

Slurry Erosive Wear Behavior of Al5083-Al₂O₃-Gr Hybrid Metal Matrix Composites

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Abstract- Material loss due to slurry erosion is a serious problem in many industrial applications such as hydraulic turbines, slurry pumps, pipe lines etc., where selection of engineering materials is a real challenge. Most of the chemical industries do deal with abrasive slurries and failure of components in this industry is due to the combination of corrosion and slurry erosive wear. The corrosion phenomenon occurs due to the corrosive nature of slurry while the slurry wear is due to the impingement of hard abrasive particles of slurry at high velocities. Since theoretical methods cannot predict these wear phenomena reliably, only experimental evaluation in special test rigs will provide an insight into these mechanisms.

In the light of the above, the present paper aims at developing aluminum based metal matrix composites and characterize slurry erosive wear properties. Al5083 based composites were prepared by vortex method of liquid metallurgy route, and since the presence of only hard particulate reinforcement in composite leads to poor surface finish and higher tool wear. Therefore composites were prepared with both hard reinforcement (SiC) and soft reinforcement (Gr). The amount of reinforcement was varied from 3wt% to 6wt% in steps of 3wt%, keeping constant 3wt%Gr. Microstructure studies, microhardness and slurry erosive wear test of these hybrid composites have been evaluated.

Keywords: Hybrid metal matrix composites, microhardness, slurry erosive wear resistance, vortex casting technique.

I. INTRODUCTION

Slurries are transported and processed by a wide range of equipment in the mining, power generation and dredging industries. Centrifugal pumps and cyclones are used extensively in these applications. A major consideration of equipment operators in these industries is the wear life of equipment. The predominant type of wear in slurry handling equipment is erosion. Studies into the factors contributing to erosive wear have focused on particle size, shape, impingement angle, impact velocities and material characteristics. While extensive general research has been carried out with the aim of better understanding the erosive process, it has not always been representative of the plant operating conditions used in industry. Wear of slurry equipment can be categorized into two major types, these being erosion and abrasion. Erosive wear is the dominant process and can be defined as the removal of material

from a solid surface due to the mechanical interaction between the surface and impinging particles in a liquid stream. Abrasion is the loss of material which occurs when particles are forced against and move along the solid surface. The main difference between the two types of wear is that erosion involves the transfer of kinetic energy to the surface, while abrasion does not. This means that in erosion, material removal is a function of the particle velocity squared (or some higher power). Abrasive wear, on the other hand, is a linear function of the particle velocity (and the applied force).

II. EXPERIMENTAL DETAILS

A. Composite Preparation

Al5083 based composites were prepared by vortex method of liquid metallurgy route. A quantity of 3kgs of Al5083 alloy was used each time in an electric melting furnace with graphite crucible for melting with furnace temperature set at 710°C. Aluminum oxide and graphite reinforcements and the permanent molds of cast iron were heated in order to reduce the effect of chilling during solidification. Degassing of the melt was done with commercially available tablets of hexachloroethane (C₂Cl₆). After degassing, the preheated Al₂O₃ and Gr were added slowly into the vortex while continuing the stirring process up to 10minutes. The amount of reinforcement was varied from 3wt% to 6wt% in steps of 3wt%, keeping constant 3wt%Gr.

B. Evaluation of Hardness

Vickers micro hardness tests were performed on all samples of Al5083 and its hybrid composites. The polished samples were subjected for micro hardness tests using shimadzu micro hardness tester. A load of 100 g for period of 10 sec was applied.

C. Slurry Erosive Wear Test

Slurry erosive test of both Al6061 and its hybrid composites were studied using slurry wear tester as shown in fig.1. Slurry was prepared by adding 20 liters of normal water with 700gms of sodium chloride. Sand particles of size up to 425µm were

added in the slurry at the range of 200gms/ltr. Both Al6061 and its hybrid composites subjected to various heat treatment processes were subjected to slurry erosive wear testing up to a period of 12hrs in step of 3hrs. The specimens were cleaned with acetone both before and after testing and the corresponding loss of weight was measured using a digital weight.

