EFFECT OF VARYING LOAD ON WEAR RESISTANCE OF PARTICULATE LIGNITE FLY ASH REINFORCED ALUMINIUM ALLOY 6063 COMPOSITES

Vivekanandhan. P[1], Vishnu Kumar[2], Simson Monfort. J[3]

[1]Department of Mechanical Engineering, SRM Easwari Engineering College, Chennai, India.
[2]Department of Mechanical Engineering, Sathyabama University Chennai, India.
[3]Department of Mechanical Engineering, Mammallam Institute of Techhnology, Kancheepuram, India.
Email: [1]vivekjpv@yahoo.co.in

Abstract

The friction and wear behaviour of particulate reinforced aluminium alloy composites produced by a stir casting process technique were investigated. A pin-on-disc type apparatus was employed for determining the sliding wear rate and the coefficient of friction in Composite samples of different volume fraction respectively 97:03 and 94:06. The effects of weight loss and wear rate against applied dry friction load were studied in the composite samples. From this effect of different volume fraction of fly ash particulate in Aluminium Matrix Material samples were evaluated. The wear rates of the composites were considerably less than that of the aluminium alloy at all applied loads. However the friction coefficients of the composites were found to be higher than that of the matrix alloy. Scanning Electron Microscopy (SEM) of the worn surfaces revealed that particulate micro fracture was the predominant mechanism of wear of the composites.

Keywords: Wear, Friction, Lignite Fly ash, Aluminium alloy 6063, Metal Matrix Composite.

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal Matrix Composites (MMCs) possess significantly improved properties including high specific strength, specific modulus, damping capacity and good wear resistance alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of lignite in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminum products. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance alloys. While investigating the opportunity of using fly-ash as reinforcing element in the aluminium melt, the high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites[8]. The particulate composite can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by casting. Casting route is preferred as it is less expensive and amenable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one [6]. The only problem associated with this process is the non-uniform distribution of the particulate due to poor wet ability and gravity regulated segregation. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface. The increase in volume percentages of fly ash, hardness value increasesss in Al–fly ash (precipitator type) composites[10]. The tensile elastic modulus of the ash alloy increases with increase in volume percent (3–10) of fly ash. The Al_2O_3 particle reinforced Al MMCs, with varying particulate volume percentages (25, 36, 46, 52 and 56) and report improvement in elastic modulus, tensile strength, compressive strength and fracture properties with an increase in the reinforcement content [1]. The interface between the matrix and reinforcement plays a critical role in determining the properties of MMCs. Stiffening and strengthening rely on load transfer across the interface. Toughness is influenced by the crack deflection at the interface and ductility is affected by the relaxation of peak stress near the interface. However, reports on friction and wear characteristics of fly ash reinforced AMCs are very limited. The addition of fly ash particles to the aluminium alloy significantly increases its abrasive wear resistance and the improvement in wear resistance to the hard aluminosilicate constituent present in fly ash particles[8]. In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides is used as reinforcing phase. Composites were produced with 0.3% & 0.6% fly-ash as reinforcing phase. Then particle size and chemical composition analysis for fly-ash was done. Mechanical, and wear properties of the composites were evaluated and compared with the commercially pure aluminium. Moreover, the composite was characterized with the help of SEM.

II. MATERIAL SELECTION

A. Matrix material Selection: Aluminium alloy (6063)

The matrix is the phase which generally weak into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In this work Aluminium alloy 6063 is chosen as a matrix material that is one of the important alloy that derived from aluminium which is most abundant elements in the earth's crust and also the most important of the non-ferrous metals.

