IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 8, April 2024

Study of Mechanical and Tribological Behavior of Fly ash with E-Glass fibre Reinforced AL MMC's

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Abstract: *AMC's specimen made by liquid stir casting technique, by addition of fixed 3% E-glass fibers and fly ash particles in different proportions (4, 6 and 8 wt.%) prepared the matrix phase. A uniform distribution of reinforcement is obtained with good bonding with matrix. Dry sliding wear behavior of the aluminum alloy and the composites has been studied and tested using a pin-on-disc wear and friction monitor. The testing carried out on sliding velocity of 1.5, 2.5 and 3.5 m/s and load ranges from 1, 2 and 3kgf. The composite shows better mechanical properties than the base alloy. Abrasive wear resistance improves by addition of fly ash reinforcement*

Keywords: Al2024 alloy composite, Al-fly ash composites, wear test, sliding wear, E-Glass fiber, mechanical properties

I. INTRODUCTION

Composites are simply the mixing of two or more materials to rectify some short comings of a particular useful component. Aluminum based Metal Matrix Composites(AMCs) have greater utilization in various fields like aerospace, automobile, construction equipment, owing to their versatile mechanical properties and tribological behavior and that are being used for varieties of applications owing to their good strength to weight ratio, excellent thermal conductivity properties. There are many situations in service that demand various property combinations like high strength to weight ratio, low densities, strong, stiff, and abrasion and impact resistance, etc.[1]

So among the lightweight materials, Al has greatly used in aerospace, ship building, automotive industries. However, the applications of aluminum alloys are limited due to poor wear resistance at ambient, elevated and cryogenic temperatures. The mechanical and wear resistance properties can be improved by the addition of hard ceramic reinforcements such as SiC, B_4C, ZrB_2, TiC, TiB_2 and Al_2O_3. Different researchers have examined the dry sliding wear behavior of aluminum metal matrix composites by incorporating the different shape, type and size of particulates.

There is increasing demands for low cost reinforcement and low density material for manufacturing purpose. Among the various reinforcements used, flyash is one of the most inexpensive and easily available with low density in large quantities as waste by-product of thermal power plant due to combustion of coal. Therefore use of flyash as alternative material for reinforcement, which overcomes the cost barrier and has potential for conserving energy intensive aluminium, so decreases the cost of aluminum component products.

In today's industrial revolution, particulate reinforced aluminium matrix composite are getting importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. As compared to unreinforced alloys, casted particle reinforced aluminium matrix composites have higher specific strength, specific modulus and good wear resistance.[1,2]

Particulate matrix composite can be prepared by reinforcing particles into liquid matrix through liquid metallurgy route of casting. Casting preferred due to its less expensive and amenable to mass production. Among the overall liquid state production routes, liquid vortex stir casting is the simplest for production and also cheapest one as well. The only care need to take with this process is the non-uniform distribution of the particulate due to poor wet ability and gravity regulated segregation, so addition of magnesium will overcome this problem.

II. LITERATURE REVIEW

Rohathgi P.K [3] reported, as we increase the amount of fly ash percentages the hardness value increased in aluminum fly ash composites and similarly tensile strength, elastic modulus were found to increase with increase in percentage (3-10%) of Fly ash.

P. Shanmughsundram, R. Subramanium, G Prabhu [4] reported that, tensile began to drop when flyash exceeds 15wt%, hardness and compressive strengths of composites began to decrease above 20wt%, while density of the composite decreased with increasing fly ash reinforcement.

Deepak Singla, and S R Mediratta [5] reported that, with increase in value of fly ash, toughness, hardness and tensile strength was increased compared to the base metal and the density got decreased, so these composites can be used in automobile and space industries due to their light weight.

N. Altinkok, I. Ozsert and F. Findik[6]: The reinforcements typically used in AMMCs are SiC and Al_2O_3 particles, whiskers and short fibers. However, for many applications these composites are too expensive to permit their widespread use. There has been an increasing interest in the composites containing low density and low cost reinforcements

S. Basavarajappa1*, et al [7]:study deals with dry sliding wear behavior of Al-Si composites,wear rates of the composites are lowerthan that of the matrix alloy and further decrease with increasing SiC content. As the load increases,cracking of SiC particles occurs and a combination of abrasion, delamination, and adhesive wear is observed.

