Comparative study of Mechanical Properties of Al 7075 Reinforced with SiC & Red Mud Composite and Al 5000 series

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Abstract— The major waste material during production of alumina from bauxite by the Bayer's process is Red mud. It is an insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure is known as red mud or 'bauxite residue'. It constitute of oxides of iron, titanium, aluminium and silica along with some other minor constituents. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud. In present work experiments have been conducted under laboratory condition to assess the mechanical properties of the aluminium red mud and silicon carbide composite under different working conditions. This has been possible by fabricating the samples through stir casting technique. To enhance the mechanical properties (tensile, compressive, yield strength and microstructure), the samples were also subjected to heat treatment. Later the obtained results are compared with Al 5005 series materials which are generally used for automobile structures, finally the red mud and Al alloy composite is replaced to Al 5005 series because red mud and Al alloy composite gives good mechanical results.

Keywords: Red mud, Al5005 series, Stir casting, Mechanical properties

I. INTRODUCTION

Engineers and Manufacturing Companies are in search with New or improved materials to lower the costs and increased profit margins, the industries like automobile and transportation are significantly getting benefits from lighter materials and reusable components, as results of increasing demand for Composite Materials. Composite materials are emerging chiefly in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries. These materials have low specific gravity that makes their properties particularly superior in strength and modulus to many traditional engineering materials such as metals. As a result of intensive studies into the fundamental nature of materials and better understanding of their structure property relationship, it has become possible to develop new composite materials with improved physical and mechanical properties. These new materials include high performance composites such as Polymer matrix composites, Ceramic matrix composites and Metal matrix composites etc. today more than 200 are composite. Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. A typical composite material is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale. Generally a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material. As defined by Jartiz, Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form. Kelly very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength or resistance to heat or some other desirable quality, it is better than either of the components alone.

II. METHODOLOGY

The problem is associated with the study of mechanical properties of Al Red Mud and Silicon Carbide Metal Matrix Composite (MMC) of Aluminium alloy of grade 7075 with addition of varying weight percentage composition of Red Mud and Silicon Carbide particles by stir casting technique. The mechanical properties were tested under laboratory conditions. The change in physical and mechanical properties was taken in to consideration. For the achievement of the above, an experimental set up was prepared to facilitate the preparation of the required specimen. The aim of the experiment was to study the effect of variation of the percentage composition to predict the mechanical properties as well as to measure the micro hardness. The experiment was carried out by preparing the samples of different percentage composition by stir casting technique. A brief analysis of microstructure had been conducted by Optical Microscope to verify the dispersion of reinforcement in the matrix.

A. *Materials Used:*

The matrix used in the present study was aluminum 7075 alloy, because of its superior properties of fluidity, corrosion resistance, mechanical properties and heat treatability. Chemical composition and physical properties is shown in the Table 1 and Table 2.

The red mud used for the present investigation was brought from the aluminium refinery of HINDALCO located at Belgaum, Karnataka. Red Mud is produced from the Bayer process from bauxite, Chemical Composition of Red Mud shown in Table 3. Silicon Carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. It was originally produced by a high temperature electro chemical reaction of sand and carbon. Silicon Carbide is an excellent abrasive and has been produced and made in to grinding wheels and other abrasive products for over one hundred years. Today the material has been developed in to a high quality technical grade ceramic with very good mechanical properties, Properties of Silicon Carbide shown in Table 4.

Mg	2.244	Ti	0.048
Si	0.022	Cr	0.210
Fe	0.195	Zn	5.159
Cu	1.526	Al	REM

Table 1: Chemical Composition of Al 7075

Density	2.8gm/cm^3
Elastic modulus	70 80GPa
Tensile strength	220MPa
Hardness	60VHN
Melting Point	483^{o}C

Table 2: Physical Properties of Al 7075.

Sl. No.	Constituents	% (wt)
1	SiO_2	10.54
2	Na_2O	0.05
3	Al_2O_3	16.78
4	TiO_2	5.07
5	Fe_2O_3	25.64
6	CaO	1.51
7	ZnO	0.02

Table 3: Chemical Composition of Red Mud

Properties	Silicon Carbide
Melting point (^{o}C)	2200-2700
Hardness (kg/mm^2)	2800
Density (gm/cm^3)	3.1
Coefficient of thermal expansion	4.0
Poisson's Ratio	0.14
Colour	Grayish Black

Table 4: Properties of Silicon Carbide

B. Precautions & Limitations:

The melt was not allowed to be heated to a temperature above 800°C 855°C as aluminium fumes start emanating from the molten metal beyond 855ºC. Rigorous stirring and quick pouring of the melt into the moulds was ensured for proper blending between the matrix alloy and the particulate reinforcement due to differences in their densities. Composites with more than 15 wt. % reinforcement could not be prepared due to rejection of the melt at the mixing stage.

