Investigation of AA 2218 Fly ash - Talc Hybrid Metal Matrix Composites

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Abstract - *A hybrid MMC was developed for the cylinder liner of advanced diesel engines. An investigation of aluminum alloy AA2218 reinforced with study 5 wt. % of Talc used as a first phase reinforcement and as in the case of second phase reinforcement, 4 wt. %, 8 wt. %, 12 wt. % of fly ash particles were added by stir casting process was investigated. The wear and mechanical properties of the hybrid metal matrix composites was obtained by performing dry sliding wear test using a pin-on-disc wear tester synthesizing AA2218 based self lubricating composite through metal stir casting route. In this self-lubricating composite characterized in terms of density, dry sliding wear, coefficient of friction and micro structural properties. Signal-to-noise ratio and analysis of variance (ANOVA) were used to investigate the influence of parameters on the wear rate.*

***Key Words*: Aluminum Alloy 2218, Fly Ash Talc, Pin on Disc, ANOVAs**

1.INTRODUCTION

The self-lubricating composites are used many applications such as aerospace for cylinder liner, piston, valve stem guide, and plain bearings. That requires improved hardness, wear resistance and low coefficient of friction with lower density. These properties enhance the usage of self-lubricating composites in automotive and tribological applications. Self-lubricating composites have found wide application in many special machine parts; yet oil or grease cannot lubricate inaccessible parts and contamination is not acceptable. On the other hand, limited information is available about the characterization of this AA2218-fly ash-Talc composite
Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface.

Wear is an important property in the selection of DRAMMCs. Wear is not an intrinsic material property but characteristics of the engineering system which depend on load, speed, temperature, hardness, and the environmental conditions .Wear performances of particulate reinforced aluminium matrix composites reinforced with various reinforcements ranging from very hard ceramic particulates stir casting, pressure infiltration technique, and spray deposition method. However, stir casting is the simplest and most economical method It has been suggested to develop composite materials have the capacity to achieve low friction and wear at the contact interface without any external supply of lubrication during the sliding

1.1 AA 2218

Aluminium (Fig 3) is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials, such as building facades and window frames the most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates. AA2218 is a heat treatable wrought alloy. Its nominal chemical composition is shown in Table 1.

Table 1: Chemical Composition Of Aa2218 Alloy In Weight Percentage

Cu	Ni	Mg	Si	Fe	Ti	Al
3.87	1.90	1.47	0.51	0.16	0.02	Balance

2.MATERIALS

2.1 Talc

A form of Talc (Fig 1) known as "soapstone" is also widely known. This soft rock is easily carved and has been used to make ornamental and practical objects for thousands of years. It has been used to make sculptures, bowls, countertops, sinks, hearths, pipe bowls and many other objects. Talc is odourless. It is insoluble in water and in weak acids and alkalis. Although talc has a marked affinity for certain organic chemicals, it generally has very little chemical reactivity. It is neither explosive nor flammable. Above 900°C, talc progressively loses its hydroxyl groups and above 1050°C, it re-crystallises into different forms of enstatite (anhydrous magnesium silicate). Talc's melting point is at 1500°C.

Fig .1 Talc

Fig .2 Fly ash

2.2 Fly Ash

Fly ash (Fig.2) is one of the residues generated in combustion, and comprises the fine particles that go up with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gas reaches the chimney of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata [6]. Its nominal chemical composition is shown in Table 1

Table 2: Chemical Composition Of Fly Ash In Weight Percentage

SiO2	Al2O3	Fe2O3	CaO	MgO	TiO2	LOI*
64.80	24.01	5.23	2.76	0.90	0.50	0.87-1.33

Fig .3 AA 2218

Fig .4 Specimen

3.MATERIAL PREPARATION

Fly ash / Talc reinforced Aluminium alloy (Al2218) composites, processed by stir casting route was used in this work. Liquid metallurgy route was used to synthesize the hybrid composite specimens. The matrix alloy was first superheated above its melting temperature and then the temperature was lowered gradually until the alloy reached a semisolid state. The required quantities of fly ash (4, 8 and 12 Wt. %) and Talc (5 Wt % fixed) were taken in powder containers. Then the fly ash and Talc was heated to 450°C and maintained at that temperature for about 20 minutes. A vortex was created in the melt due to continuous stirring by a stainless steel mechanical stirrer with a rotational speed of 650 rpm. At this stage, the blended mixture of preheated fly ash and graphite particles were introduced into the slurry and the temperature of the composite slurry were increased until it was in a fully liquid state. Small quantities of magnesium were added to the molten metal to enhance wettability of reinforcements with molten aluminium. Solidified specimens (Fig.4) were machined with the specification of 10mm diameter and 35mm in length for wear test.

4.RESULTS AND DISCUSSION

4.1. Density

The density of composites has been calculated by the “Rule of mixture”. The effect of fly ash wt. % with density of self-lubricating composites. Because of low density, a large agglomerate of fly ash particles in the composite consistently reduces the density of the composite.