Sankar L.[8]Development of lightweight materials has provided the automotive industry with numerous possibilities for vehicle weight reduction. Generally the selection of materials in automobiles plays a vital role in it. The material which has been selected should have good mechanical characteristic and less in cost. In this experiment we have suggested that the flyash composites are best suitable for automobile clutch plate compare to the exiting clutch plate materials. Due to its less coefficient of friction the fly ash composites can be used in automobiles in future.

K. PunithGowda et al[9] study revealed that as the tungsten carbide particlecontent was increased, there were significant increases in the ultimate tensile strength, hardnessand young's modulus, compressive strength, accompanied by a reduction in its ductility.

Vinitha, B. S. Motgi [10] result obtained reveals that tensile strength; impact strength and wear resistance is higher in Al7075-SiC-Redmud samples when compared to Al7075-SiC-Flyash samples.

Egberto Bedolla-Becerril [11] results made on Al2024 with TiC MMC which indicates the substantial improvement in the microhardness (289–343 HV), hardness (25–34 HRC), and wear resistance of the MMC after T6 heat treatment.

Kaczmar, J.W.; Naplocha [12] In comparison with T6 heat treated monolithic 2024 aluminium alloy composites revealed slightly better resistance under lower pressure. Probably, during wear process produced hard debris containing fragments of alumina fibres are transferred between surfaces and strongly abrade specimens. Under smaller pressures wear process proceeded slowly and mechanically mixed layer MML was formed

2.1 OBJECTIVE OF STUDY

- To produce Hybrid Composite by heating Al 2024, in electrical resistance furnace at a temperature of above 700°C separately.
- To get hybrid composites castings, by adding E Glass & Fly ash to the molten metal with varying weight fractions in Al 2024 to get ASTM standard specimens, machined from the as cast specimens.
- To study the various Mechanical properties like Tension, Compression, and Hardness Property.
- To study the tribological behavior of hybrid composites.
- To analyze the results of various weight fractions of composites specimens.
- Use of low cost reinforcement will help to decrease cost of components.

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III. MATERIAL AND EXPERIMENTAL PROCEDURE

PROCUREMENT OF MATERIALS

Al 2024

Aluminium alloy 2024 is an alloy, with copper as the primary alloying element. It is purchased in plate, small scrap of sheet form, from the Dhanlaxmi Steel Distributor, Girgaon, Mumbai.

Fig. 1.1 Al 2024 pieces,

E-glass fiber

It is electrical grade glass fibres having excellent fibre forming capabilities and made available at Jadhav Casting, Ambad.

Fig. 1.2 E glass Fiber,

Flyash(FA)

Fly ash usually refers to ash produced during combustion of coal as a byproduct. FA is taken as available from *NTPS, Eklahare ,Nashik.*

Fig 1.3 Fly ash

COMPOSITION OF MATERIAL

Comp	Cu	Mg	Mn	Cr	Fe	Si	Ti	Zn	AL
Limits %	3.80 - 4.90	1.20 - 1.80	0.30 - 0.90	Max 0.10	Max 0.50	Max 0.50	Max 0.15	Max 0.25	Rem.
Actual %	**4.32**	**1.28**	**0.47**	**0.05**	**0.21**	**0.09**	**0.06**	**0.04**	**Rem.**

Table 1: Composition of matrix metal(Al2024) alloy

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Fe	Na_2O	K_2O
31.0%	9.0%	8.15%	6.0%	2.8%	5.7%	0.3%	0.2%

Table 2: Observed chemical composition of Fly ash

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IV. STEPS INVOLVED IN CASTING PROCESS

- Composite Preparation Furnace
- Preheating of reinforcement
- Melting of Matrix alloy
- Mixing and Stirring
- Pouring of molten metal into dies
- Solidification and Specimen Preparation.

Fig. 2 Stir casting setup

An approximate amount of aluminum alloy is fed into electrical furnace in a graphite crucible and melted it above 750°C at Jadhav casting, Nashik. The experimental setup is shown in Fig2. At this high temperature, Mg is added to increase the wettability of aluminum so that the reinforcementadded to the metal is evenly dispersed.

Reinforcement material was preheated in muffle furnace up to temperature 450°C for 20 mins. So that we can reduce the temperature gradients and improve the chances of wettability in matrix.

