Experimental Investigations on Wear Properties of Al-7075/ZrO_2/ Coal bottom ash Metal Matrix Composites

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***Abstract*: Aluminium alloys and its composites have a huge requirement in the field of automobile, aerospace and other versatile engineering applications. The present study deals with Al 7075 as base matrix material, whereas ceramic particle like zirconium oxide (ZrO_2) and bottom fly ash are used as reinforcements for the production of hybrid composites. Four different MMC specimens were produced with 2% ZrO_2, 4%ZrO_2, 6%ZrO_2, 8%ZrO_2 and 10% of coal bottom ash is constant in every sample. Wear properties are studied on the fabricated composite specimens. Morphological studies are also studied on the tested samples using Scanning Electron Microscopy (SEM) to observe the bonding between matrix and reinforcements. Good wear resistant is achieved for third specimen i.e 6% ZrO_2 at 10% coal bottom ash. SEM testing results in study of various bonding structure at different microns.**

***Keywords*: MMC, Wear, Ceramic particles, Aluminium, SEM**

I. INTRODUCTION

Metal matrix composites have been emerged to counter the stipulation for materials with high specific strength, stiffness and wear resistance. Conventional aluminium is ductile and renowned for their terrible wear resistance. This problem will be overcome by including hard ceramic particles as a reinforcement to improve its mechanical properties. Chauhan *et al.* [1] studied the effect of reinforcement percent (alumina) into the matrix material. The results revealed the change in these properties is observed to be moderated up to 10 per cent addition of reinforcement and marginal changes were observed with 15 and 20 per cent of reinforcements. Boopathi *et al.* [2] worked on the silicon carbide and fly ash reinforcements into the aluminium (Al-2024) metal matrix hybrid composites and concluded that the improvement of tensile strength is taken place as the reinforcement content increases but the elongation decreases.

Mohanavel *et al.* [3] investigated on fly ash reinforced AA7075 alloy matrix composites with different weight fractions. The superior mechanical properties were achieved at AA7075/12 wt. % fly ash content. Researchers used bottom ash as reinforcement to minimize industrial waste [4]. Thamizhvalavan *et al.* [5] investigated on Abrasive Aqua Jet (AAJ) machining of hybrid composites with Boron Carbide (B_4C) and zirconium silicate ($ZrSiO_4$) as reinforcements. Kumaran *et al.* [6] investigated on wear phenomenon of aluminium based metal matrix composites with 5wt% of both boron carbide and silicon carbide. Atrian *et al.* [7] worked on the synthesis and characterization of Al7075 based metal matrix composites reinforced with SiC along with its physical behaviour. The increase in strength and hardness is perceived by the addition of nano-particles into the matrix. Dharmalingam *et al.* [8] investigated on the optimization of wear properties of aluminium based metal matrix composites using Taguchi based grey relational analysis. Praveen Kittali *et al.* [9] reviewed the effects of Al_2O_3, B_4C, Gr, Y_2O_3 and SiC as reinforcements in metal matrix composites and their mechanical and tribological properties have been presented in their work processed by different fabrication techniques. Kumar *et al.* [10] compared the mechanical properties of Al6061-SiC and Al7075-Al_2O_3 reinforced composites. The reasons for the improvements of the mechanical properties have been presented through micrographs. Reinforced composites attained higher mechanical properties including density when compared to as received aluminium alloys. Din Bandhu *et al.* [11] investigated on different reinforced materials like SiC, Al_2O_3, B_4C and TiB_2 by taking Al 7075 as a base matrix material. In each sample a constant amount of 15 wt. % of all these reinforcements are used for producing four different MMC specimens. Sujan *et al.* [12] studied the effects of SiC and Al_2O_3 into the metal matrix composites. Based on the obtained results, the authors suggested using the fabricated material for the manufacturing of car disc brakes in automobile industry.

