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Tribological Characterisation of Fly Ash Reinforced Aluminium Alloy (Al6061) Composites

Ravi MISHRA[1] Anilkumar H.C.[2*] H. Suresh HEBBAR[3]
[1,3]Dept. of Mechanical Engineering, National Institute of Technology Karnataka, Srinivasnagar, INDIA
[2] Dept. of Mechanical Engineering, Anjuman Engineering College, Bhatkal, INDIA

***Corresponding Author**
e-mail: anilkumarhc@yahoo.co.in

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Abstract

The results of a study on the tribological properties of flyash particle reinforced Aluminium alloy -Al6061 composite samples processed by stir casting route are reported in this paper. Two sets of composites with fly ash particle sizes of 45-50µm and 75-100µm were used. Each set had three types of composite samples with reinforcement weight fractions of 10%, 15%, and 20%. Sliding wear tests were conducted using Pin-on-disc apparatus with hardened steel disc as counterface material. Unreinforced Al6061 samples were also tested for sliding wear.

It was found that wear rate (WR) increased with increase in sliding velocity and decreased with increase in flyash particle size and test load when slid against hardened steel counterface materials. The composite samples with 15% weight fraction fly ash particle showed minimum WR. The surfaces of slid samples, when examined under Scanning Electron Microscope (SEM) showed that ductility of the matrix decreased with the increase in weight fraction of the reinforcement. It is also found that 15% weight fraction of Flyash is optimal for minimum wear of composite.

Key words: Aluminium alloy (Al6061), Fly ash, Tribological properties.

INTRODUCTION

Composite Materials in general are well established engineering materials with most of them possessing the advantages of higher specific weight and specific modulus [1-5] and also better thermal stability, fatigue properties and wear resistance [6-9]compared to many of the metals and alloys. Substantial progress in the development of metal matrix composites (MMCs) has been achieved in recent decades as they opened up unlimited possibilities for modern material science & development [10]. Particle reinforced metal matrix composite materials (PMMC's) are the most promising because of their higher specific strength, excellent wear resistance, near isotropic properties and superior high temperature performance[11,12,13].

Earlier studies on MMCs addressed the behavior of continuous fiber reinforcement composites with aluminum, zinc or titanium alloys matrices and Alumina fibers [14] and carbon fiber [15] as reinforcements The extensive use of these composites is limited owing to higher processing cost. This had led to the use of low cost low density reinforcements. An example is the possible use of solid or hollow spherical fly ash particles as fillers or reinforcements in aluminum matrix composites. Recently, cast aluminum–fly ash composites with low density, low cost, and improved hardness and wear resistance have been developed [16]. It is found that the properties of solid metal castings can be replicated by mixing flyash with aluminium alloys, which can be widely used in weight critical applications like aerospace and automobiles [17, 18].

EXPERIMENTAL PROCEDURE

Specimen Preparation

Fly ash particle reinforced Al6061 composites were processed by stir casting route. The chemical composition of the matrix and the reinforcement are shown in Table 1 and 2.

Two sets of composite samples with the fly ash of particle sizes of about 45-50 microns and 75-100 microns were prepared. Each set had three types of composites with fly ash weight fraction of 10, 15 and 20%. The fly ash was heated to 450°C and maintained at that temperature for about 20 minutes before mixing with the molten Al (6061) alloy. Specimens were then prepared in order to carry out the sliding wear tests.

Testing for Tribological Properties

The pin-on-disc machine was used for this work and tests were conducted as per ASTM G99-95 standard. The FRMMC pin in the form of a block (8mm×8mm×4mm) was abraded against a hardened steel counterface fixed on the disc rotating at two speeds (1.11 m/s and 2.086 m/s). The pin was loaded with various loads (9.81N and 29.43 N). The track diameter was a constant at 80mm throughout the experiment. The experiments were conducted using single pass condition.

