Dry Sliding Wear Behavior of 40 Micron Size B_4C Particulates Reinforced LM29 Alloy Composites

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Abstract

The work is carried out to investigate the dry sliding wear behavior of 40 micron sized B_4C reinforced LM29 alloy metal matrix composites. In the present work LM29 alloy was taken as the base matrix and B_4C particulates as reinforcement material to prepare metal matrix composites by stir casting method. For metal matrix composites the reinforcement material was varied from 0 to 9 wt. % in steps of 3 wt. %. The wear resistance of metal matrix composites was studied by performing dry sliding wear test using a pin on disc apparatus. The experiments were conducted at a constant sliding speed of 400rpm and sliding distance of 3000m over a varying load of 1, 2, 3 and 4 kg. Similarly experiments were conducted at a constant load of 4 kg and sliding distance of 3000m over a varying sliding speed of 100, 200, 300 and 400rpm. The results showed that the wear resistance of LM29-3, 6% and 9% B_4C composites were better than the unreinforced alloy. The wear in terms of height loss found to increase with the load and sliding speed. To study the dominant sliding wear mechanism for various test conditions, the worn surfaces were analyzed using scanning electron microscopy.

Keywords: LM29 Alloy, B_4C, Microstructure, Wear, Worn Surafce

I. INTRODUCTION

Metal matrix composites (MMCs) have been accepting extraordinary consideration because of their high rigidity, hardness and modulus, and also their high wear resistance contrasted with the framework. The tribological properties of aluminum compounds can be altogether upgraded by the addition of a dispersed ceramic particle phase [1, 2]. The subsequent material is all around known as aluminum matrix composites (AMCs). The improved properties of AMCs, for example, high particular quality, lessened wear rate and lower warm extension has pulled in the consideration of the materials designing group. AMCs are replacing regular aluminum alloys in a few applications including aviation, car, ship building and atomic designing [3]. Among different ceramic particles B_4C is progressively favored as support for AMCs because of its thermodynamic dependability, high dissolving point, high hardness, high flexible modulus and remarkable wear resistance.

AMCs could be delivered either by solid state or fluid (liquid) state preparing [4, 5]. Liquid state systems are for the most part utilized in light of the fact that these are economically viable, simple and applicable in large quantity production. Melt stirring techniques are of two sorts in particular ex situ and in-situ. In 'ex-situ' procedure artistic fortifications are added remotely to the liquid metal though 'in-situ' handle the generation of support happens inside the network accordingly of compound response. The in-situ composites represent a few focal points over ex-situ, for example, uniform dispersion of fortification particles, grain refinement, clear interface, improved warm steadiness and prudent preparing [6-8].

Al-Si based alloy is heat treatable aluminum composite, which offers high quality at low particular weight and are broadly utilized as basic segments, especially in the aerospace industry. B_4C strengthened LM29 composites are therefore be considered to have more application potential. It is however a testing undertaking to create homogeneous Al/B_4C AMCs utilizing these strategies. Regular imperfections, for example, porosity, agglomeration, isolation and slag consideration are for the most part unavoidable. A homogeneous dispersion of B_4C particles is fundamental to accomplish upgraded properties and execution.

Over the last decade, a lot of studies have been carried out to overcome these insufficiencies and plenty of experimental preparations have been performed. Several efforts have been made to improve the interface bonding between aluminium and ceramic particles by exploring surface coating of the ceramic particles. In the present study LM29-B_4C composites have been fabricated by using novel two step mixing process of reinforcements, to improve the wettability of B_4C particulates with Al alloy matrix.

In this study, an attempt has been made to prepare LM29 alloy composites by adding 3, 6 & 9 wt. % of B_4C particulates into matrix by using a novel two stage reinforcement addition method. Further, the prepared LM29– B_4C composites were studied for effect of load and sliding speed on the wear properties by using pin-on-disc wear testing machine.

