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Wear Characteristics of LM13 Alloy with Course Size of Rutile Reinforcement

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ABSTRACT

Dry sliding conditions involve wear and tear of the various components in the machinery which poses a great challenge to the material researcher. To address this issue the metallic alloys need to be strengthened in order to display better tribological and thermal behaviour. This investigation is based on the study of development of rutile reinforced aluminium composite by changing the reinforcement from 5to 15wt. % in steps of 5 % with coarse size of rutile particles. The specimens were prepared through stir casting technique. The refinement in microstructure is the probable cause of the increased strength and hardness. Wear studies of the samples revealed the phenomenon of mild-oxidational wear which was further confirmed on the basis of worn surface and wear debris nature.
Keywords: Ceramics, Reinforcement, Rutile, Wear Debris

I. INTRODUCTION

To meet the requirement of the new materials due to the rapid growth of innovative technological applications in modern industry, ceramic particles are embedded into the virgin aluminium alloys. These alloys have limited utility because of its poor mechanical and thermal resistance at high temperatures. Aluminum metal matrix composites (Al-MMCs) are used as research material as they possess desirable attributes of ceramics and Al alloys like improved strength through grain refinement, loss of material due to wear and friction, increased hardness and low coefficient of thermal expansion [1-3].

Aluminium metal composites are preferred over other matrix materials such as copper and magnesium due to its economical benefits and easy to fabricate[4,5].The characteristics of the developed composite are dependent on number of parameters like shape ,size, type of added ceramic particles and its dispersion in the matrix. The tribological properties of the composites are highly affected by the size of the ceramic particles. Tofigh and Shabani [6] investigations of the aluminium composite with of the different size of B_4C particles showed that composite displayed better abrasive wear resistance. The surface roughness of the composite material was decreased by adding the large sized B_4C particles. Kumar et al. [7] reported that increased volume fraction of reinforced ZrB_2 particles improved the hardness of the Al5052 composite which further leads to enhancement in strength of the formed material.

Based on the earlier research studies it could be inferred that metallic as well nonmetallic reinforcement are the appropriate materials which can be used for the fabrication of the aluminium matrix composites. So as a non-metallic reinforcement natural mineral was selected as the additive particulates into the aluminium matrix. Keeping in view the positive aspects of minerals like recycling and reusable properties, it was decided to use rutile for improving the mechanical properties of the aluminium composites.

In this paper, the influence of rutile content on the aluminium alloy was studied with reference to the dry sliding wear behavior of the composite. Microstructural studies were done by varying the content of rutile mineral .The prepared composite is proposed as a potential material for various mechanical applications like piston, brakes and engines.

II. EXPERIMENTAL DETAILS

Raw Materials

For the preparation of composites, a piston alloy LM13 alloy in the form of ingots which is also is used as matrix material. This alloy has excellent casting properties and reasonable strength as a base alloy. Its chemical composition is given in Table-1.

Table 1. Chemical composition of LM13 alloy

Composition of LM-13 Alloy	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Pb	Sn	Al
XRF	11.16	0.332	1.247	0.598	0.849	0.25	0.026	0.868	0.001	0.002	Bal.
Chemical analysis	11.80	0.365	1.230	0.411	0.940	0.21	0.025	0.940	0.028	0.005	Bal.

Rutile reinforced material is basically a natural mineral silicate, abundantly available in nature and having hardness of (6.5-7.5Mohs) as well as chemically inert at high temperature. The amount of rutile was taken as 5wt. %, 10wt. % and 15wt. % in the particles size ranges of coarse (106-125µm).

Preparation of Composite

Stir casting technique is adopted for the preparation of the composite. Processing variables such as holding temperature, stirring speed, size of the impeller, and the position of the impeller in the melt are among the important factors to be considered in the production of casting of metal matrix composites as these influence the mechanical properties [5]. Required quantity of LM13 alloy was melted at a temperature of 750˚C in an electric furnace. The molten mass was stirred using a graphite impeller at a speed of 630 rpm to create a vortex. The reinforcement material was then introduced at the side of the vortex with the help of funnel kept on top of vortex. The stirring was continued for 5 minutes even after complete addition of rutile particles into the melt. Finally, the slurry was casted into metallic mold and allowed to cool at room temperature.

Materials Characterization

The surface morphology of each sample was studied with the help of optical microscope (Eclipse MA-100, Nikon). Wear tests were conducted on pin shaped specimen cut from each set of composite at a constant sliding velocity of 1.6 m/**s**, using a pin on disc wear monitor (Model TR-20CH-400, Ducom, Bangalore, INDIA). The wear rates were measured as a function of sliding distance at different loads 1kg, 3kg and 5kg.The worn surfaces were analyzed under SEM for morphological study.

