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Wear Analysis of AA 6082 Aluminum alloy /Fly ash Composite

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***ABSTRACT**--Nowadays Metal matrix composites (MMCs) guides to better and attractive design. The objectives are to save structural materials and utilize the waste products that are promoting in each field of engineering purposes. The researchers have keen attention for low density and low-cost component. Fly ash is the cheapest solid waste which is available in plenty in any of the thermal power plants. Hence, aluminum and fly ash composite found to be suitable for applications in the field of automotive and small engine applications for its low density and low cost. To fabricate Al metal matrix composites by casting technique, the Fly ash particles are added into Aluminum melt about 750 degrees centigrade.The present investigation is focused on the use of sufficiently obtainable industrial throw away 'fly ash' in a beneficial approach through adding it to AA6082 aluminum metal matrix by means of fluid metallurgy route. For this purpose, following ranges of the fly ash bits ranging from 0.1µm to 100µm were used. The worn exteriors were examined using an optical microscope for varying compositions of fly-ash particles in the composites. The mechanical along with tribological properties including hardness, the abrasive wear resistance of the aluminum metal matrix was verified with the different amount of fly ash composites in the cast forms under various standardized machines and found to be improving with increasing value of fly ash content. The genuineness of improving the property is also verified as the grain size and numbers of intercepts are found to decrease in the study of the scanning microscope.*

***Keywords**--Aluminum AA6082, metal matrix composite, Fly ash, fluid metallurgy route, microstructure, hardness, abrasive wear*

I. INTRODUCTION

Standard metal alloys have limitations for the required combinations of hardness, wear, and density. So as to overcome these limitations and to satisfy the regularly growing engineering requirements of today's machinery, Metal Matrix Composites (MMCs) are showing great influence. In current years, metal matrix of aluminum-based MMCs has brought global recognition.

For attractive mechanical & tribological properties, Aluminum Metal Matrix composites are gaining momentum. Researchers are also motivated towards the production of advanced metal matrix composites that are lightweight along with consuming less fuel [1-5]. Type of reinforcement and its volume fraction make it possible to have advanced aluminum metal matrix composite to have a rare but required kind of the sequence of properties like high strength, frictional wear, and stiffness, resistance to fatigue, creep and corrosion. So in aviation as well as in space and automotive industry AMMCs are of high importance [6]. Ceramic reinforced Aluminum Metal Matrix composites (AMMCs) are nowadays extensively used for most of the advanced applications like aerospace, de-

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fense, automobiles and lightweight and fuel-efficient type of applications [7-9] Many reinforcements found in literature that are reinforced into aluminum metal matrix are SiC, Al_2O_3, fly ash, B4C, silicon nitride etc. for mechanical and wear analysis fabricated through different fabrication techniques [10-13]. A. Daoud et al [7], prepared Al_2O_3 reinforced into aluminum alloy through squeeze casting method. They studied the microstructure along with sliding wear performance of the composite. The finer microstructure is obtained on addition of Al_2O_3 and application of squeeze pressure. The applied squeeze pressure enhances the mechanical locking between the matrix and alumina (Al_2O_3) particles and eliminates interfacial properties thus improving interfacial strength. The hardness was found to increase in a linear fashion with the increase in volume percentage of particles along with externally applied squeeze pressure.