An approx. amount of preheated 3% Glass fibers added and then proportionate 4wt % of fly ash added slowly to the molten metal. Mechanical stirrer is constantly rotated at speed of 300rpm in the furnace for uniform distribution of material. The high temperature molten metal poured into preheated moulds to get the required specimens. Moulds are so made that we get casting in rod form.The same procedure was followed to get the AMC's of 6%, & 8%wt. % fly ash with fixed glass fibers.

COMPOSITION OF TEST SPECIMENS PREPARED BY CASTING:

Specification	E-glass Fiber (wt %)	Fly Ash (wt %)	AL 2024 (wt %)
A3E4F	3	4	93
A3E6F	3	6	91
A3E8F	3	8	89

Table 3: Combination of composite prepared.

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Volume 4, Issue 8, April 2024

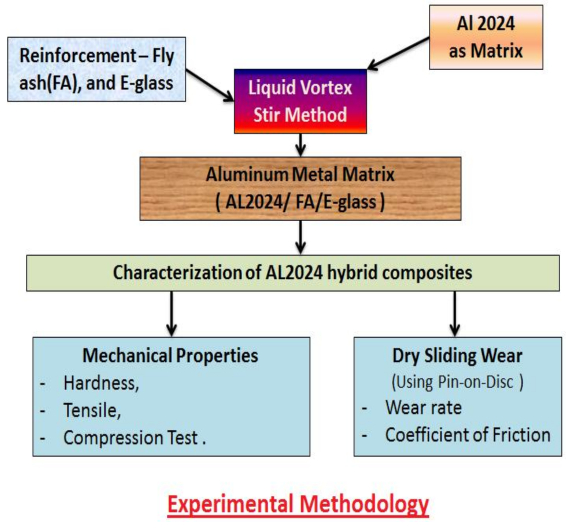

Fig. 3 Methodology chart

TESTS CONDUCTED:

The fabricated specimens were proposed to test for mechanical and tribological properties to investigate the strength and wear resistance evaluation. The test conducted as -

1. Tensile test

2. Compression test

3. Hardness test

4. Wear test

In mechanical property testing conducted from the FAN services, Nasik, where tensile tests were conducted on casted and machined samples according to ASTM E8-95 at room temperature, using a UTM Machine. The specimens used (see Fig 4). were of diameter 10mm and Gauge length 55 mm, with holding of 25mm. Specimen are machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings.

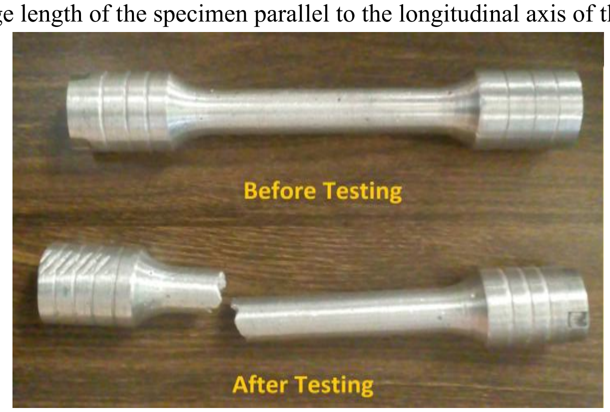

Fig 4. Tensile Testing specimen of composite

The compression tests were conducted as per ASTM-E9-95.The specimens (see fig 5)used were of diameter 25mm and length 30 mm machined from cast composites. The Vickers hardness test machine used for hardness testing were conducted in accordance with the ASTM E10 and the data converted into Brinell hardness number using conversion table

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Fig 5. Test specimen for compression test

Wear testTests were conducted under dry conditions as per ASTM G99-95 standards using the wear and friction monitor available at SND, Engg. Yeola. The test specimen prepared from the casted rod by machining on lathe machine in a workshop in the size of diameter 8mm x 30mm in length, as shown in fig.6

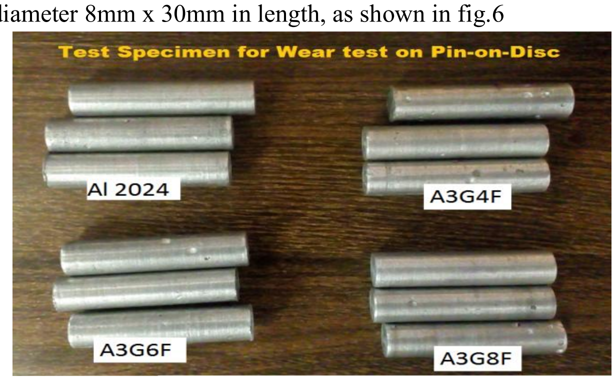

Fig 6. Test specimen prepared for wear test (before test)

