International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Characterisation of Aluminium Alloy (Lm6) Metal Matrix Composite Reinforced With Copper Slag/Ferro Sand

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Abstract: ***Metal matrix composites are found to be one of the promising materials for advanced engineering application. It now has been produced commercially. Recent researches have shown an increased affinity towards the usage of agricultural waste as well as industrial waste as a reinforcement in the composite production which will have a momentous impact on the cost effectiveness of the composite manufacturing. This also will help in sustainable waste management. One of such industrial waste is Copper slag (CS), huge quantity of waste is left as land fill, the compositions of the CS is commensurable to the composition of the fly ash. This entailed using CS as the reinforcement in this composite Fabrication. In this work Aluminium alloy is reinforced with CS to produce a metal matrix composite using stir casting process, as it is one of the cost effective and efficient method of making ALMMC. All the samples are prepared as per ASTM standards and the properties such as Tensile strength, Elongation, Micro Hardness, Specific wear rate, Wear rate and microstructures are examined.***

Keywords: Copper Slag, LM6 Aluminium Alloy, Stir casting.

I. INTRODUCTION

The introduction of various composites and the cost-effective manufacturing methods attract manufacturers to use the composite materials in the commercial applications as well. The reinforcement in the composites helps in improving the specific strength, wear resistance, stiffness, creep and fatigue property of the conventional monolithic engineering material [1].Aluminium alloy is one of the most preferred material for composite fabrication as the mechanical properties and the low melting point makes it a perfect material for stir casting. Composites usage is on the increasing scale for the past three decades mainly in the automobile industry. As far as the ability of the aluminium metal matrix composite to be used in the automobile industry the main aspect the comes into play is the cost-effectiveness of the material, the material is to compete with ferrous alloy. A study has been done on this aspect to check the cost-effectiveness that aluminium composites bring in to play when compared it with its ferrous components, the availability of technical information for the design engineers plays a vital.

Manuscript published on 30 August 2019.
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The Metal matrix composite(MMC) material is still under research state makes it challenging for the design engineers to interpret the reliability of the material as it will replace many of the crucial parts in the automobiles[2][3].
MMCs are also used in aerospace industries for its low weight which contribute for weight reduction which in turn reduces fuel consumption that also will reduce the carbon foot print[4]. The agricultural and industrial wastes are gaining attention among the researchers to be used as the reinforcement phase in manufacturing of Al metal matrix composites[5][6]. This not only helps in reducing the cost of the material but also will help in reducing the waste in the environment thereby contributing to reducing the waste that is a potential threat to the environment. It also helps in sustainable waste management which is one of the most prioritized aspects in the modern world. Many researchers are trying to develop composite materials with many agricultural waste materials but some of the industrial wastes draws less attention. One of the industrial waste materials that attracted the attention of the scholars is fly ash. It was used as a mixture in the cement manufacturing and brick making because of the researches carried out on the fly ash it as the reinforcement in the hybrid composite making now it has found its engineering application, thereby it is now seen as a value-added material[7] [8]. CS is a residue of smelting of copper, the major constituent of copper slag is Fe_2O_3 and SiO_2. The appearance of CS is crystalline and glassy. CS is used in high strength concrete manufacturing and as an abrasive particle for sand blasting but about 80% of the quantity produced is left as land fill which is leading to environmental issues. The particulate reinforced material can be perfectly tailored to provide for the asking stringent demand that the modern engineering applications demand. [9]. This encouraged to use CS as a reinforcement in this work. The composite for this work is fabricated using stir casting method, as Stir casting is one of a widely preferred method for casting of particulate reinforced aluminium composites, it is one of the liquid state processing methods[10][11]. The important parameters for stir casting are stirring speed and stirring time[12][13]. The stirring speed is selected as 600 rpm and stirring time is selected as 10 min as it will provide even distribution of reinforcement in the material which will give superior mechanical properties[14]. As it helps in improving the wettability of the reinforcement with the matrix material[15] [16]. Magnesium is also one of the material that is added as an additive in the fabrication of

aluminium composites to improve the wettability of the reinforcement with the matrix[7][17] [18].