Shamsipour et al. [14] used optimal values of the various input parameters of the Rheocasting and fabricated the Tic particles reinforced Aluminum metal matrix composites. Rahimipour et al. [15] used Artificial Neural Network (ANN) optimization technique and predicted the Aluminum reinforced with 20% B_4C particle by weight 'composite to be more wear resistance than other percentages of the B_4C reinforced AMMCs. A continuous variation of volume rates of Al_2O_3 reinforced with the aluminum metal matrix presented by Shabani et al. [16] and Shabani [17]. The presence of Al_2O_3 reduces the rate of wear but the friction coefficient rises gradually along with the continuous introduction of Al_2O_3 in the aluminum metal matrix. Prakash et al. [18] investigated MMC of AA6061 T6 alloy reinforced with rock dust particles by powder metallurgy technique. The presence of excess rock-dust particles reduces the hardness and a low quantity of it nearly 10% by volume improves the resistance to wear rate of the MMC. Shamsipour et al. [14], Shamsipour et al. [19] reinforced Tic nano-particles into the Al-Si alloy matrix. They found that adding Tic nano-particles improves the hardness of the Al-Si alloy. Mazahery and Shabani [20] and Shabani et al. [21] investigated using the B_4C particulates coated with TiB_2 in the matrix of Al-Si alloy and conducted the wear analysis on a pin-on-disc machine. They conveyed that the wear rate reduces as the volume percentage increases for the coated B_4C particles. In the production of lightweight and fuel-efficient automobiles and aircraft engines, the most sought materials are either SiC (3.21g/cm3) or Al_2O_3 (3.95g/cm^3) reinforced aluminum metal matrix composites [22-24]. These ceramic reinforcements have a higher density than those of aluminum (2.7 g/cm^3) and its alloys. It is because of that its alloys. The addition in ceramic coating content develops the weight of the composite [25]. Also, ceramic reinforcement materials are highly expansive and this creates a key problem in the design of composites [26]. So, in order to overcome the above-said problem and keep in pace with today's developing technology, composites reinforced with low density as well as low-cost reinforcements are of priority and importance. Fly ash is one such lesser cost, lesser dense reinforcement available plentifully as waste after the burning of coal in thermal power units [27-28]. Incorporating fly ash reinforcement into the aluminum alloy reduces the price and weight of composites. Fly ash can be utilized to be an efficient reinforcement in case of MMCs and its effect of land pollution along with adverse environmental impact can be reduced. [29] In the recent times, due to the low cost and low densities than ceramics, the use of industrial waste, for example, Fly Ash, Ash (RHA), Husk of rice etc. are increased. So, researchers have done a lot of work against the limitations to provide possibilities of the industrial wastes used as reinforcements [30-31]. Although aluminum has low density along with high thermal conductivity it shows poor tribological properties because it is susceptible to damage by scratches as well as by indentations very easily, so, there is a need to study & improve the tribological performance of aluminum and its alloys [32]. The MMCs are mainly fabricated by powder metallurgy, casting technique, friction stir processing, ball milling combined with hot rolling and many times with vacuum hot-pressing techniques etc. However, due to its inexpensive cost and special production rate, the casting process is mostly adopted in preparing AMMCs [33-34].

A. Fly ash

Fly ash is the solid left-over of coal obtained next to burning of coal in a furnace of power plant. The composition of fly ash based on the source and the process of burning of coal, however, all fly ash contain considerable quantities of silica (SiO_2) available in the amorphous, crystalline and lime (CaO). The major utilization of fly ash is in the concrete and cements industry, although, innovative novel usages of fly ash are now sought towards the fabrication of MMCs .Fly ash is preferred to be used as a filler and /or reinforcement in composites due to its plentily availability, low cost, low density. The fly ash can be utilized to fabricate a low-density insulator because of its high electrical resistivity as well as its low thermal conductivity. Fly ash as reinforcement not only improves the tribological properties but also enhances friction coefficient, the maintainability and damping capacity of metal matrixes which are of great importance in different advanced industries. Inhaling these fly ash particles from atmosphere is harmful to human health and keeping in mind that this waste can be recycled as reinforcement towards fabrication of advanced MMCs, we are taking fly ash as reinforcement in aluminum metal matrix in the present investigation.

1.1.1 Aluminum fly ash particulate reinforced composite

The increasing quantity of fly ash reinforcement content in Aluminum metal matrix results in reduction in density and increase in both compressive strength as well as hardness of the composites [35] Many researchers concluded that fly ash reinforced with varied percentage in aluminum metal matrix shows enhanced mechanical properties and wear resistance of the AMMCs [36-41]. Radhakrishnan et.al [32] have prepared Al (12 wt.% Si) with up to 15 % by weight of fly ash particulate reinforced MMC through the conventional stir casting route and studied the consequence of including fly ash on sliding wear performance, slurry erosive wear performance along with on corrosion behavior of AMMC. They found that fly ash enhances abrasive wear resistance from 20 to 30% and decreases the friction coefficient. Wear mechanisms observed are mainly abrasion followed by oxidation, thermal softening along with adhesion.