C. Steps Involved In Stir Casting:

- Collection and preparation of the raw material (Al 7075 alloy) by cutting the hexagonal rods in to small pieces.
- Heating the Aluminium alloy in crucible above the liquidus temperature and allow it to become completely liquid
- Stirring is initiated to homogenize the temperature and adding the reinforcement in to molten alloy
- Stirring is done according to the selected parameters and pouring the molten metal in to the mould so as to avoid the wastage of material
- Withdrawal of composite from the mould and machining the composites according to the requirements
- Samples produced is ready for different testing's

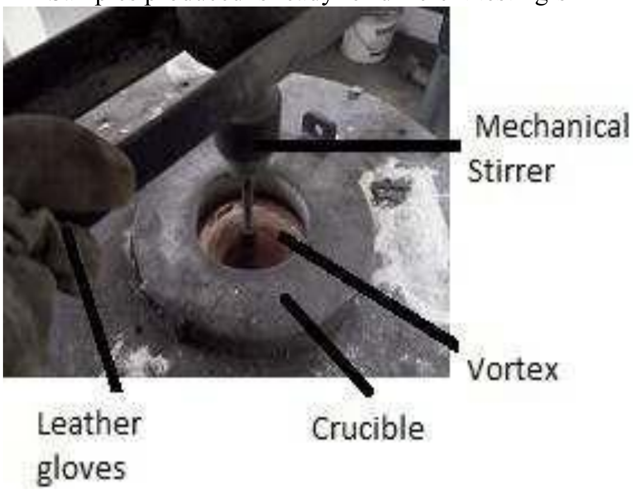

Fig. 1: Set Up of Stir Casting

Fig. 2: Molten Metal Poured out from Die Cavity

Mechanical stirrer set up is used to mix composite as per mentioned procedure which shown in fig 1. From fig 2 we observe that prepared composite from casting process brought out and for machining process to required dimensions for different testes.

D. Specimen Preparation:

The specimens are prepared with different weight percentage of reinforcement to study effect of red mud and silicon carbide. The tests performed on different types of specimens are as follows: 1) Tensile test. 2) Compression test. 3) Micro hardness test (BHN). 4) Microstructure.

E. Microstructure:

The specimens for optical microscopy were prepared according to ASTM E3 standards. The samples were first subjected to grinding and polishing followed by etching. Grinding and polishing after usual grinding and machining, the specimens were rough polished using 100, 200, 400, 600, 800 and 1200 grit silicon carbide papers. The specimens were held firmly in hand and rubbed smoothly against the SiC papers. Optical micrographs were taken using the Optical Metallurgical Microscope (reflection type), fitted with a camera. The magnification used was 100 and 500X.

F. Tensile Test:

Fig. 3: Specimens Prepared For Tensile Testing,

The tensile specimens of diameter 8.9 mm and gauge length 76 mm as shown in fig 3 were machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. Five specimens were tested and the average values of the ultimate tensile strength (UTS) and ductility (in terms of percentage elongation) were measured. All tests were conducted in accordance with ASTM standards.

G. Hardness Test:

Fig. 4: Specimen For Hardness Test.

For the Brinell hardness test the surface of the specimen on which the impression is to be made, should be smooth, clear, dry and free from oxides and scales to permit accurate measurement. Specimens for hardness are shown in fig 4.

BHN= Load/ Spherical area of indentation
= P/ (3.14 X D)/2 (D □□(D2 d2)

The hardness tests were conducted in accordance with the ASTM E10 standards A ball indenter of diameter 5 mm was used and a load of 250 Kgs was applied over the specimens of diameter 20 mm and thickness 6 mm for a period of 30 seconds. In order to minimize the error due to segregation effect of the particles, six readings were taken two each at the periphery, middle and centre.

H. Compression Test:

Fig. 5: Specimens For Compression Test

Compression tests were conducted on specimens of 20.21 mm diameter and 40 mm length machined from the cast composites, by gradually applied loads and corresponding strains were measured until failure of the specimen. The tests were conducted according to ASTM E9 at room temperatures which are shown in fig 5.