LM6 Aluminium alloy is selected for the matrix. LM6 Aluminium alloy is one of the most preferred material in an automobile as well as aerospace industries as it possesses the mechanical properties that are preferred in those industries owing to the materials high thermal conductivity as well as low weight. The process of manufacturing is comparatively simple for the material. It is a non-heat treatable casting alloy which also enhances the simplicity of the fabricating the cast. So LM6 Aluminium alloy is selected as the base material for the composite. Even though LM6 is used in stir cast composites, CS is used in high strength concrete making and as abrasive for sand blasting. But it is not tested with Metal Matrix Composites. The composition of CS (table 2) which is comparable to that of the fly ash encouraged to use it as a reinforcement in this composite fabrication. CompositionTable below shows the composition of the Aluminium alloy used.

Table 1 Composition of LM6 Aluminium Alloy

Element	Si	Fe	Cu	Mg	Pb	Ni
wt.%	10	0.6	0.1	0.1	0.1	0.1

Table 2 showcase the composition of the CS; it has a black and glassy appearance.

Constituent	Fe_2O_3	SiO_2	CaO	Al_2O_3	Cu
wt.%	55	27	3	3	Traces

II. EXPERIMENTAL SETUP

2.1 Stir casting

LM6 Aluminium alloy is the base material and CS as the reinforcement. The base material is heated to 710^0 c and the reinforcement is preheated to 550° c to remove the moisture content. Then the melt is stirred with a stainless-steel stirrer for 10min, while the reinforcement is gradually added into the melt. The mold is preheated to 500° c, then the thoroughly mixed mixture is poured into the preheated metal die. The cast is taken out when the mold cools off. The same procedure is repeated for all the 4 melts with varying wt.% of the reinforcements.

2.2 Tensile test

The specimen for the tensile test is prepared as per ASTM – B557 standard. The sample is prepared in centre lathe. The prepared sample is loaded in "TINIUS OLESEN" universal testing machine (UTM), and the samples with varying wt.%CS is tested and the values are noted.

2.3 Hardness test

Mitutoyo MVK-H11 micro hardness tester is used for micro hardness study[21], the load applied is 100kfg for 15 sec. the sample dimensions are 10x10x10mm and is polished to a mirror finish. And the results are noted.

2.4 Wear test

The specimen for wear test is prepared as per ASTM G99 standard[19][20]. The sample is prepared using centre lathe. The wear test is carried out using "DUCOM (TR-20LE-PHM-200)" machine. Tests are carried with 2kgand 3kg load, the track diameter is set as 100mm, the disc speed is set as 1000rpm and the test is run for 10 min.

Table 3 Wear Test Parameters For Various Wt.% Of CSAMM

Set number	Parameters			
	Disc speed (Rpm)	Load (N)	Track diameter(mm)	Time (min)
1	1000	20	100	5
2	1000	30	110	5

2.5 Microstructural investigation

ZEISS AXIOVERT 25CA inverted metallurgical microscope is used to study the microstructure of the samples, the dimensions of sample for microstructure is 10x10x10mm, it is polished to a mirror finish and etched using Keller's reagent.

III. RESULT AND DISCUSSION

3.1 Tensile Strength and Elongation

The fig1 and 2 shows the Tensile Strength and Elongation test values of the Copper Slag reinforced Aluminium Metal Matrix Composites (**CSAMMC**). The tensile test reveals that the CS decreases the tensile (Fig 1)

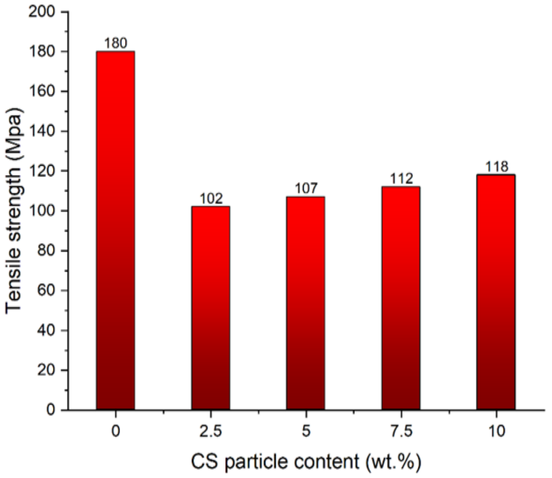

Fig 1 Tensile Strength of various wt.% of CSAMMC

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DOI: 10.35940/ijitee.J9749.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

strength of the LM6 base material, the trend is linear, the 10wt.% reinforced sample shows tensile strength of about Table 4 Tensile Strength of various wt.% of CSAMMC 118Mpa. The tensile strength of the base material is 180Mpa and it shows a reduction of 10.84% in elongation

