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The Effects of Processing Route on Mechanical and Microstructure Properties of Aluminium Metal Matrix Composite

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***Abstract*: The work focuses on sand casing and stir casing methods which are the most common fabrication methods for the production of aluminium based metal matrix composite and its effects on the mechanical properties such as tensile strength, compressive strength hardness and wear behavior of produced AMMC. The cost of the MMC is one of the main factor that defines the area of application. The properties of the MMC is also depends on the selection of the production method. From the analysis, it is found that the superior mechanical properties are achieved from the samples made by using stir casting method. Microstructure study reveals that the stir casting method produces a homogeneous distribution of PbO glass reinforcement in the LM 6 matrix.**

***Keywords*: AMMC, Sand Casting, Stir casting, PbO glass, Mechanical properties.**

1. Introduction

A composite materials are made from combining two or more constituent materials with significantly different physical or chemical properties. They remain separate and distinct within the finished structure, then work together to give the composite unique characteristics that are different from the individual components. Due to the superior properties, Metal matrix composites (MMCs) are widely used in the fields of aerospace, automotive, nuclear, biotechnology, electronics and sporting goods industries. MMCs consist of a non-metallic reinforcement which is commonly harder compared to soft metallic matrix. This can provide advantageous properties over base metal alloys. These include improved thermal conductivity, abrasion resistance, creep resistance, dimensional stability, exceptionally good stiffness-to-weight and strength-to weight ratios. They also have better high temperature performance [1]. Composite materials can be subdivided into three main groups: Polymer, Ceramics and Metals. Reinforcements added to these materials produce Polymer Matrix Composites (PMC), Ceramic Matrix Composites (CMC) and Metal Matrix Composites (MMC). Among different composites, Metal–matrix composites are the most widely used in the industrial scale due to its advantages compared to Polymer Matrix Composites and Ceramic Matrix Composites. After iron, aluminium is now the second most widely used metal in the world. This is because aluminium has a unique combination of attractive properties. Low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity, etc. Aluminium metal matrix composites are produced by combining tough metallic matrix with hard ceramic or soft reinforcement materials. The reinforcement materials systems can be generally divided into five major categories, i.e. particulates, wires, continuous fibers, discontinuous fibers, and whiskers.

2. Materials and method

Matrix is a relatively 'soft' phase with specific physical and mechanical properties, whose sole purpose is to bind the reinforcements together by virtue of its cohesive and adhesive characteristics, to transfer load to and between reinforcements. The reinforcement phase (or phases) have been usually stronger and stiffer than the matrix and mainly carries the applied load to the composite.

A. LM 6

Table 1
Chemical Composition of LM6

Material	Percentage
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.
Aluminum	Remainder
Titanium	0.2 max

LM6 alloy is actually a eutectic alloy having the lowest melting point that can be seen from the Al–Si phase diagram. The main composition of LM6 is about 85.95% of aluminium, 11% to 13% of silicon. One of the main drawbacks of this material system is that they exhibit poor tribological properties. Hence the desire in the engineering community to develop a new material with greater wear resistance and better tribological properties, without much compromising on the strength to weight ratio led to the development of metal matrix composites. Chemical composition of LM6 aluminum alloy as shown in Table 1.

B. PbO glass reinforcement

Lead glass is a variety of glass in which lead replaces the calcium content ofa typicall potash glass. Lead glass contains typically 18–40 weight% lead oxide (PbO), while modern lead crystal, historically also known as flint glass due to the original silica source, contains a minimum of 24% PbO. Lead glass is desirable owing to its decorative properties. The chemical composition of lead oxide glass is given in Table 2.

Table 2
Chemical Composition of PbO glass

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

C. Processing of metal matrix composites

Metal-matrix composites can be processed by several techniques. Liquid phase processes, solid state processes, and, two phase (solid-liquid) processes are the some of the method. Among these liquid state fabrication processes are most commonly used for the production of AMMC. Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide a high level of mechanical properties of the composite, good interfacial bonding between the dispersed phase and the liquid matrix should be obtained. The liquid metallurgy process, the particles are added above the liquid temperature of the molten alloy. Among different liquid state fabrication processes sand casting and stir casting method are compared in this paper.