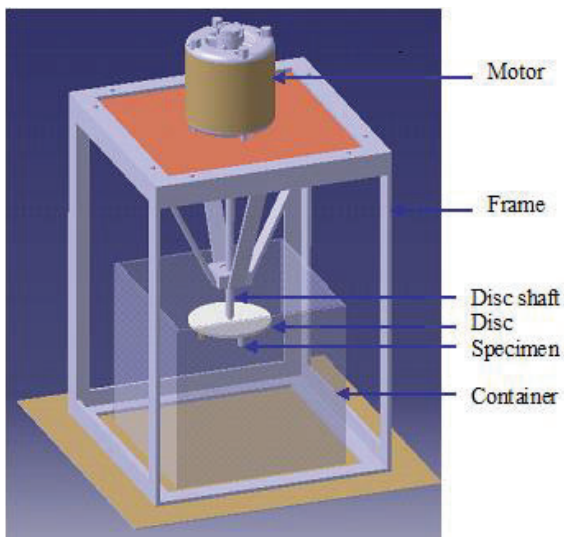
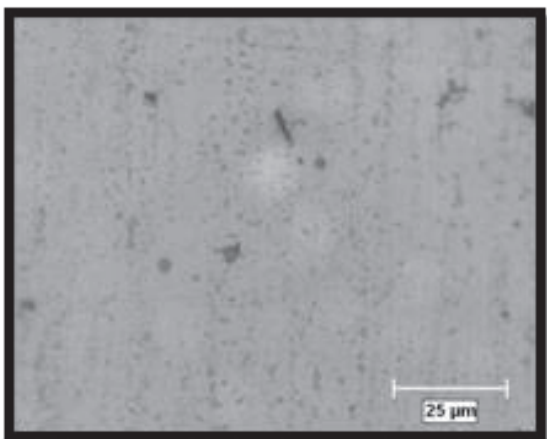


Fig.1 Slurry erosive wear tester.

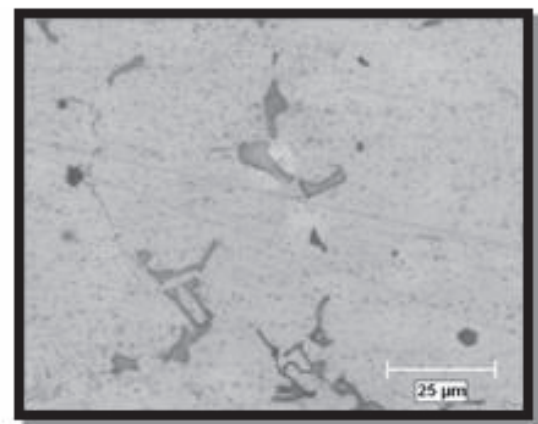
III. RESULTS AND DISCUSSION

A. Micrograph Studies

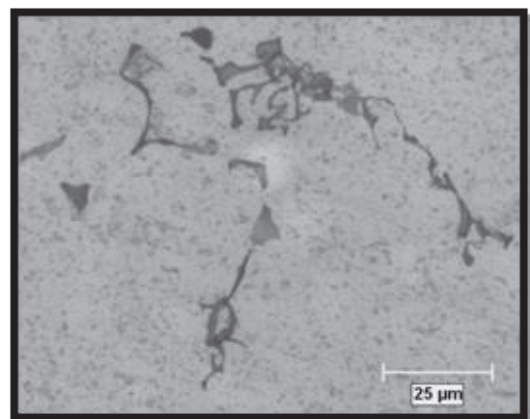
The specimens for micrograph studies were prepared from the cast composites and the polishing was done as per the ASTM recommendations. The specimens were etched with picric acid and were tested on metallurgical microscope. Fig.2 (a), (b) and (c) shows the micrographs of Aluminum-5083 and its hybrid composites in etched condition.



(a) Al5083+0%Al₂O₃+0%Gr



(b) Al5083+3%Al₂O₃+3%Gr



(c) Al5083+6%Al₂O₃+3%Gr

Fig. 2 (a-c) Optical microphotographs of Al5083 and its hybrid composites.

It is observed from fig.2 that the Al₂O₃ particles are fairly uniformly distributed. The extent of porosity noticed is also less. There is a clear evidence of homogeneous distribution of reinforcements, although a clear cut identification of Al₂O₃ and Gr is quite difficult.

B. Hardness

Fig. 3 shows the variation of micro hardness with increased content of Al₂O₃ particles in the matrix Al5083.