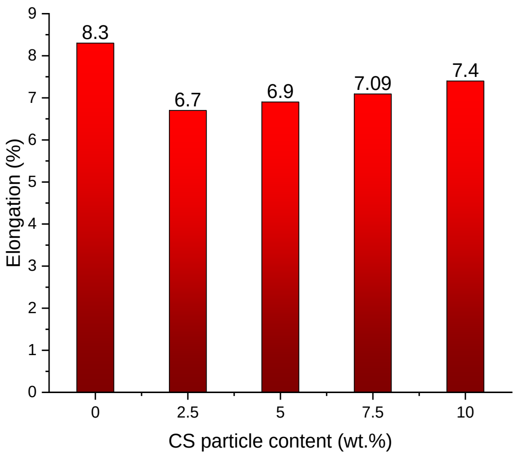

fig 2.

Fig 2 % Elongation of various wt.% CSAMMC

The elongation of the CS reinforced, and the base material

CS particle content(wt.%)	0	2.5	5	7.5	10
Tensile strength(Mpa)	180	102	107	112	118

Table 4 Tensile Strength of various wt.% of CSAMMC

are shown in the fig2, overall there is a reduction in the elongation when compared to the base material. The highest reduction was observed with 2.5wt.% CS reinforce composite which showed a reduction in elongation of about 19.27%.

3.2 Hardness test

The fig 3 shows test values for various wt.% CSAMMC.

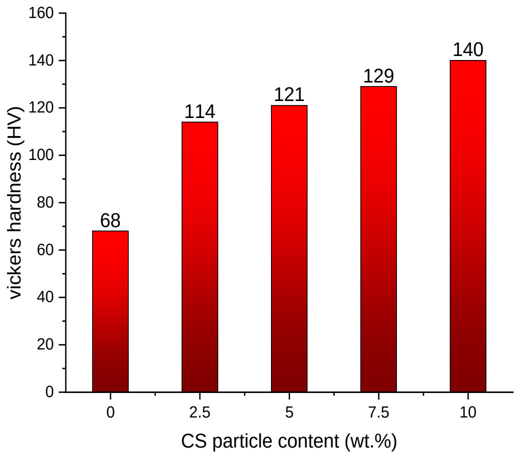

Fig 3 Vickers hardness values of various wt.% of CSAMMC

The hardness of the 10wt.% CS reinforced AMMC is 140HV, it is 105% increase over the hardness of the base material.

CS particle content(wt.%)	Set no.	0	2.5	5	7.5	10
Wear rate(mm3 /Nm)	1(20N)	3.94e-06	3.31e-06	3.12e-06	2.48e-06	1.97e-06
Wear rate(mm3 /Nm)	2(30N)	4.20e-06	3.56e-06	3.18e-06	2.80e-06	2.10e-06

CS particle content(wt.%)	0	2.5	5	7.5	10
Tensile strength(Mpa)	180	102	107	112	118

Table 5 Vickers hardness values of various wt.% of CSAMMC

CS particle content(wt.%)	0	2.5	5	7.5	10
Vickers hardness(HV)	68	114	121	129	140

The hardness value for the various wt.% CS reinforced AMMC are all higher than the base material and it is in ascending trend

3.3 specific wear rate

Two set of tests were taken with varying the load, keeping Time, Disc speed and the track diameter constant.

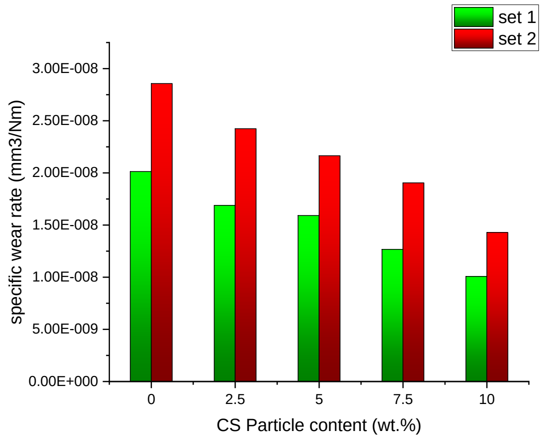

Fig 4 Specific Wear Rate Of Various Wt.% Of CSAMMC

It is found that the specific wear rate of 10 wt.% CSAMMC is 50% less when compared to the base material.

