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Fabrication and Analysis of the Properties of Coconut Shell Ash Reinforced Aluminum356 Composite

Vamsi Krishna Nadimpalli
Department of Mechanical Engineering
Sagi Ramakrishnam Raju Engineering College
Chinnamiram

***Abstract:* - Coconut shells are agricultural waste and produced in large amounts around the world. Thus it's effective, eco-friendly use has always been a challenge for scientific applications. This paper presents Fabrication of Coconut shell ash(CSA) reinforced Aluminum356 composite and analysis of Mechanical properties like Hardness and Wear. Coconut shell ash is varied from 0% to 10% weight in interval of 5%wt in the A356 alloy. The Base alloy exhibits higher Wear tendency than the composite reinforced with 10% CSA and as the percentage of reinforcement increases the Density of the composite decreases and the Hardness increases. The fabrication and Testing methods are presented in this paper.**

Keywords: Metal Matrix Composites, A356, Stir Casting, Coconut Shell Ash.

1. INTRODUCTION

COMPOSITES:

A composite material is a material made from two or more two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. Composites can also be defined as a combination of a matrix and a reinforcement, which when combined gives properties superior to the properties of the individual components. The reinforcement fibers can be cut, aligned, placed in different ways to affect the properties of the resulting composite. The matrix, normally a form of resin, keeps the reinforcement in the desired orientation. It protects the reinforcement from chemical and environmental attack, and it bonds the reinforcement so that applied loads can be effectively transferred.

Metal matrix composites:

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fibre includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibres such as silicon carbide.

MMC (Metal matrix composites) are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites. Aluminium MMC's are widely used in aircraft, aerospace, automobiles and various other fields. The reinforcements should be stable in the given working temperature and non-reactive too. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume percent) due to processing difficulties.

Particulate reinforced composites:

Particulates are microstructures of metal and ceramic composites, which have one phase of material strewn into another, to form numerous particles, which may have different shapes like triangle, square and the like. The dispersed size of these particles is of the order of few microns. The size and volume of the dispersed particles distinguish from dispersion hardened materials and they can get in volumes of as much as 28%.

The particles may have different shapes but the dimensions of their sides are observed to be more or less equal. In particulate composites, the particles strengthen the system by the hydrostatic coercion of fillers in matrices and by their hardness relative to the matrix.

PROCESSING METHOD OF THE METAL MATRIX COMPOSITE:

Stir-casting or compo casting:

According to the type of reinforcement, the fabrication techniques can vary considerably. From the contribution of several researchers, some of the techniques for the development of these composites are stir casting/ compo casting (Y.H. Seo et al 1999), Powder metallurgy (X. Yunsheng et al 1998), spray atomization and co-deposition (C.G Kang et al 1997), plasma spraying (Y.H. Seo et al 1995) and squeeze-casting (S. Zhang et al 1998). The above process are most important of which, liquid metallurgy technique has been explored much in these days. This involves incorporation of ceramic particulate into liquid aluminum melt and allowing the mixture to solidify.

Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminum alloy melt. The simplest and most commercially used technique is known as vortex technique or stir casting technique. The vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Ceramic particles ingot-grade aluminum are mixed and method and melted. The melt is stirred slightly above the liquidous temperature (600-700)C

Stir Casting offers better matrix-particle bonding due to stirring action of particles into the melts shown in Figure1.2 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 high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologic low cost aluminum composites with improved hardness values.

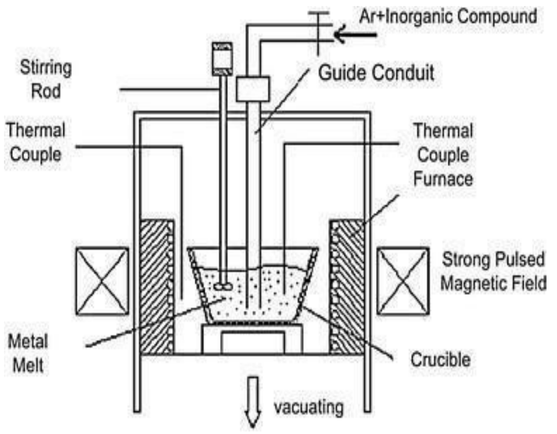


Figure1.1 Block diagram of Stir Casting

2 EXPERMENTAL WORK

This chapter describes in detail about the materials and experimental procedure carried out during the course of paper

The steps involved are

- Fabrication of coconut shell ash reinforced A356 composite Stir casting method
- Machining of samples of desired dimensions
- Hardness testing of fabricated coconut shell ash reinforced A356 Composites.
- Wear testing of fabricated coconut shell ash reinforced A356 Composites.

RAW MATERIALS:

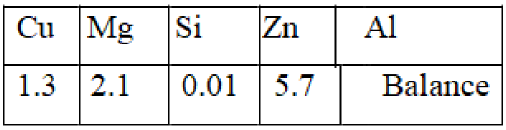
The raw materials used in this experimental work are

A356 alloy (Al-Si alloy) Coconut shell ash

2.1 A356 Alloy:

The chemical composition of A356 alloy is shown in table3.1 and it was procured from M/s HINDALCO as 20 kg ingots.A356 is Aluminum zinc alloy and it is used as matrix material.