Fig.7 wear pattern on surface of test pin (after wear test)

V. DESIGN OF EXPERIMENT

Design of Experiments" (DOE) refers to experimental methods used to quantify indeterminate measurements of factors and interactions between factors statistically through observance of forced changes made methodically as directed by mathematically systematic tables. Many tribological process parameters can affect the wear behavior of Al-EG-Flyash composites. For current study of wear behavior of Al composites, the control parameters chosen are weight % of reinforcement(wt), applied load (L), sliding speed (S), and sliding distance (D).Table 4shows the design factors with their levels. Three levels for each parameter are considered.

Design Factor	**Units**	**Level 1**	**Level 2**	**Level 3**
Reinforcement (R)	(wt %)	4	6	8
Load (L)	(N)	9,81	19.62	29.43
Speed (S)	(m/s)	1.5	2.5	3.5

Table 4: Control factors and their levels.

Based on Taguchi method, an Orthogonal Array (OA) is considered to reduce the number of experiments required to determine the optical wear for Al-EG-Flyash Metal matrix composites [4]. For this experimental purpose L^9 array is chosen. The L^9OA has 9 rows corresponding to the number of tests as below in table 5.

Expt.	Design Control factors		
	L	S	R
1	9.81	1.5	4
2	9.81	2.5	6
3	9.81	3.5	8
4	19.62	1.5	6
5	19.62	2.5	8
6	19.62	3.5	4
7	29.43	1.5	8
8	29.43	2.5	4
9	29.43	3.5	6

Table 5: $L_9\ (3)^4$ orthogonal array.

VI. RESULTS & DISCUSSIONS

Hardness:

From hardness test, conducted on the specimen of casted aluminum, which shows that hardness gradually increases with increase of wt % of reinforcement material. Thus the hard fly ash particles help in increasing the hardness of the aluminium alloy. The trend of changes in hardness is tabulated in table.

Fig 8. Hardness Tester

Sample No.	Combination	Hardness Value (BHN)
0	AL	47
1	A3E4F	84
2	A3E6F	87
3	A3E8F	91

Table 6 : Hardness Test result

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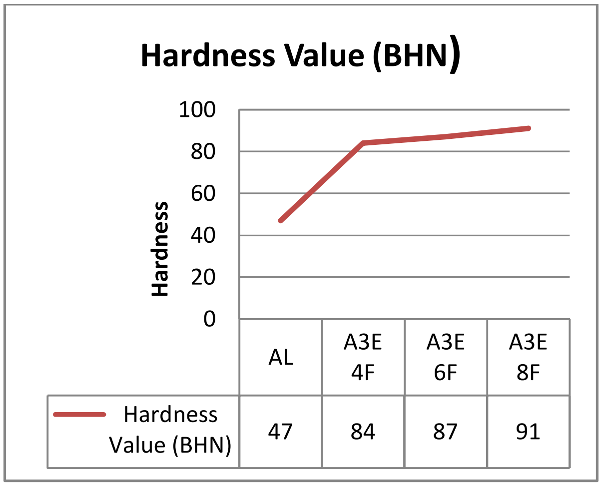

Fig9. Graph showing the trend of Hardness

Tensile Strength:

Table 2 shows the variation of tensile strength of the composites with the different weight fractions of fly ash particles. From the tests, we can note that, the tensile strength gradually increased by the increase in wt. % of the reinforcement added to the metal matrix. Therefore the fly ash particles act as barriers to the dislocations when taking up the load applied.

