Experimental Investigations on Mechanical Properties of Al 6061, Sic, Flyash and Redmud Reinforced Metal Matrix Composites

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Abstract— The aluminium Al 6061 alloys are mainly used in the application of automobile and aeronautical industries. In the present investigation Al6061 alloy composites having varying weight percentages of (3% - 6%) Silicon Carbide, Fly ash and Red mud were fabricated by liquid metallurgical (Stir Casting) method. The casted composite specimens were machined as per BS: 18: 1962 test standards. The specimens were tested to know the mechanical properties such as tensile test, impact (Charpy) test and wear test. The result reveals higher tensile strength, impact strength and wears resistance in Al6061-SiC-Flyash samples when compared to Al6061-SiC-Redmud samples.

Key words: Al6061, fly ash, mechanical properties, red mud and stir casting.

I. INTRODUCTION

A composite material is made up of reinforcement embedded in matrix. A matrix holds the reinforcement to form the desired shape while the reinforcement phase improves the overall mechanical properties of the matrix. MMCs are advanced engineering materials resulting from a combination of two or more materials in which tailored properties are achieved. Engineering MMCs consisting of continuous or discontinuous fibers or particulates in a metal or alloy possess combination of properties not achievable in monolithic. These properties could include high specific strength, specific stiffness, machinability, wear resistance and low coefficient of thermal expansion.

6061 aluminum, originally known as "Alloy 61s" was one of the first to be developed in 1935 and is one of the most commonly available heat treatable aluminium alloys for commercial use. The 6061 alloy is primarily composed of aluminium, magnesium and silicon. Its properties include structural strength and toughness, good surface finish, good corrosion resistance to atmosphere and sea water, its machinability and its ability to be easily welded and joined. Al6061 is used extensively as a construction material and most commonly used in the manufacture of aircraft and automotive components.

Silicon carbide is the only chemical compound of carbon and silicon with the chemical formula of SiC. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. It is used in abrasive, refractories, ceramics and numerous high performance applications. Some of the key properties of SiC are: low density, high strength, low thermal expansion, high thermal conductivity, high hardness and high elastic modulus.

Fly ash is also known as flue-ash, it is one of the residues generated in combustion and comprises of fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash (the mineral residue) produced during combustion of coal. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. It is one of the most inexpensive and low density reinforcement available in large quantities as waste product during combustion of coal in thermal power plants.

Red mud emerges as the waste material during the production of alumina from bauxite in Bayer's process. It comprises of iron, aluminium, titanium and silica along with some other minor constituents. The red color is caused by the oxidized iron present which can make up to 60% of the red mud. Enormous efforts have been directed worldwide towards red mud management issues i.e. utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible.

Madeva Nagral, Bharat V and V Auradi [1] reported that 6061Al-Al2O3 composites have higher hardness and lower wear rate when compared to the hardness of 6061Al alloy. Tensile strength and yield was higher and ductility of composites was less when compared to cast Al6061. H C Anil Kumar, H S Hebbar and K S Ravishankar [2] reported that tensile, compression and hardness strength increased with the increase in the weight fraction of reinforced fly ash while ductility of the composite decreased with increase in the particle size of the fly ash. For composites with more than 15%wt fraction of fly ash particles, the tensile strength was seen to be decreasing. In the paper [3] it is reported that, hardness of the composites is found to increase with increased SiC content, while percentage elongation of the composites decreased with increase in the percentage of SiC. The tensile strength and compressive strength of the composites found increased with increase in reinforcement of the composites.

II. EXPERIMENTAL DETAILS

A. *Material Preparation*

For the production of the Metal matrix composites, Al6061 alloy was used as the matrix material, containing various weight percentages of SiC, Red mud and Fly ash particles as reinforcement. The chemical composition of the 6061Aluminium alloy and fly ash is shown in table 1 and 2.