Sudarshan et.al [42] has studied A356 Al–fly ash particle composites and found that the Fly ash belonging to the fine size range of particles (53–106µm) illustrate improved properties than the wider range of particles (0.5–400µm). The damping capacity of composite rises with the volume fraction of fly ash. The fractured surface of the above-mentioned composite exhibited both ductile as well as the brittle mode of fracture (mixed mode of fracture) simultaneously. Rohatgi et.al [43] prepared A356 aluminum alloy reinforced with fly ash cenosphere particle composite by means of pressure infiltration method and found that from 20 vol % up to 65 vol% of fly ash could be effectively reinforced using gas pressure infiltration. Gupta et.al [44] had taken pure Aluminum metal with 65%in volume of hollow fly ash particulates (cenosphere) as reinforcements and found that Composites having lesser Coefficient of Thermal Expansion (CTE) can be fabricated with the incorporation of cenospheres and by controlling the process parameters of a given volume percentage of reinforcement. Bienias et.al [45] have prepared aluminum metal matrix composite reinforced by fly ash particles by both squeeze casting and gravity casting technique separately. The comparison shows that Squeeze casting is more useful as it shows structural homogeneity, less porosity, and enhanced interfacial bonding. Mishra et.al [46] have prepared Aluminum metal matrix composite toughened with fly ash and got that up to adding 17% fly ash by weight. They have reinforcement the aluminum matrix by means of liquid metallurgy route. The wettability, the mechanical properties like hardness, tensile strength along with wear resistance improved by the addition of magnesium in the aluminum melt. Weiss et.al [47] showed the beneficial utilization of Al- fly ash composite in environmental and energy sectors. This has potential application in low cost, automotive and pollution savings areas. Prabhakar et al [48] prepared Al5083 alloy with fly ash reinforcement through Friction Stir Processing (FSP) adopting a groove filling method of dispersion of fly ash particles. FSP was conducted at various speeds along with various feed rates. They found that 1450rpm speed at 20 & 25 mm/min feed showed optimal process parameters. They concluded that composite of Aluminum reinforced with fly ash particles can be effectively fabricated by Friction Stir Processing with enhanced mechanical properties. Prasad et al [49] prepared Al-fly ash composite through squeeze casting technique. They studied the abrasive wear performance using various speeds such as 250 rpm, 300rpm, and 350 rpm along with 2kg, 3kg and 4kg load respectively. The outcome of content reinforcement along with squeeze pressure on the wear rate and hardness of composite was investigated. The wear resistance of this Al-fly ash composite was significantly advanced as compared to the base alloy. Sharma et al [50] has taken different fly ash content (2-4-6) %in weight in the aluminum melt, prepared the composite by a stir casting method and investigated the wear behavior of aluminum metal matrix composite using a pin-on-disc set up. They detected that the metal matrix composites (MMCs) with 6% fly ash content by weight showed less wear. Uthaya Kumar et al [51] prepared AMMC of Al6351 alloy with 5 to 15% weight of fly ash with 5% increment each time by means of stir casting technique and studied the dry sliding wear mechanism. They took independent variables to be applied load, sliding speed along with fly ash amount and used Grey Relational Analysis (GRA) on a ‘pin-on-disc machine’ and found the influence of these independent parameters on the dependent variable such as coefficient of friction, sliding wear performance as well as the wear rate. Dry sliding wear performance is mainly affected by applied load succeeded by sliding velocity as confirmed by Analysis of variance (ANOVA). Sahu et al [52] mixed fly ash and aluminum powder in various weight percentages and prepared a coating on the aluminum substrate by plasma-spray technique. They studied the solid particle erosion wear performance by an advanced and efficient method consisting of Artificial Neural Network (ANN) algorithm applied towards Taguchi orthogonal experiment. The investigation showed that the impact velocity significantly affecting the wear rate of these composite coatings than other factors Udaya et al [53] prepared Al413 alloy reinforced with fly ash (3%, 6%, and 9% by weight) through stir casting and investigated the effect of wear parameters on adhesive wear performance of AMMC’s. Wear test accompanied a pin-on-disc apparatus with the following specification ASTMG99-05. They concluded that load shows the maximum effect on the rate of wear succeeded by sliding speed, sliding distance and weight content (in percentage) of fly ash. Selvam et al [54] prepared fly ash reinforced AMMC through compo casting technique in stir casting furnace. Wear analysis of AMMC were conducted through ‘pin-on-disc apparatus’ for various fly ash content of 0%,4%,8% and 12% by weight along with a various combination of temperature values of 400c,800c,1200c,1600c,2000c and 2400c respectively. Wear resistance improved with temperature. In case of AA6061 wear mechanism was adhesion and metal flow but in case of AA6061/fly ash composite, it is mainly adhesion, metal flow, and oxidation. Rao et al [55] prepared AA2024 alloy and 5% weight fly ash composite through stir casting technique and dry sliding wear behavior was tested. They took 2.0 m/s sliding velocity along with 60 mm track diameter while load changing from 0.5kgf to 105kgf. For lower loads, the wear resistance of composite was better than the base alloy. As loads and sliding distances increase the wear was much more pronounced as the fly ash particles become fractured and even dislodged. Ravi Kumar et al [56] prepared composites of aluminum alloy (of composition Al/3.25 Cu/8.5 Si) reinforced with various sizes of fly ash particles The ranges of particles are (53-75µm), (75-103µm) and (103-125µm) in 3 to 9 weight % with increment of 3% each time by means of liquid metallurgy technique. They found that coarse fly ash particles showed higher resistance to wear than those with fine particles. However, literature does not contain so much information of fly ash as reinforcement in aluminum matrix analyzed for fluctuating abrasion wear behavior which has been carried out in the present investigation.