The present work deals with the fabrication of composites with aluminium as base metal and zirconium oxide (ZrO_2) and bottom fly as reinforcements. A total of four different composite specimens are fabricated with varying reinforcement wt. % and keeping fly ash content constant (10%) for all the four samples. Mechanical properties like tensile and hardness is tested on the fabricated samples and their results are analysed the effects of reinforcements on the obtained results are reasoned out.

II. MATERIALS AND METHODS

A. Composite Fabrication

The fabrication of metal matrix composite was carried out by the stir casting method. Matrix material used in the present study is an aluminium alloy of 7075 was purchased from Andhra steels Pvt. Ltd. Hyderabad, Telangana. Later, the base metal is melted to form into liquid state such that the reheated reinforcements (both ZrO2 and fly ash) is added with 2% ZrO_2, 4%ZrO_2, 6%ZrO_2, 8%ZrO_2 and 10% of coal bottom ash constant for all the samples. During the addition of reinforcements into the molten metal the mechanical stirrer present in stir casting machine is set to rotate at 500 rpm to distribute the reinforcement articles uniformly into the matrix material. The stirring was continued for 10 min at a temperature of about 800°C. The molten metal which is a mixture of both matrix and reinforcements was poured into the die of diameter 20 mm and length 150 mm. The schematic illustration of these steps to fabricate the samples.

B. Wear test

The Wear test was carried out in wear Testing Machine at temperature of 25°C at G. Pulla Reddy Engineering College, Kurnool. The wear test was conducted on ever sample of specimen results are calculated for reinforcement of ZrO_2 and coal bottom ash. The test setup and testing sample holding method are shown in Fig 1.

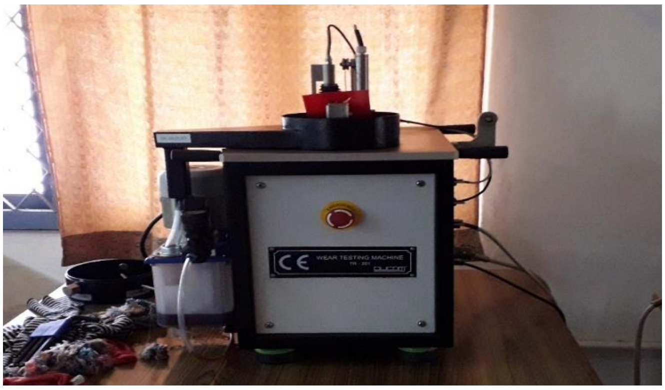

Fig. 1 Test setup for testing the composite samples

C. Sem test:

To test the micro structure of specimens Sem testing is performed . The test was conducted at yogi Vimana collage at Kadapa. The test was performed at controlled temperature in separate conditions.

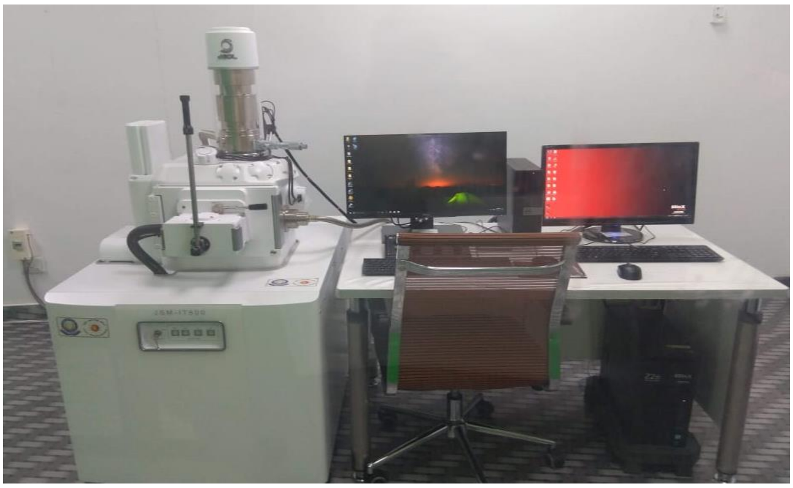

Fig.2 SEM testing equipment

III. Results and Discussions

A. WEAR:

This test method is determined by using a pin-on-disk apparatus. Firstly, clean the specimen by removing all dirt with the use of cleaning agents and solvents. For the equipment we have to fix the disk perpendicular to the axis of the rotation. And then insert the specimen perpendicular to the disk surface and it needs to be contact with the surface.

