

Investigation of density, micro hardness and structural analysis of reinforced hybrid LM25 metal matrix nano composite

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Alumina and Silicon Carbide reinforced LM25 Hybrid nano composite was fabricated by using stir casting method. The LM 25Aluminium is the matrix metal having properties like light weight, high strength and ease of machinability. Alumina which has better wear resistance, high strength, hardness and Silicon carbide which had excellent hardness and fracture toughness were added as reinforcements. The reinforcement was added as 2%, 3% & 5.5% in mass of Alumina along with 2% mass of Silicon Carbide .The influence of Alumina and Silicon Carbide nano particles in the LM 25 matrix studied. The Morphology of composite was related with the properties by conducting such as density test and micro hardness test. The internal structure of the LM 25 metal matrix nano composite was observed using Scanning Electron Microscope (SEM).

(Received March 12, 2015; accepted March 19, 2015)

Keywords: Metal matrix Nano composite, Casting, Composites, Energy Dispersive-ray Spectroscopy (EDS), Stir casting

1. Introduction

In the present investigation the addition of 1.00 wt. % Al_2O_3 crystals to the metal matrix of the liquid aluminium was studied. In order to investigate the influence of heat treatment on activation of Al_2O_3 powders and mechanical properties of Al- Al_2O_3 composites, the Al_2O_3 particles were heated at $1000^{\circ}C$. X-ray Diffraction (XRD) analysis used to characterize the crystal lattice of Al_2O_3 and its variation during heat treatment. The size and morphology of the Al_2O_3 grains was evaluated by Scanning Electron Microscopy (SEM). The results showed a considerable change in morphology of Al_2O_3 grains during the heat treatment. Mechanical evaluation such as hardness, compression and wear tests showed enhancement in the properties of Al-1.00 wt. % heat treated Al_2O_3 vs. Al-1.00 wt. % Al_2O_3 composite [1].

The functionally graded material and the pure alloy is processed by using the Stir casting method. Aluminium 356/LM 25 alloys is reinforced with Al_2O_3 Nano particles 2wt%, 3wt%,5.5wt% and 2wt%SiCNanoparticles 2.5wt%.This nano composites are characterized by Wear, Compressive, Micro Hardness and Impact tests are carried out in order to identify mechanical composites as shown in fig. 1. The result of Chemical analysis of LM25Aluminium ingots are given below table1.



Fig. 1. Chemical test analysis of LM25 Aluminium ingot.

Table 1. Chemical composition of LM25

ELEMENTS	MEAN (%)
Si	6.8329
Fe	0.3709
Cu	0.1356
Mn	0.2876
Mg	0.3371
Ti	0.0289
Zn	0.0487
Pb	0.0258
Ni	0.0205
Cr	0.0241
Ca	0.0106
Al	91.8773

2. EDS analysis OF Nano Al_2O_3 and Nano SiC powder

The Nano Al_2O_3 particles and Nano SiC supplied by Alfa Aesar, United Kingdom are 25nm and 40nm, respectively. For manufacturing of the MMNCs, 2wt. % of

SiC and 2 wt%, 3wt%&5.5% nano Al_2O_3 particles are used .To conduct EDAX test for identifying the element content in Nano Alumina and Nano SiC

Fig. 2 shows that the large amount of Aluminum present in the Nano Alumina and Very little amount of oxygen present in the Nano Alumina. Fig. 3 shows that the large amount of Silicon, Moderate amount of Carbon and Very little amount of oxygen present in the Nano SiC

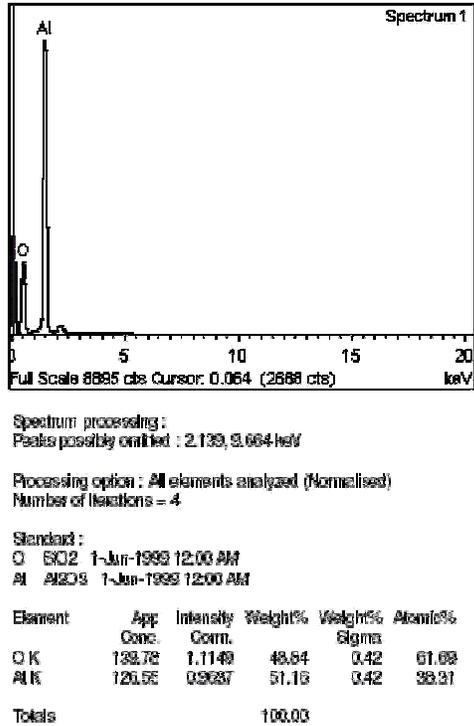


Fig. 2. EDS test for NanoAlumina.