II. EXPERIMENTAL WORK

A. Waste resources

AA6082 Aluminum alloy along fly ash particles (Table-1) of size ranging from 0.1µm to100µm is taken as the matrix material for preparation for composite. The fly ash is collected from NALCO, Odisha, India. In this investigation, fly-ash of F type has taken for preparation of metal matrix composite. The general constituents of Fly ash of type F are presented in Table 1.

Table 1: (Chemical constituent of class F type of Fly ash)

Chemical constituent	Composition (in %)
SiO_2	54.27
Al_2O_3	34.73
Fe_2O_3	6. 1
MgO	2.4
CaO	2.1

Table 2: (Constituent of AA 6082)

Composition of AA6082	% of Constituents
Al	96.95
Cu	0.1
Si	1.1
Mn	0.5
Fe	0.4
Zn	0.05
Mg	0.65
Cr	0.15
Ti	0.1

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Figure 1: AA 6082

Figure 2: Fly ash of Type F

Figure 3: Crucible 150ml capacity

Figure 1, Figure 2 and Figure 3 show the AA6082 Aluminum, fly ash and aluminum crucible of 150ml capacity. The classically shaped aluminum crucible is taken for experimental observation can operate up to a maximum temperature of 17500c degree.

B. Raw material used in sand casting

A wooden box is made having 50 cm lengths, 25cm breath, 12cm height. After which a mixture of sand and Bentonite powder is prepared in the ratio of 7:3, which is further mixed with the molasses. Then two rectangular blocks are placed inside the box having 20cm length, 2cm breath, and 2cm height. The detail for the raw material used in sand casting is presented in Table 3. With the help of sunlight, it takes 2 days to dry it. Then the cavity is to resist the molten matrix to give the desired shape.

Table 3: (Raw material used in sand casting)

SL NO.	Name of material
1	Wood
2	Bentonite

3	Sand
4	Molasses
5	Graphite

C. Specimen manufacturing

In the present work to fabricate the MMC, the Stir-casting method was chosen. The process is followed by melting the matrix with consecutive stirring and quickly discharging liquefies into a pre-formed sand cavity. MMC is allowed to cool and solidify inside the mold. The particle i.e. agglomerates in stir-casting can be melted by healthy stirring at the elevated temperature. The set up for stir casting (Fig. 4) comprised of a furnace, crucible united with rotor and motor. In the crucible the metal alloy (AA6082) is melted to a temperature of nearly 750^0C and the pretreated reinforcing substance (fly ash) was combined with externally in a particular fraction of 5–10–15% by weight. Aluminum and fly ash are processed with the help of a stirrer rod at a speed of 400 rpm for homogeneous mixing. Two blades of 900 angles are attached on each side of the stirrer with blade length 9 cm and rod length 95 cm. The matrix liquid was allowed to pour into the predefined cavity having a standard specimen dimension (Fig 5). Prepared by sand casting and allowed staying inside the mold box for few hours up to atmospheric temperature. The composite bars are fabricated by taking the various components of fly-ash % such as 5%, 10%, and 15% by weight. After subsequent cooling and machining methods, many test pieces were prepared for examination of hardness and wear.