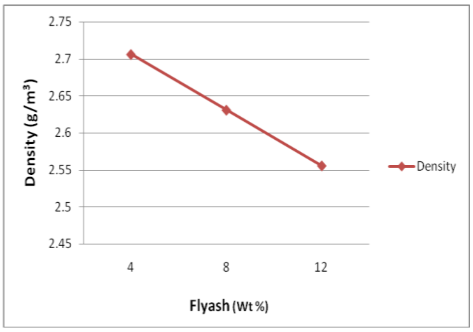

Fig .5 Density

4.2. Wear Test

The experiments were conduct as per the standard orthogonal array. The selection of the orthogonal array is based on the condition that the degrees of freedom for the orthogonal array should be greater than or at least equals sum of those of wear parameters. In the present investigation an L27 (313) orthogonal array was chosen

Dry sliding wear test “pin - on - disc” mechanism The outer diameter of the slider disc made up of hardened steel having diameter 165mm. The pin test sample dimensions are 10mm diameter with 30mm height. Prior to testing, ensure that the test sample and surfaces will be flat and polished metallograbhically. Conventional aluminium alloy polishing techniques are used to prepare the contact surfaces of the monolithic and composite aluminium specimen for the wear test.

The procedure consist of grinding surfaces manually by 240-,320-,400-, and 600- grit silicon carbide paper and then polishing them with 5, 1, & 0.5μm alumina using low speed polishing machine. When apply to composite material this preparation technique created considerable surface relief between the hard and soft aluminium matrix.

Table 4: Orthogonal Array And Results Of Hmmc's For Talc

Ex. No	Speed (m/s)	Load (N)	Time (min)	% Reinfor-cement	Wear rate (mm3/m)	S/N Ratio for Wear (db)	Coefficient of friction	S/NO Ratio for COF
1	0.785	10	5	5	0.006626	37.501	0.31	8.62728
2	0.785	10	10	10	0.005192	36.777	0.29	7.60422
3	0.785	10	15	15	0.048216	33.624	0.25	5.57507
4	0.785	20	5	10	0.004795	36.123	0.18	7.9588
5	0.785	20	10	15	0.046064	33.442	0.142	6.84845
6	0.785	20	15	5	0.007414	38.276	0.135	9.82723
7	0.785	30	5	15	0.005290	34.151	0.106	8.94316
8	0.785	30	10	5	0.008621	40.587	0.193	11.8213
9	0.785	30	15	10	0.005191	37.841	0.141	9.82723
10	1.570	10	5	10	0.006598	37.616	0.38	9.54243
11	1.570	10	10	15	0.005933	35.986	0.4	9.82723
12	1.570	10	15	5	0.009036	39.735	0.161	11.1261
13	1.570	20	5	15	0.006735	37.025	0.225	10.103
14	1.570	20	10	5	0.012660	41.938	0.38	12.8691
15	1.570	20	15	10	0.007594	39.462	0.235	11.5957
16	1.570	30	5	5	0.021688	43.463	0.263	13.8039
17	1.570	30	10	10	0.009859	42.144	0.186	13.2552
18	1.570	30	15	15	0.076127	41.214	0.163	13.0643
19	2.355	10	5	15	0.008386	43.346	0.48	14.4855
20	2.355	10	10	5	0.034921	45.008	0.68	15.417
21	2.355	10	15	10	0.010068	43.463	0.54	15.1175
22	2.355	20	5	5	0.039012	46.235	0.331	16.2583
23	2.355	20	10	10	0.031394	44.811	0.325	15.8478
24	2.355	20	15	15	0.009473	44.910	0.275	15.2686
25	2.355	30	5	10	0.058607	46.063	0.213	17.0252
26	2.355	30	10	15	0.001074	45.008	0.196	16.777
27	2.355	30	15	5	0.060102	47.384	0.296	18.1697

4.3 Analysis Of Variance For Wear Rate

Test shows the results of the analysis of variance on the wear rate for Fly ash and BN particulates reinforced Al-2218 alloy matrix composite. This analysis is carried out at a level 57 of 5% significance that is up to a confidence level of 95%. The last column of the table indicates the percentage of contribution (Pr) of each factor on the total variation indicating the degree of their influence on the results.

Table 5: Analysis Of Variance For Wear Rate (Mm3/M) For Talc

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Pr (%)
Speed	2	0.000855	0.000855	0.000428	1.33	0.333	48.30314311
Load	2	0.000740	0.000740	0.000370	1.15	0.378	25.72176452
Time	2	0.000434	0.000434	0.000217	0.67	0.545	2..36932475
Reinforcement %	2	0.000310	0.000310	0.000155	0.48	0.640	14.60827215
Residual Error	16	0.001931	0.001931	0.000322	7.997495	Residual Error	16
	26	0.011479					100

4.4 S/N Ratio Analysis

The influence of control parameters such as load, sliding speed and fly ash content on wear rate has been evaluated using S/N ratio response analysis. The control parameter with the strongest influence was determined by the difference between the maximum and minimum value of the mean of S/N ratios. The S/N ratio response analysis, presented in Table 4 shows that among all the factors, load was the most influential and significant parameter followed by sliding speed and fly ash content.

