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Research Article

Study on Mechanical and Microstructure Properties of LM6 Metal Matrix Composite with PbO Glass Reinforcement

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Abstract

In this study, the metal–matrix composites of an aluminum–silicon based alloy (LM6) with Lead oxide glass particles with % addition of 2.5%, 5%, 7.5%, and 10% were produced using a sand casting technique. The variation in composition, hardness, tensile strength and microstructure properties were examined. The change in volume of Silicon and lead content was examined in the spectroscopic analysis. The tensile strength and hardness of the composite increased with increasing the % reinforcement. The microstructure shows the formation silicon dendrites and the dispersion of the glass particle.

Keywords: *PbO Glass; Aluminum–silicon; metal matrix composite; microstructure;*

1. Introduction

LM6 alloy is a eutectic alloy which is having a major composition of 85.95% of aluminium and 11% to 13% of silicon. Its ability to resist hot cracking, pressure tightness, die-filling capacity, and corrosion resistance makes it as a commonly used alloy for automotive as well as the aeronautical applications (Sourav Kayal, *et al*, 2012). Applications of Aluminum-based MMCs have increased in recent years as engineering materials. The introduction of a ceramic material into a metal matrix produces a composite material that results in an attractive combination of physical mechanical properties which cannot be obtained with monolithic alloys.

When producing a metal matrix composite cost is the main factor for their wider application in automotive and aerospace industries, although the potential benefits in weight saving, increased component life, and improved recyclability should be taken into account. Today, even in those terms, MMCs are still significantly more expensive than their competitors. Only simpler fabrication methods, higher production volumes, and use of cheaper reinforcements can reduce the cost of MMCs (Madhu Kumar YC, *et al*, 2012).

In the past, several studies have been carried out on metal matrix composites. SiC, TiC and TaC are the most commonly used particulates to reinforce in the metal or in the alloy matrix or in the matrices like aluminium or iron (S. Rama Rao, *et al*, 2012). while the study of PbO glass reinforcement in LM6 alloy are rare. PbO glass is easily available and will significantly reduce the cost MMCs which make this study a significant one.

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The present study investigates on the mechanical and microstructural properties of PbO glass particulate reinforced LM6 alloy matrix composites with different volume fractions. The test samples were fabricated by the sand casting method.

2. Experimental procedure

The chemical composition of LM6 aluminium alloy is given in table 1. The required aluminium Metal Matrix specimens are prepared by the sand casting technique with 0%, 2.5%, 5%, 7.5%, and 10% of lead oxide glass reinforcement material.

Table 1: Chemical composition of PbO glass

Chemical composition	Weight %
Copper	0.1 max
Magnesium	0.10 max
Silicon	10.0-13.0
Iron	0.6 max
Manganese	0.5 max
Nickel	0.1 max
Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminum	Remainder

The chemical composition of lead oxide glass is given in table 2. The aluminum alloy was melted in a crucible by heating it in a furnace at 800°C for three to four hours. The lead oxide glass particles were heated at 800oC to 700oC for one to three hours to make their surfaces oxidized. The molten melt is poured in the cylindrical mould for the

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development of the required samples. Mechanical stirrer is used for the homogeneous distribution of the lead oxide glass throughout the melt.

Table 2: Chemical composition of PbO glass

Chemical composition	Weight (%)
Silica	59
Soda (Na_2O)	2
Lead oxide (PbO)	25
Potassium oxide (K_2O)	12
Alumina (Al_2O_3)	0.4
Zinc oxide (ZnO)	1.5

Tensile test specimen and with hardness test specimen dimensions respectively were cut from the cast composite. For tensile test the specimens of dimensions 300 mm × 25 mm (L×D) are prepared for various volume fractions. The tensile tests for various specimens were carried out at room temperature using Universal Testing Machine (UTM). The brinell hardness test was carried out on various MMC samples of size 20 mm x 25 mm (Lx D) with a load of 187.5 kg and using a ball indenter of 2.5 mm in diameter.

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where,
P is the load (in kgf),
D is the ball diameter (in mm),
d is the diameter of the indentation (in mm).

Spectroscopy analysis was done to find out the chemical change by the addition of the PbO glass reinforcement by using the equipment "Metal Scan 2500 series" which is manufactured by the ARUN TECHNOLOGY, UK. Optical microscope is used to study the general structure and the dispersion of the reinforcement in the metal matrix. The specimen is prepared to a size of 20 mm x 20 mm by using various grade emery papers, diamond paste and a disc polishing machine.