B. *Specimen Preparation*

In this study, the stir casting method was used in the synthesis of the metal matrix composites. The cylinders of 15mm X 125mm cast composites of Al6061-SiC-Flyash and Al6061-SiC-redmud were obtained. The samples for tensile test were prepared by machining from cylindrical bar castings, each having 10mm dia X 50mm gauge length in size. For wear test the specimens with 8mm dia X 22mm in length were prepared. The specimen for impact testing, the samples for Charpy test 10mm X 55mm in length with 2mm V- notch at the centre.

III. RESULTS AND DISCUSSION

A. Tensile Testing.

Tensile test was carried out at room temperature using a universal testing machine. The samples were subjected to uniaxial tension until fracture. The specimens used were of diameter 10mm and 50 mm gauge length according to BS: 18:1962. Al6061 + 6 % SiC + 3 % Flyash and Al6061+6%SiC+3%Redmud resulted in higher tensile strength.

B. Impact Testing.

A standardized high strain- rate test which determines the amount of energy absorbed by material during fracture, is called the Charpy Impact test also known as Charpy V-notch test.

Impact test was carried out at room temperature. The reading was taken by breaking specimen due to the impact of the pendulum. Al6061+3%SiC+6%Flyash and Al6061+6%SiC+6%Redmud resulted in higher impact strength.

C. Wear Test.

The prepared Al6061 with varying percentages of (Sic & Fly ash) and (SiC & Red mud) were subjected to wear test under dry sliding conditions. The specimen size of 8mm dia and 22mm in length were tested against a rotating EN- 32 steel disc. For each type of material, test were conducted at 60mm track dia, 30N load and keeping the sliding speed fixed at 300rpm, wear tests were carried out at room temperature without lubrication for 5mins

IV. FIGURES AND TABLES

Components	Weight %
Magnesium	0.84
Silicon	0.62
Iron	0.23
Copper	0.03
Zinc	0.25
Titanium	0.15
Manganese	0.03
Chromium	0.22
Aluminium	Bal

Table. 1: Chemical composition of Al 6061

Components	Weight %
SiO_2	44.8
Al_2O_3	22.2
Fe_2O_3	24
MgO	0.9
CaO	1.8
TiO_2	0.8
K_2O	2.4
Na_2O	0.9
SO_3	1.4
Balance= Oxides of other trace elements	

Table. 2: Chemical composition of Fly ash

Constituents	%	Constituents	%
Na	5.20	Na_2O	7.01
Al	7.67	Al_2O_3	14.49
Si	3.22	SiO_2	6.89
Ca	3.67	CaO	5.13
Ti	12.37	TiO_2	20.63
Fe	30.70	Fe_2O_3	39.49
Cu	2.94	CuO	3.68
Zn	2.14	ZnO	2.68
O	32.09	Total	100
Total	100		

Table. 3: Chemical composition of Red mud in element and compound form

Sample	Composition	Tensile strength N/mm^2
F1	Al6061+3%SiC+3%Flyash	147.346
F2	Al6061+3%SiC+6%Flyash	112.691
F3	Al6061+6%SiC+3%Flyash	165.549
F4	Al6061+6%SiC+6%Flyash	108.565

Table. 4: Results of Tensile test for Fly ash

Sample	Composition	Tensile strength N/mm^2
R1	Al6061+3%SiC+3%Redmud	96.595
R2	Al6061+3%SiC+6%Redmud	101.656
R3	Al6061+6%SiC+3%Redmud	150.953
R4	Al6061+6%SiC+6%Redmud	144.245

Table. 5: Results of Tensile test for Red mud

	Composition	Energy Absorbed kg-m
F1	Al6061+3%SiC+3%Flyash	18
F2	Al6061+3%SiC+6%Flyash	23.05
F3	Al6061+6%SiC+3%Flyash	21.7
F4	Al6061+6%SiC+6%Flyash	22.5

