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Preparation and Characterization of an Aluminium 6061 Alloy based Metal Matrix Composite

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Abstract: ***The preparation and characterization of an aluminum 6061 alloy with low-cost reinforcements such as fly ash, alumina oxide and magnesium powder in different combinations is presented in this study. The reinforcements alumina oxide and fly ash were varied as 5%, 10%, 15%, 9% and 11% by volume and fabricated using stir casting process. Six samples were fabricated and their mechanical properties and micro structural properties were analyzed and results are obtained. The composite with Al 6061 and reinforcements Fly Ash-3%, Al2O3-6%, Magensium-1%by volume fraction has shown improved mechanical properties like tensile strength, wear resistance and hardness compared as compared to the parent material. The microstructural properties analyzed using SEM and EDAX shows good bonding between the reinforcements and matrix materials in the composite.***

Index Terms: Al 6061, metal matrix composite, stir casting, microstructural properties

I. INTRODUCTION

The aluminum alloy AA6061 is one of the vastly used alloys in engineering and commercial applications due to its appreciable mechanical properties and weldability. In addition to that, the use of metal matrix composites with AA6061 as parent material and inclusion of reinforcements like Fly Ash, Silicon Carbide etc have resulted in materials with improved mechanical strength and usability. The application of such composites is found in almost all the fields of engineering especially in Mechanical, automobile and aerospace applications. These light weight, but strong materials have almost replaced heavy metals used in the past like cast iron and Bronze. As more and more materials are needed with improved strength and less weight, there is a huge scope of development of such materials.

II. BACKGROUND LITERATURE

During the recent past, due to the increased usage of metal matrix composites with improved properties, there are many researches performed towards achieving the same. A few of the relevant findings from the reported literature is presented below :

Kumar et.al (2009) performed analysis on a press-extruded AA6061/fly ash composite and investigated the dry sliding wear behaviour using the pin-on-disc method. They found that the composite showed a mild to severe wear at higher temperatures due to the formation of protective layer of reinforced materials at the high temperatures. Zahi et.al (2010) conducted characterization studies on an Al- based Mg alloy prepared by stir casting process. It was concluded that the presence of Fly Ash in the composite led to the reduction in wear and improved hardness and strength of the material. Moutsatsou et.al (2010) did a micro structural characterization of aluminum and Silicon based composites reinforced with lignite fly ash using powder metallurgy technique. Results show that the presence of Fly Ash in the composite material increased the micro hardness of the material leading to harder surface of the composite.

Uju et.al (2011) carried out a study to estimate the thermal expansion of a stir-casted Al-Mg and Silicon Carbide alloy containing fly ash. The addition of Fly Ash and Silicon Carbide reduced the coefficient of thermal expansion of the composite to a great extent. Babu Rao et.al (2011) prepared a AA2024 composites alloy with Fly Ash using stir casting. The SEM images show good bonding between Fly Ash and the matrix material thereby increasing the hardness of the composite while reducing the density of the material and hence the weight of the material. The results also show improved mechanical properties of the composite under compression. Grigorios et.al (2012) synthesized a A356 Al-high-Ca fly ash composite using pressure infiltration technique to carry out tribology studies on the composite. Results show that the tribological performance and the wear resistance improved considerably. The use of fine fly ash particles is found to strongly improve the mechanical properties of the composite. Kountouras et.al (2015) prepared Fly Ash/Al Alloy composites by Infiltration process. The microstructural and chemical analysis of the composite was performed using SEM and XRD. Properties like macro-hardness, wear, thermal expansion, and corrosion behaviour were analysed. The corrosion behaviour of the composite material was also evaluated by means of potentiodynamics corrosion experiments using a 3.5% NaCl solution. It is seen that the presence of fly ash particles in the Al alloy matrix considerably decreased the coefficient of thermal expansion, while resulting in an altered corrosion mechanism of the composite materials with respect to the matrix alloy.

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However, from the reported literature it was found that the mechanical and structural analysis of an aluminum based alloy with Fly Ash and Alumina as reinforcement was not reported. Alumina and Fly Ash are easily available and low cost materials that can be used as reinforcement. Hence, the present study aims at analyzing the properties of a metal matrix composite formed by combining aluminum AA6061, Fly Ash and Alumina (Al_2O_3).

III. MATERIALS AND PROCESSES

The Table 1 given below shows the chemical composition of the parent material chosen in this study.

TABLE 1 Composition of Aluminium 6061 by weight percentage

Elements of AA6061	Wt %
Copper	0.15%- 0.4%
Manganese	0.15%
Magnesium	0.8%- 1.2%
Chromium	0.04%- 0.35%
Zinc	0.25%
Titanium	0.15%
Aluminium	95.85%–98.56%
Other Elements	0.05%

For the present study, Fly Ash is chosen as one of the reinforcement material. Fly Ash is left-out residue from the boilers in thermal power plants. Since it is a by-product, it is available in plenty and also at very low cost. The chemical composition of Fly Ash used in the study is shown below in Table 2.

