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Investigation on mechanical and tribological properties of Al 7175 matrix composite with graphite and fly ash

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Abstract

Metal matrix composites (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications Aluminum metal matrix composites (AMMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the stiffness, specific strength, wear, creep and fatigue properties compared to the conventional engineering materials.The aim involved in designing aluminum based metal matrix composite by combining different percentage of particulates in the combination. Current investigation is concentrated on the fabrication of aluminum 7175 based metal matrix composites reinforced with Graphite & Fly ash by crucible casting technique to determine Wear resistance, Hardness, Tensile strength various volume-based ratio.

Keywords: Al 7175 Matrix; Stir Casting; Micro-hardness; Microstructure; Tensile Test; Pin-On-Disc; Wear

1. Introduction

Metal composite materials have found application in many areas of daily life for quite some time. Materials like cast iron with graphite or steel with a high carbide content, or tungsten carbides, consisting of carbides and metallic binders are belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). In the automotive industry, MMC have been used commercially in fiber reinforced pistons and aluminium crank cases with strengthened cylinder surfaces as well as particle strengthened brake disks. These type of surface composites are produced by impregnating the particulates in the surface while keeping the core free from it. Conventional monolithic materials have limitations of achieving the good combination of strength, stiffness, toughness and density. The mechanical and machinability properties of Fly ash particle reinforced AlMMC are as follows, With the increase in reinforcement ratio, tensile strength, hardness and density of Al-MMC material increased, but impact toughness decreased. Compo forging of Al-Si Metal Matrix Composites reinforced with Fly ash increased the mechanical resistance to elongation.G. Venkatachalam et.alGray cast iron is the most commonly used material in automobile brake rotors. It generates heat easily during braking which affects its mechanical properties and the Coefficient of friction varies depending on the type of material used for the brake rotor. Aluminium (Al) based metal matrix composite can be an efficient and effective braking material compared to cast iron and matrix alloy. In the present investigation, Al6082 composites were fabricated by stir casting method by varying weight percentage of reinforcements for Sample1 (Al 90% + SiC 10%), Sample 2 (Al 90% + SiC 5% + fly ash 5%) and Sample 3 (Al 90% + SiC 5% + basalt 5%). Chemical compositions, micro hardness, wear test and tensile test were performed to study the mechanical behavior of all the test specimens. The surface morphology was studied using microscopic inspection to indicate the distribution 17 of reinforcement particles and bonding between the matrixes. Composites containing hard oxides (like SiC) are preferred for high wear resistance along with increased hardness and high temperature oxidation resistance. The result reveals that wear rates of the composite materials is lower than that of the matrix alloy and friction coefficient was minimum. Also, it improves the micro hardness and tensile strength. The addition of fly ash and basalt

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decreases the wear and it acquired density almost three times lower than that of gray cast iron. In this investigation, the alternate materials for automobile brake rotors with Al reinforced composites were studied. M.Barmouz et.al By harnessing the benefits from both construction and demolition waste recycling and geopolymer binders, geopolymeric recycled aggregate concrete (GRAC) can 24 contribute to the green and eco-friendly construction material products. In this study, the compressive behavior of GRAC based on fly ash and slag was experimentally investigated under both quasi-static and dynamic loadings. Quasistatic compressive tests were performed by using a high-force servo-hydraulic test system, while dynamic compressive tests were carried out by using a Ø80-mm split Hopkinson pressure bar (SHPB) apparatus. The compressive properties of GRAC under dynamic loading, including stress-strain curves, energy absorption capability, and failure modes were obtained and compared with those under quasistatic loading. The results show that the compressive properties of GRAC exhibit a strong strain rate dependency. Although the recycled aggregate replacement decreases the quasi-static compressive strength, it exhibits a slight effect on the compressive strength at high strain rates. Dolata-Grosz.A et., al, the article presents the research results on tribological properties (friction coefficient, wear) of the frictional couple cast iron-composite. The subject of that research was aluminum hybrid composites containing two carbide phases: chromium **(Cr_3C_2)** and titanium carbides (TiC).Design/methodology/approach: The friction process was conducted on a tribological pin-on-disc tester (T-01M) 27 under technically dry friction conditions.Findings: The results of friction and wear coefficients' investigation allowed the determination of how the volume fraction of NiCr/Cr_3C_2+TiC composite powder can influence on the course and degree of cast iron and composite wear.Practical implications: An increase in the reinforcing phase fraction allowed the elimination of the phenomena connected with adhesion wear. The 10% fraction of a carbide reinforcing phase ensures a uniform wear mechanism and has a beneficial influence on the operation of the tribological couple: cast iron – hybrid composite, during which no negative effects of increased wear of the cooperating material are observed. Originality/value:

1.1. Experimental methodology

Figure 1 Proposed methodology

2. Selection of base material

A7175 is selected as the base material due to its excellent welding characteristics and formability along with good corrosion resistance. But it has low wear resistance and low strength; these problems may be overcome by proper selection of reinforcement material. A7175 has excellent cold working characteristics but cannot be hardened by heat treatment. The chemical composition and mechanical properties of base metal A7175 are listed in the Table 1 and 2

Table 1 Chemical composition of A7175 alloy (weight %)

Elements	Si	Mg	Mn	Fe	Zn	Cu	Ni	Ti	Al
Weight (%)	6.5 - 7.5	0.4	0.10	0.15	0.07	0.03	0.05	0.1	91.1 - 93.3

Table 2 Mechanical properties of A7175 alloy

Properties	Values
Elastic Modulus (Gpa)	71
Density (g/cc)	2.7
Poisson's Ratio	0.33
Brinell Hardness (HB 500)	75
Tensile Strength Mpa	220
Melting temperature (°C)	660
Elongation (%)	0.2

2.1. Selection of reinforcement material

Fly ash (Fly ash) and Graphite (Gr) have been selected as the reinforcement material due to its excellent wear, corrosion resistance and warping at the elevated temperature. These particles frequently acts as a third body abrasives that lead to increase in these mechanical properties. The Fly ash and graphite particles are shown in Figure 2 and 3.

Figure 2 Fly ash particles (Size -45 to80 microns)

Figure 3 Fly ash particles (Size -25 to 45 microns)

2.2. Experimental setup for stir casting

Performing the stir casting operation and testing of composites the following Machines/equipment was used

• Sieve Analysis Tester • Reinforcement (Fly ash and Graphite) • Matrix (Al 7175) • Muffle Furnace • Radial Drilling Machine • Crucible/ mould	• Fly ash and magnesium Stirrer • Rod (SS3l6) of diameter 20mm, Length 300mm • Micro hardness testing machine • Optical Microscopy • Scanning electron microscope • Power Hacksaw

2.3. Composites preparation by stir casting method

A stir casting setup which consisted of a resistance furnace and a stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a 36 graphite turbine stirrer, which was connected to a variable speed vertical drilling machine (speed 0 to 890 rpm) by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size manually. The stirrer consisted of three blades at angles of 120° apart. Figure 4.2 show the photograph of the stirrer from two different angles. Clay graphite crucible of 1.5 Kg capacity was placed inside the furnace. The stirrer assembly consisted of a graphite turbine stirrer fixed to a steel rod. Approximately 1Kg of alloy was then melted at 820°C in the resistance furnace of stir casting setup. Preheating of Silicon Nitride, Aluminum Nitride, and Zirconium Boride mixture at 800°C was done For one hour to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 800 rpm and the preheated Silicon and Iron particle was added with a spoon at the rate of 10- 20g/min into the melt. The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Aluminum alloy 2618 , Silicon and Iron particle, stirring was continued for 10 minutes for better distribution. The melt was kept in the crucible for one minute in static condition and it was then poured in the metal mould.

3. Results and discussion

3.1. Micro hardness Testing

The hardness test is conducted at room temperature (300 ºC) and the measurement of hardness is taken at five different places on each sample to obtain an average value of hardness shown in the table 3. The results obtained from micro hardness analysis using Micro Vickers hardness tester with a load of 0.5Kg are shown in **Figure 4.** Which indicates the increasing wt 10% of reinforcements, The hardness value also increases due to reduced plastic deformation by the reinforced particles.