II. EXPERIMENTAL DETAILS

Materials Used

Metal matrix composites containing 3, 6 and 9 weight rates of 40 micron sized B_4C particles were created by liquid metallurgy course. For the generation of MMCs, an LM29 alloy was utilized as the framework material while B_4C were utilized as the fortifications. The theoretical density of grid material LM29 amalgam is 2.7g/cm^3 and support particulates B_4C is 2.52g/cm^3. The chemical substance of LM29 composite utilized as a part of the work is given in the table 1.

Table.1 Shows the Chemical Composition of the LM29 alloy used in the present study.

Elements	Si	Cu	Mg	Ni	Al
Wt. %	24.0	1.0	1.0	1.0	bal

Synthesis of Composites

The B_4C particle reinforced LM29 alloy metal matrix composites have been produced by using a vortex method. Initially calculated amount of LM29 alloy was charged into SiC crucible and superheated to a temperature 730˚C in an electrical resistance furnace. The furnace temperature was controlled to an accuracy of ±10 degree Celsius using a digital temperature controller. Once the required temperature is achieved, degassing is carried out using solid hexachloroethane (C_2Cl_6) to expel all the absorbed gases. The melt was agitated with the help of a zirconia coated mechanical stirrer to form a fine vortex. A spindle speed of 300 rpm and stirring time 3-5 min. were adopted. The B_4C particulates were preheated to a temperature of 500 degree Celsius in a pre-heater to increase the wettability. The pre-heated B_4C particles introduced into melt in steps of two at constant feed rate of 1.2-1.4 g/sec. After holding the melt for a period of 5 min., the melt was poured from 710 degree Celsius into a preheated cast iron mould having dimensions of 120mm length x 15mm diameter.

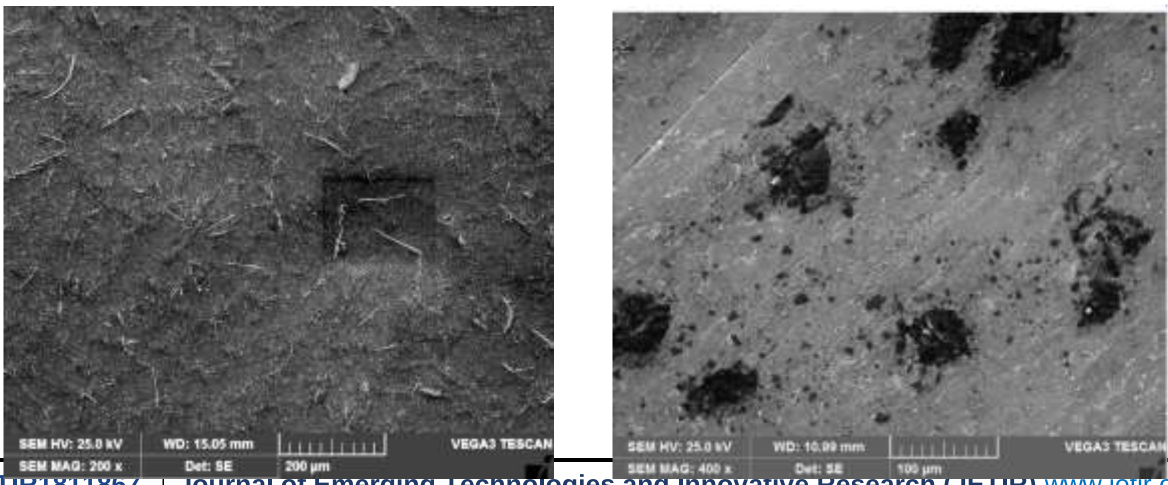
Testing

Metallographic test specimens of 5mm thickness were prepared by cutting the as cast and B_4C strengthened LM29 combination composites. Test samples were polished according to the standard metallographic methodology and etched with Keller's reagent. The microstructure was viewed utilizing scanning electron microscope instrument.