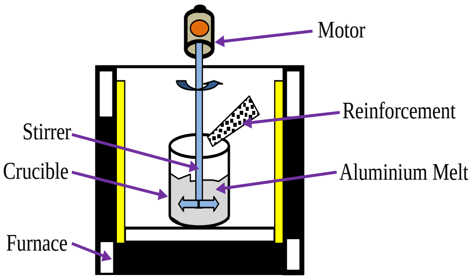

Figure 4: Set up for stir casting furnace

Figure 5: Aluminum metal matrix composite

III. RESULTS AND DISCUSSION

A. Micro structural characterization Inverted metallurgical microscope (Optical microscopy)

The various properties of the composite are affected by the nature of reinforcement along with its size, density as well as its distribution, whereas distribution is dependent on the solidification rate combined with its fluidity and the process of addition. Microstructure analyses are conducted on different fly ash composite samples. The composite bar samples are cleaned and polished before inspection. Collected pieces of different composite (with % change of fly ash) are polished by the polishing machine (Fig.6) for 12 hr. An inverted metallurgical scanning microscope is presented in Fig 7. It is predicted that by increasing fly ash percentage decreases the grain size of the composites. Thus, it is concluded that the mechanical properties of the composite have improved. Outcomes of the microstructure analysis of the composite are presented in a tabular form as given below in Table 4.

Figure 6: Material for polishing

Figure 7: Scanning Microscope

Table 4: Micro Structure of MMC

SL. No	% of Fly Ash	Avg Grain Size	No. of Intercepts	Total Length
1	5	8	433	9.401
2	10	6.5	296	9.401
3	15	6.1	270	9.401
4	20	6	252	9.401

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B. Analysis of SEM

Observations are taken using an optical microscope with a progressing order of magnification from 100X to 300X with ascending order of fly ash contains. The general defects of casting as porosity, shrinkage or slag inclusions are not visible as per the feathers observed in the microstructures. It also reveals from the figure (8a, 8b, 8c, and 8d) that particles of fly ash are dispersed homogeneously in the MMC, which is a necessary requirement to get better the mechanical properties. Fly ash particles act as a grain nucleation site and the aluminum grains solidified on it.

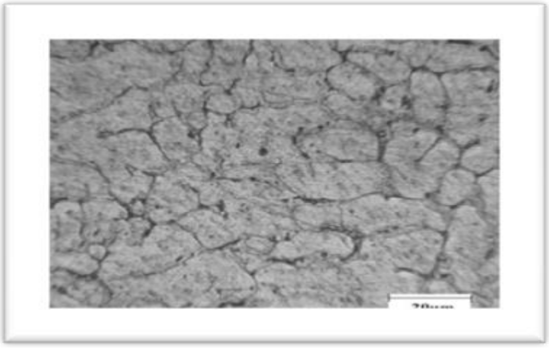

Figure 8(a): Microstructure of MMC Pure AA 6082

Figure 8(b): Microstructure of MMC 5% fly ash with AA 6082

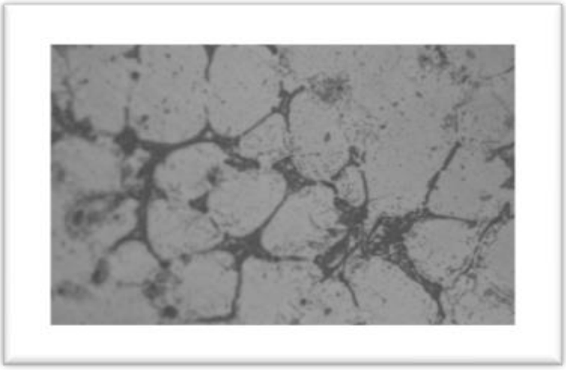

Figure 8(c): Microstructure of MMC 10 % fly ash with AA 6082

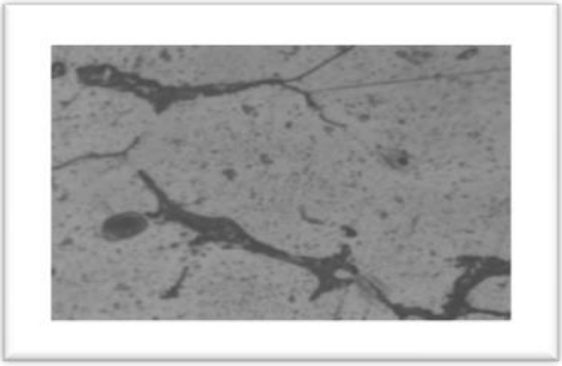

Figure 8(d): Microstructure of MMC 15% fly ash with AA 6082

Fig 8: Microstructure of MMC with (a) Pure AA 6082, (b) 5 %, (c) 10 % and (d) 15% Fly ash