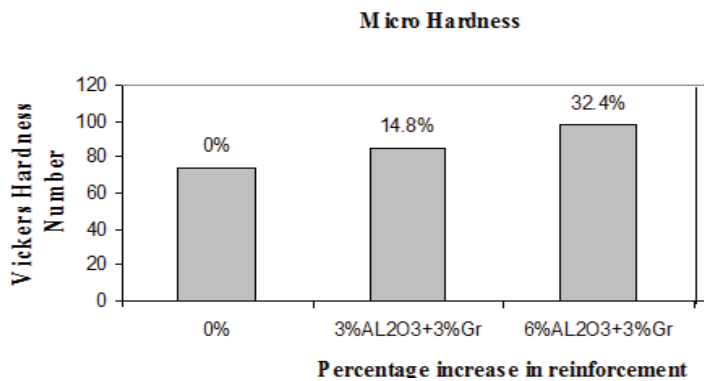


Fig. 3 Variation of microhardness with increased content of Al₂O₃ particles in the matrix Al5083

It is observed that with increased content of Al₂O₃ in the matrix alloy, there is a significant improvement in the micro hardness of the composites. An improvement of around 32.4% is observed in Al5083-6wt%Al₂O₃-3wt%Gr hybrid composites when compared with the unreinforced Al5083 matrix alloy. Al₂O₃ is a hard reinforcement. Hard reinforcement in a soft and ductile matrix always enhances the hardness of the matrix alloy in general, probable increased density of dislocations due to thermal mismatch between the matrix alloy and the Al₂O₃ due to the large differences in coefficient of thermal expansion. The increased level of dislocations motion increases the resistance of the materials to plastic deformation.

C. Slurry Erosive Wear Study

Fig. 4 shows the variation of slurry erosive wear of the matrix alloy and its composites for different time duration.

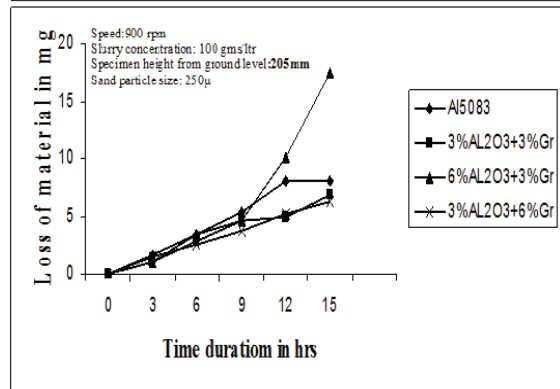
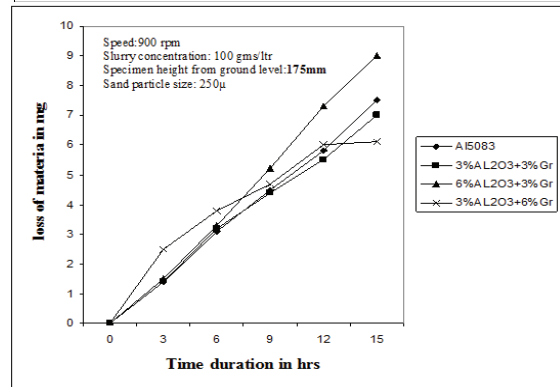
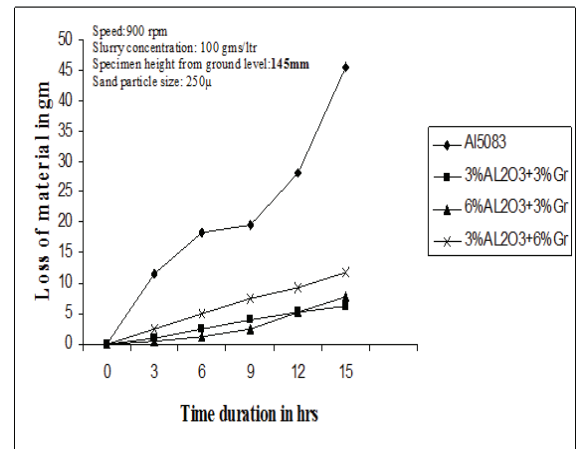
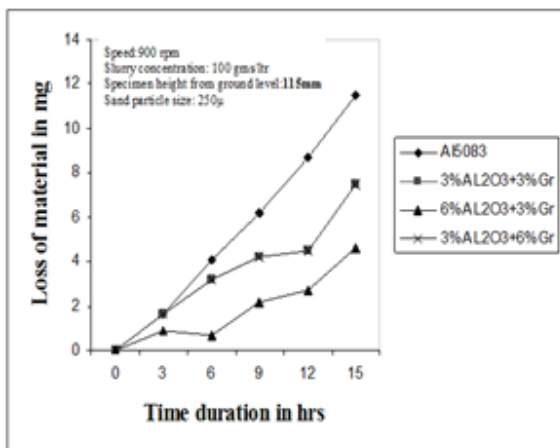


Fig. 4 Effect of time duration on material loss due to slurry erosive wear of Al5083 matrix alloy and all its hybrid composite systems for different time exposure.