Table. 6: Results of Impact test for Flyash

Sample	Composition	Energy Absorbed kg-m
R1	Al6061+3%SiC+3%Redmud	20.3
R2	Al6061+3%SiC+6%Redmud	15.6
R3	Al6061+6%SiC+3%Redmud	19.2
R4	Al6061+6%SiC+6%Redmud	22.3

Table. 7: Results of Impact test for Red mud

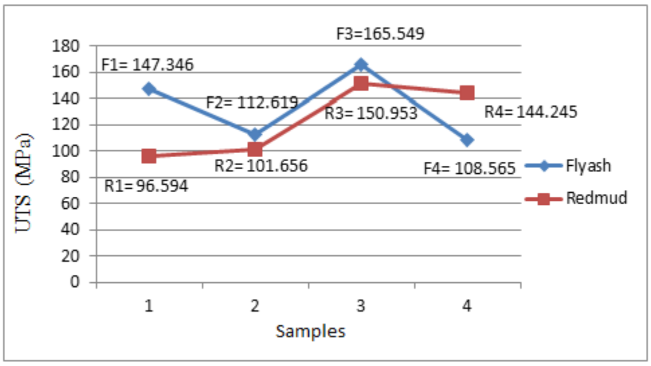
Sample	Composition	Wear in µ m	Wear rate in mm^3/m	Wear resistance in m/mm^3
F1	Al6061+3%SiC+3%Flyash	114.12	$12.171X10^{-3}$	82,163
F2	Al6061+3%SiC+6%Flyash	210.17	$22.411X10^{-3}$	43.621
F3	Al6061+6%SiC+3%Flyash	158.10	$16.864X10^{-3}$	59.298
F4	Al6061+6%SiC+6%Flyash	146.27	$15.595X10^{-3}$	64.123

Table. 8: Shows the result of wear rate and wear resistance for Fly ash

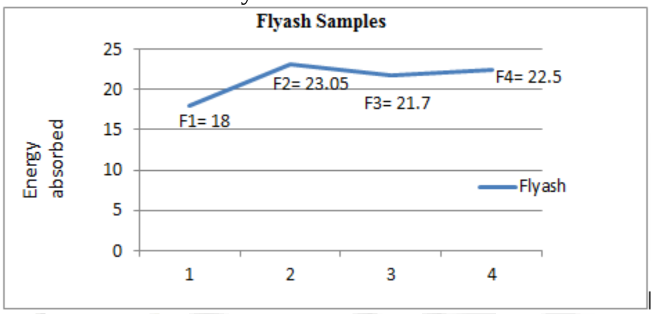
Sample	Composition	Wear in µ m	Wear rate in mm^3/m	Wear resistance in m/mm^3

R1	Al6061+3%SiC+3% Redmud	157.75	16.821X 10^{-3}	59.449
R2	Al6061+3%SiC+6% Redmud	85.27	90.880X 10^{-3}	11.004
R3	Al6061+6%SiC+3% Redmud	125.05	13.333X 10^{-3}	75.002
R4	Al6061+6%SiC+6% Redmud	219.73	23.435X 10^{-3}	42.671

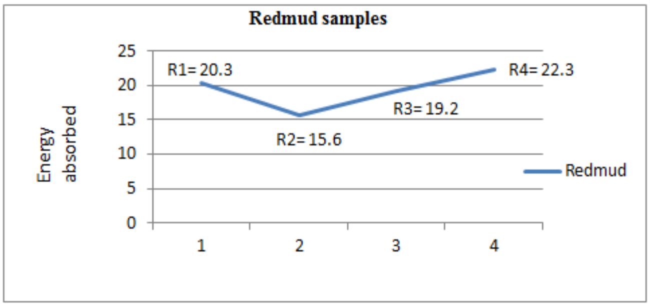
Table. 9: Shows the result of wear rate and wear resistance for Red mud