IV. HARDNESS TEST OF ALUMINUM FLY ASH

Hardness is quantified as the resistance of solid matter to localized plastic deformation due to scratch or dent when a force is applied. Generally, three types of Hardness tests are preferred by the metals industry. In the present work, the Brinell hardness test was conducted to determine the hardness of MMCs. Hardness is not a fundamental physical property, rather it is a fundamental property of a matter and defined as the resistance to indentation. It is estimated by measuring the permanent depth of the indentation on the composite. The applied load and indenter diameter are related using the Equation $P=5D^2$ for the non-ferrous metal as Aluminum in the Brinell hardness tester, where P in kgf and diameter of the ball in mm. In the present investigation, the load is taken as 500kgf and diameter of the steel ball as 10mm Figure 9 shows the Brinell hardness testing machine. The hardness of the composite is shown in Table 5. The highest value of hardness is 76.4 when 15% Fly Ash.

Figure 9: Brinell hardness testing machine

Table 5: Result of Brinell hardness Test for AA6082

Amount of fly ash in Aluminum (in %)	HRB
0	44
5	52.1

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10	66
15	76.4

V. TRIBOLOGICAL ANALYSIS OF ALUMINUM FLY ASH

Wear Behavior of Aluminum Matrix Composites

The phenomena of wear endure amongst the most critical problem in mechanical components where the material is particularly affected by various activities with reasonable restrictions and operating conditions. Wear is common and continuous damage for material that is subjected to a repeated rubbing action. Therefore, the machinery parts require a continuous repairing or providing a new supplement which increases maintenance cost of Machine. The enhancement of wear properties of AA 6082 Aluminum matrix composites augmented including fly ash particles were favorably formed by a stir casting process. It noted that stability of worn out surface for pure AA 6082 Aluminum is developed due to rise in % change of particles of fly ash. The coefficient of friction along with resistance to wear of the specimens' increase with the upgrading of the fly ash contains in the AMMC. Basically, resistance to wear for given composite matrix depends on different microstructure characteristics similar to the size of the molecule, part of the fractional volume, the scattering of augmented material along with shape.

The pin-on-disc machine was used to analyze the dry sliding wear behavior of the contact surface of the specimens as shown in Figure 3. As per ASTM G99-95 standards, the tests were conducted. The pin was initially treated with acetone. The test was conducted at 100 rpm at 30N of load and with a constant sliding velocity of 18.8m/sec of different aluminum and fly ash composites (base metal, 5%flyash, 10%fly ash, 15%flyash).The disc material was of EN-32 steel with the hardness of 65 HRC. The dimensions of test specimens are 10mm in diameter and 30mm of height. The sliding track diameter of 30mm was selected. The results obtained from this work have been presented in terms of specific wear rate, sliding wear, and frictional coefficient. Sliding wear is linked to interactions between surfaces and the removal and deformation of material on a surface due to shear action.

Figure 10: Pin-On-Disk Wear testing equipment.

The wear resistance of MMC depends principally on different microstructure qualities like molecule size, volume part, dispersion of reinforced material, and shape.

VI. MICROSCOPIC EXAMINATION

Under Optical microscopic examinations, the worn pin surfaces are classified into five different wear mechanisms i.e. operating, either singly or in combination. They are abrasion, oxidation, delaminating, adhesion, thermal softening and melting. In the existing work, the composition of fly ash percentage in the composite are interpreted based on the wear mechanisms corresponding to the rate of wear.

A. Abrasion

Grooving and scratching found on all the worn surfaces more severe at the high loads and high sliding velocity. Such features are the uniqueness of abrasion, in which the asperities of the disc counter face, or reinforced fly ash particles between the surfaces in contact, cause wear by the removal of tiny fragments of material. The abrasion causes generally via ploughing, in which usually material is not removed from the pin surface, but dislocated on either side of the grooves of abrasion, or formed a wedge, where small wedge-shaped fragments are worn only during the initial contact with an abrasive particle. The fractured fly ash particles trapped between the sliding surfaces also cause abrasion of the steel disc.

B. Oxidation

Under the SEM, the dark surfaces are found to be filled with extensively by a thin layer offline particle. The wear debris content bulk amounts of fine powder. This uniqueness is an indication of oxidative wear. At the time of sliding the heat generated due to friction causes the oxidation of the surface resulting wear through the removal of oxide fragments. Due to continuous sliding, oxide wear debris covers the sliding surface of the pin, creates a layer of the shield and prevents metallic contact; resulted in the reduction of wear rate of the composites.

