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Characterisation of Silicon Carbide and Fly Ash in LM13 Aluminium Alloy Matrix Composites

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ABSTRACT:

The modern vehicles demand more thermal and mechanical properties as the speed of the vehicles is increasing. The materials used should be able to not only withstand the high temperatures but to dissipate it at a faster rate without deformation. This paper investigates the characteristics of silicon carbide (SiC) and fly ash in LM13 aluminium alloy matrix composite prepared by stir casting. The LM13 alloy has high thermal property which makes it ideal for making engines and gears. The effect of fly ash and SiC on LM13 and its influence on increasing the surface roughness was analyzed by varying their proportion. The addition of SiC and fly ash to the matrix composite increases the hardness and tensile strength of the composite which is validated by experimental results.

KEYWORDS:

Metal matrix composites; LM13 aluminium alloy; Fly ash; Silicon carbide; Hardness; Tensile strength

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1. Introduction

A composite material is made by combining two or more materials - often ones that have very different properties. The two materials work together to give unique properties [2]. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. Metal matrix composites (MMC) have high strength, fracture, toughness and stiffness than those offered by the polymer matrix composites [1]. They can withstand elevated temperature in corrosive environment than polymer composites [4]. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive [12]. Titanium, aluminium and magnesium are the popular matrix metals are particularly useful for aircraft applications [3]. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

Recent developments in MMC fabrication are aimed at cheaper and simple techniques. Liquid state processing incorporating various casting methods and powder particulate reinforced aluminium matrix composites. However, the powder metallurgy route is difficult to automate, and for this reason may not be the right answer for metallurgy methods and, in-situ processing are being used in current economical production of aluminium matrix composites [5]. The most economical techniques are found among the liquid state and in-situ processes. Amongst them the most simple, inexpensive and widely used methods are casting methods. In some fabrication techniques, the size and shape of component are limited and standard metalworking and machining methods normally cannot be applied. Machining of MMC components will always give a very bad surface finish and demand the use of special tools. Consequently, the production costs of these materials remain high. The production cost of aluminium is expensive compared to other commercial materials such as steel, but if aluminium is recycled, great savings in energy consumption can be gained [7, 9]. The energy consumed when aluminium is recycled is only about 5% of that used in primary production. It is important to choose matrix and reinforcement with the consideration that detrimental inter-metallic may be formed that will make recycling difficult. The formation of certain intermediate phases will decrease the possibilities of recycling [11]. This problem is possible to avoid by carefully selecting reinforcements having compatibility with the matrix [13].

In general the prime role of the reinforcement material and the matrix metal is to carry load [10]. The reinforcement may be continuous or discontinuous. In general the reinforcement increases strength, stiffness, and temperature resistance capacity but lowers the density fracture toughness and ductility of the MMC. The correct selection of reinforcement type, geometry or shape is important to obtain the best combination of properties at substantially low cost.

In stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of MMC was initiated in 1968. Ray introduced alumina particles into aluminium melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquid temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquid and solid points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum. Among all the well-established MMC fabrication methods, stir casting is the most economical.

2. Materials & specimen fabrication

LM13 ($Al\text{-}Si_{12}Cu_1Mg_1$) aluminium alloy conforms to BS 1490:1988. Castings are standardized in the precipitation treated (TE) condition, solution treated, artificially aged and stabilized (TF7) condition and the fully heat treated (TF) condition. The mechanical properties of LM13 alloy is given in Table 1. Silicon carbide is originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive. Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. LM13 alloy, silicon carbide and fly ash are mixed through a stir casting process to fabricate MMC rods. Schematic of stir casting set-up is shown in Fig. 1. LM13 aluminium alloy generally melts at 650°C. The processing temperature mainly influences the viscosity of LM13 matrix. The change of viscosity influences the particle distribution in the matrix. In order to promote good wet ability, the operating temperature is kept at 630°C which keeps LM13 in semisolid state. Reinforcement was preheated at a specified 500°C temperature for 30 min in order to remove moisture or any other gases which are present within reinforcement. The preheating of also promotes the wetability of reinforcement with matrix. Addition of magnesium enhances the wet ability. However increasing the magnesium content above 1% by weight increases the viscosity of slurry and hence uniform particle distribution will be difficult.