3. Results

Various test results that are conducted on MMC are

3.1 Tensile test

Table 3: Variation in tensile strength

% reinforcement of pbO glass	Ultimate tensile strength (MPa)
0%	73.88
2.5%	92.37
5%	96.07
7.5%	107.15

Table 3 shows the variation in ultimate tensile strength values of LM6 MMC with various reinforcements. The tensile strength of the MMC increase with an increase in the % reinforcement up to 7.5 % after that it reduces. The decrease in the UTS of MMCs with increasing PbO glass particle content may be due to the fracture of pbO glass particle during tensile loading. On the other hand, PbO glass particles in this study have sharp corner shape. These shaped particles behave like a notch effect and decrease the UTS.

Figure 1 shows the variation of tensile strength with increasing the % addition of the PbO glass reinforcement.

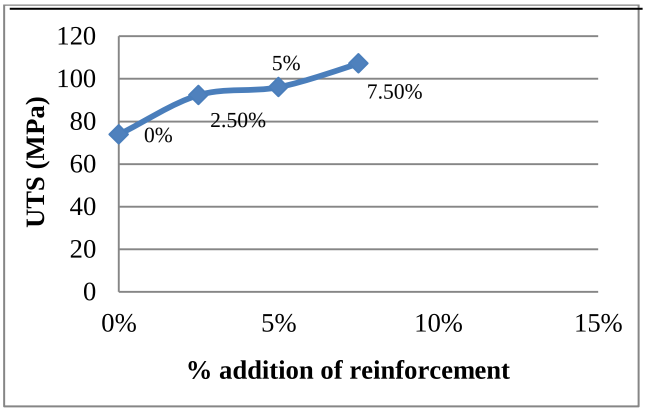

Figure 1: Variation of Tensile strength

3.2 hardness test

The brinnel hardness test machine is used for the hardness measurement. The Load applied for the hardness test was 187.5 kgf at dwell time 30 seconds for each sample. The result of the Brinell hardness test for various different reinforcements such as lead oxide glass and Al alloy LM6 are shown in the table.

Table 4: variation in hardness

% reinforcement of PbO glass	Brinell hardness number (HB)
2.5%	107.10
5.0%	109.23
7.5%	110.67
10.0%	120.48

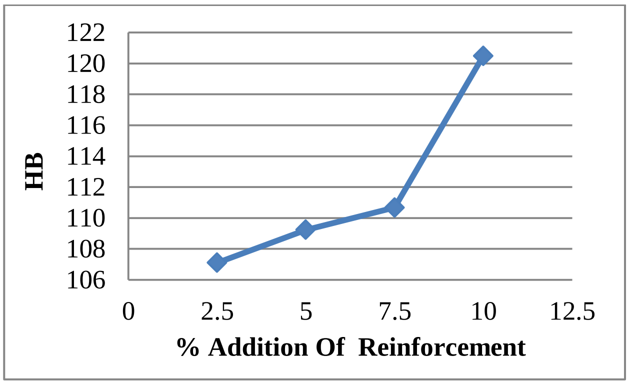

Figure 2: Variation of hardness

The hardness of the metal matrix component increases with increase in PbO glass reinforcement. It reaches maximum at 10% PbO Glass reinforcement. The figure 2 shows the variation of brinell hardness number with increasing % of pbO glass reinforcement. The steep increase in 10% is may be due to the transformation from eutectic phase to hypereutectic phase.

3.3 Spectro analysis test

Spectrometer is used for analysis the variation in chemical composition of the MMC. The major change of variation occurred in the composition of Pb and Si. The results are given in table 5.

Table 5: Variation in Pb and Si

% reinforcement of pbO glass	% Variation in Pb	% Variation in Si
0%	0.157	12.1
2.5%	0.404	12.3
5.0%	0.413	12.6
7.5%	0.501	12.9
10%	0.871	13.1

From the spectroscopic analysis it is found that the silicon content in the metal matrix component increases with increase in PbO glass reinforcement. As silicon content increase the cast ability and hardness also increase. At 10 % of lead oxide glass addition the silicon content increase beyond 13% and this will tend to form a hypereutectic structure in the metal matrix composite

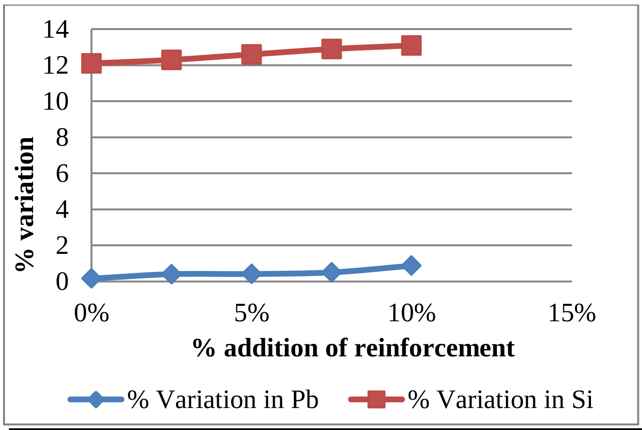

Figure 3: Variation in Pb and Si

The lead content in the metal matrix increases with increase in lead oxide glass reinforcement. The addition of lead improves machinability and hence possesses free-machining characteristics. These constituents form low melting point compounds in the LM6 alloys that readily melt or soften due to the friction heat created during machining. Thus, material removal required for the manufacture of complex parts and components is easily facilitated.