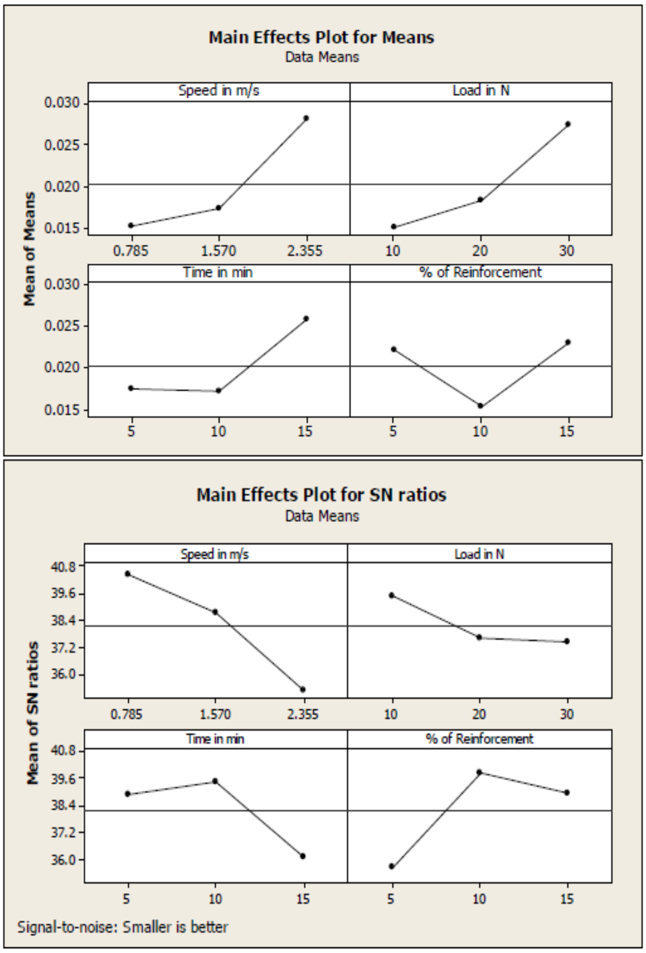

Figure. 6 Main Effects Plot For Means – Wear Rate & Coefficient Of Friction For Talc

4.5 Confirmation Test

A confirmation experiment is the final step in the design process. A dry sliding wear test was conducted using a specific combination of the parameters & levels to validate the statistical analysis. After the optimal level of testing parameters have been found, it is necessary that verification tests are carried out in order to evaluate the accuracy of the analysis & to validate the experimental results.

Table 6: Confirmation Experiment For Wear Rate And Coefficient Of Friction

Level	Speed (m/s)	Load (N)	Time (min)	Percentage of Reinforcement (%)
1	0.889667	10	4	5
2	1.413	20	8	10
3	2.198	30	12	15

The experimental value of wear rate is found to be varying from wear rate calculated in regression equation by error percentage between 3.18% to 7.36%, while for coefficient of friction it is between 2.80% to 7.38% for self-lubricating hybrid metal matrix composites. As these values are closely resembling the actual data with minimum error, design of experiments by Taguchi method was successful for calculating wear rate and co-efficient of friction from the regression equation. Figure 9.1 shows a comparison between wear rate and co-efficient of the obtained contribution percentage (Pr %) of each factor with the source of variance.

4.6 Analysis of Variance For Wear Rate

Test shows the results of the analysis of variance on the wear rate for Fly ash and BN particulates reinforced Al-2218 alloy matrix composite. This analysis is carried out at a level of 5% significance that is up to a confidence level of 95%. The last column of the table indicates the percentage of contribution (Pr) of each factor on the total variation indicating the degree of their influence on the results.

Table 7: Result Of Confirmation Experiment And Their Comparison With Regression For Talc

Exp. No	Exp.Wear rate mm3/m	Reg. Model wear rate (mm3/m)	% Error	Exp. Coefficient of friction	Reg. Model Coefficient of friction	% Error
1	0.002528	0.0026082	3.18073	0.29	0.311	7.384
2	0.003051	0.0032761	7.36911	0.235	0.246	4.893
3	0.00416	0.0044136	6.10754	0.2066	0.212	2.802

5.CONCLUSION

The results confirmed that stir formed Al alloy 2218 with fly ash, talc reinforced composites is clearly superior to base Al alloy 2218 in the comparison of hardness i.e. the hardness increases after addition of talc and fly ash particles in the matrix alloy.

[1] Co-efficient of friction is dominated by different parameters in the order of percentage of reinforcement, applied load, sliding speed and sliding time.

[2] The dry sliding test at room temperature shows that there is a definite increase in the wear resistance of Al 2218 alloy by the addition of fly ash and Talc particles.

[3] Even at higher load 5 wt. % of Talc exhibits better lubricity and the formation of Talc sacrificial layer at the interface was rich in worn surface. It played

an important role in reducing the friction coefficient and wear rate.

[4] Optimum wear rate and coefficient of friction were obtained from the experiment. The wear rate is dominated by different parameters in the order of sliding speed, applied load, percentage of reinforcement and sliding time. ANOVA test concluded that as sliding speed increases the wear rate also increases significantly.

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