The dry sliding wear behavior of as cast LM29 alloy and LM29-B_4C composites were evaluated using a pin-on-disc wear apparatus at room temperature according to ASTM G99 standard. Pins of length 30 mm and diameter 8mm were prepared from the cast samples. The experiments were conducted at a constant sliding speed of 400rpm and sliding distance of 3000m over a varying load of 1kg, 2kg, 3kg and 4kg. Similarly experiments were conducted at a constant load of 4kg and sliding distance of 3000m over a varying sliding speed of 100, 200, 300 and 400rpm. The polished surface of the pin was slide on a hardened chromium steel disc. A computer aided data acquisition system was used to monitor the loss of height. Wear value is presented in terms of height loss.

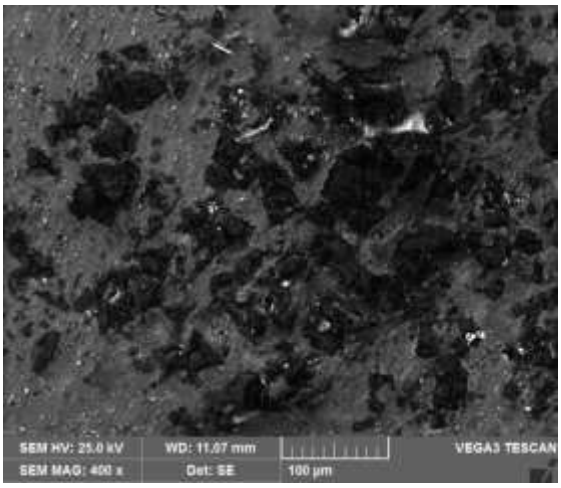
Results and Discussions

Microstructural Studies



(a)

(b)



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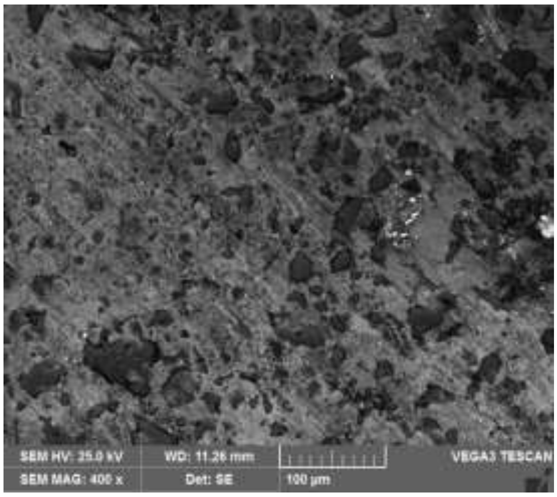

(d)

Fig. 1. a-d Showing the scanning electron microphotographs of (a) as cast LM29 alloy (b) LM29- 3 wt.% of B_4C (c) LM29- 6 wt.% of B_4C & (d) LM29- 9 wt.% of B_4C

Figure 1 (a-d) shows the SEM microphotographs of LM29 alloy as cast and LM29 with 3, 6 and 9 wt. % of 40 micron sized B_4C particulate composites. This reveals the uniform distribution of B_4C particles and very low agglomeration and segregation of particles, and porosity.

