CHARACTERIZATION AND MECHANICAL BEHAVIOUR OF FLY ASH/BASALT COMPOSITE-EFFECT ON METAL MATRIX COMPOSITES

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Abstract

Rheological behaviour of the matrix melts, the particle incorporation method, interactions of the particles and the matrix before, during and after the mixing, and the changing particle distribution during solidification are considering as major area of concern. Fly ash is also known as alumina-silicate particles, has been incorporated in to metal matrix composites for the last few decades mainly to reduced their weight, manufacturing cost and enhancing selected properties. Gray 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 of reinforcement particles and bonding between the matrixes. This paper represents an overview of the morphology and composition of both cenosphere (hollow) and precipitator (solid) fly ash particles of different sizes. The effects of various fly ash reinforcement on microstructure and mechanical properties, tribological behaviour and thermodynamic characteristics of different matrix of metallic alloy through highlighting their merits and demerits have been reviewed rigorously. Effects of volume fraction, particle size on the mechanical properties like hardness, tensile strength, strain, wear and fatigue is discussed in detail. Major occurrence like agglomerating phenomenon, formation and distribution of in situ Mg_2Si, $MgAl_2O_4$ and MgO into the metallic matrix, filler-matrix bonding, and phase transition are discussed in this article. 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 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.

Key words: Aluminum 6082 Grade, silicon carbide, Stir casting technique, Wear properties.

1. Introduction

Most disc brake rotors in use today are made of gray cast iron containing 3.25% to 3.70% dissolved carbon within its matrix and various additives. Due to its low cost and relatively ease of manufacture in high volumes, gray cast iron is a more specialized material for almost all the automotive disc brakes1,2. Due to the temperature generated in braking, the frictional surface of the brake rotor undergoes compressive yield followed by plastic deformation. When the disc brake subsequently cools down, it suffers from residual tensile stress generated in these spots. In addition, repetitions of such actions will cause cracks to appear on the friction surface. This may also lead to a variety of performance related problems such as distortion, heat cracking, brake fade, excessive component wear and judder. The thermal stability of a disc brake is greatly influenced by the behaviour of the material used, which leads to the undesirable effects3,4. Metal Matrix Composite (MMCs) has been playing a significant role in engineering applications particularly in lightweight material applications. Aluminium (Al) based metal matrix composites can be an efficient and effective braking material compared to cast iron5,6,7. Al 6082 has the highest strength of the 6000 series alloys also known as a structural alloy has attractive properties as lightweight, wear resistant, high stiffness and high thermal conductivity. Due to the poor wear resistance and high thermal elongation properties Al alloys are behind the selection of material for brake disc. The reinforcement of silicon carbide will help to enhance the wear behavior, hardness strength and reduce the thermal elongation without any modification of the base material properties. One of the inexpensively available waste from thermal power plant is fly ash. Composites produced using waste as reinforcement helps to minimize the environmental issues and also used to increase the mechanical properties of the composites. Al-alloy reinforced with fly ash that reveals the superior damping characteristics, increases mechanical properties and improved wear resistance. Basalt is a natural material that found in volcanic rock has good thermal, electrical and sound insulating properties.

2. Experimental procedures

2.1 Materials

For the present experimental investigation, Al alloy 6082 is used as a matrix material while SiC, basalt and fly ash are used as reinforcement material for the preparation of composite specimens. The chemical compositions of the fly ash and basalt were shown in **Tables 1** and **2** respectively.

Table 1. Chemical composition of the fly ash (wt.%)

Constituents	Composition (wt.%)
Al_2O_3	30.40
SiO_2	58.41
Fe_2O_3	8.44
TiO_2	2.75
Loss on ignition	1.43

Table 2. The chemical composition of basalt (wt.%)

Constituents	Composition (wt.%)
O	30.6
Si	26.09
Fe	12.14
Mg	3.59
Na	2.54
Ca	6.94
Br	3.31
K	0.51
Ti	1.35
Al	6.8

2.2 Fabrication method

The stir casting technique (also called the vortex method) is the most commercial while relatively low cost liquid processing method to fabricate MMCs. This method is simple, flexible and attractive as it also allows fabricating very large size components and also applicable to large quantity production. This processing technique also ensures the attainment of undamaged reinforcement materials. The stir casting equipment setup is shown in **Figure 1**.