To develop the selected force to pressing the pin against disk by adding some weights. Start the motor and adjust the speed to the desired value while holding the pin specimen out of contact with the disk. Set the revolution counter (or equivalent) to the desired number of revolutions. The specimens are tested under contact loads.

The test is stopped when the desired number of revolutions is achieved. Remove the specimen and clean off any loose wear debris. Repeat the test with additional specimens to obtain sufficient data for statistically significant results.

Taguchi L9 design is used for wear testing simulated by mini tab.

The strength of the composite increases with the addition of ZrO_2 and coal bottom-ash is noted from the wear testing machine for different varying proportions. Due to even distribution of reinforcement particles into the matrix results is the reason for the increment of the mechanical properties.

Table 1. Experimental results for wear

Composition (%)	Speed(rpm)	Load(Kg)	Wear
4	500	5	106
4	750	10	54
4	1000	15	272
6	500	10	126
6	750	15	222
6	1000	5	511
8	500	15	110
8	750	5	94
8	1000	10	60

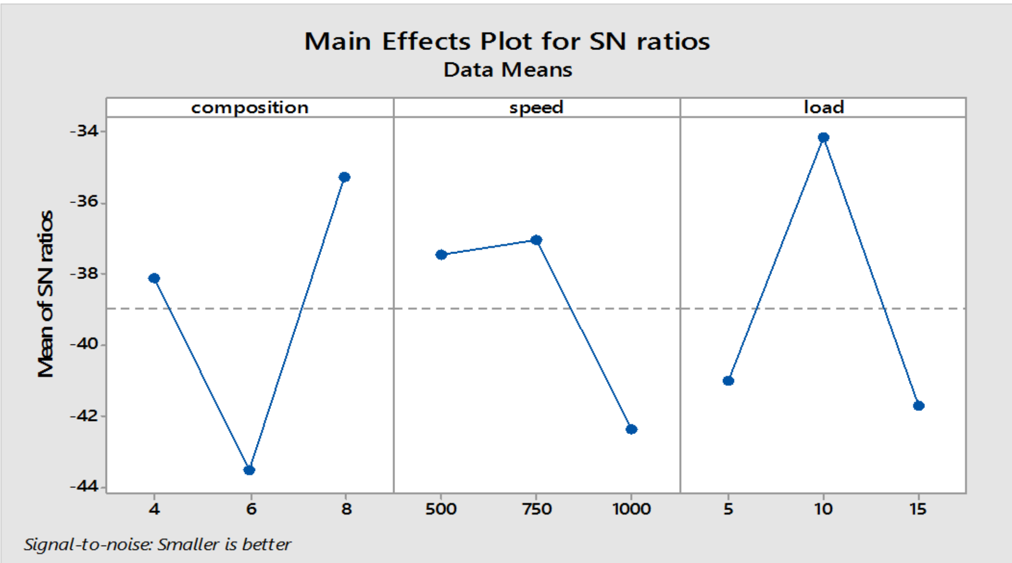

Fig 5: Main effects plot for SN ratio

Above plot showing the signal-to-noise ratio for the composition, speed and load. These results are obtained after performing wear analysis.

From the above discussion represented by graphs and tables after performing wear test, on specimens for different composition at three different speeds and loads conditions. These analysis reveals that the optimal condition is obtained at 6% composition and 750 rpm at 10kgs. From this composition we can get good wear properties. Remaining samples wear rate is much more when compare to 6% sample i.e (6% ZrO_2 + 10%fly ash).

