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STUDY OF WEAR RESISTANT AL COMPOSITE REINFORCED WITH RUTILE FOR HIGH APPLIED LOAD APPLICATIONS

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ABSTRACT

The aluminum matrix composites are extensively used in the numerous applications in the engineering owing to their due to high strength, excellent fatigue resistance; good machinability and surface finish capabilities. These light weight materials with high thermal conductivity are the right choice of the materialist for the wear resistant applications. The natural rutile mineral is used as reinforcement with the LM13, a piston alloy for the preparation of the composite. The wear studies have been carried out with the fine size rutile particles of range 50-75 µm with 20% wt. in the aluminium matrix with the variation in applied load. The wear track morphological studies were done using scanning electron microscope and wear debris analysis carried out with electron dispersive spectroscopy.

Keywords*: Composites, Stir Casting, Rutile, Wear*

I. INTRODUCTION

The development of Metal Matrix Composites (MMCs) has been one of the major innovations in engineering materials because of their advantages of high stiffness and strength over traditional alloys. MMCs offer higher ductility and better environmental stability due to considerable improvement in mechanical, electrical and thermal properties as they ability than the aluminium alloys. Light weight metal-matrix composites have been introduced into the most important applications in the automotive industry because of their custom-made nature. These cost effective MMCs will become a general use engineering material due to the reproducibility of properties in the commercial component and meeting specifications with high yields at the acceptable cost [2]. Aluminium metal matrix composite (MMC) is potentially an important material for tribological applications because of its low density and high thermal conductivity [3]. Al composites due to high strength, excellent fatigue resistance, good machinability and surface finish capabilities can be commonly used on structures and components in the aircraft and transportation industries [4]. The particulate ceramic reinforcement is very effective in carrying the applied load due to its hardness. At the same time, particles not only improve the mechanical properties of a matrix by dispersion strengthening but also block the movement of dislocations [5].The particles addition as reinforcement components impart isotropic properties with certain amount of directionality [6].

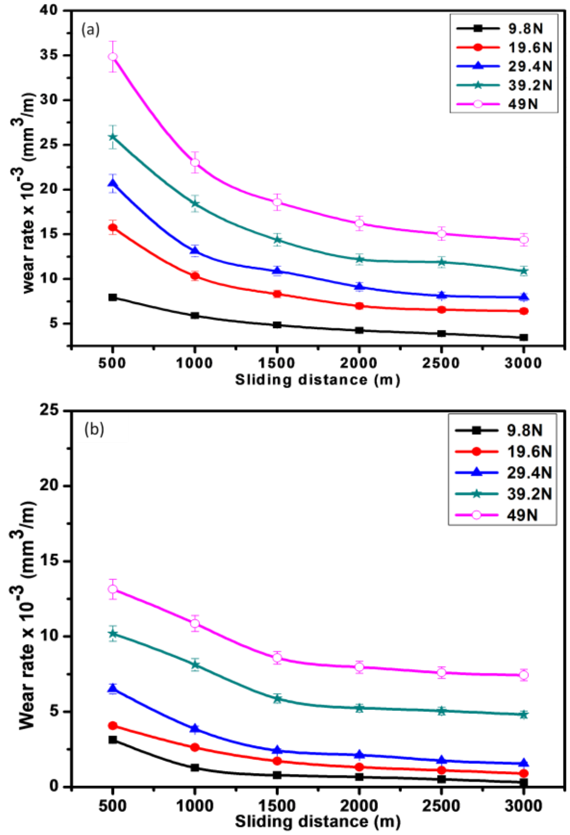
The use of natural minerals as reinforcement make them an attractive ecological alternative to others ceramics due to their availability at low cost, renewability as well as satisfactory mechanical properties [7]. Natural minerals like garnet, zircon, rutile, sillimanite etc. can be used as the reinforcement of composites to study the mechanical and wear resistance of the composites in the dry sliding conditions [8-12]. The wear characteristics of the mineral reinforced composites need to be explored for high applied load and temperature for industrial applications. As limited literature on rutile mineral reinforced AMCs is available, so in the present study an effort has been done to develop the wear resistant rutile reinforced LM13 composite which can be used as a component material in automobile industry for high load applications.

II. EXPERIMENTAL

High-purity rutile particulate mineral reinforcement of fine size (50–75 µm) was added to the LM13 alloy to develop the composite. Different composites with the varying volume fraction of rutile from 5 -20%wt. was prepared using simple stir casting route. The detailed description of the casting process is given in other works [7]. To study the wear resistant of the material, the dry sliding wear tests was performed by using pin-on-disc method by varying the load from 9.8 to 49 N. Wear rate was determined by measuring specimen height change using a linear variable displacement transducer (LVDT). To study the wear behavior, wear rate was calculated by using the formula, [W (mm3/m) = height change (mm) × pin area (mm2)/sliding distance (m)]. To get a better idea about the wear mechanism during the wear tests in different conditions, wear tracks of some selected composite materials were studied with the help of SEM (JOEL, JSM-6510LV) [12]. Average wear rate was calculated taking a set of three observation.