C. Delimitation

At a higher load of Pins tested, the mechanism of wear i.e. been linked to the process of delimitation. This kind of wear is similar to the trend of fatigue mechanism of wear where repeated sliding cause's subsurface cracks which steadily grow and ultimately shear to the surface, causing long thin wear sheets. Subsurface deformation, crack formation and propagation will accelerate with an increase in load and speed of the pin generating in a higher rate of wear. The interfaces of fly ash and matrix provide additional void nucleation sites and favored crack propagation paths. In the present work, rates of wear of the composites reduce with a rising in fly ash percentage in the composites.

D. Adhesion

At higher sliding speeds and higher loads the features of delimitation wear was replaced by adhesive wear as material transfer is evident on the pin surfaces. At the higher load of 30N and sliding speed of 18.8m/sec for base alloy and 5% fly ash reinforced MMC, the wear track on the disc is covered with a layer of plastically deformed material. The extensive transfer of material signifies that wear is of the adhesive type. In case of the composite adhesion is less severe than that of the base alloy. The volume of wear debris is considerably less from i.e.base alloy (Fig.11) than those collected due to abrasion, oxidation and delimitation

In pins tested at a speed of 18.8m/sec and 30Nload, It was found Large protrusion were observed in case of MMC containing with high fly ash particles (15% fly ash).Fig.14 from that of MMC containing with low fly ash particles(5% fly ash) Fig.13 indicating thermal softening. It was observed that 5% fly ash MMC, the gross plastic deformation of the pin surface material i.e. extruded from the interface (before re-solidifying around the periphery of the pin) is large from that of 10% fly ash (Fig.12), MMC, 15% fly ash MMC respectively.

At the time of sliding the temperature of both the surfaces in contact increases, could reach the melting temperature of base material. The asperities trapped between both the surfaces in contact become soft and there is an improved wear rate observed. This type of wear is generally observed in MMC specimens containing less amount of fly ash and in base metal.

E. Wear debris

The worn debris of metal matrix composite with 10% of fly ash is shown in Fig. 12. During the tests a substantial quantity of wear debris was generated, flake-like aluminum and black powder of fly ash particles. A typical example of the flake type Al is given in Fig. 14, shows flake-like wear debris formed under a load of 30N and 18.8 m/min on 15% fly ash MMC specimens .On the other hand, Fig. 14 shows flake like aluminum debris of medium size collected from the same test In fact, these wear debris could be influenced to a great degree by the composition of MMC (% of fly ash). The volume of the wear debris increases with increasing normal loads and sliding velocity, thereby resulting in greater wear loss for higher loads and sliding velocities.