TABLE 2 Composition of Fly Ash by weight percentage

Elements Of Fly Ash	Wt%
SiO_2	59.98
Al_2O_3	19.09
Fe_2O_3	2.78
TiO_2	1.14
K_2O	1.09
CaO	0.63
MgO	0.38
Na_2O	0.34
CuO	0.01

The composite samples in the present study are obtained by stir casting method. The stir casting apparatus used in the study is shown in Figure 1.

Fig. 1 Stir Casting Apparatus

Alumina oxide particles were also used as reinforcement in the study along with small amounts of Magnesium to prevent oxidation of the molten metal. The composition of the samples by volume percentage casted in the present study is given in Table 3.

TABLE 3 Composition of AA6061 in the present study

SPECIMEN	AA6061	FA	Al_2O_3	Mg
Specimen 1	100	0	0	0
Specimen 2	95	2	2	1
Specimen 3	90	3	6	1
Specimen 4	85	5	9	1
Specimen 5	91	4	5	1
Specimen 6	89	6	4	1

A sample specimen obtained by stir casting as per the composition above is shown in figure 2.

Fig. 2 Fabricated Metal Matrix Sample

The specimen fabricated were cut according to ASTM standards using wire cut machine and tests like tensile test (Universal Testing Machine), hardness test (Vickers Micro Hardness apparatus), wear test (Pin-on-Disk wear testing apparatus) and micro-structural analysis (SEM-Scanning Electron Microscopy) were performed and the results obtained are analysed.

IV. RESULTS AND ANALYSIS

The mechanical and microscopic analysis of the 6 stir-casted specimens of AA6061 with varying proportions of Fly Ash and Alumina were estimated as shown below :

a) Tensile Test:

The variation of tensile strength of the specimen as compared to the parent material (sample 1) is shown in Fig 1.

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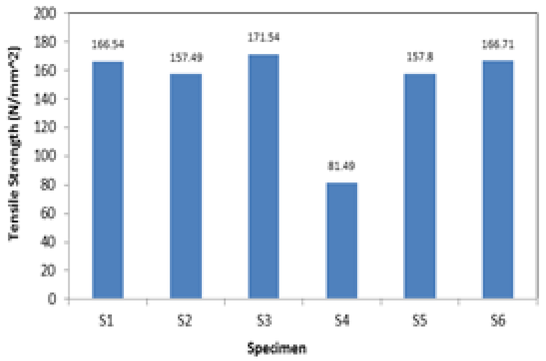

Fig 1. Variation in the Tensile strength of Specimen

From Fig 1 it can be concluded that the metal matrix composite with AA 6061, fly ash, Alumina in the proportions 90%, 3% and 6% respectively has greater tensile strength compared to the parent material without reinforcements. The presence of 3% fly ash and 6% alumina in specimen 3 is seen to possess a maximum tensile strength of 171.54 N/mm^2. However, further increase in fly ash does not contribute to the increase in tensile strength. On the other hand, the addition of Alumina increases the tensile strength. The tensile strength of specimen 3 is found to increase by 3% due to the addition of 3% fly ash and 6% alumnina.

b) Elongation Test :

Elongation test is performed to measure the elongation undergone by the specimen during breaking and this elongation serves as an index of the material's ductility and elongation. Elasticity also specifies the ability of the specimen to resist changes of shape without cracking. The results of the elongation test are shown in Fig 2.

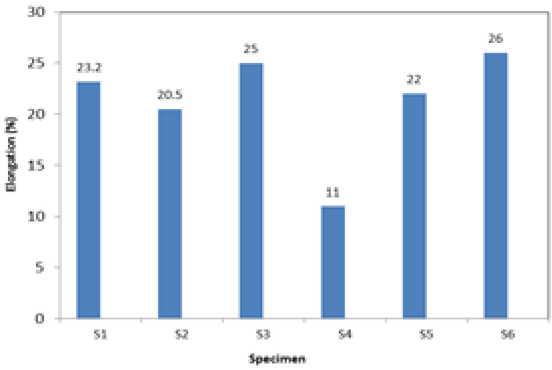

Fig 2 Elongation of the composite samples

It is observed from Fig 2 that, specimen 2 (2% flyash, 2% alumina, 1% magnesium) and specimen 4 (5% flyash, 9% alumina, 1% magnesium) have recorded less elongation than other samples. On the other hand, the elongation observed in samples 3 & 6 are found to be maximum, implying that the presence of more reinforcement increases the ductility of the composite. The elongation of sample 3 with 3% Fly Ash and 6% Al_2O_3 is found to be 25% and the sample 6 with 6% Fly Ash and 4% Al_2O_3 is found to be 26%.

c) Hardness Test

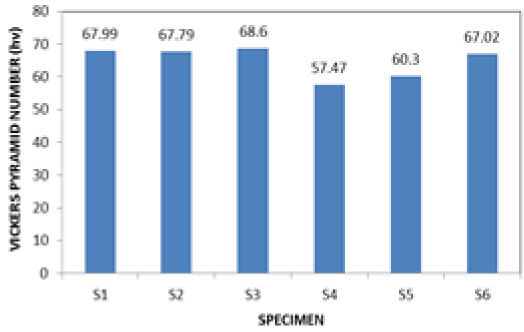

Fig 3 Variation in the Hardness of the samples

Figure 3 shows the variation in the hardness of the samples with varying proportions of Fly Ash and Alumina. It is clearly seen that the hardness of AA6063 is found to have increased marginally by nearly 1% in sample 3 with 3% Fly Ash and 6% Alumina. However, the hardness reduces with increase in Alumina in sample 4.