B. SEM Testing

Testing of specimens for different composition are loaded in to equipment and studied under microscope to study their structure. Study of structure at different micron levels are shown in below figure 3,4.

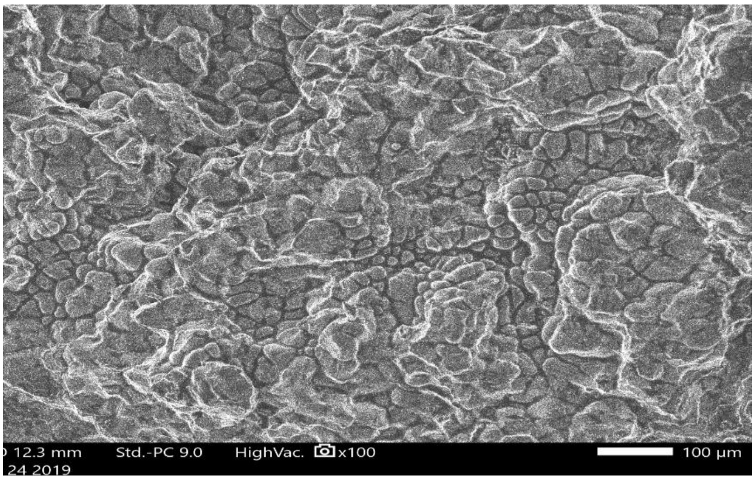

Fig 3. WEAR specimen with good bonding 4%ZrO_2 + 10% coal bottom ash

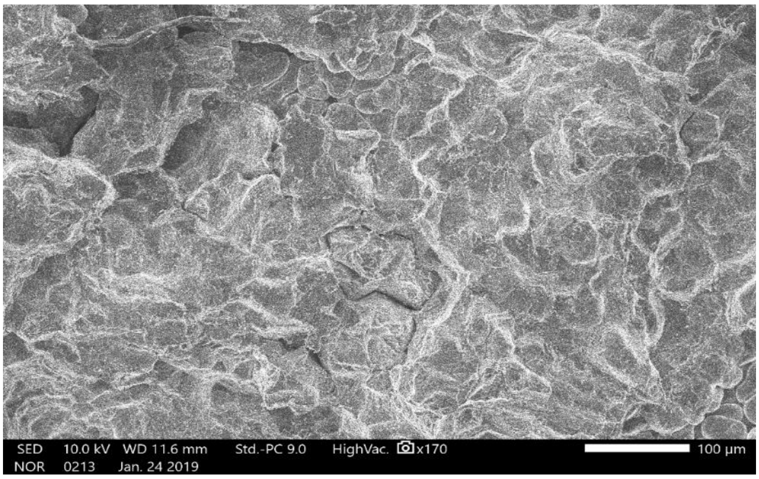

Fig.4 WEAR specimen with good bonding 6% ZrO_2 + 10% coal bottom ash

From the above fig 4, for sample three i.e 6%ZrO_2 to 10% coal bottom ash shows the even bonding with reinforcement and filler.

iv Conclusion:

The following are the conclusions are drawn from the experimental investigation and analysis are made on various specimens. The results are obtained by testing the various specimens are listed below and are follows:

- Stir casting method can be successfully used to manufacture metal matrix composite with desired properties.
- Aluminium Reinforcing with ZrO_2 and coal bottom ash particles has show appreciable increase in wear resistance.
- Wear testing best results can be obtained for the sample of 6% ZrO_2+10% coal bottom ash composition with less amount of wear rate. For Remaining samples and also increase in composition percentages results in high materials removal rate by this, we conclude that above sample.

SEM analysis revealed that there is a good bonding between the matrix and reinforcements, this leads to attaining greater tensile strength and elongation when compared to the virgin matrix materials.

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