shilpa P.S et al (2016) studied the effect of reinforcement of Boron Carbide with the Al2024. By adopting stir casting technique fabricated the specimen by varying the wt% of Boron Carbide. The specimens are developed as per the ASTM. In the end they come to know that as the reinforcement Boron Carbide increased by wt% increases the Hardness, Tensile strength and Yield strength. The percentage of elongation decreases with the increase of Boron Carbide in the composition. [3] **Sandeep Kumar Ravesh et al (2015)** investigated the effect of the various weight fraction of SiC i.e.2.5%, 5%, 7.5% and 10% and 5% flyash is reinforced with Aluminium 6061 metal matrix composite by using the stir casting method. They observed that Tensile strength, Harness and Impact strength increased with the increase in weight fraction of SiC particle. A best tensile strength 115 N/mm2, hardness 93RHN and toughness value 7.8 for 10% SiC and 5% flyash reinforced composite material was obtained. [4] F.Abdi et al (2015) investigated the effect of 5 wt% of TiB2 as a reinforcement with the Al356.1 metal matrix at various temperature i.e.750℃, 850℃, 950℃ using stir casting technique. They found that at temperature 950℃ shows best result s for Tensile strength and Hardness and the TiB_2 particles are homogenously distributed. [5] K.L. Meena et al (2015) investigated the mechanical properties of the developed SiC reinforced with Al6063 metal matrix composite material using Melt stirring technique where the experiment was carried out by varying the reinforcement particle size such as 200 mesh, 300 mesh, 400 mesh with the different weight percentage i.e..5%, 10%, 15% and 20% of SiC particle reinforced material. The stirring process was carried out at the speed of 200rpm using the graphite impeller for a period of 15min. A homogenous dispersion of SiC particle in the aluminium matrix was observed. The tensile strength, hardness and yield strength were improved with the enlargement of particulate size and weight percentage of SiC. Percentage reduction area and percentage elongation and impact strength decreases as the increase in reinforced particle size and weight percentage of SiC particle. Maximum hardness (HRB) 83 and impact strength 37.01 Nm was achieved.

[6] H.G.Rana et al (2015) investigated the mechanical properties and wear properties of Al7075 with the reinforcement of Boron Carbide. They concluded that using the using Friction Stir casting the fabricated specimens provides uniform mixing and enhances the tensile strength and hardness. Hence the microstructure are studied with the help of Image analyzer. [7] Ram Narayan et al (2014) investigated the effect of fly-ash and zirconia with the mechanical properties of Aluminium 6061 alloy composite samples developed by using the technique Stir casting. They developed the specimen by varying the zirconia (5% and 10%) and kept the fly-ash 10% as a fixed percentage by weight fraction. They observed that due to the presence of fly-ash and zirconia Hardness and Tensile strength was increased where the elongation decreased as compared to the unreinforced aluminium. The characterization will be done using the scanning the electron microscope machine and image analyzer. [8] Roseline et al (2014) observed the mechanical properties of aluminium alloy mmc with the reinforcement of fused Zirconia alumina. They developed the specimens by varying by the weight fraction by percentage. They evaluated the mechanical properties which indicates the variations in the Hardness, Tensile strength and Impact strength. The optimum result for mechanical properties found on the reinforcement to be 90 and 10 by weight percentage of the matrix respectively. [9] Jithin Jose et al (2013) investigated the effect of fly-ash and zircon (zirconium silicate) with the mechanical properties of Aluminium 7075 alloy and the stir casting technique was adopted to develop the specimens by varying weight percentage .They

after conducting the different test concluded that keeping the zircon at a fixed weight percentage and varying the fly-ash found that the wear rate decreases where the tensile strength and the hardness increases.

[10] Adil Ahmed.S et al (2013) studied the incorporation of Zirconium Nano Particles in Al356.2.The stir casting technique was used for the development of composite specimen where the Al356.2 is heated at around 750℃ and the Zirconium Nano particles are added. Mechanical properties are increased for 15wt% of reinforcement particle developed at 750℃ shows homogenous reinforcement particle and through using the Scanning Electron Microscope the microstructure of the specimen shows homogenous reinforcement. [11] J.Jenix Rino et al (2013) investigated the mechanical properties of Aluminium 6063 alloy composite enhance i.e. strengthened by the addition of alumina particle and zircon sand with an overall reinforcement in the Al6063 material matrix. They observed the Hardness and Tensile strength of the composite having higher value at the composite developed specimen, which having reinforcement mixture of 4wt%ZrSiO4+4wt% Al2O3. [12] K.B. Girisha et al (2012) studied the effect of various weight fraction of zirconium oxide nanoparticle i.e. 0.5%, 1%,1.5% and 2% reinforced with Al356.1 metal matrix composite by using stir casting technique. Here they observed that particle agglomeration in the composite is due to high amount of zirconium oxide nanoparticle. Hardness and wear properties are increased as the increase in weight fraction of zirconium dioxide nanoparticle.