Table 1: Mechanical properties of LM13 aluminium alloy

LM13-TF	Sand cast	Chill cast
Modulus of elasticity (GPa)	73	73
Tensile strength (MPa)	170-200	280-310
0.2% Proof strength (MPa)	160-190	270-300
Shear strength (MPa)	-	190
Elongation (%)	0.5	1
Impact resistance izod (Nm)	-	1.4
Brinell hardness	100-150	100-150
Endurance limit ($5x10^7$ cycles; MPa)	85	100

Fig. 1: Schematic of stir casting set-up

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Micro hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation. The diameter of the impression is the average of three readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. The dimensions of hardness test specimen and tester are shown in Fig. 2 and Fig. 3 respectively.

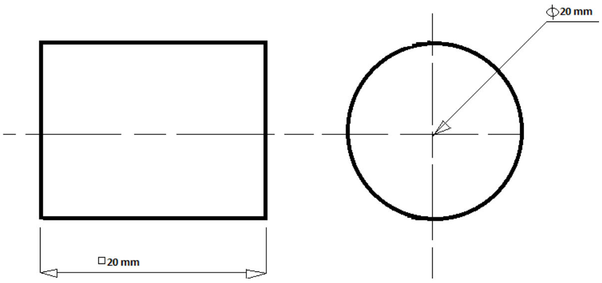

Fig. 2: Micro hardness tester

Fig. 3: Brinell hardness tester

In tensile testing, the specimen is subjected to a controlled tension until failure. Uni-axial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. The tensile test specimen dimensions and photograph of fabricated specimens are shown in Fig. 4 and Fig. 5 respectively. The specimen under tensile load using universal tensile strength test rig is shown in Fig. 6.

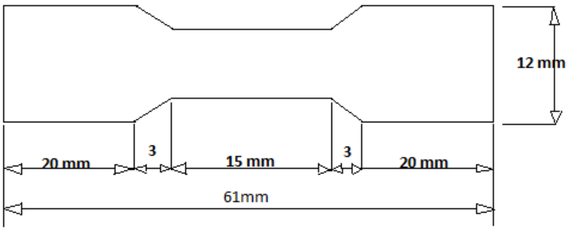

Fig. 4: Dimensions of tensile test specimen

Fig. 5: Test specimen

Fig. 6: Test specimen under load

Microstructure is defined as the structure of a prepared surface as revealed by a microscope above ×25 magnification. The specimen geometry is same as that of hardness test. Metallurgical microscope, Model Epimet-3, inverted model comes with magnification - x50 - x1250 and 6V/ 30W illumination, as shown in Fig. 7, is used for microstructure characterisation.

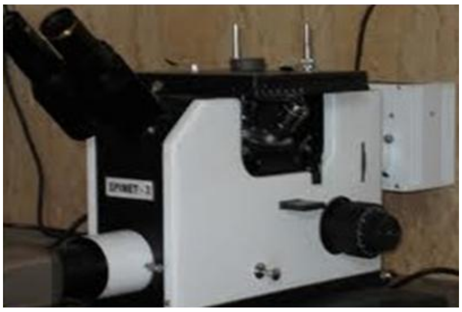

Fig. 7: Epimet-3 microstructure tester

3. Results and discussion

Brinell hardness test results for the six MMC specimens of various compositions are shown in Fig. 8. The MMC specimen with LM13 Al (240g), SiC (5g) and fly ash (5g) composition exhibited maximum hardness value with 6% increase in the property of LM13 material. Tensile test results for all the six MMC specimens are summarised in Table 2. For illustration, typical load vs. displacement and stress vs. strain curves from the tensile test for the MMC specimen with LM13 Al (240g), SiC (5g) and fly ash (5g) composition have been shown in Fig. 9 and Fig. 10 respectively. This specimen has shown a 4% improvement in the tensile strength when compared with LM13 aluminium alloy. The proportional limits of strength and extension are also encouraging when fly ash and SiC are added to the LM13 aluminium alloy matrix composite specimens.