Table 6 specific wear rate of various wt.% of CSAMMC

CS particle content(wt.%)	Set no.	0	2.5	5	7.5	10
Specific wear rate(mm3/Nm)	1 (20N)	2.01e-08	1.68e-08	1.59e-08	1.26e-08	1.00e-08
Specific wear rate(mm3/Nm)	2 (30N)	2.85e-08	2.42e-08	2.16e-08	1.90e-08	1.42e-08

3.4 Wear rate

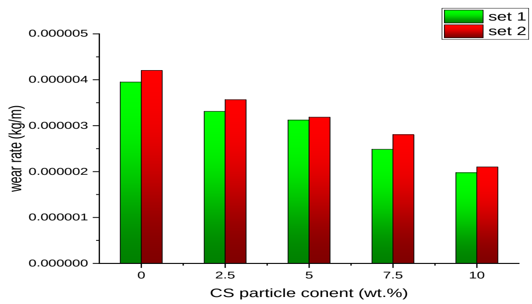

Fig 5 wear rate of various wt.% of CSAMMC

The wear rate of the 10 wt.% CSAMMC is the lowest with a reduction of about 50% when compared to base material.

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DOI: 10.35940/ijitee.J9749.0881019
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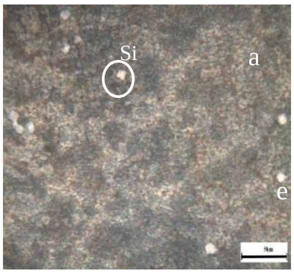
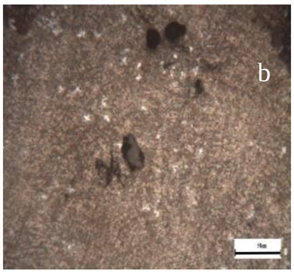
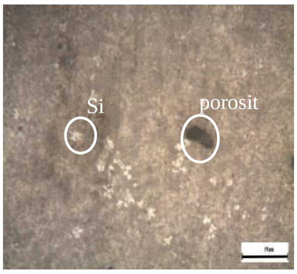
Table 7 wear rate of various wt.% of CSAMMC

3.5. Microstructure:







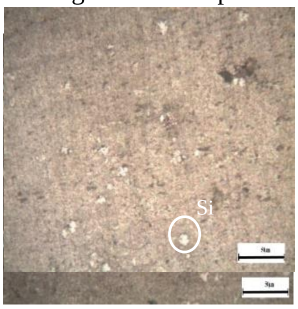


Fig 6 Microstructures of (a) base material, (b) 2.5 wt.%, (c) 5wt.%, (d)7.5wt.% & (e)10wt.% of CSAMMCs

The light circular spots are the Silicon which accounts for about 10wt% of the base material is visible clearly fig5a, b, c, d and e. The Dark spot on the fig 5 (e) shows the presence of porosity in the castings.

IV. CONCLUSION & FUTURE SCOPE

- The Tensile strength of the various wt.% CS reinforced AMMC is in ascending order linearly, the highest tensile strength is observed at 10wt.% of the CS, the value observed is 118Mpa. The trend may keep moving in the same pace it can't be concluded as the experiment is conducted using 2.5wt.%, 5wt.%, 7.5wt.% and 10wt.%. So further research by increasing the CS content will help in deciding the trend. But overall the values are very low when compared to the base material. There is an average tensile strength reduction of about 39.02%, when compared to the base material.
- The Impact strength for all the variants is higher than that of the base material, the 7.5wt.%CSAMMC showed highest improvement in impact strength, the impact strength increased about 20.7% when compared to the impact strength of the base material.
- It is found that the specific wear rate and the wear rate of 10 wt.% CSAMMC is 50% less when compared to the base material.
- The hardness expressed an increasing trend as the highest hardness was with the 10wt.% reinforced AMMC, the hardness value observed is 140HV, which is 105% increase over the hardness of the base material.
- This experiment shows that CS can be used as a reinforcement material in composite manufacturing, it will help in reducing the composite

cost as well as provides engineering application to a waste that is left as land fill. Further research on CS will help in optimizing the processing parameter and which will help CS to enter mass producing composite manufacturers.

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