d) Wear Test

Wear test is performed to find out the performance of the composite material in terms of wearing under usage. All the samples were tested on a pin disc wear testing machine. The load applied during the test was 20 KN. The disc velocity was set as 1.55m/s on a track which had a diameter of 80 mm while revolving at 185 rpm for a time period of 10 minutes. The results as in Fig 4 shows that the wear of the samples 2, 5 & 6 are found to be less when compared to the other samples in this study. The wear in the Aluminium material has decreased by 4.2 % in sample 6 and 2.4 % in sample 3. The presence of Alumina is seen to increase the wear resistance of the aluminum composite.

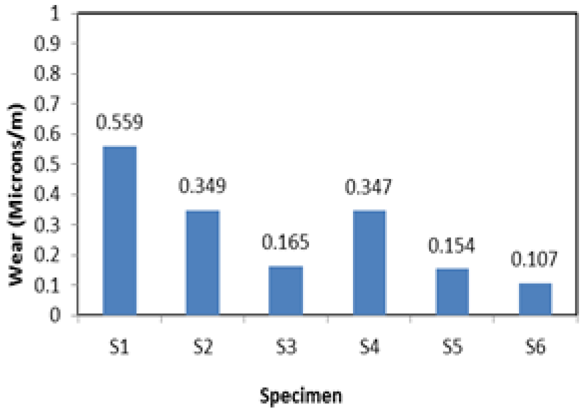

Fig 4 Variation in the wear resistance of the samples

e) SEM Analysis

The SEM images of the samples are obtained and the wetability and bonding of the constituents is analysed.

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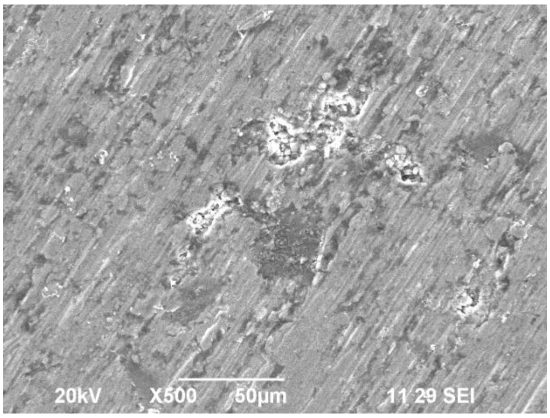

Fig 5 SEM analysis of metal matrix composite sample 3

From the Figure 5, it is seen that there is better wetting of reinforcements into the matrix shown by the dark patches of fly ash and also alumina particles. It can be concluded that the better wettability results in deagglomeration of reinforcements thereby improving the tribological characteristics of the composite. Also, the addition of Magnesium enables the elimination of voids in the composite, thereby increasing the bonding and strength of the matrix and reinforcement materials.

The EDX analysis was done to identify the elemental composition of the Metal Matrix composite. The EDX image shown in Figure 7 shows the peaks generated by the presence of various constituents of the composite.

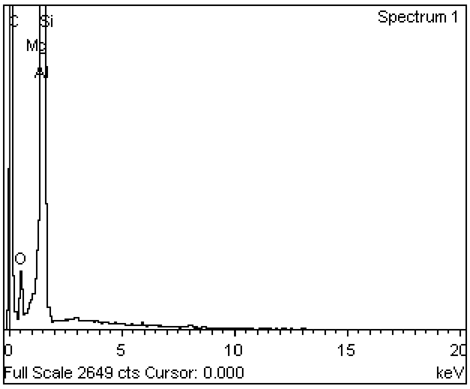

Fig 7. EDX analysis of Sample 3

V. CONCLUSIONS

A Metal matrix composite with AA6061 as matrix and reinforcements alumina and Fly Ash along with small quantities of magnesium as a wetting agent is stir casted and analysed. The mechanical properties and micro level analysis of the samples is performed and the following results are obtained.

The presence of fly ash and alumina with composition of (90% AA 6061, 3% FA, 6% Al_2O_3 & 1% Mg) used in sample 3 has shown increased tensile strength by 3%. Similarly the ductility of metal matrix composite used in this study with different volume % has increased by 12% for sample 6 and 7.5% for sample 3. Also the presence of 3% FA, 6% Al_2O_3 in the parent material has increased its hardness by 1%. The specimen with this combination is found to have a maximum hardness value of 68.6 HV. The wear results shows that the metal matrix composite having Vol% of 90% AA 6061, 3% FA, 6% AL_2O_3,1% Mg used in sample 3 has the less wear rate compared to the pure aluminum. The micro structural analysis using SEM and EDAX shows good bonding of the reinforcement with the matrix material.

It is evident that from the above study that Fly Ash and Alumina are low-cost materials that can be used as reinforcements in Metal Matrix of Aluminium 6061 with improved mechanical properties.

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