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Influence of the Rutile Reinforcement on the Abrasion Resistance of LM 13 Alloy

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Abstract

The present investigations explored the use of the natural rutile mineral as a reinforcement to improve the abrasive wear behavior of the aluminium composite. The Al-Si alloy LM13 composite reinforced with the fine size (50-75µm) with 15wt.% rutile particle was fabricated by using simple stir cast technique. Abrasive wear of the material is significantly controlled by the applied load. Wear tests of the prepared samples were performed by varying applied load from 9.8 N to 49 N. The modifications in inter phases of matrix and particles with the addition of rutile offer the improved the wear resistance of the material. The effect of the applied load on the wear rate was studied from the scanning electron micrographs of the wear track and debris. Transition in wear mode can easily be understood from the size and shape of the wear debris.

Keywords: *Aluminium composites, Stir casting, Abrasive wear, Rutile, SEM*

1. Introduction

The development of the modern technology is purely based on the fabrication techniques of the light and innovative material. The industrial consideration is to develop environment friendly green materials which can be used as different components in automobile, aerospace applications as replacement of cast iron which is prone to rust. The ceramics addition to the light, high corrosive aluminium alloy provides more strength [1-3].To attain the higher wear resistance and elastic modulus than the matrix alloy, rutile mineral particles are incorporated using stir casting method. These hard particles have the ability to resist the destructive action of the forces during the non-lubricated sliding conditions [4]. The abrasion resistance of the material provides the long life to the components due to the lower wear and tear of the machinery during the sliding motion. It can be improved by adding hard particles like ceramics to the aluminium during casting by different processing techniques. Generally the ceramics particles have low wettability with the metal melt which can be enhanced through the addition of preheated reinforcement at high temperature above the melting point of aluminium. The homogeneous distribution of the particles is ensured by rotating the melt at very high speed of the impeller during casting. The crushing and detachment of particles can be prevented by the high strength material with strong matrix –particle interface which in turn enhances the abrasion resistance [5-7].

The required properties of the material can be achieved by the combination of the dimensions, ratio and compatibility of the base matrix with the reinforced particles as well as their dispersion. The interfacial properties are determined by the chemical reaction between the hard particles and melted metal during casting and then solidification.

The mineral particulates have higher hardness thus can be used as the reinforcement to enhance the abrasion resistance. The larger sized and net-like structure reinforced particles are best suitable will reduce the inter-particle spacing; thereby can decrease the abrasive wear of the material [8]. The increased volume fracture enhances the abrasive wear resistance by preventing the cracking or damage to the ceramic particles. Even the strong bonding at the interface reduces the probability of pull out of the matrix.

The rutile mineral reinforced Al alloy casted by liquid metallurgy procedure was used for investigating the study hardness and the abrasive wear under applied load. This fabricated green material can be recycled and environment friendly as particles.

The attempt has been made to study the influence of the reinforced rutile particles on the abrasion wear of fine size rutile particles reinforced of the aluminium alloy under variable loading conditions. Based on the experimental observations of wear studies, use of rutile reinforced aluminium composite is recommended for fabrication of components which are exposed to abrasive wear during working.

2. Experimentation Procedure

The processing parameters elucidate the optimum ratio in the liquid metallurgy fabrication method need to be optimized because of the cost performance and limitable in the size of the component for which composite is to be used. As in the vortex casting process the reinforcement particles are thrown in the melt stirred at high temperature it has advantage in formations of the product using simple procedure [9]. This conventional method is widely experienced for the fabrication of the composites with high volume fraction 15% and 20% of reinforced rutile particles. So in this research area the addition of high content of rutile particles plays a significant role in protecting the specimen under abrasive conditions which owe to the higher hardness and (structure of the composite after wear).