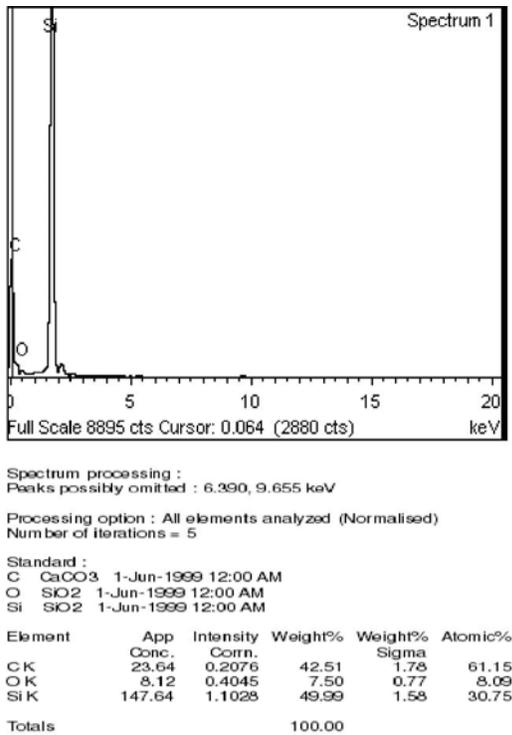


Fig. 3. EDS test for Nano SiC.

2.1 Casting and sample preparation

Stir-casting method is used for preparing aluminium metal–matrix composite. This whirlpool technique provided high strength and homogeneous set of aluminium composite materials. Initially the LM25 Al alloy was charged into the crucible, and heated to about 750°C, which was above the liquid us, temperature of the Al alloy as shown in fig. 4. Then, the mixer was lowered into the melt slowly to stir the molten metal as shown in fig.5.



Fig. 4. Stirring of Molten metal.



Fig. 5. Pouring of molten metal.



Fig. 6. Specimen of the Master Sample S0, S1, S2&S3.

The experimental arrangement consists of the main furnace and components along with four mild steel stirrer blades. Fig. 4 shows that this metal–matrix is then kept into the furnace at the same temperature. The furnace completely melted the pieces of aluminium alloy and the powders of nano alumina and nano Silicon carbide. The

stirring mechanism was lowered into the crucible inside the furnace and set at the required depth. The vigorous automatic stirring of the material takes place for 10 min with 550 rpm of stirring rate, thereby uniformly dispersing the additive powders in the aluminium alloy matrix. The temperature rate of the furnace should be controlled at 830 ± 10 °C in final mixing process. The degasser removed all the trapped gases from the mixture in the crucible and ensures that the temperature of the mixture in the crucible did not get transferred easily to the atmosphere. This experiment was repeatedly done by varying the compositions of the composite powder. For each composition is shown in a below table-2, a total of 1.5 kg (1500 g) material mix used for preparing the samples. Table 2 shows the volume fraction of LM25 MMNC [2]. In this study, LM25 aluminium alloy is used as the matrix material while nano Al₂O₃ (alumina) 2 wt%, 3wt%&5.5% and 2% of Nano SiC particles are used as the reinforcements. The furnace had a provision for bottom tapping and this permitted heating as well as stirring to be continued even during tapping of the melt. Finally four MMNC molten metal is poured in the casted billets are of 20mm diameter and of 300mm Length as shown in fig. 6.

Table 2 Volume fraction of LM 25 MMNC.

Sample	LM 25	Nano SiC	Nano Alumina
S0	100%	-	-
S1	96%	2%	2%
S2	95%	2%	3%
S3	92.50	2%	5.50%

3. Results and discussion

The results of the test are discussed in this section. In this paper, four specimens from each sample is test.