Table 1. Chemical composition of Aluminium alloy 6063

Component	Amount (wt.%)
Aluminium	Balance
Magnesium	0.45 - 0.9
Silicon	0.2 - 0.6
Iron	Max. 0.35
Copper	0.10
Zinc	Max. 0.10
Titanium	Max. 0.10
Manganese	Max. 0.10
Chromium	0.10
Others	0.05

Physical Properties of Al. alloy 6063:

Density : 2.70 g/cm

Melting Point : 600°

Modulus of Elasticity: 69.5 GPa

B. Reinforced Material (Lignite Coal Fly Ash)

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The chosen reinforcement is Lignite fly ash of Thermal power plant in the form of particles which dimensions varies from microns to nano scale. Due to chemical constitution that serves good physical property in matrix phase. Fly ash is a fine, glass powder recovered from the gases of burning lignite during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with lime and water the fly ash forms a cementations compound with properties very similar to that of Portland cement.

Table 2. Chemical Composition of Lignite Fly ash

Constituents	Contribution (in %)
Loss on Ignition	0.42%
Silica (as SiO_2)	57.32%
Iron (as Fe_2O_3)	5.92%
Titanium (as TiO_2)	3.96%
Aluminium (as Al_2O_3)	25.89%
Calcium (as CaO)	4.77%
Magnesium (as MgO)	0.69%
Sodium (as Na_2O)	0.60%
Potassium (as K_2O)	0.43%

The lignite coal fly ash used for the stir casting with aluminium alloy is an CLASS F* (low-Fe) type and the composite of the lignite coal fly ash match with the standard composites of the fly ash.

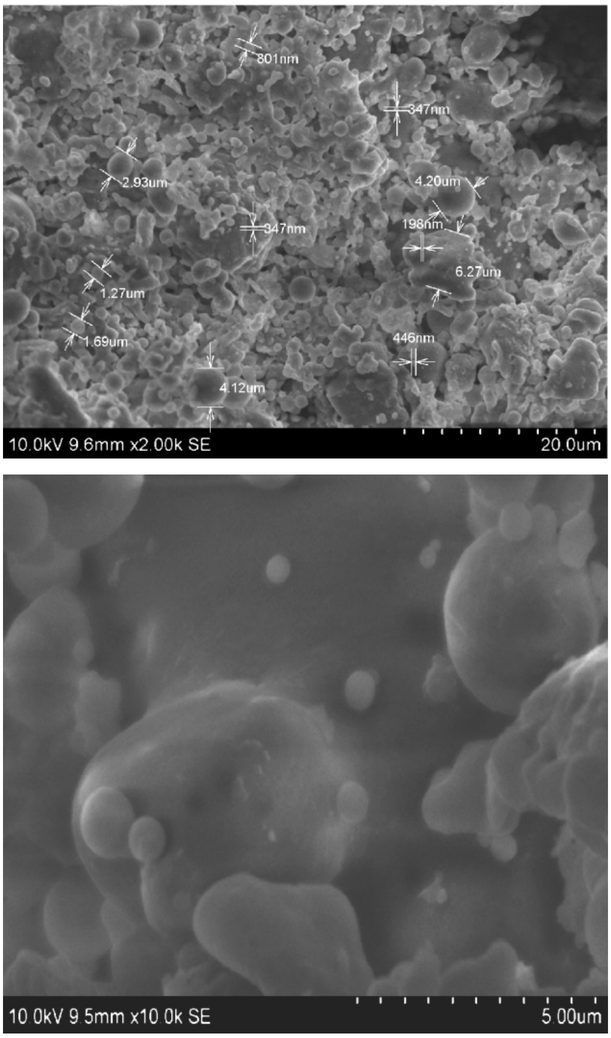

Fig. 1. SEM images of Lignite Fly ash.

III. SAMPLE MATERIAL PREPARATION METHOD

The samples were prepared by using stir casting procedure which is traditional and economic process. Prior to stir casting process two muffle furnaces were used. In one of the muffle furnace the 1kg of aluminium with 5 g of coverall is heated to 800 c temperature for 50 minutes. And the coverall is used to store the heat within the crushable. The aluminium is heated to 800°C to remove the impurities. Then the degasser of 5 g is added to the molten aluminium and the furnace is heated to 800°C for 5 minutes. After that nucleant of 5 g is added to the molten aluminium and heated to 800°C for 5 minutues. And both the degasser and nucleant are used to remove the impurities from the molten metal. Again the 5 g of coverall is added and heated to 800°C to regain the heat inside the crushable. At the same time in the other muffle furnace the lignite fly ash is heated in the furnace at 1000°C. Then the heated lignite fly ash is mixed with the molten metal alloy along with coverall. The mixtures were made in two different volume fractions (97:03 & 94:06). Then the mixtures of aluminium alloy and lignite fly ash are stirred at 125 rpm for 10 minutes. Before the casting the die is heated in the furnace to 300 c. And then the mixture of the aluminium alloy fly ash is poured into the die. Then it allowed solidifying the red hot molten metal to get the fly ash reinforced aluminium Metal Matrix Composites.