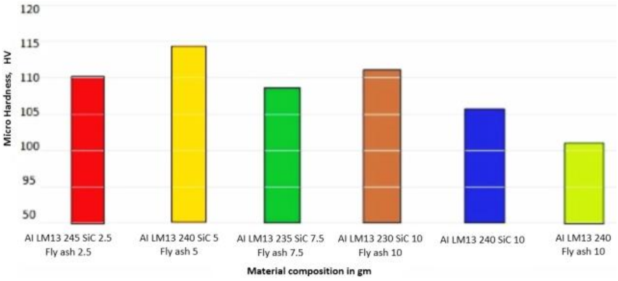

Fig. 8: Bar chart of hardness test results

Table 2: Tensile test results

MMC specimen #	1	2	3	4	5	6
LM13 Al (g)	245	240	235	230	240	240
SiC (g)	2.5	5	7.5	10	10	-
Fly ash (g)	2.5	5	7.5	10	-	10
Elastic mod. (GPa)	2.00	1.78	2.21	2.42	0.98	4.44
Yield load (kN)	2.19	2.35	2.08	2.33	1.77	1.78
Prop limit (kN)	0.55	0.49	0.46	0.61	0.02	0.07
Prop limit (mm)	0.24	0.27	0.21	0.23	0.27	0.35
Yield stress (MPa)	174.5	186.6	167.0	185.4	140.9	141.6
Strain at Max (%)	9.33	12.33	8.94	9.47	13.13	7.73
Prop limit (MPa)	43.45	38.85	39.24	48.48	1.20	5.81

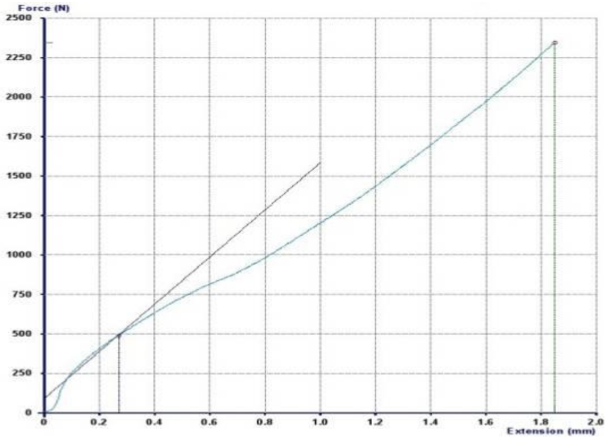

Fig. 9: Tensile test load vs. Extension displacement for LM13 Al (240g), SiC (5g) and fly ash (5g) specimen

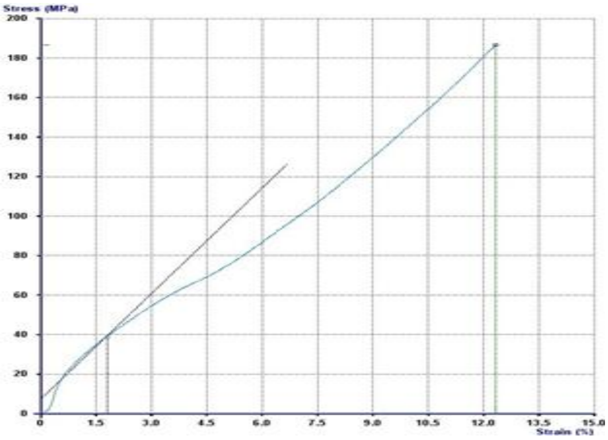

Fig. 10: Stress vs. Strain for LM13 Al (240g), SiC (5g) and fly ash (5g) specimen

The microstructure of all six MMC specimens and the LM13 aluminium alloy are investigated using Epimet-3 metallurgical microscope and their respective images with x100 magnification are shown Fig. 11 to Fig. 17. Addition of fly ash to MMC did not change the microstructure abruptly when compared to LM13 aluminium alloy. The surface roughness results are provided in Table 3. MMC with LM13 Al (235g), SiC (7.5g) and fly ash (7.5g) composition gave good surface finish. Hence this composition can be used for places where precise surface finish is required.

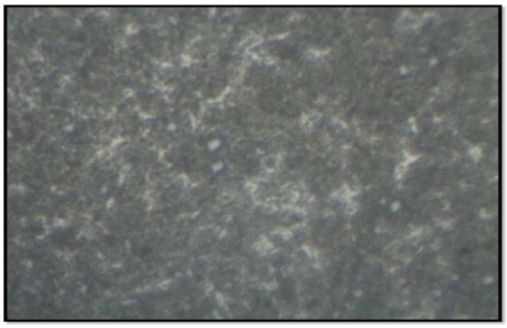

Fig. 11: LM13 aluminium alloy (250g) microstructure (x100)

