A Comparative Investigation on Tribological Properties of Al-Si Alloy based MMC Reinforced with Waste Materials

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Abstract— In the present study Al-Si alloy (LM6) was reinforced with 15% of flyash and rice husk ash. This experimental analysis shows that Al-Si Alloy based MMC reinforced with fly ash and rice husk ash have a better Tribological behaviour as compared to the Al-Si alloy. The wear test was carried out using pin-on-disk machine with a constant load of 30N with varying sliding speed. The experiments are conducted at both elevated and ambient temperature. Based on the observations of weight loss, wear graphs and C.O.F graphs corresponding observations were drawn. With the help of these experiments it was found that the Al-Si alloy reinforced with waste materials shows a better wear behaviour than the existing Al-Si alloy.

Index Terms— Aluminium alloy MMC, reinforcement, tribological properties, wear resistance, waste materials

1. INTRODUCTION

Metal matrix composites (MMCs) create a new era of engineering materials in which a strong reinforcement is added into a metal matrix to improve its wear properties and Tribological properties even at elevated temperature. In the recent years d metal matrix composites (MMCs) have been transformed into a topic of scientific and intellectual interest to a material of broad technological and commercial significance [3,4].Because of their excellent corrosive properties it has various underwater applications. They show excellent properties at high temperature the reason behind their importance in aircraft engines. Because of the light weight and increased performance they are hot picks for sports car chassis. Aluminium silicon based MMCs have received increased attention in recent decades as engineering materials with most of them possess the advantages of high strength and wear resistance [9,10]. Fly ash is the waste material of every coal based power plants. So it costs zero .It has low density so ultimately reduces the weight of the MMC and has some of the important components like SiO2, Al2O3, Fe2O3 and CaO. So it can be used as a reinforcing
agent. Rice husk is a waste product of the agricultural farms. The rice husk ash can be used as a reinforcing agent to aluminium–silicon based composite. Many experiments have been carried out to test the wear properties at ambient temperature. But very little work has been done at elevated temperature. So this experimental work has been conducted at various elevated temperatures. The results of these experiments show a great improvement to the existing alloys.

2. EXPERIMENTAL PROCEDURE

2.1. Material Composition
In this experiment aluminium silicon alloy (LM6) was used as the matrix containing 12.25% of silicon and 86.73% of aluminium. It also contains many other materials the composition of which is given in the Table 1.

Table 1: Wt% of Aluminium-Silicon Alloy

| AL  | Si  | Fe  | Mn  | Cr  | Zn  | Cu  |
|-----|-----|-----|-----|-----|-----|-----|
| 85.73 | 12.25 | 0.45 | 0.18 | 0.1 | 0.09 | 0.09 |
| Ti  | Sn  | Ni  | Co  | Ca  | V   |     |
| 0.06 | 0.05 | 0.03 | 0.03 | 0.02 | 0.01 |     |

Flyash as reinforcement to Al-Si Alloy
As we know flyash is a low cost reinforcement so it is used in the Al-Si alloy based mmc. The composition of flyash used in the experiment is given in Table 2.

Table 2: Composition of Fly Ash

| Compound | Na₂O | CaO | MgO | SiO₂ | Al₂O₃ | K₂O | Fe₂O₃ |
|----------|------|-----|-----|------|-------|-----|-------|
| Wt%      | 0.10 | 1.24 | 0.58 | 56.43 | 31.54 | 0.59 | 4.97  |

Rice-Husk Ash as reinforcement to Al-Si Alloy
Rice husk ash is a major reinforcing agent now a day in AL-SI alloy because of its characteristics such as easily availability and low cost. The composition of flyash used in this experiment is given in Table 3.

Table 3: Composition of Rice husk Ash

| Compound | Fe₂O₃ | SiO₂ | CaO | Al₂O₃ | MgO  | L.O.I |
|----------|------|------|-----|-------|------|------|
| Wt%      | 0.93 | 67.33 | 1.35 | 4.90  | 1.79 | 17.80 |

2.2. Production of Metal Matrix Composite
The Al-Si ingot was cut into required dimensions after being cleansed thoroughly. Then they were weighed and finally put into a bottom poured melting furnace (Fig. 1). To improve the wet ability of the MMC the fly ash was pre heated to 670°C, and then 15% wt. % fly ash was added to the Al-Si alloy. The preheating also helps to remove any residual moisture present
and it is in Muffle Furnace (Fig. 2). A coated stainless steel rotor was used to stir the molten metal at 450rpm. Due to this a vortex is created with the molten metal where the fly ash which was preheated was poured slowly at the centre of the vortex. To maintain a distance of 11mm the motor was slowed from top to bottom. The pouring temperature of the liquid was maintained at 750℃. A rectangular mould of dimension (250*20*45mm, Fig. 4) was prepared for the casting.

![Fig.1-Bottom Pouring Furnace](image1)

![Fig.2-Muffle Furnace](image2)

The same Al-Si ingot was cut into required dimension after being cleaned properly. Before getting the ingot into furnace it is pre heated to 800℃ then they are put into the bottom pouring furnace for melting. The rice husk ash is preheated to 675℃ for removing the moisture content from it. The molten Al-Si was stirred at 450 rpm. When the vortex was created due to the rotation the pre heated rice husk ash was added to its centre. The rice husk added is 15 wt. %. Stir casting technique is followed for the proper mixing of the rice husk with the molten Al-Si. At last a rectangular mould of dimension (250*20*45). The Al-Si pre-heater is shown in the Figure 3.