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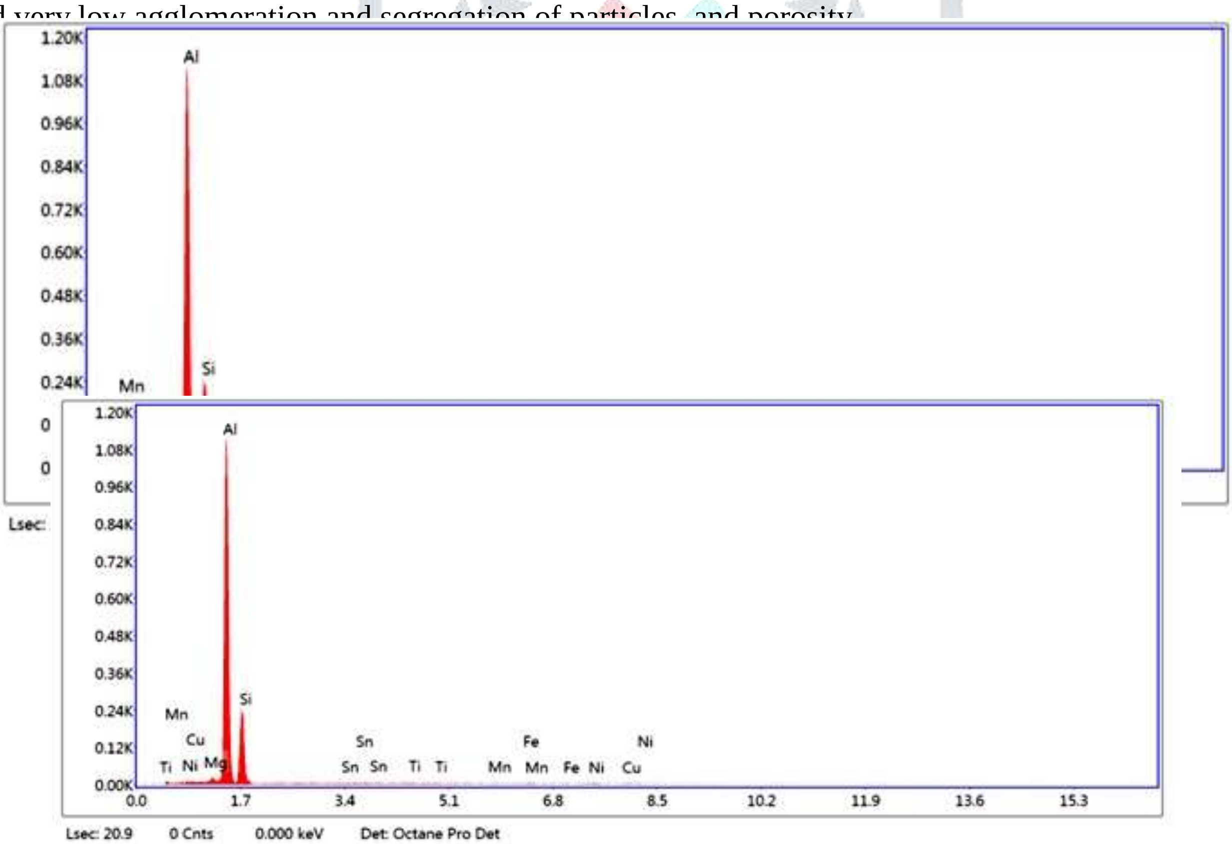
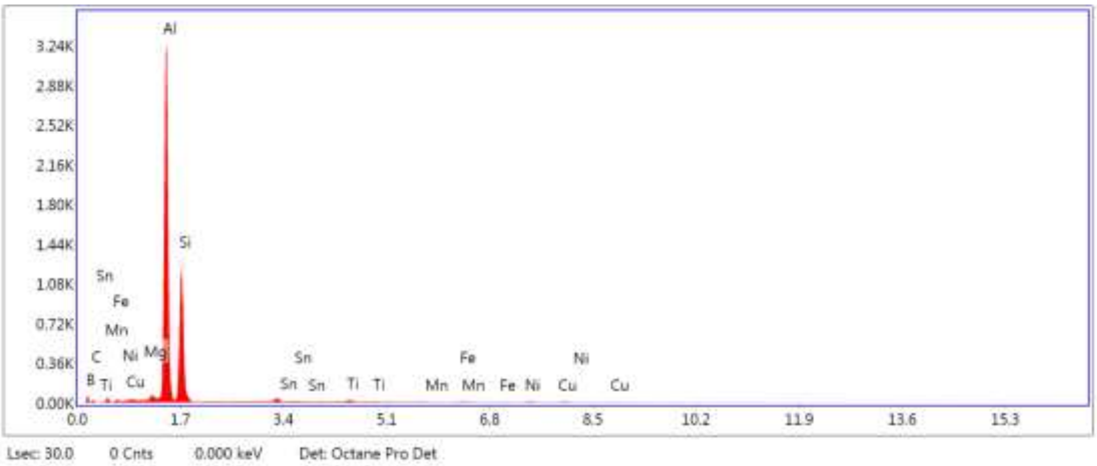


(a)



(b)

Fig. 2 EDS spectrum of (a) as cast LM29 alloy (b) LM29-9% B_4C composites

In order to confirm the presence of B_4C energy dispersive spectroscope analysis was carried out at the edge of the B_4C particle and Al alloy matrix. The EDS spectrum reveals the presence of B and C elements in the interface reaction layer of LM29 alloy (fig. 2-b).