[13] M.A.Baghchesara et al (2012) studied the mechanical properties of developed composite specimen using the stir casting method where they considered zircon and TiB_2 ceramic particles with size 1 micron and the temperature 750℃ respectively. The microstructure were studied by using scanning electron microscopy and hence the dispersion of reinforcement as noted. Situation of compounds of the developed specimen were examined by XRD. The end results shows mechanical properties and microstructure behavior of composite was improved compared to the monolithic alloy. Microstructures of the composites in as cast conditions shows uniform distribution of the particles and reveals the better bending in case of zircon reinforced composites compared to the TiB2 composites. But increase in the amount of reinforcement shows better conditions in case of TiB2 reinforced composites. [14] H.C. Anilkumar et al (2012) investigated the mechanical properties of Al6061 reinforced by fly-ash. They fabricated the composite specimens using the stir casting method. They developed three sets of composites with particle size of fly-ash of 4-25, 45-50 and 75-100μm was used. The three set of composites are developed by varying weight fraction of 10%, 15% and 20%. The mechanical properties are like Tensile strength, Compressive strength, hardness and Ductility are studied. They found that increase of particle size of fly-ash decreases tensile strength, compressive strength and hardness of the developed specimens. They also find that by increase of weight fraction of fly-ash increases compressive strength ultimate tensile strength, hardness but decreases with increase of fly-ash particle size. [15] Muruganandhan.P et al (2012) investigated the effect of fly-ash reinforced with Al6061.By varying the wt% of fly-ash using the stir casting method the specimens was developed. The found that increase of fly-ash increase the mechanical properties up to 20% of fly ash in the metal matrix but the corrosion resistance decreases with increase of fly-ash addition. [16] Ramesh et al (2017) investigated the high entrophy aluminium alloy and its stability while reinforced with nanocrystalline Al2Mg2Ni2Cr2Ti2. Also they studied about the corrosion behaviour of hot forged Cu-Al-Ni alloy reinforced with copper. It is found that as the reinforcement contents increased in the matrix material, the composites hardness also increased. Tensile strength decreased with increased amount of reinforcement. The wear rate of the composites reduced with increased weight percentages of the reinforcements. Dinesh et al [7,8] studied about the machining of AISI 4340 steel and attempted to optimize the input parameters using GRA, RSM and Taguchi methods. A.M.Rameshbabu et al [9] has analysis nanocrystalline

equiatomic AlMgNiCrTi high entropy alloy has been successfully synthesized by mechanical alloying and consolidated by spark plasma sintering at 800°C with 50 Mpa pressure. B. Radha Krishnan et al [10] the paper, classification algorithms ANFIS and random forest are used to classify the test data samples for determining the error rate by comparing its classification response with its corresponding actual response.

3. MATERIAL SELECTION

3.1. SILICON CARBIDE POWDER

Silicon carbide also known as carborundum is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been mass produced since 1893 for use an abrasive. Large single crystals of silicon carbide can be grown by this method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material and shown in figure 1.

Figure 1 Silicon Carbide

SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material. Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Silicon carbide is not attacked by the acids alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C. It has low density, high strength, low thermal expansion, high hardness and high elastic modulus are shown in table 1. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide are light emitting diodes and detectors.

Table 1 Silicon carbide properties

S.NO	PHYSICAL PROPERTY (gm/cc)	SILICON CARBIDE
1	Density (MPa)	3.1
2	Flexural strength (GPa)	550
3	Elastic modulus (MPa)	410
4	Hardness (Kg/mm2)	2800

3.2. TITANIUM POWDER

Titanium powder metallurgy (P/M) offers the possibility of creating net shape or near net-shape parts without the material loss and cost associated with having to machine intricate components from wrought billet. Powders can be produced by the blended elemental technique or by pre-alloying and then consolidated by metal injection molding, hot isostatic pressing, direct powder rolling or laser engineered net shaping and it is shown in figure 2.