III. Results and Discussions

A. Microstructural Studies:

It is observed that in all the MMCs, Red mud particles are segregated in the interdendritic regions of Al 7075 and SiC are found as fine particles. One such typical microstructure of Al MMCs (Red mud and Silicon Carbide), revealing segregation of Red mud and SiC particles in the interdendritic regions. Fig. 6(a) & (b) shows the microstructures of interdendritic fine dispersion of Red mud and SiC in Al 7075 Composites of 2 and 4% of Red mud and SiC. It can be noted that there is a significant refinement in the grain structures at 6% SiC and 2 % Red mud combination.

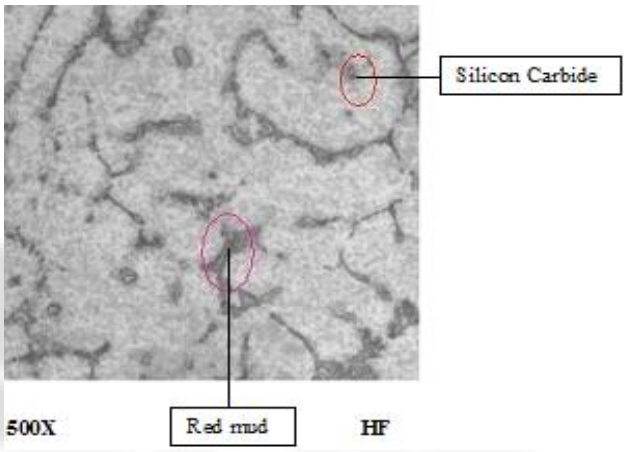

Fig. 6(a): Micro Structural Studies of Aluminium Alloy7075+6% Sic+2% Red Mud

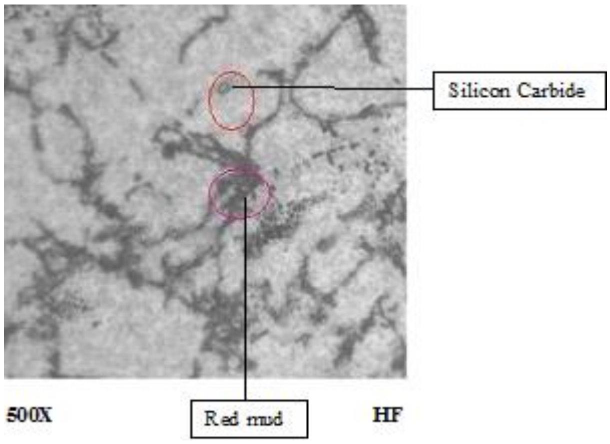

Fig. 6(b): Micro Structural Studies of Aluminium Alloy7075+4% Sic+4% Red Mud

B. Mechanical Properties:

Table 5 shows obtained results of mechanical properties of UTS, hardness, Yield strength, compression strength and percentage elongation for the Al matrix alloy, red mud and silicon carbide composites. The results of Tensile strength, Compressive strength and Yield strength for different percentage of Red mud and SiC are shown in Figure.7.

Remarkable improvement in Tensile Strength was observed at SiC 6%+Red Mud 2%+Al7075 combination. It remained almost same in the range 60-80 Mpa with the other combinations. The increase in the ultimate tensile strength of the Red mud and Silicon Carbide particulates composite could be due to the diffusion of segregated components to produce a more uniform composition is allowed by homogenization.

At 8 % of SiC the yield strength is less and is increased with addition of Red mud. High Yield Strength was observed at SiC 6%+Red Mud 2%+Al7075 combination. Further increase in the percentage of Red mud and SiC there was decrease in the Yield Strength.

The compression strength of the MMC increases with the addition of Red mud and SiC particulates percentage. The compressive strength for the SiC 8% was very less compare to other combinations. The compression strength was considerably increased with the addition Red mud particles, varying from 2 8%. The compression strength was maximum at SiC 6%+Red mud 2% combination. The reinforcement causes a high dislocation density in the matrix, resulting in improved compressive strength.