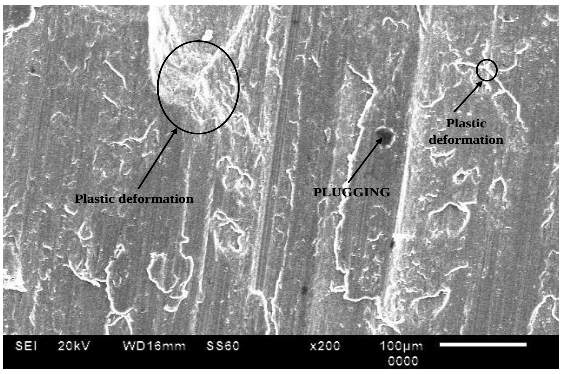

Figure 11: Base metal AA6082

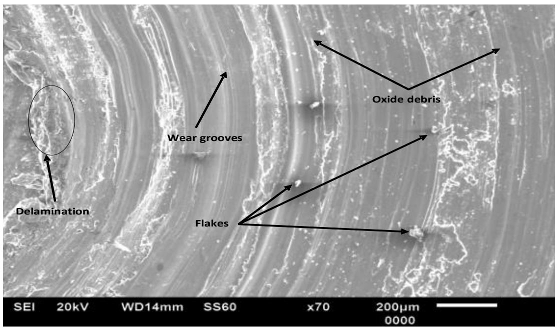

Figure 12: Composites with 10% of Fly Ash

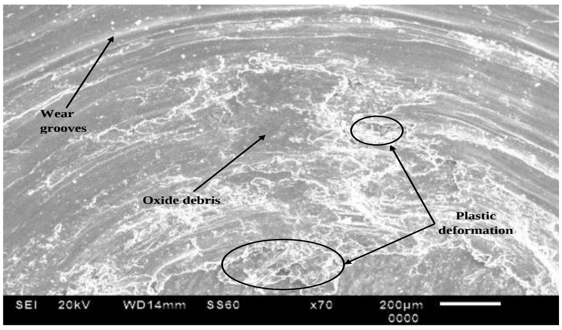

Figure 13: Composites with 5% of Fly Ash

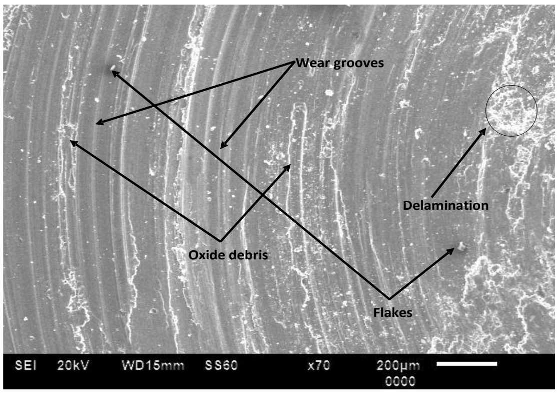

Figure 14: Composite with 15% Fly Ash

F. Analysis of Wear Loss

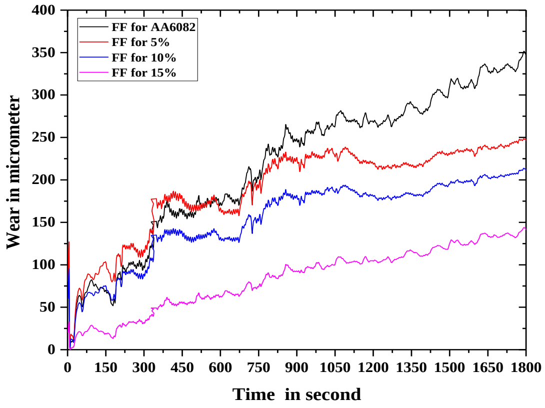

Figure 15: Wear loss with respect to time

The wear loss is presented with respect to time at a sliding speed of 18.8m/sec applied load of 30N for different fly ash percentage of MMC. It was found that for initial 3minutes the wear loss near about to same for base metal, 5% fly ash composite, and 10% composite. Then the 10% composite shows better wear resistance than that of base metal and 5% fly ash composite. The 15%fly ash MMC composite show better wear resistance throughout the 30minutes of sliding operation and the wear loss increase steadily. Figure 16 represents a good relation between the co-efficient of friction with time for different composition of fly ash present in the MMC .It is observed that the frictional coefficient increases due to the % of increasing of fly ash with respect to base AA6082.Initially the frictional coefficient increases suddenly to a certain limit and then becomes steady for rest of the operational time.

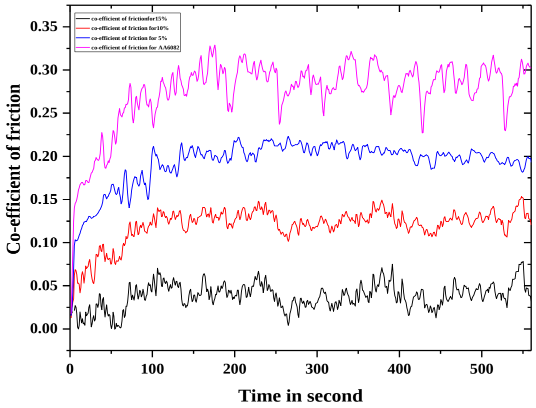

Figure 16: Co-efficient of friction with respect to time

VII. CONCLUSION

Fly Ash reinforced Aluminum metal matrix composites (AMMCs) are fabricated by stir casting process at various weight percentages of fly-ash for study of microstructure, Brinell hardness and dry sliding wear. In the present investigation, it was observed that tensile strength, Brinell hardness number of composite increases with increasing fly-ash content in the composite while grain size and number of intercept decreases. For same sliding velocity (18.8m/sec) and same load (30N) the wear behavior of the composites of different percentage of fly ash was analyzed. It was found that as the fly ash percentage in composites increases the wear resistance increases. The wear characteristics like oxidation and delimitation were dominant in case of high percentage of fly ash content composites in comparison to the low fly ash content composites, where the adhesive wear was dominant for low content fly ash composites and base metal in comparison to high fly ash content composites. We can have effective use of the fly-ash in the composites production and this industrial waste can be recycled into industrial asset along with there will be no problem of storing and dumping of fly ash. Stir casting process proved to be a good method for production of composites. Other methods of production are important scope of further research.

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