3. Abrasive wear at different loads

Abrasive wear rate of LM13 base alloy and the composite with 15wt. % fine size rutile reinforced particles were evaluated at different loads from 9.8N to 49N is shown in Fig.2. This wear is the main cause of the loss of material because of the relative sliding motion in the start of run. The abrasive wear is significantly controlled by rubbing of the asperities of the contact surfaces. The pin sample of the composite and the hard steel disc contains large asperities of different characteristics like shape, height and sharp edges [10].The extended asperities penetration into the softer pin and its sliding due to the upward motion leads to the loss of material. This abrasive wear is accompanied by the formation design pattern of thin and shallow grooves in the form scars on the specimen. So the initial stage of wear is dominated by the abrasion resistance of the composite. The continuous grinding of these abrasive particles while sliding reduces the sharpness of the asperities. The steady state of wear is achieved when blunt shaped smooth abrasives are formed due to continuous sliding which also lowers the wear loss [11, 12]. The increase in load accelerates the grinding action of the protruded asperities and its crushing causes the abrupt change in the wear loss due to the application of high load of 49N which is supported by the plastic deformation as observed by Das et al. [13] .All metal surface are surrounded with a thin oxide film and its breakage under high pressure exposes the inner material which is responsible for the plastic deformation. The removal of the soft material from the specimen is observed as wear debris. It is proven fact that the wear rate of the composite improves with the increase in ceramic rutile particulate content at all loads because of the increased hardness. Rutile particles presence in the composite impede the plastic flow of low strength aluminium matrix hence imparts higher hardness to the composite [11].

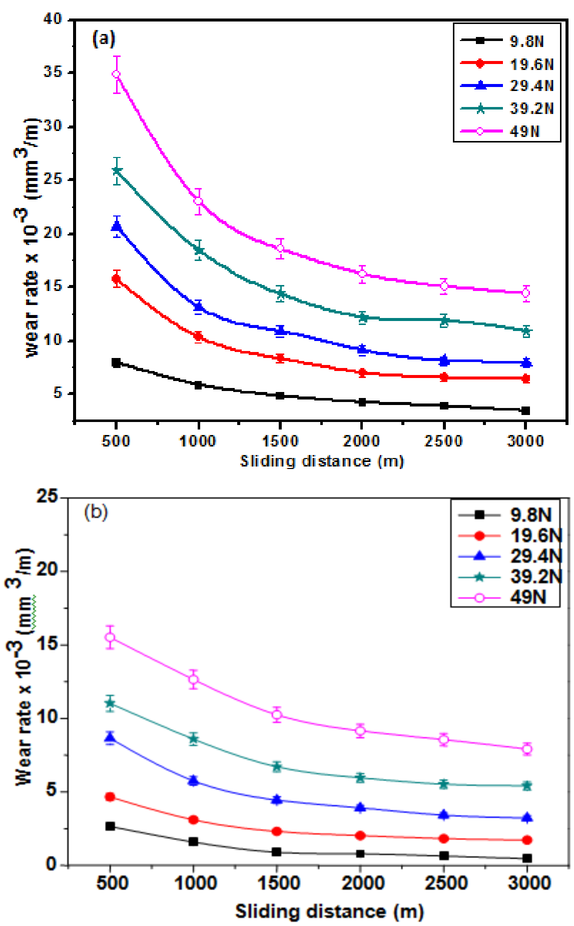


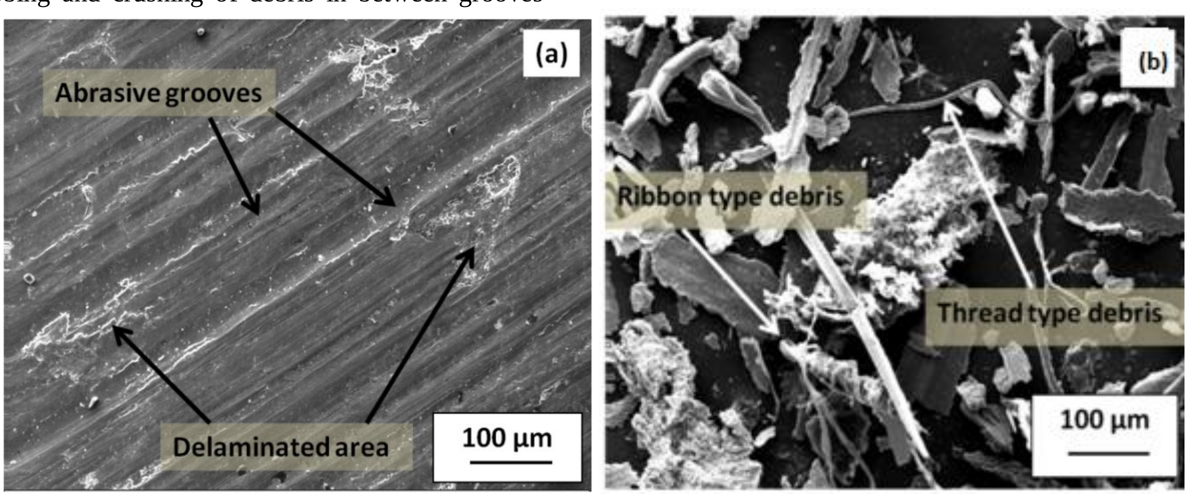
Fig. 1 Wear rate of composites against sliding distance at different loads for (a) LM13 base alloy and (b) composite-^{15}**C**$_{fine}$