Table 1. Chemical composition of Al (6061) alloy by Weight Percentage

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Al
0.90	0.75	0.25	0.22	0.09	0.10	0.05	0.04	Bal

Table 2. Chemical composition of Flyash

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss on ignition
28.44	59.96	8.85	2.75	1.43

Before starting the experiment, pin was abraded against a fine abrasive paper of grade 1200 (grit size 5μm) for uniform contact and the pin was cleaned with acetone. A brush was used to remove foreign particles followed by weighing on a Precisa XB120A balance with an accuracy of 0.0001g.

After running the specimen through calculated duration or through specified distance on the counterface of pin-on-disc machine, the pin was once again cleaned with acetone and a brush was used to remove particles/ wear debris.

The weight of the pin was once again measured by weighing on Precisa balance and the experiment was repeated for two samples and the average value of wear obtained from three trials was considered. Then the tests were conducted for various volume fractions of FRMMCs and the results were tabulated. In all the experiments the 8×8 cross section of the pin was in contact with the counterface.

The data collected from the experimental work were then used to calculate the Wear Rate. The behaviour of the composite with respect to the wear rate was analysed by plotting the graph of WR against Sliding distance, Load and Sliding velocity for all the cases. WR, defined as volume loss per unit sliding distance having unit (mm^3/m) is often used as measure of wear.

$$Ks = \frac{\Delta V}{d} \quad (mm^3/\,m)$$

Where, d is sliding distance in m.

RESULTS AND DISCUSSION

For all the experiments the track diameter was set to 80mm and in order to achieve sliding velocities 1.11m/s and 2.086m/s the rotational velocity of the disc was set to 265 rpm and 498 rpm respectively. The pin was loaded with 9.81N and 29.43 N loads manually. Each setup condition was repeated for three trials and the average value was taken for calculations.

Discussion on sliding wear.

From the Fig.1,2,3 and 4, it is clear that as the weight fraction increases from 0%(Pure Aluminium6061) to 15%, Wear Rate decreases, having a minimum value at 15% weight Fraction, then it again increases. This may be due to the fact that Strength and hardness of the composite increases till 15% and decreases afterwards, attaining the maximum value at 15% weight fraction. [19].