3.1 Density test

The densities of the composites were determined by means of Archimedes’ principle. Archimedes’ principle states that when a body was immersed in a fluid, there was buoyant force acting upward on the body equal to the weight of the displaced fluid. The weight of the displaced fluid equals its volume when water was used (density of water = 1 g/cm³). The volume of water displaced was equal to the volume of the body immersed. All weights were obtained by means of an Oahu’s Scout TM Pro Balance SP2001 equipped with a spring balance. The cast material was suspended in air on the spring by means of a thin thread and its weight determined as W1. It was then completely submerged in a beaker of water and the new weight recorded as W2. Its density was then calculated from equation: Density of Sample = Weight of Sample / Volume of Sample

Application of Archimedes' principle leads to the

following expression for the density (ρ) of the sample in terms of measured weights (W) as shown in figure 7. The procedure is repeated to find the volume of liquid with density of sample1, 2 &3 and Mass of the sample1, 2 &3. By using above Archimedes' Principle the mass and volume of the sample are given in Table 3. Table 3 shows the density of hybrid composites increased with the increase in percentage of the reinforcement of LM 25 Metal matrix Nano composites of Samples0, 1, 2 &3

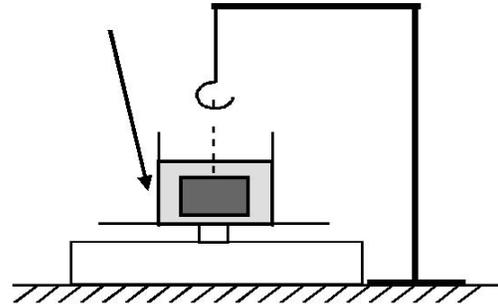


Fig. 7. Schematic Diagram of Liquid in a Beaker Metal Platform Number contact with the weight pan.

Table 3. Volume & density of samples test conducted Archimedes' principle.

Samples	Weight of Sample (g)	Volume of Sample (cm ³)	Actual Density of Sample (g/cm ³)
S0	3.639	1.583	2.298
S1	3.901	1.680	2.322
S2	3.885	1.672	2.323
S3	3.982	1.595	2.495

3.2 Micro hardness test

Table 4. Micro hardness of LM25 MMNC samples

Sno	Force (g)	Hardness Value(HV)			
		S0	S1	S2	S3
1	25	96.9	102	106	107
2	50	98.4	103	104	105
3	100	99.1	104	105	106
4	200	99.3	103	104	105
5	500	100	104	105	106
6	Average	98.74	103.2	104.8	105.8

The ball shaped indenter made of hardened tungsten was used for this test. The diameter of ball shaped indenter is 10 mm and the load applied is 25g, 50g, 100g, 200g

&500g. It can be noted that sample 3 has the maximum Hardness followed by sample0, 1, 2 and sample 3 in all trials. The hardness test measures the resistance of a solid to Permanent shape change. When a forces 25g, 50g, 100g, 200g &500g were applied to the Specimen S0, S1, S2 & S3in Micro Vickers hardness test. It was carried out in this work to find out the deformation of the composite under constant compressive load from an object which was sharp. The Vickers hardness test was carried out on the four samples and the results were furnished in Table 4.



Fig. 8. Scanning electron microscope setup.

3.3 Morphological analysis using Scanning Electron Microscope (SEM)

The Scanning Electron Microscope (SEM) uses electrons instead of light to form an image. The main principle of SEM is the bombarding of electrons and the secondary electrons which are reflected are formed as an image. Figure 8 shows the setup of a Supra 55 Scanning Electron Microscope. The sample Holder stub was cleaned with acetone and dried in the sputter coater machine with 240 volts. After the sample was prepared, its microstructure was analysed using SEM & EDS Test.

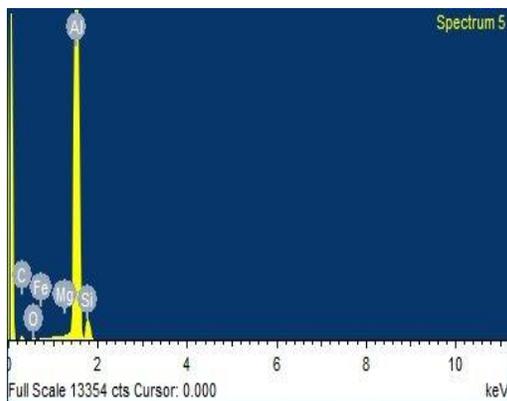


Fig. 9. EDS test for Pure S0.