D. Sand casting technique

In this method the cylindrical mould of dia 25mm × length 300 mm and a plate die of dimensions 10 × 10 × 100mm were made by Green sand. The crushed PbO glass of definite quantity is prepared by using a ball mill and weighing machine. 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 into the cylindrical mould for the development of the required samples. Manual stirring is done to get a homogeneous distribution of the lead oxide glass throughout the melt.

E. Stir casting technique

In this method the cylindrical die of dia 25mm and length 200 mm and a plate die of dimensions 10 × 10 × 100mm ware made by Green sand. The crushed PbO glass (105µm) of definite quantity is prepared by using a ball mill and weighing machine. The Glass particle was preheated to 400˚C for 30 min to remove moisture in the Pre – heating chamber. LM 6 was melted in a resistance furnace where the furnace temperature was raised up to 850˚C. The melt was stirred with the help of a stainless steel stirrer. The stirring was maintained between 5 to 6 min at an impeller speed of 300 rpm. Then the crucible were taken out and poured the homogeneous mixture in the prepared die.

3. Experimental procedure

The specimens for different tests are prepared as per ASTM standards for material testing. The tensile test specimens are prepared as per the standard ASTM B557 to conduct the test at room temperature. The impact test specimens are made according to ASTM standard E23 and the hardness test is conducted on the Rockwell hardness testing machine. The specimen for the test is prepared (dia 20mm and length 20 mm) from the cast samples and the surface were ground using a grinding machine. The indenter has 1.588 mm diameter and a force of 100 Kgf was applied on the surface for 30 Sec.

4. Results and discussions

A. Density analysis

From the density analysis, it's clear that the addition of PbO glass increases the density of the MMC as the % reinforcement of the glass increases. The sample made by using sand casting have less density compared to the specimens made by using stir casting. This is because of the sand samples have higher porosity comparing to stir cast samples. The results of density analysis are shown in the Table 3.

Table 3
Density vs. Percentage of Reinforcement

S. No	Composition	Density of sand cast sample	Density of stir cast sample
1	LM 6 + 0.0% PbO Glass	2.67	2.68
2	LM 6 + 2.5% PbO Glass	2.68	2.69
3	LM 6 + 5.0% PbO Glass	2.69	2.70
4	LM 6 + 7.5% PbO Glass	2.70	2.71
5	LM 6 + 10.0% PbO Glass	2.71	2.72

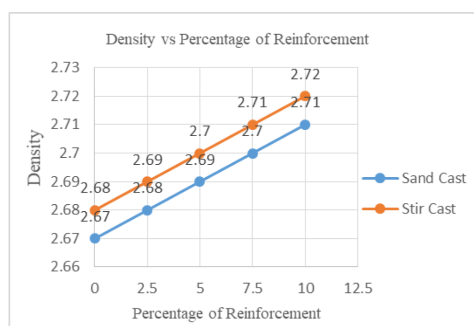

Fig. 1. Density vs. Percentage of Reinforcement

B. Tensile strength

The variation in the tensile strength and compressive strength by adding different percentage of reinforcement is shown in the Table 4. It shows that the addition of reinforcement material increases as the tensile strength and compressive strength as percentage reinforcement reaches 7.5% and then decreases. Stir cast samples have better tensile strength due to homogenous distribution of PbO glass which prevents the clustering of reinforcement and very low porosity.

Table 4
Tensile and Compressive strength vs. Percentage of Reinforcement

S. No	Composition	Tensile strength of sand cast samples(MPa)	Tensile strength of stir cast samples (MPa)
1	LM 6 + 0.0% PbO Glass	74.88	82.18
2	LM 6 + 2.5% PbO Glass	93.51.	98.44
3	LM 6 + 5.0% PbO Glass	98.12	106.43
4	LM 6 + 7.5% PbO Glass	108.74	120.47
5	LM 6 + 10.0% PbO Glass	100.67	110.70