Table 3 Hardness value at different composition

EQUIPMENT USED : METALLURGICAL MICROSCOPE-METSCOPE-1A				
Aluminium 7175 Reinforced Fly ash And Graphite	HVI KG	HVI KG	HVI KG	AVG
SAMPLE 5%	62.5	67.7	70.1	67.7
SAMPLE 10%	67.9	86.4	92.2	86.4
SAMPLE 15%	70.7	74.7	77.9	74.7

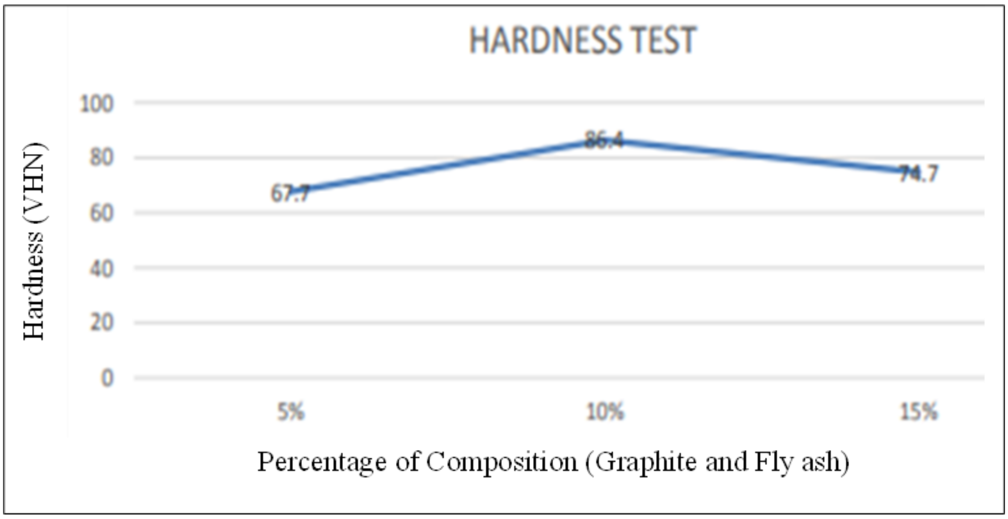

Figure 4 Hardness Test at different composition (Ambient Condition)

3.2. Tensile Testing

As per the ASTM standard, the tensile strength is evaluated on the cylindrical rod of reinforced composites. The universal testing machine (UTMAuto instrument) loaded with 10KN load cell is used to conduct the tensile test. The tensile strength (Table 4) is evaluated at cross head speed of 2.5mm/min. Figure 5, tensile test was conducted on different composition like 5%, 10% and 15% at ambient condition. From the results which is got higher tensile value 97 MPa at 10% with the composition of reinforced fly ash and Graphite**.**

Table 4 Tensile test value at different composition

Equipment Used :Utm.Make : Fie. Model Utn 40. Sr No: 11/98 – 2450.			
Aluminium 7175 Reinforced Fly ashand Graphite	5%	10%	15%
Tensile Strength In Mpa	94.4	97.7	92.5
Yield Stress In Mpa	210	237	247
Elongation	10.26 %	14.56 %	5.86%