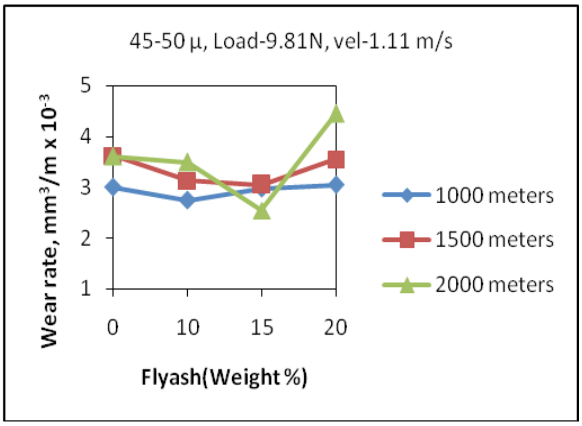

Fig. 1. Variation of Wear Rate with weight % of Flyash

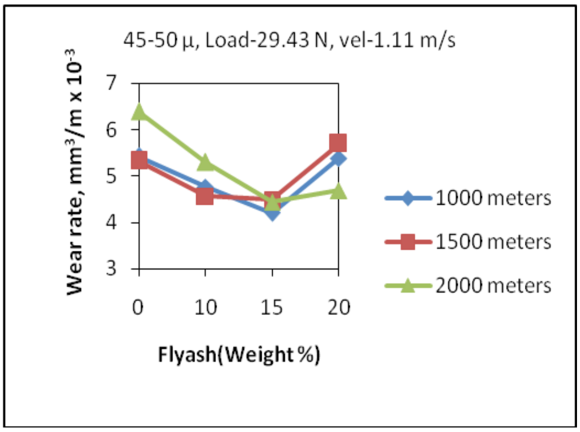

Fig. 2. Variation of Wear Rate with weight % of Flyash

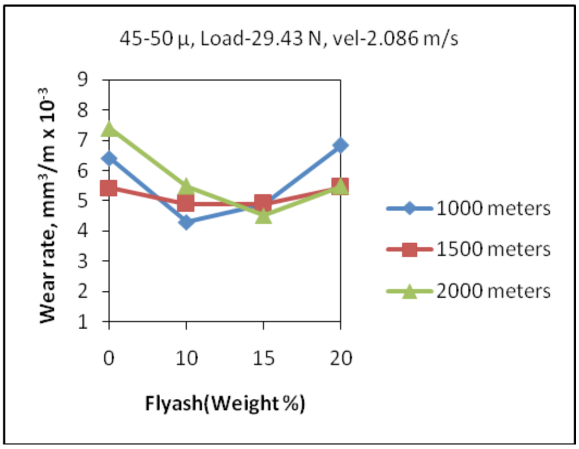

Fig. 3. Variation of Wear Rate with weight % of Flyash

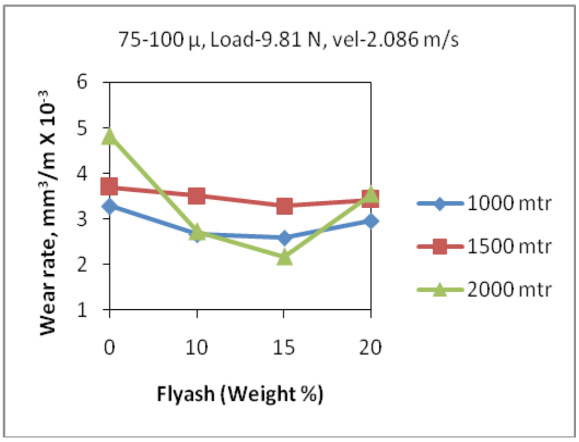

Fig. 4. Variation of Wear Rate with weight % of Flyash

Fig. 5, 6 and 7 show that with increasing the grain size of flyash particle Wear Rate of composite decreases in all the working conditions. This is due to the fact that ploughing of the Flyash particle becomes difficult as the grain size increases.

With increase in sliding velocity, Wear Rate also increases as is seen in the Fig. 8, 9 and 10. During sliding, the hard Flyash particles present in the sliding interface interact with the composite surface and do the ploughing and microcutting of the composite surfaces, which increases with increase in sliding velocity.

As the load increases the Wear Rate value decreases as is seen from Fig.11, 12 and 13. However, Wear rate and Volumetric wear increases with load. Increase in load results in the increase of the frictional force at the interface; hence material loss also increases. This is due to the higher bonding between Flyash particle and Al alloy matrix.

Observation from SEM Micrograph

From the SEM micrographs above i.e. Fig.14 to Fig.18 many conclusions can be drawn. The wear phenomenon occurring here involves the lip formation and further the material removal takes place by plastic deformation. It can be observed that the surface undergone sliding wear is smoother in comparison to the one undergone abrasive wear. It can be further observed that Wear mechanism had changed from micro ploughing to microcutting as the wear mode was changed from sliding to abrasive. It can be further observed that as the % weight fraction of flyash or particle size increases the morphology of the worn surfaces gradually changes from fine scratches to distinct grooves. Energy Dispersive Analysis of X-rays (EDAX) in SEM depicts the transfer of carbon from the counterface to the composite material specimens during the wear out process.

CONCLUSIONS

The Flyash reinforced Al6061 alloy Metal Matrix Composite was prepared by the stir casting method with Al6061 as the matrix and Flyash as the reinforcement. Three weight fractions of 10, 15 and 20% and particle size 45-50 um and 75-100um flyash was used. Also in pin on disc machine Hardened Steel was used counterface material. An experimental approach to evaluate the SWR of Flyash Reinforced Metal Matrix Composite was employed in this study. The SEM analysis was carried out to study the phenomenon of wear in detail.

The results can be summarized as follows: Adding Flyash in Al6061 alloys increases its Wear resistance. Hardened Steel counterface shows a minimum wear condition with 15% weight fraction of flyash. In case of Hardened Steel increasing grain size also helps in reducing the SWR .SEM micrographs highlight that the sliding wear surface is smoother. It can be concluded that that as the weight fraction of flyash or grain size is increased the morphology of the worn surfaces gradually changes from fine scratches to distinct grooves.