Effect Load on Wear

The variation of wear loss at steady 400rpm sliding speed and changing loads of 1kg, 2kg 3kg and 4kg is as appeared in fig. 3. Applied load influences the wear of LM29 compound and the composites fundamentally and is the most overwhelming component controlling the wear conduct. The wear misfortune changes with the typical load and is altogether lower if there should arise an occurrence of composites [9]. With increment in loads there is higher wear misfortune for matrix alloy and the composites. However at all the loads considering wear resistance of the composites is better than the framework combination. At higher loads and the transition to sever wear the surface temperature exceeds a critical value. So as applied load increases ultimately there is an increase in the wear loss for both the reinforced and unreinforced composite materials. The variation of wear loss of the matrix alloy and its composites with 3, 6 and 9 wt. % of B_4C content is shown in fig. 3.

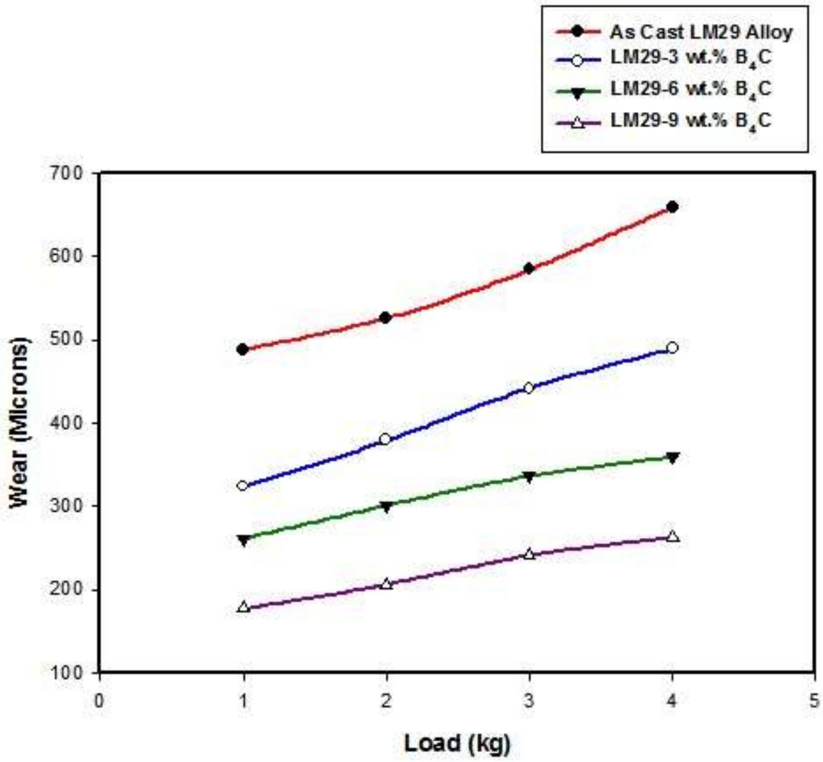


Fig.3 **Showing wear of LM29 alloy and its composites at varying loads and sliding speed of 400rpm and 3000m sliding distance**

The improvement in the wear resistance of the composites with 40 micron B_4C reinforcement can be attributed to the improvement in the hardness of the composites and improved hardness results in the decrease in the wear loss of the composites [10].