The materials used for fabricating MMCs are Al alloy 6082 as a matrix material and SiC, fly ash and basalt as reinforcement particles. Al alloy rods were first cut into smaller pieces then 1 kg of Al alloy is placed in the crucible at temperature of 750 °C for 1 hour. The molten metal matrix is stirred for the first two minutes to create a vortex before adding in the preheated particulates. It recommended in order distributing the particles among the metal matrix more evenly. The reinforced particles are preheated in advance at 500 °C for 1 hour in the furnace to remove all the moisture on the particles surface for better binding results. Preheated reinforcement particles were then added into the molten Al alloy. Then stirring is done vigorously for 3 minutes at 200 rpm in order to avoid air bubbles and impurities on the surface which could lead to porosity. Subsequently the composite is poured (by bottom pouring casting) into a mould made of cast iron. The casted MMC samples were shown in **Figure 2**.

The final casted MMC samples were then made into specific specimen sizes. The varying weight percentage of reinforcements of samples was shown in **Table 3**.

Table 3. Constituents of samples

Sample	**Composition (wt.%)**
Sample 1	Al6082 - 90% SiC-10%
Sample 2	Al6082 - 90% SiC- 5% Fly Ash - 5%
Sample 3	Al6082 - 90% SiC- 5% Basalt- 5%

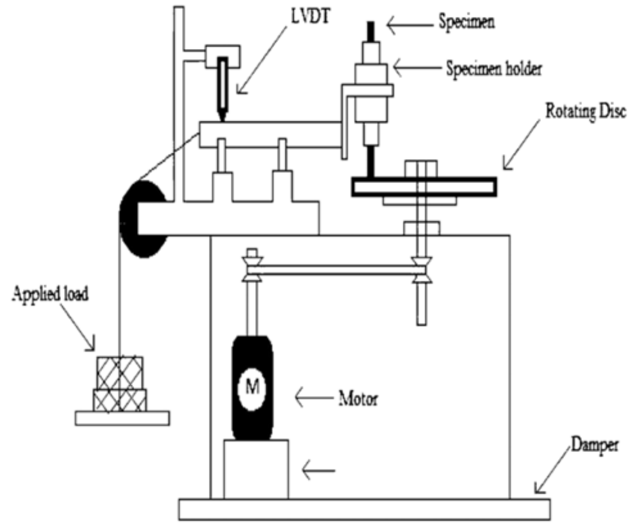
Figure 1. Stir casting equipment setup

Figure 2. Final casted AMMC samples

2.3 Wear Test

A pin-on-disc wear testing tribometer was used to investigate the dry sliding wear behavior of the Al 6082 MMC specimens. The wear tests were conducted as per ASTM G99 standards. From the cast samples a typical pin in cylindrical shape with 9 mm diameter and 50 mm length were machined.

Figure 3. Pin-on-disc test setup



2.4 Microstructure Test

Formicro structural study, samples were examined under optical microscope used to determine the morphology of samples and to investigate the distribution of reinforcement and interfacial integrity between the Al and reinforcements.

3. Results and discussions

3.1 Chemical Composition of Samples

Spectro -analysis technique were used to investigate the chemical composition of Al MMCs, the presence of reinforcement particles and the confirmation of weight percentage added in the Al matrix. The effect of reinforcement (SiC, fly ash and basalt) increases the percentage of copper, silicon, iron and zinc. The addition of copper increases the strength and facilitates precipitation hardening. The addition of silicon to Al reduces melting temperature and improves fluidity. The addition of zinc produces higher strength also it permits precipitation hardening. Iron is the common impurity that found in Al and it is intentionally added to some pure alloys to provide a slight increase in strength.