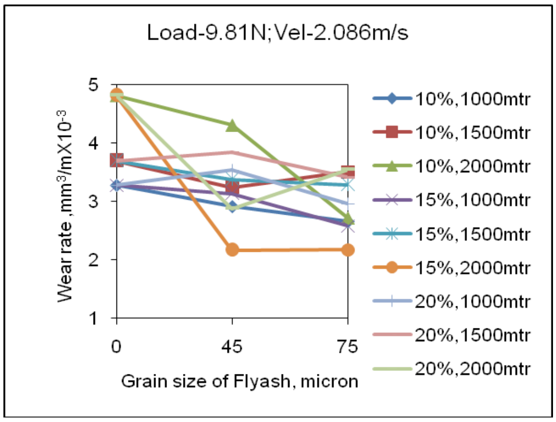

Fig. 5. Variation of Wear Rate with Grain Size of Flyash

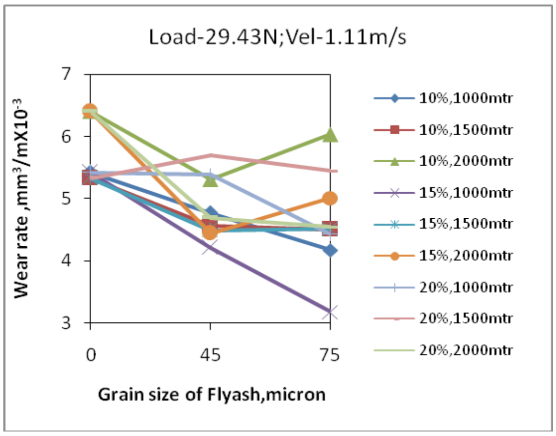

Fig. 6. Variation of Wear Rate with Grain Size of Flyash

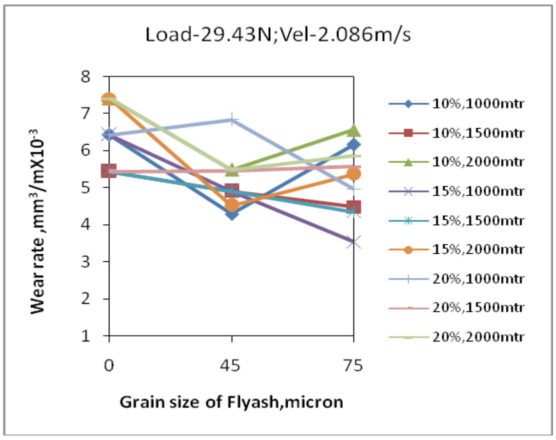

Fig. 7. Variation of Wear Rate with Grain Size of Flyash

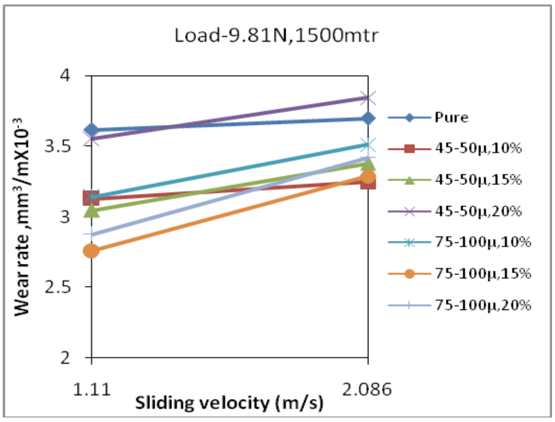

Fig. 8. Variation of Wear Rate with Sliding Velocity

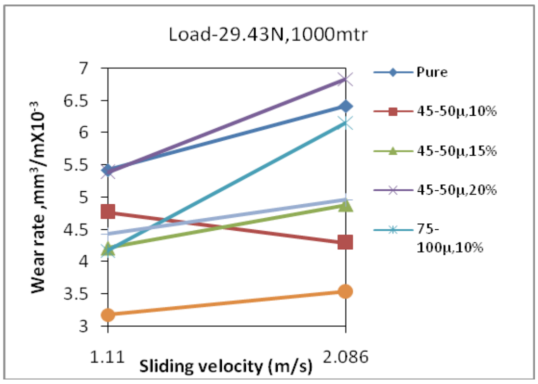

Fig. 9. Variation of Wear Rate with Sliding Velocity

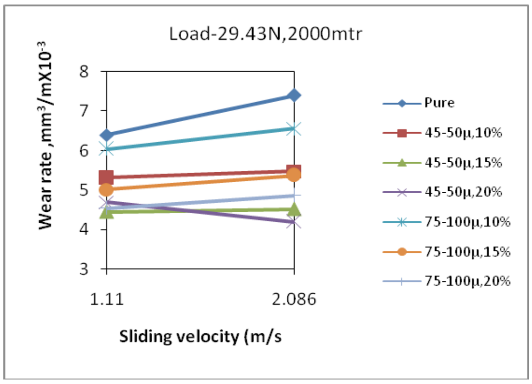