Effect Sliding Speed on Wear

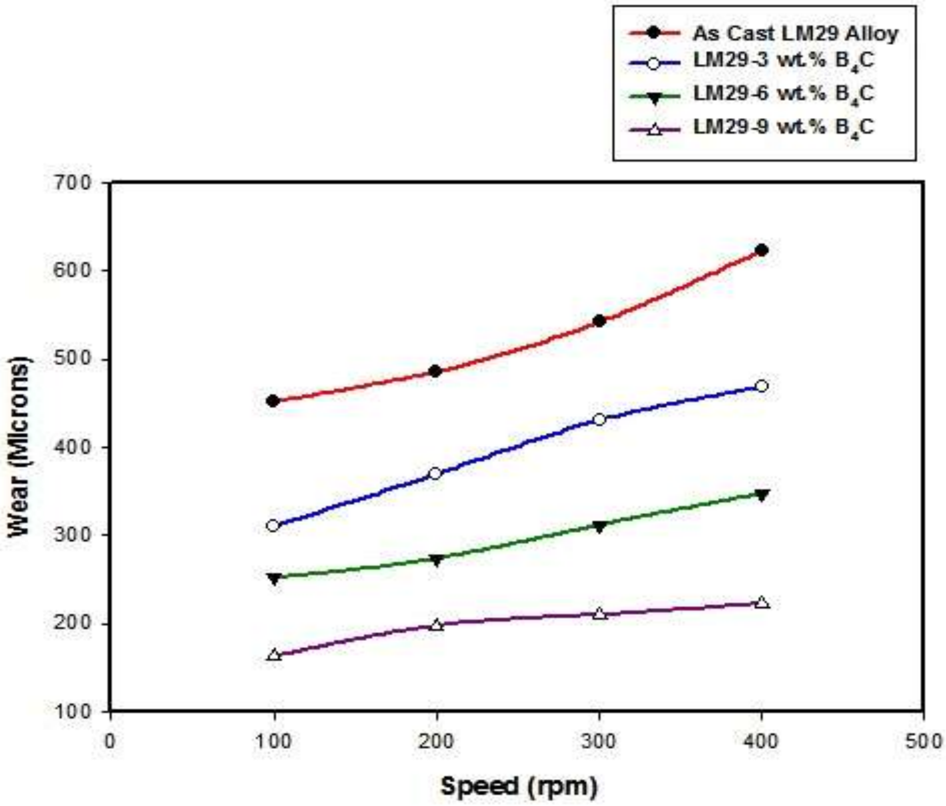
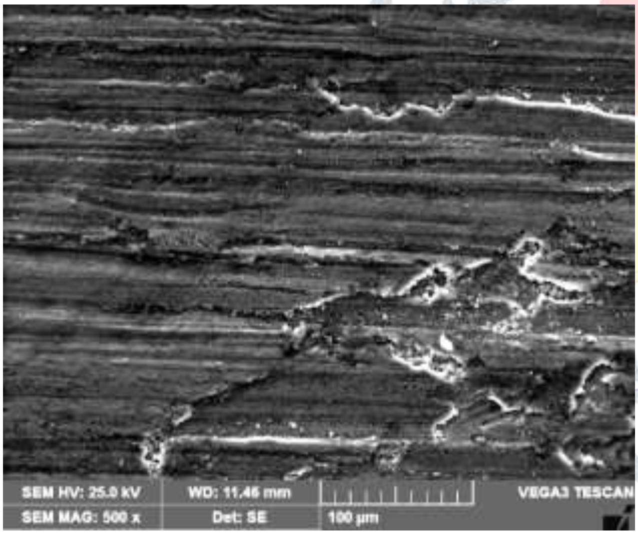