Figure 2 Titanium Powder

Titanium powder takes place at temperatures as high as 1040°C. The sponge particle range in size from 45 to 180 μm, with particles ~150 μm termed ‘sponge fines’. These fines are irregularly shaped and porous with a sponge-like morphology. The fines are then blended with alloy additions; cold compacted into a green compact at up to 415 MPa then vacuum sintered at 1260 °C to produce a 99.5% dense component.

Hot isostatic pressing (HIP) can further increase the density of these parts and produce components more economically than cast or wrought parts, but the porosity present in the material degrades fatigue and fracture properties. Constituent in pyrotechnic fuses and combustible compositions, photographic/ignition pastes, glass to metal or ceramic to metal joining material, gas turbine engines, intermetallic compositions, ship structures, pumps. deep-sea submersibles, condensers, airframes, water-jet propulsion systems, weapons, systems, flue gas desulphurization, steam turbines, fan blades, piping systems, compressor discs, heat exchangers, wing structures, vessels, tanks, agitators, eyeglass frames, medical implants, nuclear waste storage, valves, springs, connecting rods, jewelry and sports equipment.

3.3. FABRICATION OF COMPOSITE

The composite is fabricated by using the stir casting process. Here, we fabricate the composite by reinforcing Silicon Carbide powder and Titanium powder in proportion. Here, we take composite with different ratios and fabricate them. Here, we take Silicon Carbide (SiC) as 3% and Titanium (Ti) as 0.1% with Aluminium as base metal. These compositions are made to be done by stir casting and being tested for its properties. The plate has been fabricated and the stir casting equipment is shown in the figure 3.

Figure 3 Stir casting setup

4. RESULTS AND DISCUSSION

In this study, aluminium was reinforced with Silicon Carbide (SiC) and Titanium (Ti) to study the wear characterization of this composite. Pin on disk test, SEM and EDAX were taken and results are discussed below.

4.2. EDAX TEST

EDAX test was taken in order to study the metal composition and the percentage of materials added to the material. From the figure 4 we can justify the various compositions in the materials. The result also helped us to verify the amount of the composition added to the aluminium scarp material which can be seen in the below figure 6.