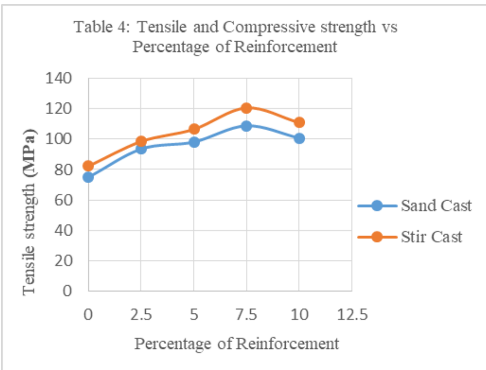

Fig. 2. Tensile and Compressive strength vs. Percentage of Reinforcement

C. *Impact strength*

Table 5
Energy absorbed vs. Percentage of Reinforcement

S. No	Composition	Energy absorbed by sand cast samples (J)	Energy absorbed stir cast samples (J)
1	LM 6 + 0.0% PbO Glass	3.9	4.1
2	LM 6 + 2.5% PbO Glass	4.2	4.7
3	LM 6 + 5.0% PbO Glass	4.4	5.0
4	LM 6 + 7.5% PbO Glass	5.3	5.9
5	LM 6 + 10.0% PbO Glass	5.0	5.3

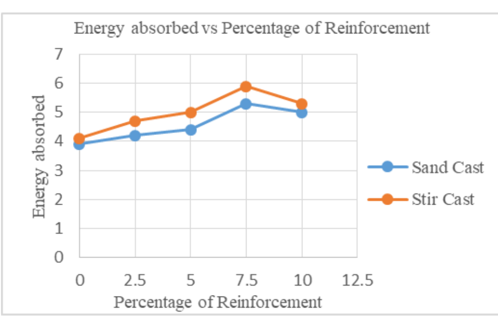

Fig. 3. Energy absorbed vs. Percentage of Reinforcement

Impact tests are used in studying the toughness of the material and values is recorded and shown in Table 5. The impact test specimens were made as per the ASTM standard E23. The notches on the sample were cut by using the milling machine. From the results it can be seen that the stir cast sample has superior impact strength and has maximum value at 7.5 % of reinforcement in both cases. Due to the clustering of reinforcement particles in sand cast specimen the crack propagates easily.

D. *Hardness measurements*

The hardness of matrix metal enhances due to reinforcement of PbO glass particles with it. Hardness test has conducted on each AMMC specimen using ASTM standard E23. These experimental values show that the hardness of the samples tends to increase as the % addition of reinforcement increases. The clustering of PbO glass made variation in the hardness values from point to point. The average values are shown in the Table 6.

Table 6
Hardness Test Results

S. No.	Composition	Hardness of sand cast samples (HRB)	Hardness stir cast samples (HRB)
1	LM 6 + 0.0% PbO Glass	56	55
2	LM 6 + 2.5% PbO Glass	61	59
3	LM 6 + 5.0% PbO Glass	67	63
4	LM 6 + 7.5% PbO Glass	67	67
5	LM 6 + 10.0% PbO Glass	70	69

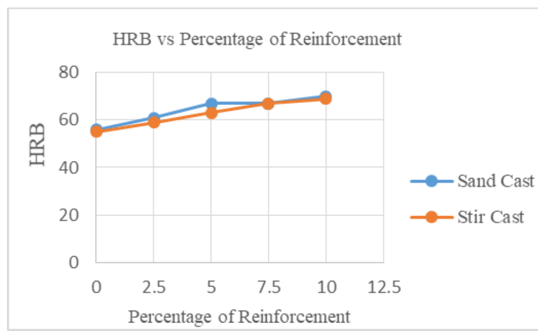

Fig. 4. HRB vs. Percentage of Reinforcement

E. *Microstructure analysis*

The figures show the optical microstructure of 7.5 % PbO glass reinforced metal matrix composite. The glass particles were homogeneously distributed throughout the matrix and good bonding between the aluminium and glass particles were observed in stir cast samples, but clustering of glass particles were observed in sand cast samples.