IV. EXPERIMENTATION: WEAR TEST -PIN ON DISC METHOD- SAMPLE PREPARATION

The wear test is carried out in Pin on disc apparatus which is most frequently used to find out the wear and weight characteristics against the applied loads. The tests were conducted for the two samples as per the ASTM G99 Standard. The cylindrical specimens are prepared to the dimensions as 5 cm in length and 1 cm in dia and clamping end is chamfered to 2×45.

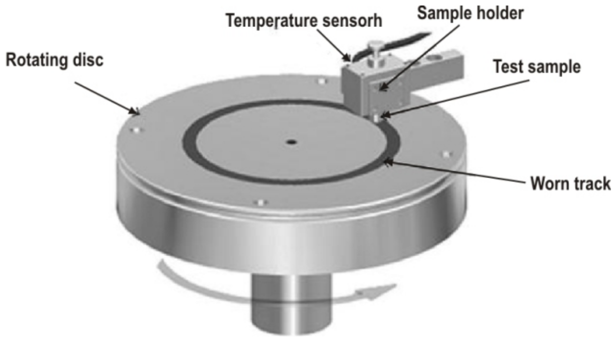

Fig. 2 Systematic diagram of pin on disc setup

A. Experimental Procedure in Sequential Step

The specimen's pins are clamped to loading lever tip by hardened jaws with the help of relevant size clamp to hold cylindrical specimen pin. The path generated is circle, so the specimen pin can be positioned over wear disc. By this the wear disc between each grid can be used for many tests by positioning the specimen pins at different diameter (Wear track diameter) on wear disc. In our experimentation we have carried out the wear at 220 grid with the weighing balancing accuracy of 0.0001 gm. The steady load applied to pin varies from 5 N - 40 N to know its wear characteristics and weight loss of material against mentioned load intervals.

IV. RESULTS AND DISCUSSION

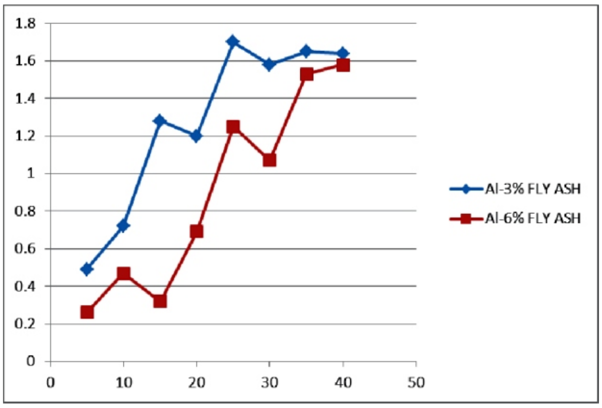

Fig. 1 Load (Newton) Versus Weight loss (gm)

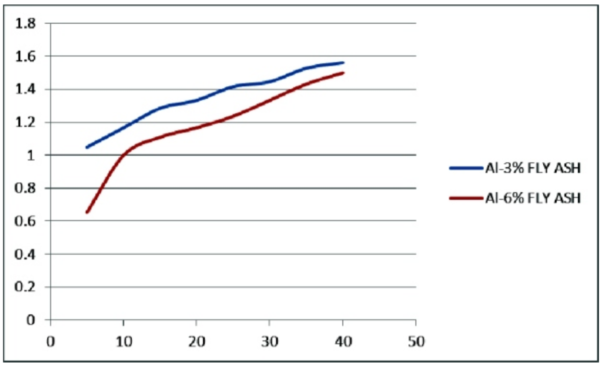

Fig. 2 Load (in N) Versus Wear Rate (cm^3)