The variation of material loss in milligrams with increased content of Al₂O₃ in the matrix Al5083 for different time exposure is shown in fig. 4. It is observed that with an increase content of Al₂O₃ in the matrix alloy, there is a significant reduction in the material loss of the composites. At specimen dept level of above 117mm the material loss for the composites

Al5083-6wt%Al₂O₃-3wt%Gr is more when compared to other composites

Fig. 5 shows the effect of reinforcement on material loss due to slurry erosive wear of Al5083 matrix alloy and its entire composite for time duration of 15 hrs.

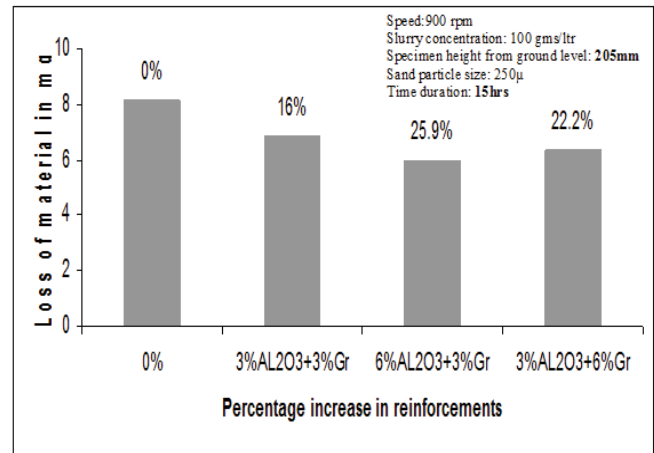
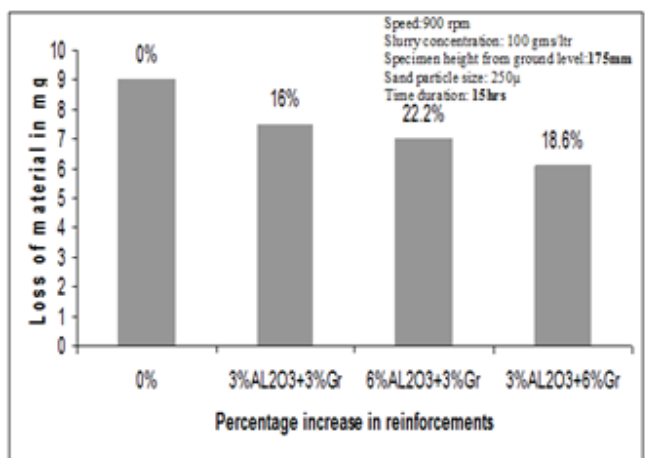
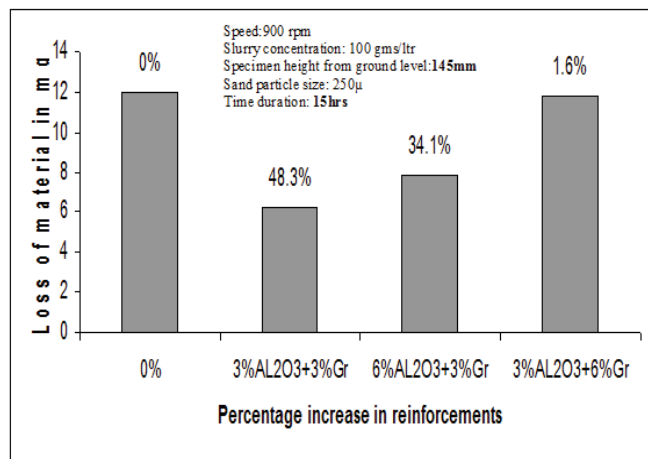
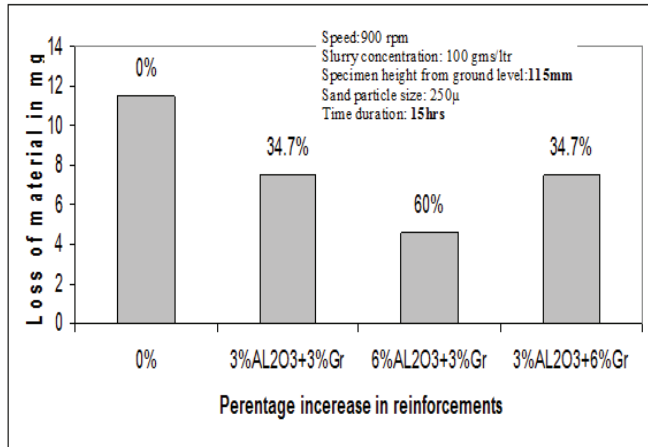


Fig. 5 Effect of reinforcement on material loss due to slurry erosive wear of Al5083 matrix alloy and its entire composite.