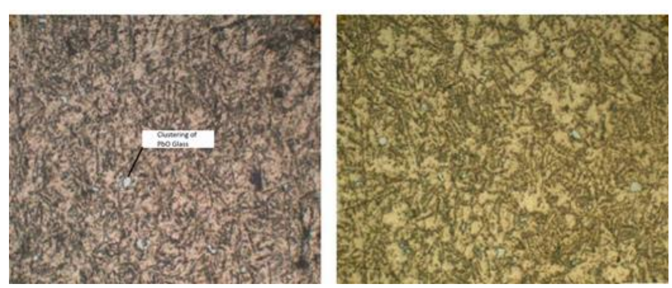

Fig. 5. (a) Optical Microstructure of sand cast sample having 7.5% of PbO glass reinforcement. (b) Optical Microstructure of Stir cast sample having 7.5% of PbO glass reinforcement

5. Conclusion

Aluminium metal matrix composite made with stir casting process shows homogenous distribution of PbO glass particles throughout the matrix. This results, variation in the properties across the MMC is minimum.

- Tensile and impact strength of the AMMC made with Stir casting method is superior and uniform throughout the MMC. This is due to clustering of PbO glass in the LM 6 matrix.
- The hardness of the MMC made with Stir casting method is marginally higher and uniform.
- Microstructure of the MMC shows clustering of PbO glass in sand casted samples and Homogenous distribution of the reinforcement in the LM 6 matrix.

References

[1] P.O Babalola, C.A Bolu, A.O Inegbenebor and K.M Odunfa, "Development of Aluminium Matrix Composites: A review" *Online International Journal of Engineering and Technology Research.* Volume 2: pp. 1-11; April, 2014.
[2] Gautam Choubeya, Lakka Suneethab, K. M Pandey. Composite materials used in Scramjet. *Materials Today Proceedings* 5:1321–1326
[3] M. A. El Baradie. 1990. Manufacturing Aspects of Metal Matrix Composites. Journal of Materials Processing Technology, 24: 261-272. 2018
[4] P Shiva Shanker. A review on properties of conventional and metal matrix composite materials in manufacturing of disc brake. *Materials Today: Proceedings 5*: 5864–5869, 2017.
[5] .W. Kaczmara, K. Pietrzakb, W. WoosinAskic. The production and application of metal matrix composite materials. *Journal of Materials Processing Technology*, Vol 106 : 58-67. 2000
[6] Holley. R.. The Great Metal Tube in the Sky. *Material Strategies, Innovative Applications in Architecture*, 2013
[7] David Charles,. Unlocking the potential of metal matrix composites for civil aircraft. Materials Science and Engineering, A 135 : 295-297, 1991
[8] M Haghshenas. Metal–Matrix Composites. Reference Module in Materials Science and Materials Engineering, *Elsevier Publications*: 1-28
[9] ASM international. Casting. Vol 15, available from *ASM Handbook*
[10] Siddique Ahmedet al, Investigation of Tensile Property of AluminiumSiC Metal Matrix. *International Journal of applied mechanics and Materials*, Volume 766-767: 252-256, 2015.
[11] V. K. Lindroos and M. J. Talvitie. Recent advances in metal matrix composites. *Journal of Materials Processing Technology*, Vol.53: 273-284. 1995.
[12] Ibrahim, I.A., Mohammed, F.A. and Lavernia, E.J. Particulate reinforced metal matrix composites - *a review. Journal of Materials Science*, 26(5): 1137- 1156, 1991
[13] M. Badiey, A. Abedian. Application of metal matrix composites (mmc's) in a satellite boom to reduce weight and vibrations as a multidisciplinary optimization. *International Congress of the Aeronautical Sciences*, 1-12. 2010.
[14] Suraj Rawal. Metal-Matrix Composites for Space Applications. *Journal of The Minerals, Metals & Materials Society*, Vol 53: 14-17. (2001)
[15] Chawla, K.K., 2012. Composite Materials: Science and Engineering. New York: *Springer Science Media*.
[16] D.R. Tenny, G.F. Sykes, and D.E. Bowles, "Composite Materials for Space Structures," *Proceedings, Third European Symp. Spacecraft Materials in Space Environment*, ESA SP-232:9–21.
[17] A.J. Juhasz and G.P. Peterson, Review of Advanced Radiat or Technologies for Spacecraft Power Systems and Space Thermal Control, *NASA* TP-4555 (1994).
[18] C. Thaw et al., "Metal Matrix Composites for Microwave Packaging Components," Electronic Packaging and Production pp. 27–29. August 1987.