The wear tests were performed for the samples having different volume fraction of reinforcements respectively 97:03 & 96:06. From the Fig.1 observations, at increasing in load the weight loss of the Metal Matrix Composite sample materials seems gradually increasing. As recorded, the weight loss of 6% reinforcement is comparatively less than the 3% of reinforcements in Aluminium alloy 6063 matrix material. From Fig. 2 the wear rate of 6% reinforcement sample possess the good resistance against increasing loads comparing to 3% addition of reinforcement in Al alloy. The results reveal that considerable addition of reinforcements provides a higher resistance against the increase in loads.

V. CONCLUSION & FUTURE WORK

In current scenario, the applications of composites material in the mechanical industries are more. In this present experimental investigation we have made a fly ash reinforced metal matrix in different volume ratio. After the casting process we analyzed the weight loss and wear performance against the increasing loads. From our observation, addition of fly ash with aluminium alloy the wear resistance is increased that result in less material loss of the casted metal matrix composite material. The proposed material exposes better wear properties which can be used in the automobile components where the wear is the great matter of concern. As a future work, we would like to extend this work to find out the other properties such as thermal, chemical, physical etc. of the same composite samples. As far as environment concern, by commercializing this material the fly ash of lignite will be used in a useful way.

REFERENCES

[1] Aghajanian.M.K, Langensiepen.R.A, Rocazella.M.A, Leighton. J.T Andersson. C.A, 1993, Mater. J. Sci. 28, 6683–6690.

[2] Barber. E.C, 1999, Reduce Part Weight and Cast with Hollow Microspheres for Plastics, 3M Company, Technical Report, St. Paul.

[3] Bandyopadhay. S, Das.T, and Munroe. P.R ,Metal Matrix Composites -The Light Yet Stronger Metals For Tomorrow, A Treaise On Cast materials, p-17-38.

[4] Clyne .T.W, Withers.P.J, 1993, An Introduction to Metal Matrix Composites, Cambridge University Press, Cambridge, UK, pp. 166–217.

[5] Chawla.K.K, 1974, On the applicability of the “Rule-of-Mixtures” to the strength propertie of metal Matrix composites, Revista Brasileira de Física, pp 411-418.

[6] Cao. L, Wang. Y, Yao. C.K, The wear properties of an SiC–whisker reinforced aluminium composite, Wear 140, 1990, 273–277.

[7] Clyne T.W, Metal Matrix Composites: Matrices and Processing,Encyclopedia of Materials: Science and Technology, 2001, p-8.

[8] Guo. R.Q, and Rohatgi.P.K,1998, “Chemical Reactions Between Aluminium and Fly Ash During Synthesis and Reheating of Aluminium-Fly Ash Composite”, Metallurgical & Materials Transaction B, Vol. 29B.

[9] Liu. Y.L, Kang. S.B and Kim. H.W, 1999. “Complex Microstructures in As-Cast Al-Mg-Si Alloy”, Materials Letters, Vol. 41.

[10] Lloyd. D. J, 1994. “Particle Reinforced Aluminium and Magnesium Matrix Composites”, International Materials Reviews, Vol. 39.

[11] Matsunaga. T, Kim. J.K, Hardcastle. S and Rohatgi. P.K, 2002, Crystallinity and selected properties of fly ash particles, Materials Science and Engineering A325 333–343.

[12] Radhakrishna. K, and Ramachandra. M, 2007, “Effect of reinforcement of fly ash on sliding wear, slurry erosive wear and corrosive behavior of aluminium matrix composite”, Wear 262, pp.1450– 1462.

[13] Rajan T.P.D, Pillai. R.M, Pai. B.C, Satyanarayana. K.G, Rohatgi. P.K, 2001, Proceedings of National Conference on: Recent Advances in Materials Processing RAMP-2001, India, pp.327–334.