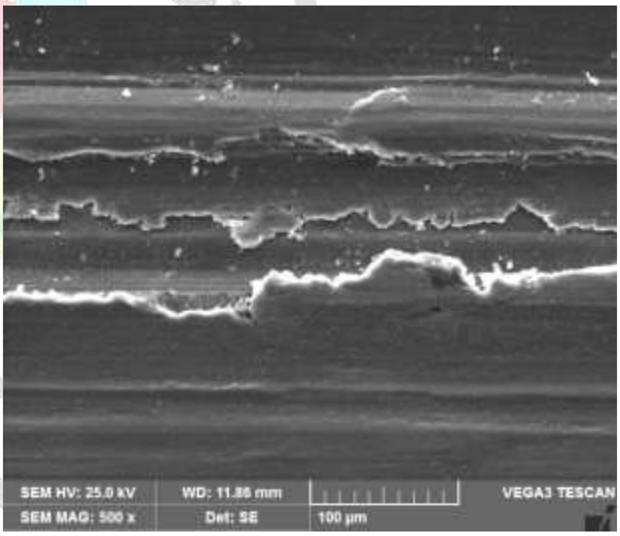
Fig.4 Showing wear of LM29 alloy and its composites at varying sliding speed, constant load of 4 kg and 3000m sliding distance

Fig. 4 shows the variation of wear loss of LM29 matrix alloy and LM29-3, 6 & 9 wt.% of 40 micron B_4C composites at constant 4kg load and varying sliding speeds. With an increasing speed i.e. 100, 200, 300, and 400 rpm, there is an increase in the wear loss for both matrix alloy and its composites. However at all the sliding speeds studied, the wear loss of the composite was much lower when compared with the matrix alloy. Further increased wear rate with increased sliding speed is due to thermal softening of the composite. On the other hand the increased temperature at higher sliding speeds can cause severe plastic deformation of the mating surfaces leading to form high strain rate sub-surface deformation [11, 12]. The increased rate of sub-surface deformation increases the contact area by fracture, and fragmentation of asperities. Therefore this leads to enhanced delamination contributing to enhance wear rate. Further, 9wt. % of B_4C particulates reinforced LM29 alloy composites shown more resistance to wear.

Worn Surface Morphology



(a)



(b)

Fig. 5 Shows the SEM microphotographs of worn surfaces of (a) as cast LM29 alloy (b) LM29 – 9wt. % B_4C at 4kg load and 400rpm

Wear surface analysis of composites were examined by scanning electron microscope. Fig.5a-b represents the wear surface of as cast LM29 alloy and specimens containing 9 wt. % of B_4C particles reinforced composite at 4 kg load and 400rpm sliding speed.

The examination of worn surface as appeared in figure 5a, that the worn surfaces of base combination are considerably rougher than composites. Cavities and extensive furrowed surfaces are found on worn surface of LM29 amalgam. The sign of pits and scores underpins the way that delicate Al composite disfigured at higher load of 4kg and at 400rpm speed and hauled out from the surface. The wear track perception demonstrates that grip and delamination are prevailing wear instruments seen at higher loads. This is supported by the large sized delamination flakes and severe adhesion resulting in bulk removal of material at higher loads [13].

Fig. 5b shows the SEM image of the worn surface of LM29-9 wt. % of B_4C composite tested at applied load of 4kg and 400rpm speed. The grooves are very small due to the hard nature of B_4C reinforcement and poor wear losses. As the ceramic particles resist the delamination process, composites are found to have greater wear resistance [14]. Worn surface shows less cracks and grooves mainly due to the presence of hard particulates.

Conclusions

The present work on processing and evaluation of LM29-B_4C metal matrix composite by melt stirring has led to following conclusions. LM29 alloy based composites have been successfully fabricated by melt stirring method using two stage addition method of reinforcement combined with preheating of particles. The SEM microphotographs of composites revealed fairly uniform distribution of reinforcement particulates in the LM29 metal matrix and EDS spectrographs confirmed the presence of B_4C particles. The addition of B_4C particles to Al alloy matrix improves the wear resistance of the composite. The wear loss is dominated by load factor and sliding speed. The increase of loads and sliding speeds leads to a significant increase in the wear loss. The LM29-9% B_4C composites have shown lower wear loss as compared to that observed in as cast LM29 alloy and 3 and 6 wt. % B_4C reinforced composites matrix. Worn morphology showed the effect of hard ceramic particulates addition on wear behavior of Al alloy and its composites.

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