Varying Wt % Composition	Hardness (BHN)
SiC 8%+Al7075	107
SiC 6%Red Mud 2%+Al7075	121
SiC 4%+Red Mud 4%+Al7075	57.3
SiC 2%+Red Mud 6%+Al7075	95
Red Mud 8%+Al7075	69

Table 6: Results of Hardness Test For Different Varying Wt% Composition

Varying Wt % Composition	UTS	Hardness	Yield Strength	Compression strength	Elongation
	MPa	BHN	MPa	MPa	%
SiC 8%+Al7075	65.65	107	56.0	44.71	1.32
SiC 6%Red Mud 2%+Al7075	118.4	121	103.48	57.28	2.08
SiC 4%+Red Mud 4%+Al7075	77.26	57.3	68.84	50.53	1.92
SiC 2%+Red Mud 6%+Al7075	77.37	95	66.60	52.92	2.24
Red mud 8%+Al7075	59.92	69	51.01	47.05	2.26

Table 5: Mechanical Properties of Al/ Red Mud And Sic Composite

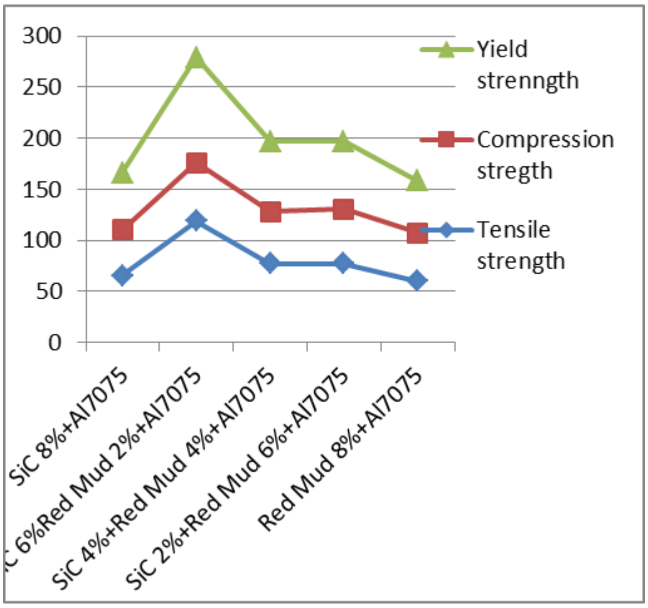

Fig. 7: variations in tensile, compressive and yield strength for different wt% composition of SiC and red mud composite.

It has been reported previously that the addition of SiC particulate brings about considerable increase in hardness of the composite. The increase in hardness is to be expected because SiC and Red mud particulates are very hard which act as barriers to the movement of dislocations within the matrix and exhibit greater resistance to indentation of the hardness tester. Hardness was found to be maximum with SiC 6%+Red Mud 2%+Al7075 combination. Which is Shown in table 6

C. Aluminium Alloy 5000 Series:

Aluminium Alloy 5005 is the most suitable grade of Aluminium for anodizing. AL 5000 is a medium strength alloy with very good resistance to atmospheric corrosion and very good weldability that is highly suitable for decorative anodizing. These AL 5005 series materials generally used in Manufacture of appliances, small boats Signage, Road Signs & Name Plates, Food & Chemical Equipment, Anodized Parts, Packaging, Architectural components, Furniture. Main these materials used comparability and light in weight because these have good malleability more likely these are easily available and economically less compared to other Al alloys .

Tensile strength, Compression strength, Yield strength, Hardness of a Composite Material (AL7075 reinforced with SIC & Red Mud composite) is quite higher than the AL5000 Series; So AL5000 can be replaced by AL7075. Which as been shown in table 8.

Property	Value
Density	2.70 g/cm^2
Melting Point	655 ^{0}C
Modulus of Expansion	23.5×10^{-6}/K
Modulus of Elasticity	69.5 GPa
Thermal Conductivity	201 W/m.K
Electrical Resistivity	0.033×10^{-6} Ω.m

Table 7: Generic Physical Properties

The some of important properties of Al5005 series materials such as density, Modulus of Elasticity, Melting Point, etc. are given in table 7.

	TENSILE STRENTH (Mpa)	COMPRESSION STRENTH (Mpa)	YIELD STRENTH (Mpa)	HARDNESS (BHN)
Al 7075 (composite)	118	57.28	103	121
Al 5000	105-115	40-60	90-110	47

Table 8: Comparison of Mechanical Properties of Al7075 Reinforced With Sic & Red Mud Composite with Al5000 Series.

IV. CONCLUSIONS

The general conclusion that is revealed from the present work is that by the combination of a matrix material with reinforcement such as SiC and Red mud particles, it improves mechanical properties like tensile strength, compressive strength, hardness and yield strength.

From the graph it is clearly seen that with the composition of 6% of SiC and 2% of red mud, the mechanical properties have been considerably increased.

The microstructure studies indicate the presence of Aluminium dendrite like structure with fine inter metallic particles of SiC and Red mud reinforced in between.

Al 7075 composite have higher tensile, compression strength and higher in hardness while compared to Al5000 series. Hence Al7075 can be replaced with Al5000 for automobile works.

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