3.2 Wear Test

When the load is applied, the weight percentage of reinforcement particles increased, the wear rate increased significantly. The present results reveal that the wear rate of AMMC increases as load increase. This can be due to the wider size of SiC particles being pulled out from the matrix material hence causing the increased wear of the Al alloy matrix. A stable coefficient of friction is essential for car brake applications. Typical range of coefficient of friction (COF) for car brake is from 0.3 to 0.6. AMMC exhibited reasonable COF values within the range of 0.3 to 0.6, when applied load between 1 kg and 2 kg. As the weight percentage of fly ash increased, the COF decreased but remained at a reasonable range.

3.3 Tensile Test

In this study the experimental result shows that the addition of reinforcement particles improves the tensile strength of the MMCs. The tensile strength of composite has increased for sample 2 when compared to other composites due to good wettability of particles with Al melt. It was observed that the tensile strength enhanced with the addition of the fly ash and SiC particulates due to the absence of micro porosity, grain reinforcement and better interfacial bond between matrix and reinforcement.

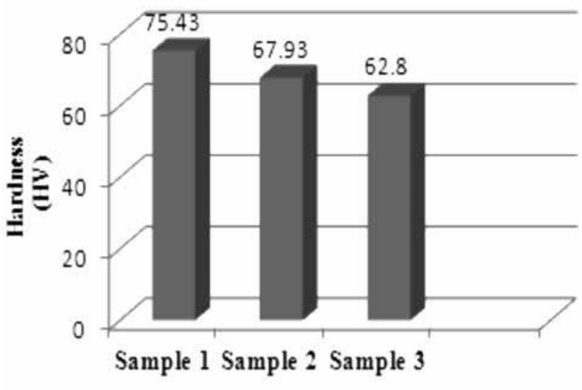
3.4 Hardness Test

In the hardness test to eliminate the possibility of error minimum three hardness readings were taken for each sample and the average value is calculated. The factors such as cooling rate, gravity effect and non-uniform distribution of particles give the different values of hardness in the cast MMCs. The experimental result shows that sample1has maximum hardness due to the complete uniform distribution of SiC particles. The influence of smaller particle size of SiC reinforcement increases the hardness.

3.5 Microstructure Analysis

The microstructure of 10% SiC was confirms the presence major elements like copper, zinc and iron in the composite and these particles are reasonably well distributed within the Al matrix as shown in **Figure 4**. The uniform distribution of SiC particles without voids and discontinuities can be observed from these micrographs. It was also found that there was good bonding between matrix material and SiC particles; however no gap is observed between the particle and matrix. The basalt distribution was observed and some pores were absorbed in the centre of a cluster of composite. Among the three composites, particle distribution in Al/ SiC composites is found to be better than other composite. This is due to the wetting of ceramic particles in Al controls the quality of MMC's.

Figure 4. Vickers hardness values



4. Conclusions

From the test result the tensile strength of the three different wt.% composite sample is increased gradually and addition of 5%SiC+5%fly ash sample is to get higher tensile strength 158.579 N/mm2compared with other samples. The percentage of elongation of the composite 5%SiC+5%fly ash sample was to get higher elongation 11.281 %. The hardness of the composite 10%SiC sample is to get higher hardness strength 75.43 HV compared with other samples. Dispersion of SiC particles in Al matrix improves the hardness of the matrix material. But only the third sample shows decreased hardness and tensile strength. The microstructure of 10%SiC confirms the presence of major elements like copper, zinc, iron and silicon in the composite and these particles are reasonably well distributed within the Al matrix based on the presented research work, it is found that the weight to strength ratio for Al alloy 6082 with SiC + basalt is about three times that of mild steel during tensile test. Al alloy 6082 with SiC + fly ash composite material is two times less in weight than the Al of the same dimensions. For all applied loads, AMMC show a stable friction coefficient (0.30-0.60) which is essential for brake rotor applications. This indicates that the AMMCs having low weight and high strength, it is very much useful in practical automobile and aerospace applications.

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