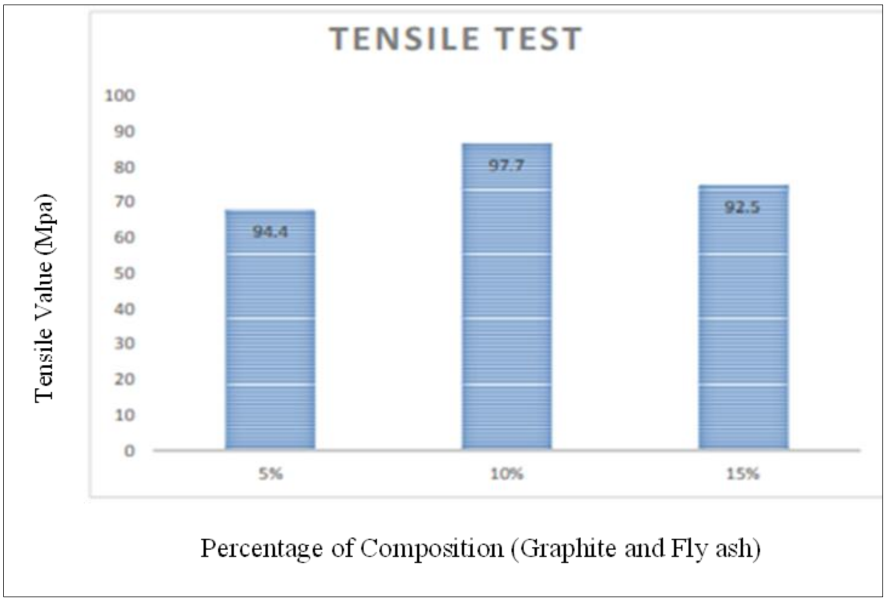

Figure 5 Tensile Test at different composition (Ambient Condition)

3.3. Pin-On-Disc Test

In this test, a normal load is applied via a pin onto a rotating disc. The sliding motion may be in one direction or reciprocating. The tests may be conducted in dry or under lubrication. The coefficient of friction, μ, can be obtained from this 94.4 97.7 92.5 0 10 20 30 40 50 60 70 80 90 100 5% 10% 15% TENSILE TEST 52 test at any point in the test. Typically one measures the mass before and after the wear test by means of a sensitive microbalance. The wear rate is given by The wear test for all specimens was conducted under the normal load (10 N,), sliding distance (1000 m, 1500 m, 2000 m), and sliding velocity (1.5 m/s, 2.5 m/s and 3.5 m/s). The samples were weighed (using electronic microbalance up to an accuracy of ±0.0001 g) before and after each test and weight loss was calculated as the difference between these two **data as mentioned in the Table 5**. The wear of the composite was studied as a function of the sliding distance, applied load and the sliding velocity. The surface of the pin samples rubbed using emery paper of Fly ash (1000 grit size) prior to test in ordered to ensure effective contact of fresh and flat surface with the steel disc.

Table 5 Wear test value at different composition (Pin-On-Disc)

SAMPLE ID	INITIAL WEIGHT (G)	FINAL WEIGHT(G)	ABRASION (G)	%
5%	3.2928	3.0862	0.2066	6.27
10%	3.2927	3.0862	0.2065	6.24
15%	3.2946	3.0852	0.2075	6.48

3.4. Microstructure Results

Figure 6 reveal the micro structure analyses were carried out with various samples 5% 10% 15% taken at optimized condition for the work piece. The main reason for this could be due to the increase in thickness of smeared graphite layer at the sliding surface of the wear sample, which is generated due to the extrusion of brass to the surface of the tested pin during sliding and which acts as a solid lubricant. Better homogeneity of brass phase spatial distribution leads to lower coefficient of friction of composite or better wear properties. However in conventionally sintered cu-graphite MMC, there is high probability of clustering of brass particles. This may be the only plausible explanation for such high wear depth of brass sample (even with such high brass concentration).

