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# Wear Behavior of Aluminium Alloy 2218 Fly ash - Talc Hybrid Metal Matrix Composites

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**ABSTRACT**

The aim of this work is to study the mechanical properties of Aluminium alloy Metal Matrix Composites (MMCs) as they are gaining wide spread acceptance for automobile, industrial, and aerospace applications because of their low density, high strength and good structural rigidity. In the present work an attempt has been made to synthesize Al-6061 with Graphite and fly ash by using stir casting technique. The addition level of reinforcement is being varied from 5 to 10 wt%. Preheated particle reinforcements are added to Al 6061 Alloy to improve wettability and distribution. Structural analysis was carried out for the above prepared composites by using universal testing machine **(UTM)** and also in Ansys workbench. The density of both theoretically and experimentally of Flyash is higher than Graphite. Increase in the weight fractions of the fly ash and graphite particle increases the ultimate, compressive strength, and decreases the ductility of the composite. The compressive strength of the composites was found to increase confirming the dispersed graphite and fly-ash in Al-6061 alloy contributed in enhancing the compressive strength and wear resistance tool of the composite.

***Key Words: Aluminium Alloy 2218, Fly Ash Talc, UTM, Pin on disc, ANOVAs***

## I. INTRODUCTION

Metal Matrix Composites (MMCs), particularly aluminium matrix ceramic reinforcement composites have emerged as a potential material for automotive and aerospace industries. In this study, fly ash and graphite particles which are extracted from residues generated in the combustion of coal and graphite particles from local scientific store were chosen as reinforcement material.

In any production process, superior quality of the product can be achieved only when the process is run with the optimum parameters. Mechanical properties of composites are affected by the size and shape of the matrix and reinforcement materials, weight fraction of the reinforcement as well as reaction at the interface.

Interfacial strength between the matrix and reinforcement plays a significant role in determining the properties of MMCs. These aspects have been discussed by many researchers. Fly ash and graphite particles were incorporated into the molten Al they were observed to be floating on the molten Al surface due to the high surface tension which leads poor wettability.

Mechanical stirring can be done in a semisolid state rather than in the completely liquid state in order to break away the gas layers there by reducing surface tension. Al-fly ash and graphite composites offer many potential applications particularly for internal combustion engine pistons and brake rotors. Hence application of aluminium matrix composites is gradually increasing in the automotive industries in making pistons, cylinder heads and connecting rods. Wear resistance of particulate composites significantly depends on the grit size, hardness, weight fraction and distribution of reinforcement particles, properties of matrix material, interfacial bonding between the matrix and reinforcement particles and experimental conditions such as hardness of the counter surface, applied load. The present work aims to investigate, mechanical behaviour of fly ash and graphite particle reinforced commercial aluminium composites fabricated by a stir casting method.

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.

## II. MATERIALS

### 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. 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

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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


Fig .2

### 3. Fly ash

Fly ash (Fig.3) 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

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $TiO_2$ | LOI* |
|---|---|---|---|---|---|---|
| 64.80 | 24.01 | 5.23 | 2.76 | 0.90 | 0.50 | 0.87-1.33 |


Fig .3

Fig .4

## III.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 450ºC 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.