III. RESULTS AND DISCUSSION

In this section, the microstructure, wear rate and analysis of worn surface of specimen after wear tests are analyzed to understand the microstructural evolution and wear mechanism involved in material removal of the composites during dry sliding wear test.

Microstructural Studies

The optical micrographs of 5, 10 and 15wt. % rutile reinforced with coarse particles (106-125µm) in the composites are shown in Figure 1(a-c), respectively. The distribution of the second phase dispersed particles in the alloy with high viscosity during solidification strongly governs microstructural features of the composite. Homogeneous distribution of rutile particles in the composites is achieved by the constant stirring action of the impeller which provides the normal shear strain and delays the particle settling tendency during stirring [1].

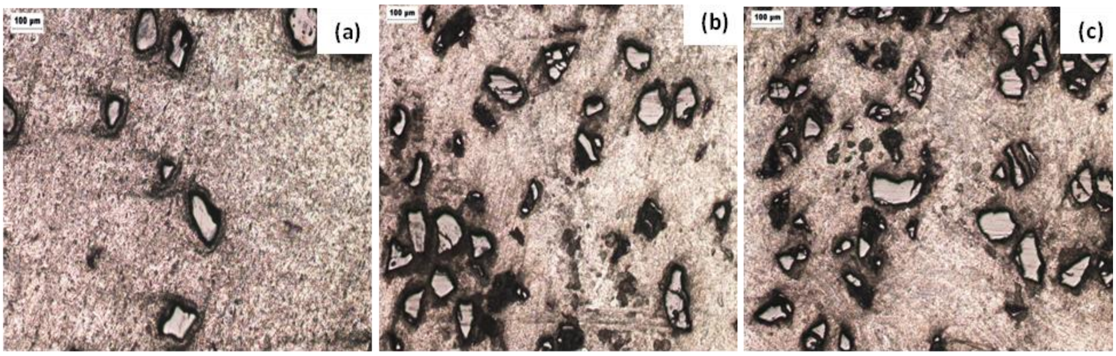

Figure 1. The optical micrographs of composite with different reinforced coarse particles size at (a) 5wt.% (b). 10wt.%, and (c) 15wt.%.

The dendritic morphology changes to cellular one in composite as reinforced particles restrict the solute transport processes by diffusion and flow [3, 4]. The fragmented dendrites due to the stirring action of the impeller are clearly observed in the particles depleted regions. The floral pattern of the dendrites can be observed in some regions in the micrograph of the higher concentration of rutile particle as can be seen in the Figs.1b and 1c. Overall, the rutile particles are well dispersed in the matrix phase.

Effect of Applied Loads on the Wear Rate

Wear rate of aluminum composites as a function of sliding distance at variable loads from 1kg, 3kg and 5 kg is shown in Fig. 2 (a-c). Abrasive wear behavior is dominant in the initial stages of run and is controlled by the asperity to asperity contact during the relative motion between two surfaces. The steady state is attained due to the continuous sliding which reduces the sharpness of the asperities hence causes fall in wear loss [8].The continuous increase in wear rate is observed with the increase in applied load due to the huge removal of material which may be explained on the basis of plastic deformation. High pressure during sliding, fractures the oxide cover envelope thus leading to the exposure of the substrate material hence causing plastic deformation beneath the surfaces

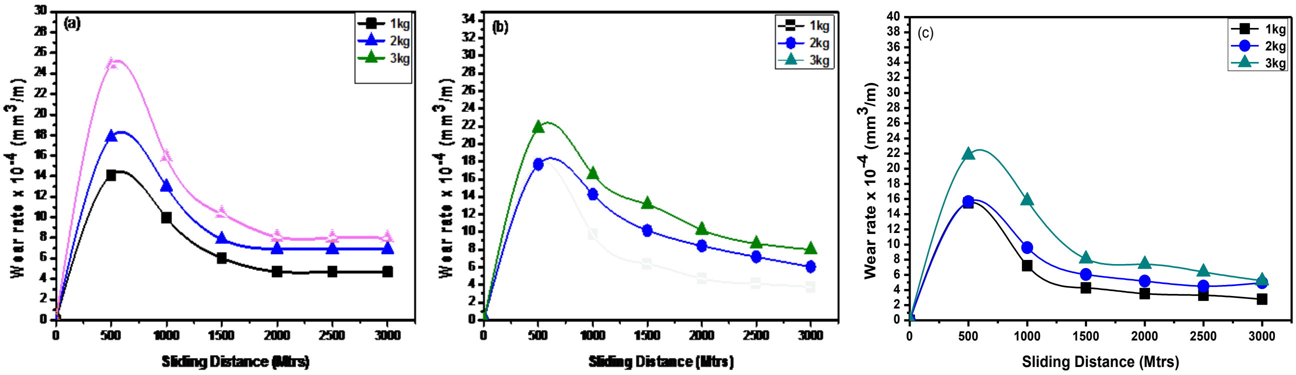

Figure 2. Wear rate against sliding distance of composite with coarse size reinforced (a) 5wt. % (b). 10wt. %, and (c) 15wt. % at different loads.