Fig. 10. Variation of Wear Rate with Sliding Velocity

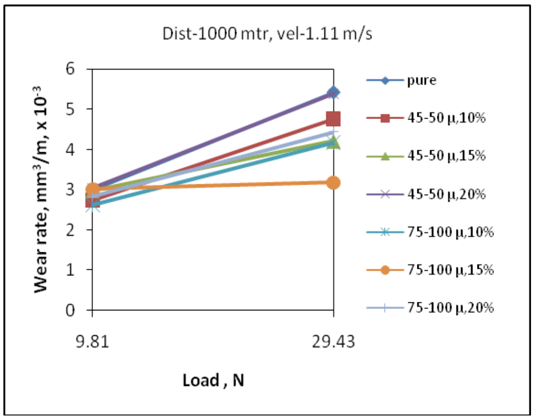

Fig. 11. Variation of Wear Rate with load

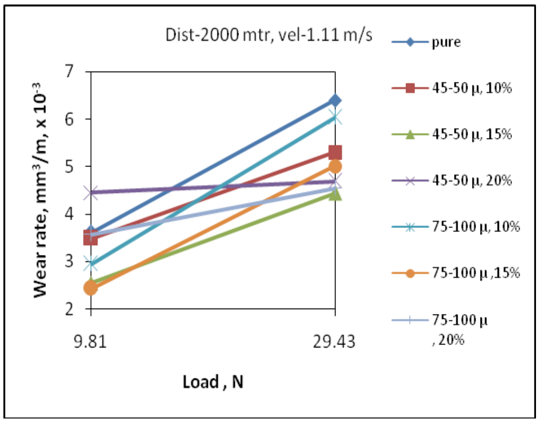

Fig. 12. Variation of Wear Rate with load

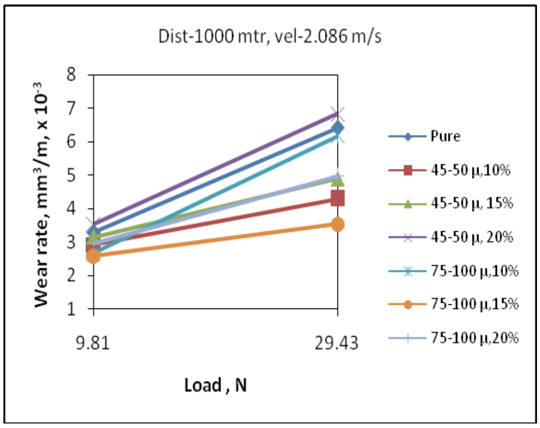

Fig. 13. Variation of Wear Rate with load

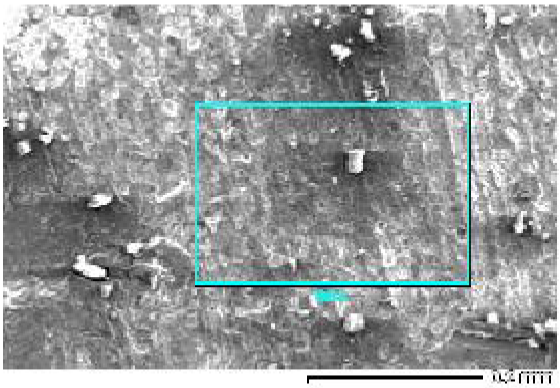

Fig. 14. Micrograph for Pure Al6061Alloy Unslid

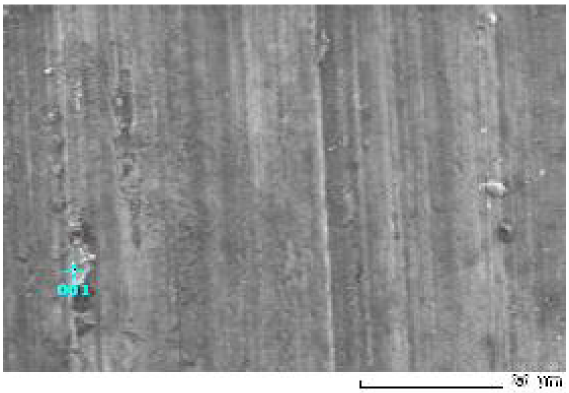

Fig. 15. Micrograph for Pure Al6061 Slid at 2.086m/s Sliding Speed, 29.43 N Load for 2000m Sliding Distance