3.4 Microstructure analysis

The microstructure of the each sample having %variation of pbO glass ranging from 2.5%, 5%, 7.5%, 10% are obtained using a metallographic microscope at the magnification level of 100x. 200x, 500x.

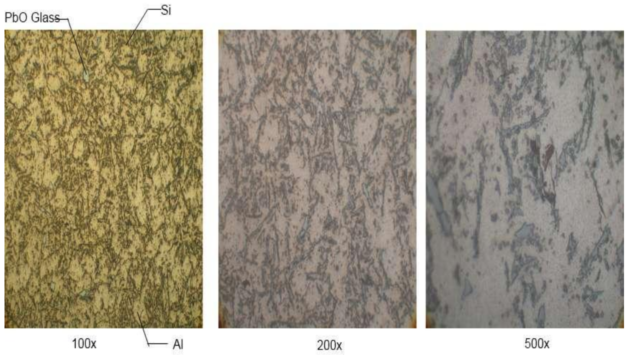

Figure 3: Microstructure of sand cast Al metal matrix composite with 2.5% of Lead glass

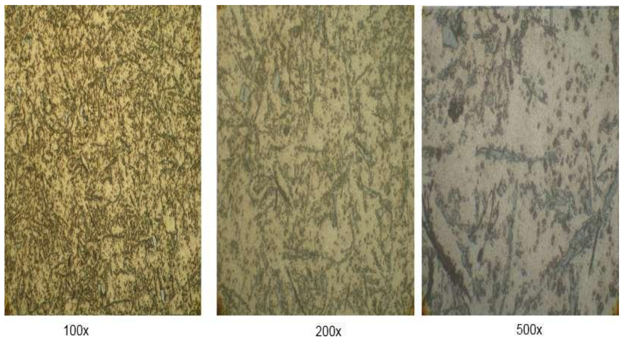

Figure 4: Microstructure of sand cast Al metal matrix composite with 5.0% of Lead glass

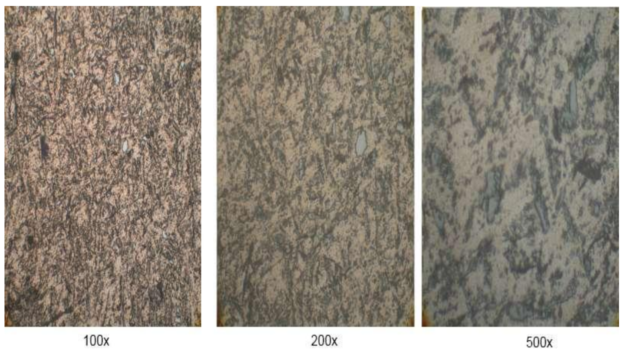

Figure 5: Microstructure of sand cast Al metal matrix composite with 7.5% of Lead glass

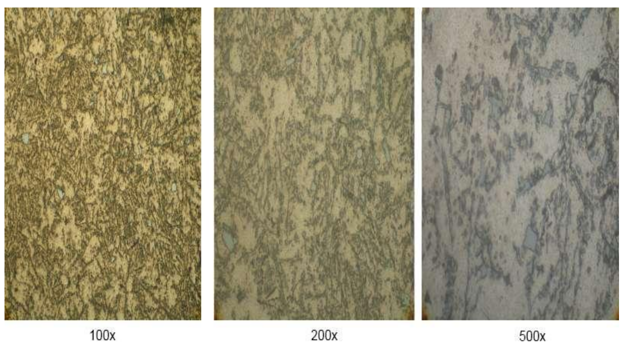

Figure 6: Microstructure of sand cast Al metal matrix composite with 10.0% of Lead glass

From the microstructure analysis it is observed that the lead oxide glass not dispersed uniformly in the aluminium matrix phase. Some amount of segregation was happened due to the density differences while solidifying. It also shows that the silicon is present in the form of network structure which surrounds by the aluminium matrix. As the reinforcement amount increases the glass particles are aligned closer to each other which increase the tendency of the propagation of the cracks.

Conclusions

The addition of lead oxide glass increases the mechanical properties such as hardness and tensile strength of the of the aluminium metal matrix composite. Spectro analysis shows that increasing the amount of PbO reinforcement will increase the Si as well as Pb content in the metal matrix material. The silicon content provides better castability to the metal matrix composite and the increase in lead provides better machinability. The micro structure study shows that the generation of Si dendrites in the Aluminium matrix and also shows the non-uniform dispersion of the PbO glass by the use of the sand cast technique.

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