The increase of hard rutile particles into the matrix reduces the wear rate for all the applied loads[10]. Hard asperities of the composites safeguard the matrix from the abrasive action of the asperities of the counter surface. Arora et.al [11] in the earlier studies found that the increase in amount of the rutile particles increased the hardness which significantly reduces the wear rate of the composites.

Morphological Studies of Wear Tracks

The morphological studies of the wear track as shown in Figure 3 clearly depicts the increase in wear loss with the applied load in the form of ridges and grooves formed due to the abrasive action of the protruded asperities of the counter surface. During the dry sliding conditions, the friction between the relative motion of the two contact surfaces generate high heat which further accelerates the formation of tribo-oxides. The transition of mild wear regime is associated with an oxidational process that involves the formation of tribo-layers which seems to be crucial factor to decide the mode of wear mechanism [8]. With the increase in applied load and contact pressure to the critical point, a transitions of mild wear into mild-oxidational wear and then to severe-oxidational which is observed in the form of white oxidised depositions on large sized craters resulting due to heavy loss of material[12,13,14]. The wear debris generated from the abrasive wear at low load are in the form of thin ribbons during the mild wear regime and the delamination wear mechanism removes the oxidised material in the form of chips which is shows in (Figure 3c). The severe oxidative wear at high load could not safeguard the matrix from plastic deformation and therefore generate very large sized molten debris along with the debonding of the rutile particles from the matrix.

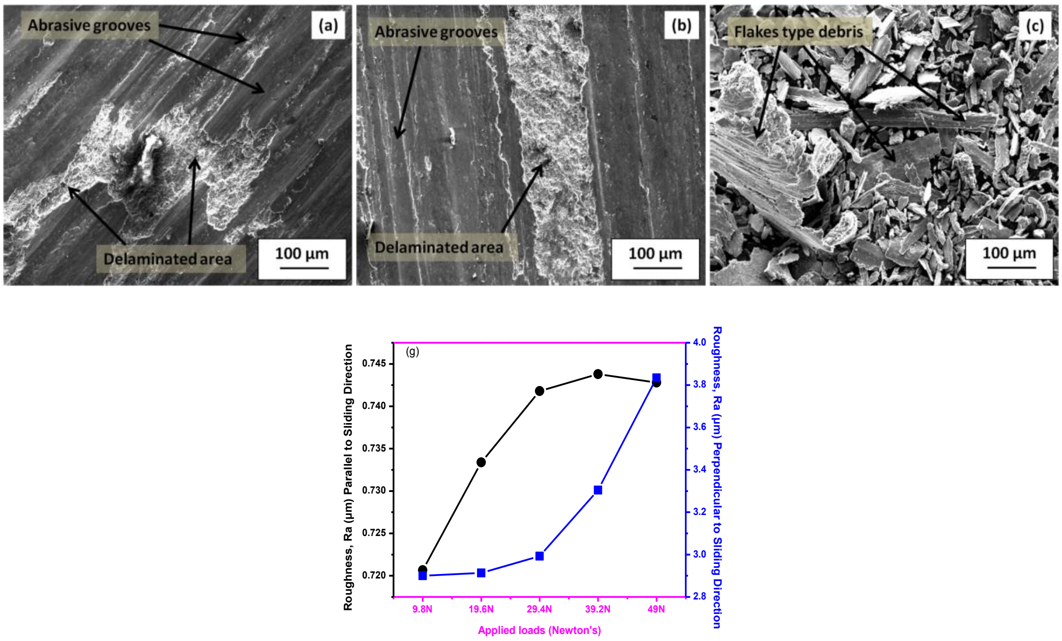

Figure 3. SEM micrographs of composite-$^{15}C_{coarse}$: wear tracks (a) 9.8N, (b) 49N and wear debris: (c) 9.8N, and (d) roughness of wear tracks at different loads.

The oxidation of the surfaces resulting from the frictional heating in the initial stages protects the matrix. At higher load temperature generation arising in counter surface due to high contact pressure involves the plastic deformation which is responsible for the transition of wear mechanism from mild wear to severe oxidation.

IV. CONCLUSIONS

The distribution of the reinforced rutile particles in the composite produces modification in dendritic structure which also provides more strength to the matrix.The frictional heat generation accelerates the oxidation process which is responsible for the transition in wear mode from mild to mild-oxidational wear and then to severe-oxidational.

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