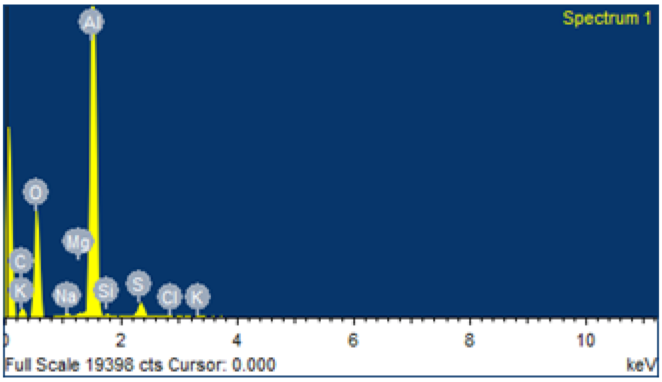


Figure 4 EDAX Test result image

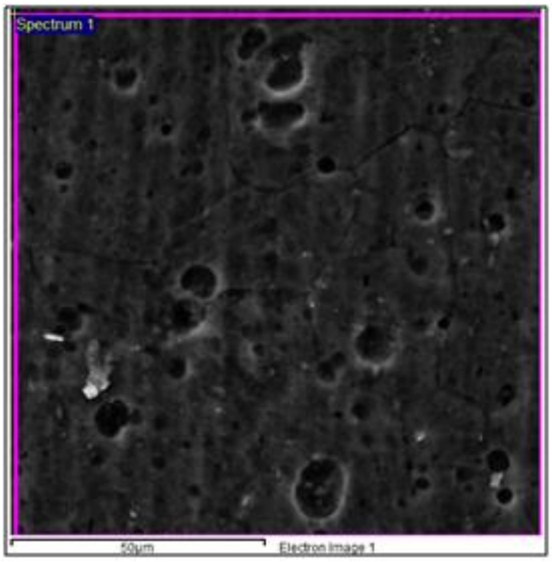


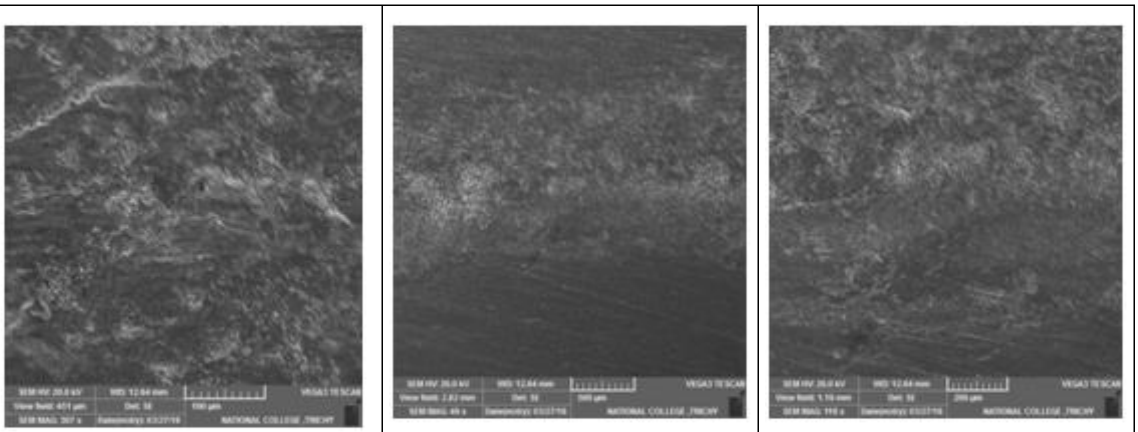
Figure 6 Spectrum Image

Table 2 List of Elements

ELEMENTS	WEIGHT %	ATOMIC %
C	13.15	19.68
O	19.68	19.91
Na	0.25	0.20
Mg	0.19	0.14
Al	33.96	22.62
Si	0.33	0.21
S	2.09	1.17
Cl	0.22	0.11
K	0.13	0.06

4.3. Scanning Electron Microscopic image analysis

The Scanning electron Microscope was taken in order to study the grain structure of the fabricated material and the result can be obtained from the figure 7 (a) – (c). From these figures, the grain structure of the material is studied and the uniform particle distribution is found. Therefore, strength is comparatively high with addition of Ti and SiC. The SEM images for 200µm and 500µm also reveals the uniform distribution of reinforcement particles inside the metal matrix.



(a) 100μm (b) 500μm (c) 200μm

Figure 7 Scanning electron microscope of wear surfaces

4.4. WEAR TEST

The wear test (Dry testing) is done by using pin on disc apparatus the specimen is the pin which attached to a holder and is slides on the disc. It is a computerized apparatus so the result is generated by the computer.

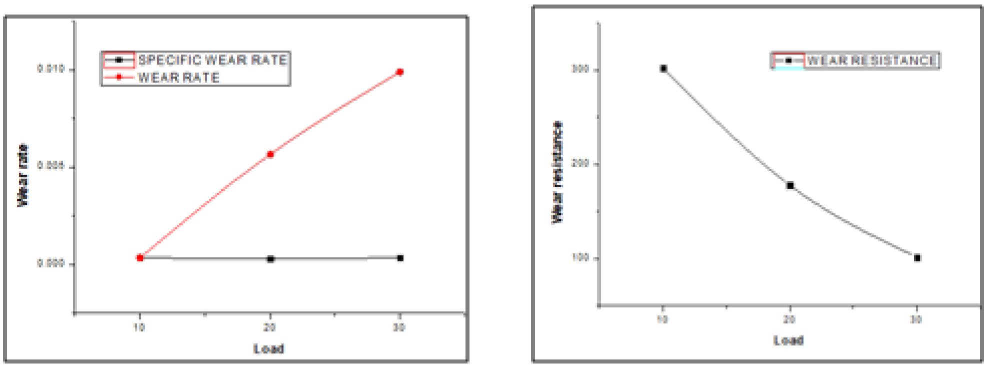


Figure 8 Wear behavior of composites

The fig. 8 shows the results of the three different composite having different SiC and Ti content. The addition of graphite particles increase the van der wall forces inside the metal matrix. This will reduce the dislocations and thus the wear resistance increases. It can be understood that the composite having silicon content 3% shows lesser wear rate. When we add silicon content the wear rate increases. This is because the addition of titanium beyond a limit will reduce the bond strength among the particles and thereby reduces the wear resistance. The load applied is varied from 10 to 30N. When load increases, the wear rate increases with decrease in wear resistance behavior.

5. CONCLUSION

- The tests are to be carried out to find out their wear properties and grain structure.
- The experimental results are to be compared with the conventional Al, where we can see the impact of this addition of Titanium and SiC particulates.
- Grain structure result is found to be low when strength is high and the grain structure is found to be high when strength is low.

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