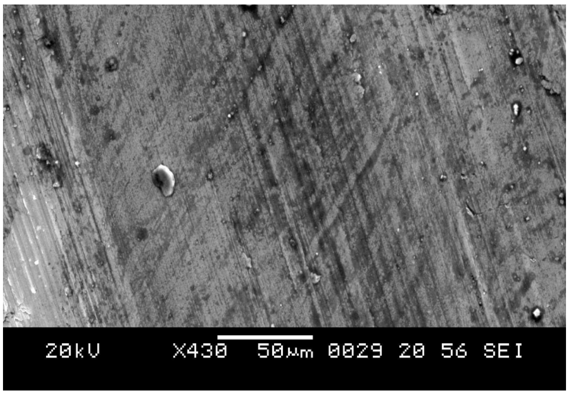

Fig. 16. Micrograph for Specimen (45-50 μ, 10 Wt %) slid at 2.086m/s sliding velocity, 29.43 N load for 2000m sliding distance

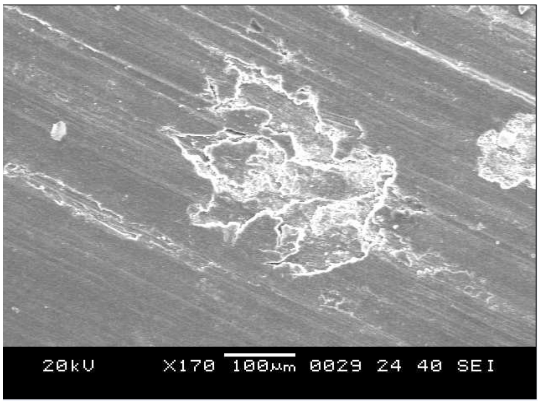

Fig. 17. Micrograph for Specimen (45-50 µ, 15 Wt %) slid at 2.086m/s sliding Velocity, 29.43 N load for 2000m sliding distance

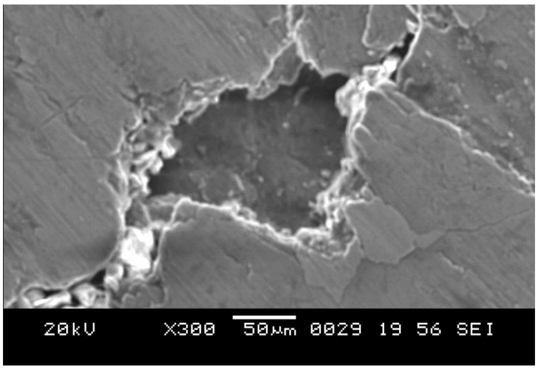

Fig. 18. Micrograph for Specimen (75-100 µ, 10 Wt %) Slid at 2.086m/s sliding Velocity, 9.43 N load for 2000m sliding distance

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