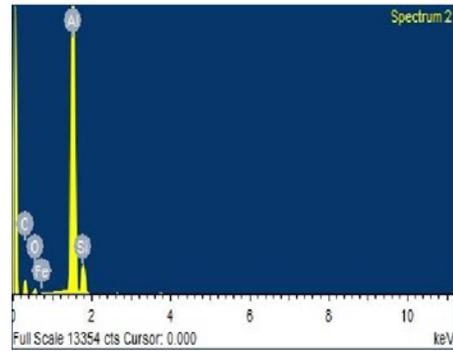


Fig.10. EDS test for S1.

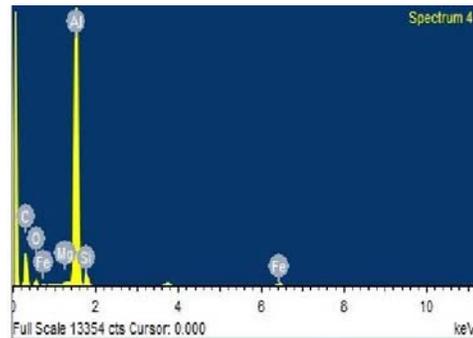


Fig. 11. EDS test for S2.

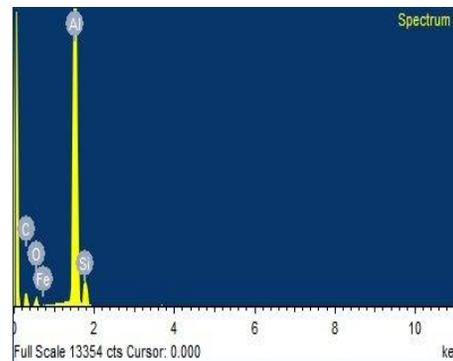


Fig. 12. EDS test for S3.

3.4 EDS test

The EDS analysis showed that darker phase was the Al matrix and the white particles were alumina as shown in figure 9. The second phase did not seem to have any preferred site of accommodation. As it was clear in figure 10, the amount of Al_2O_3 in the grain boundaries and the bulk of the grains was the same. The micrographs in fig. 11 show that grain size of the reinforced composite was smaller than the Pure Sample alloy without reinforcement as shown in fig. 12 because particles act as nucleation sites [3, 4, 5]. Also, due to the modified structure of Al_2O_3 particles after heat treatment, the grain size was smaller than that of without heat treatment.

As Fig. 5 reveals, during solidification of composite reinforcement particles were pushed by Al dendrites into the last freezing eutectic melt. Therefore, the strength particles are surrounded by silicon eutectic [6, 7]. The Scanning Electron Microscope (SEM) uses electrons instead of light to form an image as shown in Fig. 8. The main principle of SEM was the bombarding of electrons and the secondary electrons which are reflected. Fig. 8 shows the setup of a Supra 55 Scanning Electron Microscope. The sample holder stub was cleaned with acetone and dried in the sputter coater machine with 240 volts. After the sample was prepared, its microstructure is analyzed using SEM. Fig. 16 shows the microstructure of sample 3 which consist of aluminium alloy [LM 25]. The picture shows the inner surface of sample 3 which consist of aluminium and other components like copper, silicon, magnesium, etc. properties of the sample 3 compared to samples 2 and 3. The images of sample 1&2 can be clearly distinguished from those of samples 3 as these images lack the elliptical molecules of the reinforcements which are visible in the cases of samples 1 and 2 [8.9].

Fig. 14 shows the microstructure of the test of sample 1 at 100X magnification. The general arrangement of aluminium molecules and reinforcements of the aluminium alloy are faintly visible in the image. The darker particles are Silica carbide and the lighter ones are aluminium. The elliptically shaped aluminium particles in the matrix are more clearly visible at a magnification of 500X as shown in Fig. 13. It is seen that the reinforcements of the matrix are predominantly located in the centre of the image and aluminium molecules at the outer region, suggesting that the reinforcements are unevenly distributed in the matrix. The uneven distribution of the matrix and reinforcement is attributed to poor stirring during the manufacturing of the sample.