**2.3. Testing of Wear Rate at Elevated Temperature**

The wear tests were carried out in the pin-on-disc wear testing machine. All the experiments were conducted at elevated temperature conditions with varying loads. The test samples had dimensions of 8mm diameter and 27.5mm in length. The samples were made to slide on the
low alloy steel disc (material EN-31-HRS 60 W 61 equal to 4340). The track diameter was set to 75mm. Before beginning the experiment the track was cleaned with acetone. The experimental parameters including the time and temperature were set as required. The wear and the frictional force are brought to 0 before beginning. The wear and coefficient of friction electric sensors attached to the machine give the reading in form of graphs. Electric sensor weighing machine was used to measure the initial weight before beginning the wear test and after conducting the experiment the samples were cleaned with acetone and again weighed with the weighing machine to get the weight loss.

3. RESULTS AND DISCUSSION

The experiments were conducted using pin-on-disk machine (Fig. 3) and the wear were recorded by the sensors attached to the machine and weight loss was measured using electronic weighing machine. The results were plotted in form of graphs. The test conditions for flyash, rice husk ash and the Al-Si alloy are given in Table no 4, 5, and 6 respectively. The wear graph of the three samples at ambient temperature is given in Fig 5, and Fig. 6 represents the wear results at elevated temperature.
**Table 4 - Test Conditions for Al-Si Alloy**

| SL. No. | Load (N) | Temp. (°C) | Time (sec) | Sliding Speed (m/s) | Int. wt. (gm) | Final Wt. (gm) | Wt. Loss (gm) | Avg Wt. Loss | C.O.F Avg | C.O.F Avg |
|---------|----------|------------|------------|---------------------|---------------|----------------|---------------|--------------|-----------|-----------|
| 1       | 30       | 150        | 1000       | 1                   | 3.521         | 3.553          | 0.032         | 0.0335       | 0.345     | 0.392     |
| 2       | 30       | 150        | 1000       | 2                   | 3.534         | 3.569          | 0.035         | 0.0439       |           | 0.2927    |
| 3       | 30       | Room Temp. | 1000       | 2                   | 3.561         | 3.588          | 0.027         | 0.025        | 0.2981    | 0.2973    |
| 4       | 30       | Room Temp. | 1000       | 1                   | 3.555         | 3.578          | 0.023         | 0.2873       | 0.2873    | 0.2873    |

**Table 5 - Test Results for Fly Ash**

| SL. No | Load (N) | Temp. (°C) | Time (sec) | Sliding Speed (m/s) | Int. wt. (gm) | Final Wt. (gm) | Wt. Loss (gm) | Avg Wt. Loss | C.O.F Avg | C.O.F Avg |
|--------|----------|------------|------------|---------------------|---------------|----------------|---------------|--------------|-----------|-----------|
| 1      | 30       | 150        | 1000       | 3                   | 3.553         | 3.548          | 0.005         | 0.0035       | 0.224     | 0.2485    |
| 2      | 30       | 150        | 1000       | 4                   | 3.546         | 3.544          | 0.002         | 0.0015       | 0.213     | 0.2275    |
| 3      | 30       | Room Temp. | 1000       | 3                   | 3.557         | 3.556          | 0.001         | 0.002        | 0.297     | 0.3095    |
| 4      | 30       | Room Temp. | 1000       | 4                   | 3.546         | 3.544          | 0.002         | 0.242        |           |           |

**Table 6 - Test Results for Rice Husk Ash**

| SL. No | Load (N) | Temp. (°C) | Time (sec) | Sliding Speed (m/s) | Int. wt. (gm) | Final Wt. (gm) | Wt. Loss (gm) | Avg Wt. Loss | C.O.F Avg | C.O.F Avg |
|--------|----------|------------|------------|---------------------|---------------|----------------|---------------|--------------|-----------|-----------|
| 1      | 30       | 150        | 1000       | 4                   | 3.537         | 3.531          | 0.006         | 0.0055       | 0.293     | 0.351     |
| 2      | 30       | 150        | 1000       | 3                   | 3.588         | 3.583          | 0.005         | 0.004        | 0.297     | 0.3095    |
| 3      | 30       | Room Temp. | 1000       | 4                   | 3.543         | 3.498          | 0.005         | 0.004        | 0.297     | 0.3095    |
| 4      | 30       | Room Temp. | 1000       | 3                   | 3.458         | 3.455          | 0.003         | 0.003        | 0.322     |           |
Fig. 5. Representing the wear behaviour of 3 samples at ambient temperature.

Fig. 6. Representing wear of 3 samples at elevated temperatures.

4. CONCLUSIONS
The stir casting method used for the preparation of composites is easy, efficient and most economical method. It also helps in the uniform distribution of reinforced particles (Fly ash and RHA) with the matrix metal. The wear behavior is higher for MMC with fly ash than MMC with RHA. Not only at ambient temperature but also at elevated temperatures, fly ash reinforced MMC showed better results than rice husk reinforced MMC as well as virgin Al-Si Alloy. This is because due to the presence of more amount of aluminum oxide and calcium oxide in Fly ash than rice husk ash. The experimented data shows that the selection of reinforced particle when Tribological properties are considered is one of the major aspect for the production of metal matrix composite.

5. REFERENCES
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