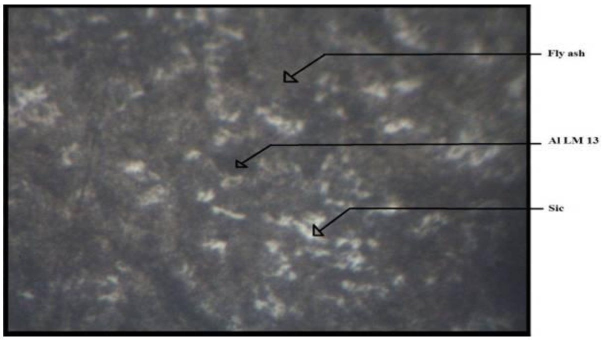

Fig. 12: LM13 Al (245g), SiC (2.5g) & Fly ash (2.5g)

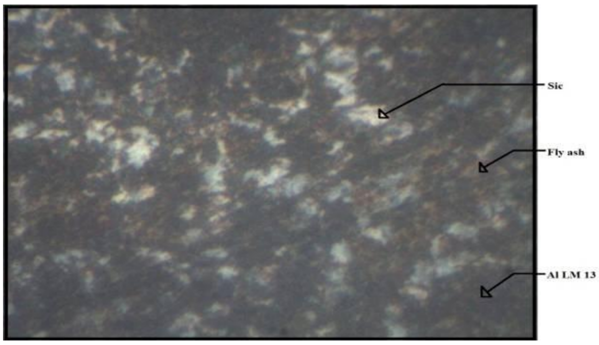

Fig. 13: LM13 Al (240g), SiC (5g) & Fly ash (5g)

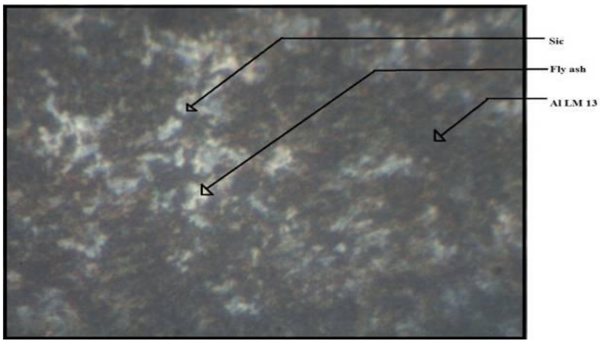

Fig. 14: LM13 Al (235g), SiC (7.5g) & Fly ash (7.5g)

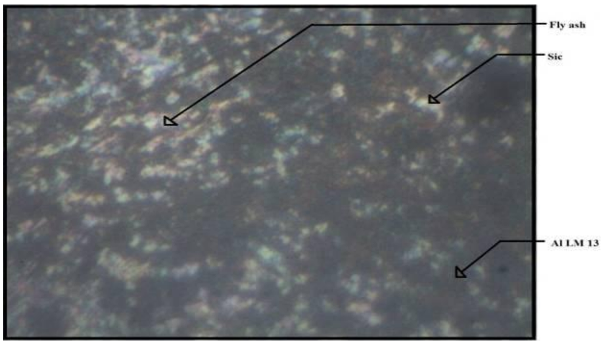

Fig. 15: LM13 Al (230g), SiC (10g) & Fly ash (10g)

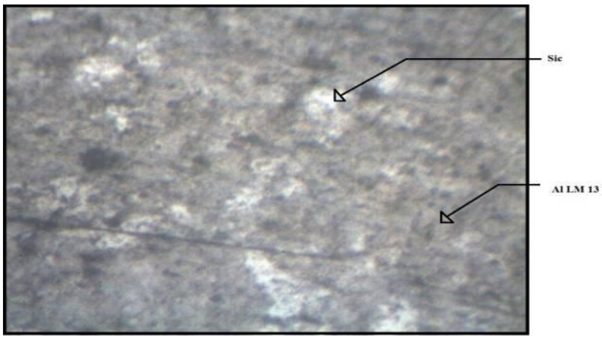

Fig. 16: LM13 Al (240g) & SiC (10g)