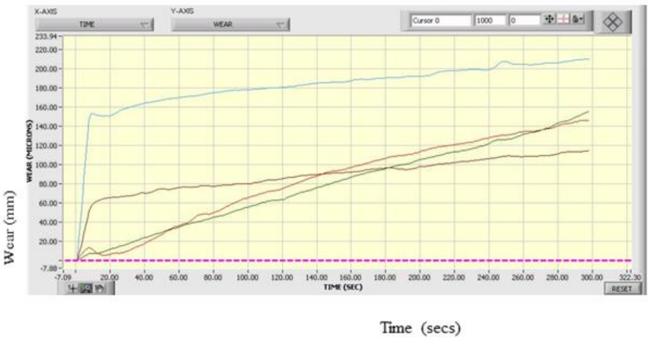
Graph 1: Shows the effect of weight fractions of Al6061+SiC+Flyash and Al6061+SiC+Redmud

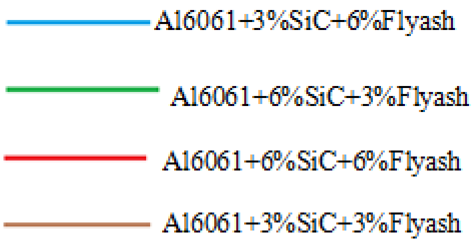


Graph 2: Shows the result of Impact test on Fly ash Samples

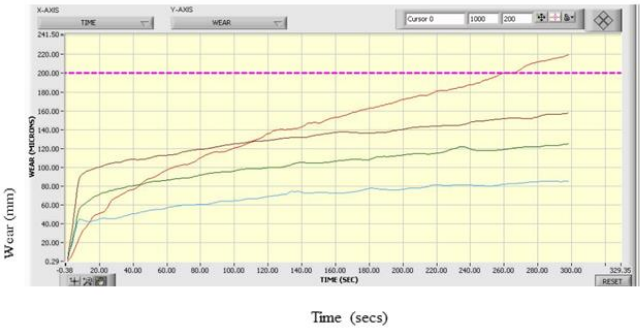


Graph 3: Shows the result of Impact test on Red mud Samples

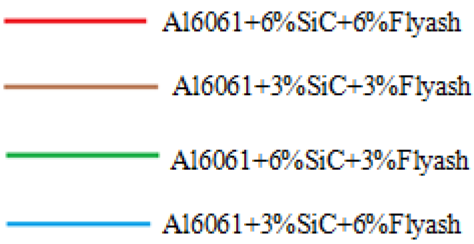




Graph 4: Shows the result of Wear test on Fly ash Samples



Graph 5: Shows the result of Wear test on the Red mud Samples



V. CONCLUSION

- Based on the experiments conducted to investigate the effects of Al6061 by adding various weight % fractions of (Sic & Fly ash) and (SiC & Redmud), the following conclusions can be made;
- Aluminium based MMCs containing Al606-SiC-Fly ash and Al6061-SiC-Redmud have been successfully fabricated by stir casting technique with fairly uniform distribution of Silicon carbide, fly ash and red mud.
- The tensile strength in Al6061+SiC+Flyash and Al6061+SiC+Redmud, is found to increase with increase in SiC weight percentage, while it decreases with increase in Fly ash and Red mud weight percentage respectively. Higher tensile strength was observed in Al6061+SiC+Flyash samples when compared with Al6061+SiC+Redmud samples.
- The impact strength in Al6061+SiC+Flyash is found increase with increase in Fly ash content. In Al6061+SiC+Redmud the impact strength is found to increase by maintaining constant weight percentage of SiC and Red mud. Higher impact strength was observed in Al6061+SiC+Flyash.
- The wear resistance of the composite Al6061-SiC-Flyash is found to higher by maintaining the constant weight percentage of SiC and Fly ash. In Al6061-SiC-Redmud wear resistance increases with increase in SiC weight percentage content.

Higher wear resistance was found in Al6061-SiC-Flyash samples when compared with Al6061-SiC-Redmud samples

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