The variation of material loss in milligrams with increased content of Al₂O₃ in the matrix Al5083 is shown in fig. 5. It is observed that with an increase content of Al₂O₃ in the matrix alloy, there is a significant reduction in the material loss of the composites. An improvement of around 60% is observed in Al5083-6wt%Al₂O₃ 3wt%Gr hybrid composites for a ground level surface of 115mm. An improvement of around 48.3% is observed in Al5083-3wtAl₂O₃ 3wt%Gr hybrid composites for a ground level surface of 145mm. An improvement of around 22.2% is observed in Al5083-6wtAl₂O₃ 3wt%Gr hybrid composites for a ground level surface of 175mm. An improvement of around 25.9% is observed in Al5083-6wtAl₂O₃ 3wt%Gr hybrid composites for a ground level surface of 205mm.

This might be due to formation of passive layer over the exposed surface of the specimen's. However, increased content of Al₂O₃ in the matrix alloy reduces the material loss from the surfaces. This can be attributed to the higher hardness of the composites with increased content of SiC as discussed earlier.

Fig. 6 shows the effect of specimen depth location on material loss due to slurry erosive wear of Al5083 matrix alloy and its entire composite for time duration of 15 hrs.

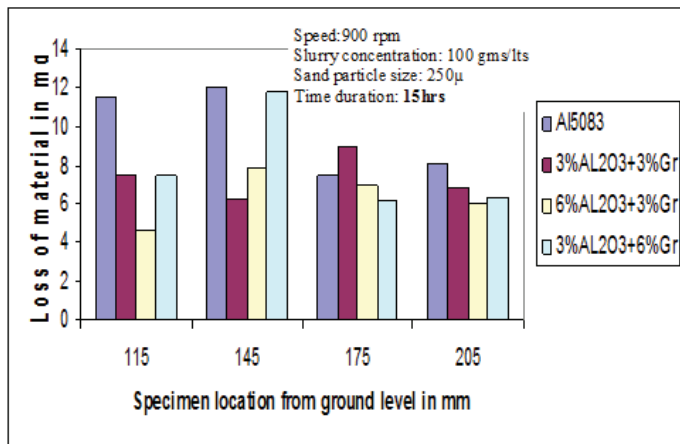


Fig. 6 Effect of specimen depth location on material loss due to slurry erosive wear of Al5083 matrix alloy and its entire composite.

It is observed that with an increase content of Al₂O₃ in the matrix alloy, there is a significant reduction in the material loss of the composites. There was gradual decrease in material with increase in specimen depth location. Maximum wear was observed for specimen depth location of 145mm. Lesser material loss for base alloy was seen for specimen depth location of 175mm, lesser material loss for Al5083-3wt%Al₂O₃ 3wt%Gr was seen for specimen depth location of 145mm, lesser material loss for Al5083-6wt%Al₂O₃ 3wt%Gr was seen for specimen depth location of 115mm while, lesser material loss for Al5083-3wt%Al₂O₃ 6wt%Gr was seen for specimen depth location of 175mm,

IV. CONCLUSION

Al5081- Al₂O₃-Gr hybrid composites have been successfully produced by vortex method. Microstructure studies clearly revealed uniformity in the distribution of reinforcements and excellent bond between the matrix and the reinforcement. Microhardness of Al5081 based hybrid composites is higher when compared with that of the matrix alloy. Increased content of hard reinforcement in the hybrid composites leads to enhancement in slurry erosive wear resistance of the hybrid composites. There was decrease in material loss due to slurry erosive wear with gradual increase of hard reinforcement and passage of time. For a given specimen depth of immersion with increase in the distance the wear gradually decreases.

ACKNOWLEDGMENT

We are thankful to Dr. Mir Safiulla, Professor and Head, Research Center, Ghousia College of Engineering, Ramanagaram for his valuable suggestions throughout the course of work.

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