Combination	Tensile Strength in N/mm^2	% Elongation
AL	178	17
A3E4F	262	13.44
A3E6F	284	10.22
A3E8F	274	6.84

Table 7: Tensile Test result

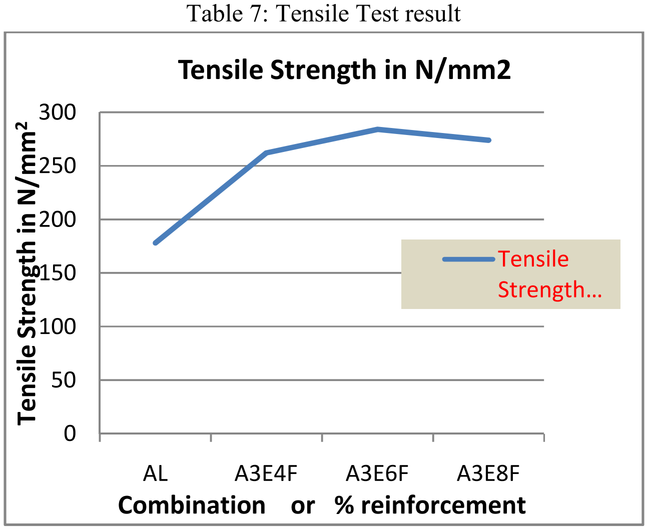

Fig10. Graph showing the trend of Tensile Strength with different % of reinforcement composites.

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Compression Strength:

Graphs and tables showing the effect of E-Glass and Flyash content on thecompressive strength of the composites. It can be seen that the compressive strength of thehybrid composites increases monotonically as the reinforcement contents are increased.

Fig 11. View of Compression Testing on test specimen

Combination	Compressive Strength in N/mm^2
AL	220
A3E4F	702
A3E6F	716
A3E8F	736

Table 8: Compression Test result

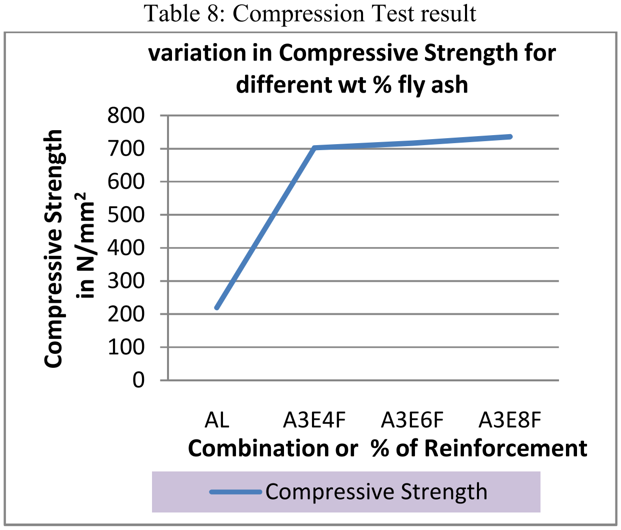

Fig12. Graph showing the trend of Compressive Strength

The increase in compression strength is mainly due to the decrease in the inter-particle spacing between the particles. Since E-Glass fibres are much harder than 2024 aluminium alloys. The presence of E-Glass fibre and Flyash resist deforming stresses, thus enhance in the compressive strength of the composite material.

Wear test:

Evaluations of friction and wear response between the two sliding contact surfaces of specimens with the help of pin-on-disc are done as shown in fig.Tests were conducted under dry conditions as per ASTM G99-95 standards. The test was carried out by applying load (9.81, 19.62, and 29.43 N) and run for a constant sliding distance (1500 m) at a sliding velocity of 2.5 m/s). The counter disc was made of EN-31 steel with the hardness of 65 HRC.

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Each test carried for 10mins,and the wear and friction monitor give the reading for wear in micrometer and coefficient of friction. The data results obtained during this work have been presented in tabular form in terms of sliding wear, specific wear rate, and friction coefficient

Sliding wear is the interactions betweensurfaces and more specifically the removal anddeformation of material on a surface as a result of mechanical action offered by pin on the opposite surface. Specific wear rate is the volume loss persliding distance and load. Coefficient of Friction is the ratio of the avg. force of friction between two bodies and the actual applied force pressing them together.