Fig. 15 reveals the fractured surface of the sample 2 at 108X magnification. The general arrangement of the composite is clearly visible in the image. Many micro cracks and porous sites are observed in the sample which is attributed to poor manufacturing and improper stirring of the composite. Fig. 16 shows the microstructure of sample 2 with a magnification of 500X. Typical examples of crack paths on the specimen surface of the composites are seen in the image. However, only a few debonding particles are observed compared to sample 1.

Fig. 16 shows the microstructure of sample 3 which consist of aluminium alloy [LM 25]. The picture shows the inner surface of sample 3 which consist of aluminium and other components like copper, silicon, magnesium, etc. properties of the sample 3 compared to samples 2 and 3. From Fig. 17, the images of sample 1&2 can be clearly distinguished from those of samples 3 as these images lack the elliptical molecules of the reinforcements which are visible in the cases of samples 1 and 2.

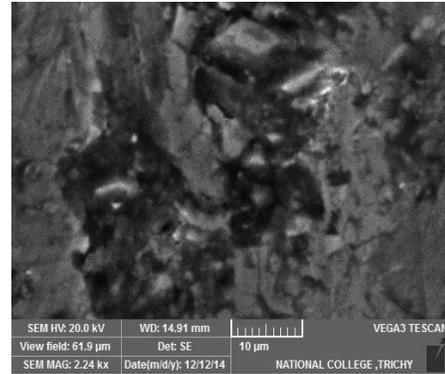


Fig. 13. SEM results for S0.

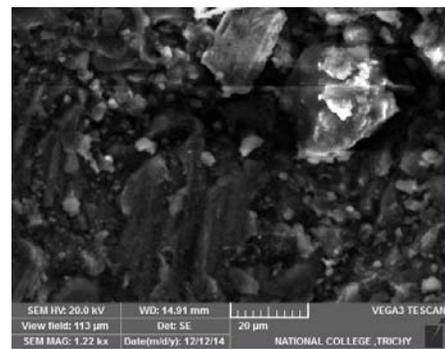


Fig. 14. SEM result for S1.

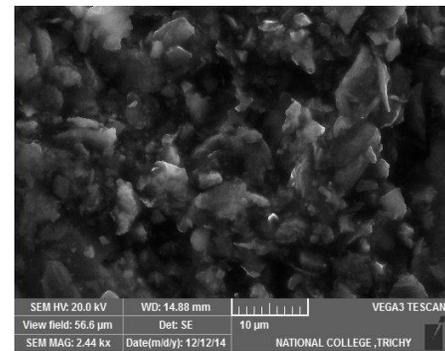


Fig. 15 SEM result for S2.

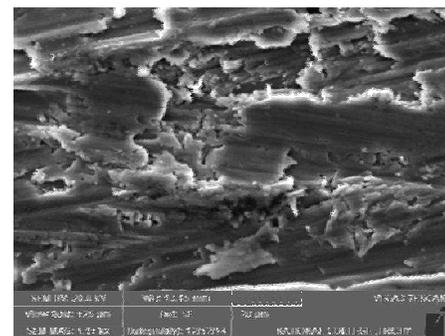


Fig.16. SEM result for S3.

4. Conclusion

Four different samples are fabricated and the following inferences are made; LM25 aluminum alloy reinforced with nano SiC and nano-sized Al_2O_3 was successfully produced via stir casting method. The following conclusions can be made based on the studies carried out:

1. Nano Al_2O_3 and Nano SiC particle reinforced MMNC exhibit better hardness and strength when compared to Pure Lm 25
2. Uniform distribution of reinforcement particle has been achieved in all the MMNCs
3. All the 3 samples of MMNCs had been found to have lower porosity and so exhibit better strength
4. By proper optimization of the process parameters, stir casting can be a promising and economically viable route for the production of nano particle reinforced MMNCs.
5. The Micro Vickers hardness of sample0 (98.74) was marginally lower than that of sample1 (103.20), Sample2 (104.8) & Sample 3(105.8)

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