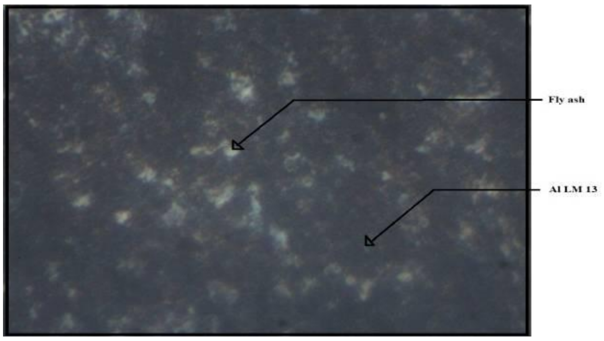

Fig. 17: LM13 Al (240g) & Fly ash (10g)

Table 3: Surface roughness results

S. No.	Material composition (g)			Surface roughness (μm)
	LM13 Al	SiC	Fly ash	
1	245	2.5	2.5	0.032
2	240	5	5	0.093
3	235	7.5	7.5	0.031
4	230	10	10	0.0335
5	240	10	-	0.034
6	240	-	10	0.0365

4. Conclusions

From the experimental results presented, it is concluded that we can use fly ash for the production of metal matrix composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash. The MMC specimen with LM13 Al (240g), SiC (5g) and fly ash (5g) composition has maximum hardness value with 6%increase and also has good tensile strength with 4% increase when compared to LM13 aluminium alloy properties. LM13 Al (235g), SiC (7.5g) and fly ash (7.5g) composites have good surface roughness (0.031µm). Addition of fly ash more than 10% by weight will affect the wetting property; thereby it leads to defective test specimen.

REFERENCES:

[1] A.P. Sannino and H.J. Rack. 1995. Dry sliding wear of discontinuously reinforced aluminum composites: review and discussion, *Wear*, 189, 1-19. http://dx.doi.org/10.1016/0043-1648(95)06657-8.

[2] T.P.D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana and P.K. Rohatgi. 2007. Fabrication and characterisation of Al-7, Si-0.35, Mg/ZrB-2 and SiC metal matrix composites processed by different stir casting routes, *Compos. Sci. Technol.*, 67(15-16), 3369-3377. http://dx.doi.org/10.1016/j.compscitech.2007.03.028.

[3] C. Krishnaraj. 2015. Characterization of hybrid black toner using the parameters waste toner and Nano phase carbon, *ARPN J. Engg. and Applied Sciences*, 10(14), 6135-6139.

[4] S.C. Tjong and Z.Y. Ma. 2000. Microstructural and mechanical characteristics of in situ metal matrix composites, *Mater. Sci. Eng. R*, 29, 49-113. http://dx.doi.org/10.1016/S0927-796X(00)00024-3

[5] P.K. Rohatgi, J.K. Kim, N. Gupta, Simon Alaraj and A. Daoud 200. Compressive characteristics of A356/fly ash cenosphere composites synthesized by pressure infiltration technique, *Composites Part A: Applied Science and Manufacturing*, 37(3), 430-437. http://dx.doi.org/10.1016/j.compositesa.2005.05.047.

[6] T.P.D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana and P.K. Rohatgi. 2009. Microstructure and mechanical behavior of die casting AZ91D-Fly ash cenosphere composites, *Composites Part-A Applied Science and Manufacturing*, 40(6-7), 883-896. http://dx.doi.org/10.1016/j.compositesa.2009.04.014.

[7] C. Krishnaraj and K.M. Mohanasundram. 2012. Design and implementation study of knowledge based foundry total failure mode effects analysis technique, *European J. Scientific Research*, 71(2), 298-311.

[8] P.K. Rohatgi, A. Daoud, B.F. Schultz and T. Puri. 2006. Thermal expansion of aluminum–fly ash cenosphere composites synthesized by pressure infiltration technique, *J. Composite Materials*, 40(13), 1163-1174. http://dx.doi.org/10.1177/0021998305057379.

[9] R.N. Rao and S. Das. 2011. Effect of SiC content and sliding speed on the wear behaviour of aluminium matrix composites, *Mater. Des.*, 32, 1066-1071. http://dx.doi.org/10.1016/j.matdes.2010.06.047

[10] S.N.S. Kumar. 2012. Forward Kinematics Analysis of SCORBOT ER V Plus using Lab VIEW, *European J. Scientific Research*, 72(4), 549-557.

[11] C. Krishnaraj. 2015. Analysis of machining and surface finishing of various materials in EDM, *ARPN J. Engg. and Applied Sciences*, 10(14), 6140-6146.