The introduction of rutile hard particles in the aluminium alloy by 15wt. %,[Fig. 1] facilitate the matrix to transfer the load to particle hence reduces the wear loss. The inter-metallic phase formation of $AlTiO_2$ as verified from the XRD analysis imparts more strength to bonding between two phases which imparts more hardness to the composite [10].. However, improvement in wear resistance of composite-$^{15}C_{fine}$ (Fig. 1b) is obvious because of the improved mechanical properties of alloy with rutile particles in the matrix. There is significant rise in wear loss due to the increase in contact pressure and this also transform the material wear severity from mild to severe at high load of 49N.

It is observed from Fig. 2, worn out surfaces of the composite-$^{15}\mathbf{C}_{\mathbf{fine}}$ after wear tests at low 9.8N and high 49N load have sliding marks which are the abrasive grooves. The continuous sliding of the specimen material with hard ceramic particles creates abrasive grooves [12, 13]. Rutile particles restriction imposed on the abrasive movement of asperities resist the plastic deformation at all loads. But at high stress, continuous loss of the material can be attributed to the delamination arising from the crack nucleation at week interfaces and their further movement damages the matrix causes damage to the matrix. The large size of craters are and surface underneath which are visible in micrograph in Fig 2b indicates onset of delamination wear [7].

At low load of 9.8 N, reduction in the abrasive wear of composite-$^{15}\mathbf{C}_{\mathbf{fine}}$is confirmed from ribbon type morphology of the debris.(Fig. 2c).The continuous rubbing and crushing of debris in between grooves give rise to noodles type structure. At higher load 49N, specimen is strongly adhered to the steel disc surface so higher energy is required to slide the pin which consequently increasing the temperature at the tip. These rises in temperature causes loss of material and oxidative thin layer which can easily be fractured and fragmented are visible in wear debris. [11]. The continuous rubbing of the thread like debris between the two surfaces leads molten metal balls formation. [14]. The surfaces with the increased roughness are visible due to the presence of large amount of rutile particles in the matrix (Fig. 2d).Fig. 2e shows the EDS images of the worn surfaces loads, presence of the oxygen in the spectra supports the formation of oxide layer on the wear tracks during the sliding.

From the Fig. 2g it is observed that roughness in the sliding direction is less as compared to perpendicular to sliding direction at the higher load of composite-$^{15}\mathbf{C}_{\mathbf{fine}}$.The tribo-layer formed filling and covering the machined grooves during wear test provide smoothness to the tracks more roughness in the perpendicular to sliding direction was observed that indicates that the depth of scratches observable is more and amount of loose particles is less.