Fig 13. Wear and Friction Monitor (Pin-on-Disc)

. Load in kg	Wear in Micrometer		
	A3E4F	A3E6F	A3E8F
1	19	67	157
2	24	84	164
3	91	139	259

Table 9: Wear test result in micron

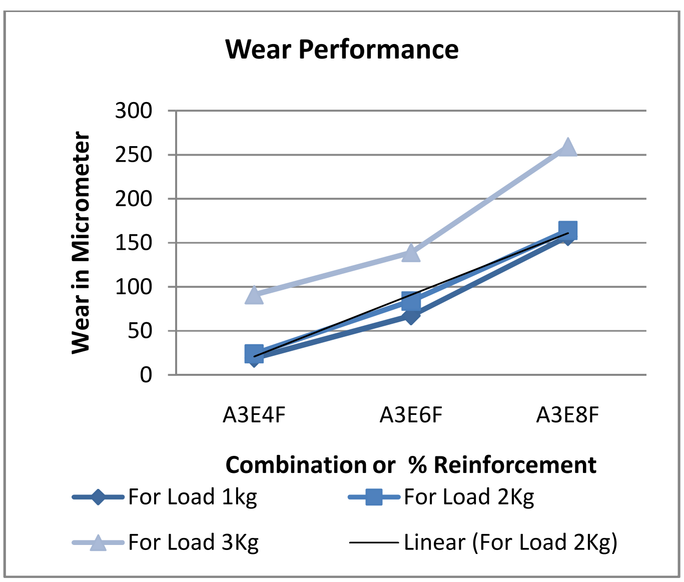

Fig 14 Graph of wear for different load condition & % reinforcement

DOI: 10.48175/IJARSCT-17954

IJARSCT

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Wear resistance of composites at low loads improves due to the presence of reinforcement, which forms a thin film at the contact surface between the composites and the counter face. i. e. at low loads the composites derives their wear resistance from the reinforcement.

Load in kg	**Wear rate at sliding speed of 2.5 m/s**		
	A3E4F	A3E6F	A3E8F
1	6.48998E-05	0.000228868	0.000536302
2	4.09922E-05	0.000143469	0.000280107
3	0.000103618	0.000158272	0.000308501

Table 10: Wear rate calculated for Sliding speed of 2.5m/s for different loading condition

At high loads however, due to load fracture, composites lose theirability to support the higher load which result in the counter disc face comes in direct contact with thematrix alloypin in which high strains are developed causing removal of the surface layers bymarking out without much restriction.

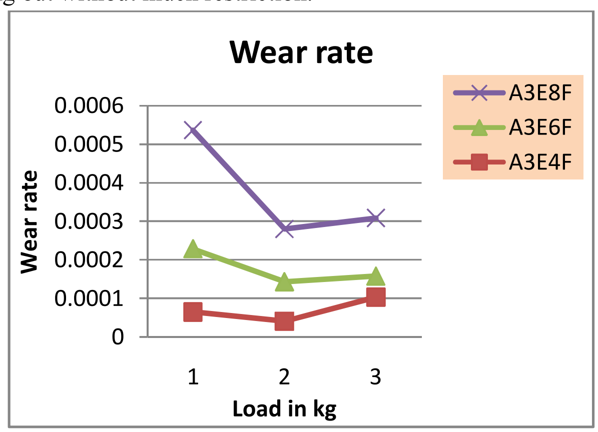

Fig 15. Graph showing the trend of wear rate

From the above graph, shows the wear rate initially decreases with load, but beyond certain it starts increase. The variations in different composites are recorded showing typical similar results in wear rate.

VII. CONCLUSION

- Aluminium - fly ash composites were successfully produced by liquid vortex stir casting method.
- There was a fair distribution of fly ash particles in the matrix phase and a bonding between the matrix and fly ash reinforcements was achieved.
- The hardness of the composites increased tothe value higher than that of the base alloydue to addition of fly ash.
- The composite showed better wearresistance for theapplied load of 2 kg.
- The wear was extensive in Al-fly ashcomposite for higher loads and longersliding distances, might be due to the presence ofdislodged and fractured fly ash particles inthe alloy matrix.

Future Scope:

Composite material can be more effective if

- More combination for optimization of solution
- Heattreatment (ageing) is taken into consideration.

ACKNOWLEDGEMENT

I wish to place on record my sincere thanks, indebtedness and deep sense ofgratitude to my friend s and my family members who give me inspiration and cooperation for ding this study and experimentation.

I also thanks to Prof. BC Londhe, Gujrathi Sir, SND Engg, Yeola for tribologcal wear testing, Fan services for mechanical testing, Jadhav Casting, Nasik for manufacturing process guidance and many more for their support in work.

I much obliged towards all the staff members, librarians, and my friends those supported directly and indirectly. I will keep my improvement curve on the rise path.

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