## IV.RESULTS AND DISCUSSION

### 1. 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

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 | 0.0066266 | 37.5012 | 0.31 | 8.62728 |
| 2 | 0.785 | 10 | 10 | 10 | 0.0051928 | 36.777 | 0.29 | 7.60422 |
| 3 | 0.785 | 10 | 15 | 15 | 0.0482164 | 33.6248 | 0.25 | 5.57507 |
| 4 | 0.785 | 20 | 5 | 10 | 0.0047952 | 36.1236 | 0.18 | 7.9588 |
| 5 | 0.785 | 20 | 10 | 15 | 0.0460641 | 33.442 | 0.142 | 6.84845 |
| 6 | 0.785 | 20 | 15 | 5 | 0.0074145 | 38.2763 | 0.135 | 9.82723 |
| 7 | 0.785 | 30 | 5 | 15 | 0.0052903 | 34.1514 | 0.106667 | 8.94316 |
| 8 | 0.785 | 30 | 10 | 5 | 0.0086217 | 40.5877 | 0.193333 | 11.8213 |
| 9 | 0.785 | 30 | 15 | 10 | 0.0051918 | 37.8419 | 0.141333 | 9.82723 |
| 10 | 1.570 | 10 | 5 | 10 | 0.0065984 | 37.6163 | 0.38 | 9.54243 |
| 11 | 1.570 | 10 | 10 | 15 | 0.0059339 | 35.9868 | 0.4 | 9.82723 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 | 1.570 | 10 | 15 | 5 | 0.0090361 | 39.7354 | 0.161 | 11.1261 |
| 13 | 1.570 | 20 | 5 | 15 | 0.0067354 | 37.0252 | 0.225 | 10.103 |
| 14 | 1.570 | 20 | 10 | 5 | 0.0126605 | 41.9382 | 0.38 | 12.8691 |
| 15 | 1.570 | 20 | 15 | 10 | 0.0075944 | 39.4626 | 0.235 | 11.5957 |
| 16 | 1.570 | 30 | 5 | 5 | 0.0216880 | 43.4637 | 0.263333 | 13.8039 |
| 17 | 1.570 | 30 | 10 | 10 | 0.0098592 | 42.1442 | 0.186667 | 13.2552 |
| 18 | 1.570 | 30 | 15 | 15 | 0.0761278 | 41.214 | 0.163333 | 13.0643 |
| 19 | 2.355 | 10 | 5 | 15 | 0.0083867 | 43.3463 | 0.48 | 14.4855 |
| 20 | 2.355 | 10 | 10 | 5 | 0.0349217 | 45.0084 | 0.68 | 15.417 |
| 21 | 2.355 | 10 | 15 | 10 | 0.0100687 | 43.4637 | 0.54 | 15.1175 |
| 22 | 2.355 | 20 | 5 | 5 | 0.0390121 | 46.2351 | 0.331 | 16.2583 |
| 23 | 2.355 | 20 | 10 | 10 | 0.0313948 | 44.811 | 0.325 | 15.8478 |
| 24 | 2.355 | 20 | 15 | 15 | 0.0094731 | 44.9103 | 0.275 | 15.2686 |
| 25 | 2.355 | 30 | 5 | 10 | 0.0586077 | 46.0639 | 0.213333 | 17.0252 |
| 26 | 2.355 | 30 | 10 | 15 | 0.0010741 | 45.0084 | 0.196667 | 16.777 |
| 27 | 2.355 | 30 | 15 | 5 | 0.0601024 | 47.3843 | 0.296667 | 18.1697 |

## 3. ANALYSIS OF VARIANCE FOR WEAR RATE

Test shows the results of the analysis of variance on the wear rate for Fly ash and BNparticulates reinforced Al-2218 alloy matrix composite. This analysis is carried out at a level57 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 |

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## 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.

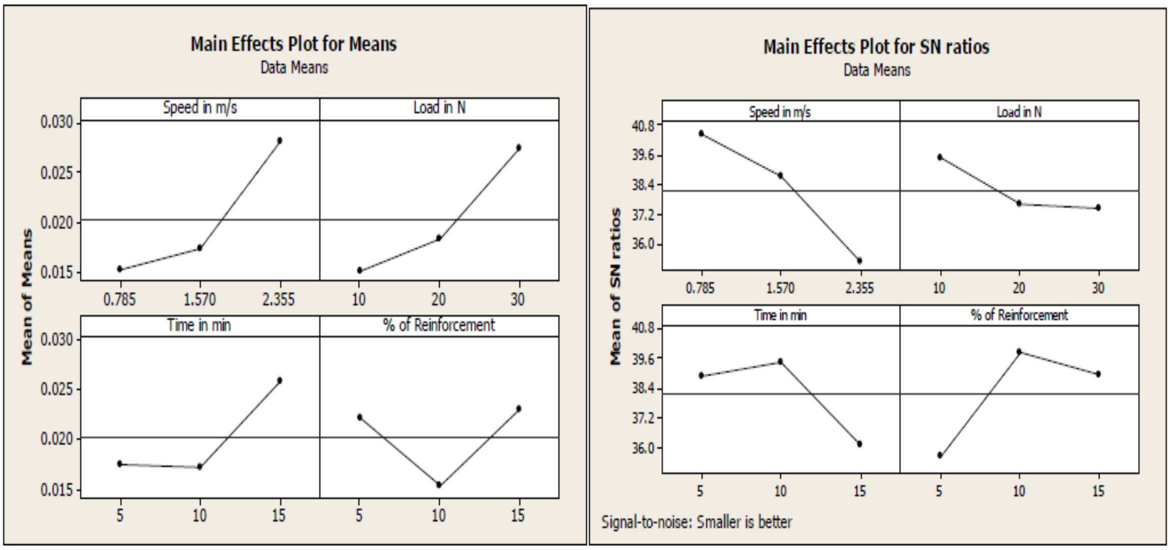


Figure.5 Main Effects Plot for Means – Wear Rate & Coefficient of Friction for talc

## 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.

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 |

## V.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.

[4] Al 2218 It played an important role in reducing the friction coefficient and wear rate.

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