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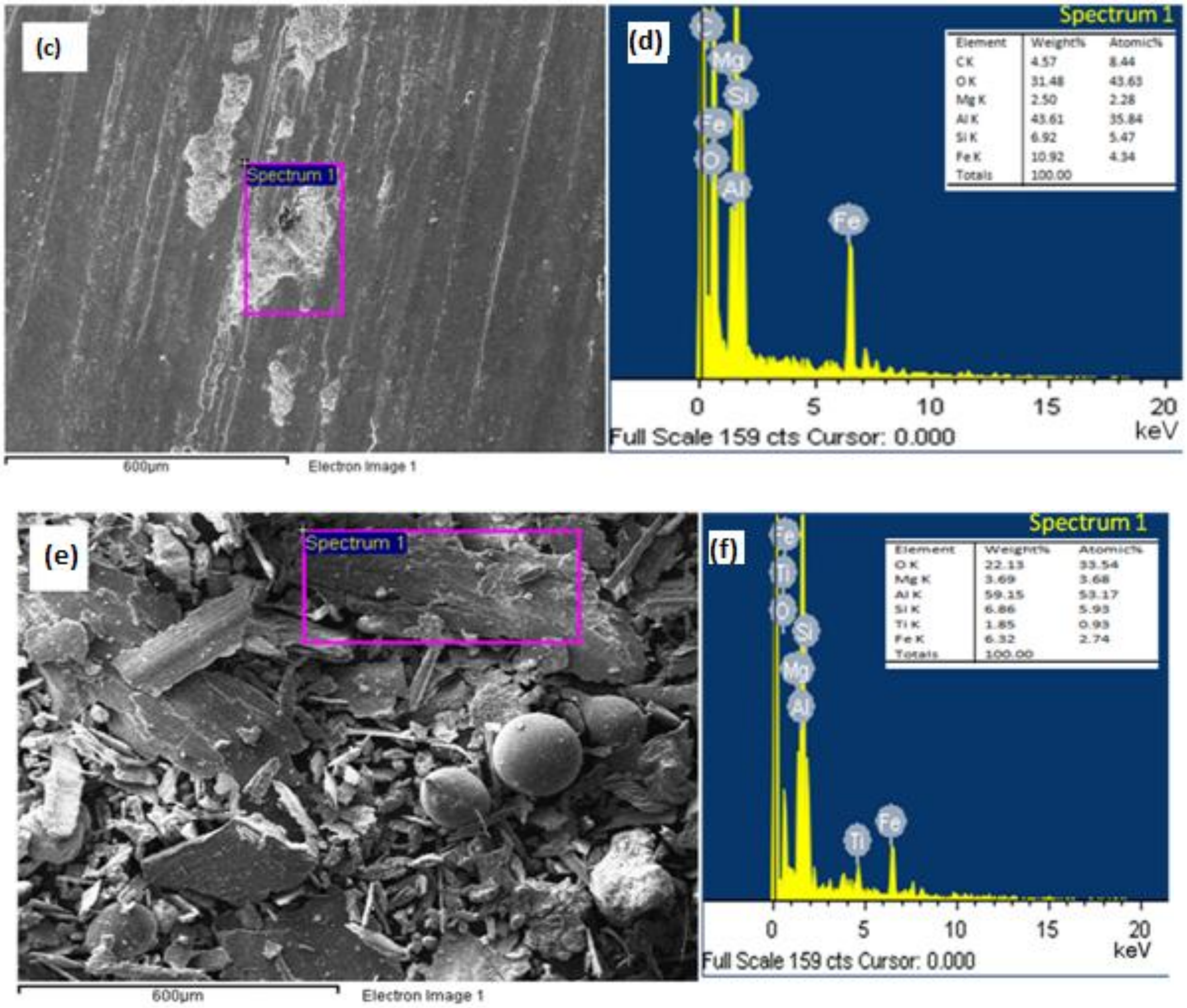

Fig. 2: SEM micrographs of composite-^{15}**C$_{fine}$**: wear tracks (a) 9.8N, (b) 49N and wear debris: (c) 9.8N, and (d) 49N loads and EDS of (e) wear track, (f) debris at 49N loads and

4. Conclusion

The composite reinforced with 15wt. % rutile particle completely protects the matrix by reducing abrasive wear at low loads on the other hand high load wear is dominated by the delamination. The rutile particles impeded the plastic flow of the material and capable of protecting the matrix against heavy losses even at high load due to the covering of the wear tracks by the thin oxide layer which provide more strength. Ribbon type morphology of the debris also confirms reduction in the abrasive wear of composite at low load.

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