III. RESULTS AND DISCUSSION

Wear rate studies with applied load



Wear rate of composites against sliding distance at different loads for
(a) LM13 base alloy (b) composite-$^{20}C_{fine}$

Wear rate of LM13 base alloy and 20%wt. of rutile particles reinforcement as a function of sliding distance at variable loads from 9.8N to 49N is shown in Fig 1.comparison of the wear rate of base alloy and prepared composite is clearly visible in the graphs. The wear rate of LM alloy in the initial stage at 500m of sliding distance is three times than the composite. On the other hand while reaching at the steady state the wear loss in the composite is approximately half than the base alloys which clearly indicates the major improvement in the wear resistance. The abrasive wear is dominating in the initial stages because of the sharp edges of the reinforced particles and the steel disc on which the specimen is rotating. With the passage of time and distance the rutile particles acquire smooth surfaces and are less prone to the wear loss. The similar type of trend in wear rate is also observed in the studies [Also the change in type of wear from abrasive to delamination [9-11]. The above graphs clearly predict the increase in wear with the variation in applied load from 9.8 -49 N similar type of wear behavior as observed by Kumar et al. [7]. Application of high load causes heavy loss of material because of plastic deformation caused by the fracture of the oxidized film surrounding the metal surface hence exposing the substrate material. Partly this material is welded with the counterface and rest may fall out as wear debris. Abrupt fall in wear rate with the addition of 20% rutile ceramic particles can be attributed to the large number of fine rutile particles reduces the exposed area of the matrix for the wear which leads to the improvement in wear resistance. Figure 1.b indicates that the wear rate of the composite-$^{20}C_{fine}$ increases with increasing the applied load due to the change in severity as the frictional heat accelerates the plastic deformation which changes the wear mode from mild to severe

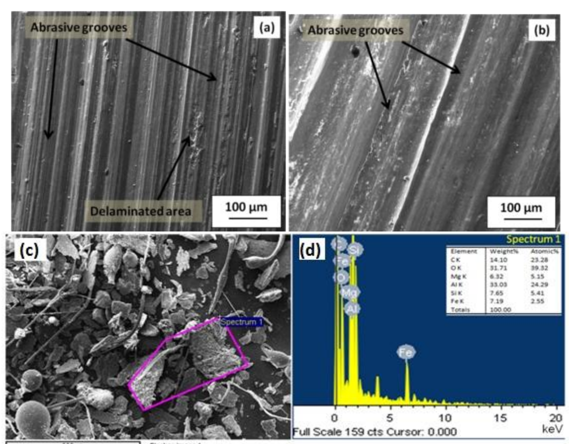
It is observed that 20 wt.% rutile reinforced composite, because of high hardness, suffers minimum loss of material. The wear loss in the composite with 20 wt.% rutile particle has reduced significantly as compared to the unreinforced base alloy. It can also be observed that for fine size distribution of reinforcement, the wear resistance of composite materials is higher. The composite containing 20% fine sized rutile particles demonstrated excellent wear behaviour under high loading conditions which makes it a better material for the high wear resistant applications.

Morphological Studies

The permanent scars on the surface of the composites are formed due to the removal of the material from the sliding surface during the wear tests. Three types of wear mild wear, severe wear and seizure wear are identified by Alpas and Zhang [13]. The number of factors like sliding distance, applied load and surrounding temperature affect the performance of the composite in wear tests. SEM micrographs of the worn samples after the tests and the collected debris material studies are useful to understand the phenomenon which causes wear and tear of the composite. The studies of the worn surfaces and the wear debris provide information about the wear mechanism.

The SEM micrographs of the composite-$^{20}C_{fine}$ at low and high load along with the wear track and debris are shown in Fig 2.One common feature observed in Fig 2(a-b) is the formation of grooves and ridges running parallel to the sliding direction in composite. Delamination of matrix because of the removal of the oxidized contact surface layers is observed mostly along the sliding direction.

Small craters grow along longitudinal direction of the sliding surface, which is shown in Fig 2a.
Severe wear is observed at higher load by formation and delamination layer of oxide on the wear surface as shown in Fig 2b.



SEM micrographs of composite-$^{20}C_{fine}$: wear tracks (a) 9.8N, (b) 49N and (c) debris at 49N loads.

The plastic deformation initiates from the weak interfaces at the surface layer and its propagation of cracks due to the joining of the voids can also be seen in Fig 2b. which is responsible for increase in wear rate at higher load. At higher load (49N), the increased depth of the ploughing marks is responsible for damage in the form of large patches and scars which is the indication of the significant increase in the wear rate.

Compositional variations of wear tracks of composite-^{20}**C**$_{fine}$ are presented in Fig 2c from the electron dispersive spectroscopy. Higher oxygen content about 32% of oxide layer might be due to the oxides of elements C, Mg, Al, Si, Ti, and Fe present in the composite specimen. This concludes that wear debris are generated from the fracture of cover envelope of oxide surface layer with the constituent elements of the specimen and counter surface formed by the compositional mixing at the interface during typical wear tests under the application of high applied load. These results are also in agreement with results from the literature [14].

At 49N load, these oxide (Al_2O_3/Fe_2O_3) debris in the form of shining balloons with tail of the molten metal's lowers the friction inside the grooves hence reduces the wear rate of composite at higher load .The oxidation wear is the mechanism behind the enhancement of the wear resistance of the composite for high load applications.

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