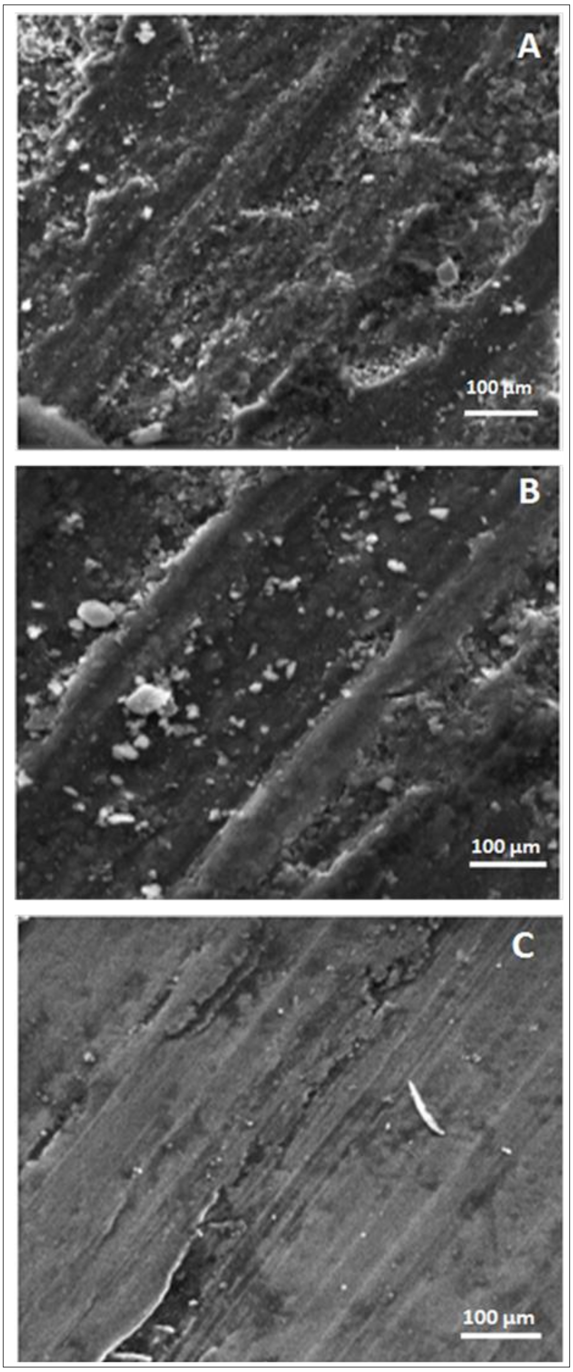

Figure 6 Composite fly ash-GR reinforced AL7175 at A) 5% B) 10% C) 15%

4. Conclusion

Fly ash-graphite reinforced aluminum 7175 particulate composite was successfully synthesized by the Stir casting method. This may be attributed to the fact that Cu particles greatly interact with each other leading to clustering of particles and consequently settling down.

The micro structural behavior of Fly ash-graphite reinforced aluminum 7175has been studied by varying mass fractions of 5%, 10%, 15%, and 15%. Micro structural observations show that the Fly ash-graphite reinforced aluminum 7175 particulates are uniformly distributed in the AL matrix. In all microstructures consist of coarse grains of AL 7175 solid solution with brass inter metallic particles in the grain boundaries are observed and this can influence the fracture behavior.

It is observed from results that the hardness of AL7175 reinforced Fly ash-graphite MMC increases with increasing wt% of AL 7175 particulate up to 10 wt% and then decreases with increasing wt% of brass particles. The tensile strength and impact strength (by using Charpy test) of the composite significantly increased the value in wt% of brass particulates up to 10%.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no any conflict of Interest for Publication.

References

[1] Tribological Properties Of Micro And Nano Sic Reinforced Aluminium Metal Matrix Composites -2017

[2] Mechanical Behaviour Of Aluminium Alloy Reinforced With Sic/Fly Ash/Basalt Composite For Brake Rotor G. Venkatachalam* And A. Kumaravel -2017

[3] Optimization Of Hardness In Aluminum Hybrid Metal Matrix Composite Mohammed AzamAliissn 2394 – 3386 Volume 4, Issue 12 December 2017

[4] Fabrication And Characterization Of Al356.2, Rice Husk Ash And Fly Ash Reinforced Hybrid Metal Matrix Compositevol.94 (2016), Pp.49-56

[5] Experimental Investigation And Mechanical Behavior Of A356.1 Aluminium Alloy Matrix Composite Reinforced With Silicon Carbide Volume: 02 Issue: 03 | June-2015

[6] Improvement In Tribological Behavior Of Aluminum 356 Hybrid Metal Matrix Compositesl Issue 9: April 2015

[7] Barmouz.M, Asadi P, BesharatiGivi.M.K, And Taherishargh.M., 2011,"Investication Of Mechanical Properties Of Cu/Flyash Composite Fabricated By Fsp: Effect Of Flyash Particles' Size And Volume Fraction',Material Science And Engineering A, No.528, Pp.1740-1749.

[8] Devinder Yadav, And RanjitBauri, 2010,"Nickel Particle Embedded Aluminium Matrix Composite With High Ductility",Material Letters,No.64, Pp.664-667.

[9] Lloyds.D.J,2009,"Particle Reinforced Aluminium And Magnesium Matrix Composites",International Materials Reviews,No.1, Pp.1- 23. 57

[10] Dolata-Grosz.A, And Wieczorek.J. 2007, Tribological Properties Of Hybrid Composites Containing Two Carbide Phases",Archives Of Material Science And Engineering, No.28, Pp.149-155.