Table 2.1: Chemical composition of A356 alloy, wt. %.



Cu	Mg	Si	Zn	Al
1.3	2.1	0.01	5.7	Balance

COCONUT SHELL ASH:

The coconuts were procured from a nearby local temple is shown in the figure3.1.The coconuts were broken manually to drain out the water. The 40 coconut half shells were sun-dried for three days. Sun-drying was necessary to ease removal of the meat from the inner shells of the coconut pieces. After scraping the meat from the inner shells, the inner portions of the shells were cleaned using knives. The fibers on the outer shells were also scraped and cleaned. Emery paper was used to clear the outer shells.

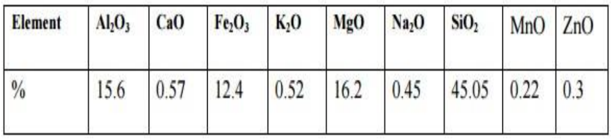
The cleaned coconut shells obtained from were cut into pieces of dimensions of 1 sq.cm. Using hammer and were put in stainless steels containers.

The containers were then kept into muffle furnace for carbonization (carbonization is the production of charred carbon from a source material. The process is generally accomplished by heating the source material usually in the absence or limited amount of air to a temperature sufficiently high to dry and volatilize substances in the carbonaceous material). The carbonization temperature selected as 600 and 800 degrees. After a soak time of 4 hours, the sample gets carbonized. As the furnace cools down, containers were taken out. The collected char was ground to form powder using a grinding machine. The powder was then sieved to a size of 40 µm is shown in Figure2.2.

Figure 2.2 Coconut shell ash Powder

The chemical composition of coconut ash powder is shown in Table3.2.

Table2. 2: Chemical composition of Coconut Ash powder



Element	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	MnO	ZnO
%	15.6	0.57	12.4	0.52	16.2	0.45	45.05	0.22	0.3

In the present investigation, aluminum based hybrid metal matrix composites containing 5 and 10wt% Coconut ash particulates of 53µm were successfully synthesized by vortex method.

FABRICATION OF COMPOSITES:

The synthesis of these composites was carried out by stir casting technique. A356 alloy were taken into a graphite crucible and melted in an electric furnace as shown in figure 3.3. After maintaining the temperature at 770 °C, a vortex was created using mechanical stirrer made of graphite.

Figure 2.3 Stir casting

While stirring was in progress, the preheated particulates Coconut ash at 300^{0}C for 2 hrs were introduced into the melt. Care has been taken to ensure continuous and smooth flow of the particles addition in the vortex.

The molten metal was stirred at 800 rpm under argon gas cover. The stirring was continued for about 2 minutes after addition of particles for uniform distribution in the melt. Still, the melt with reinforcement was in stirring condition the same was poured into permanent casting mould and the Figure 3.4 shows the composite samples after casting.

Figure 2.4 Cast Iron Die and Composite samples

HARDNESS TEST:

The hardness of the alloy and composite was evaluated by using Leco Vickers hardness tester. An average of ten readings was taken for each hardness value. Vickers hardness studies were carried out for the investigated materials using micro Vickers micro hardness tester (Banbros (Model: LV 700) Hardness tester) with 1kg load. The Vickers hardness tester used for testing the composite samples is shown in Figure2.5.The indentation time for the hardness measurement was 15 seconds. An average of six readings was taken for each hardness value.

Figure 2.5 Vickers Hardness tester

2.5 DENSITY AND POROSITY TESTS:

The density of the alloy and composites was measured by the Archimedes drainage method by using the following equation:

$\rho_{MMC} = (m) / ((m-m_1) X \rho_{H2O})$

Where ρ_{MMC} is the density of the composite, 'm' is the mass of the composite sample in air, 'm_1' is the mass of the same composite sample in distilled water and 'ρ_{H2O}' is the density of distilled water (at 293K) is 998 kg/m^3.

Theoretical density calculations, according to the rule of mixture were also used to determine the densities of the composites. This was obtained from the below equation.

$\rho c = Vr \ \rho r + (1-Vr)$

Where ρ_c is the density of the composite, Vr is the weight ratio of reinforcement, ρ_r is the density of reinforcement and ρ_m is the density of the Unreinforced A356 alloy. The porosity of the test materials were also calculated from the following equation.

Porosity (%) = (1- (measured density / calculated density)) X 100

The average theoretical and measured density values of the A356 alloy and its respective composites were given in table 2. It was observed that the addition of Coconut Ash particles into the A356 alloy matrix significantly decreases the density of the resultant composites in compare to the base alloy.

2.6 DRY SLIDING WEAR TEST:

Dry sliding wear tests have been carried out on a pin-on - disc apparatus (Model: Ducom TR- 20 LE) is shown in figure3.8 by sliding a cylindrical pin against the surface of hardened steel disc (with a hardness value of HRC 62) under ambient condition. The Pin-on-disc wear testing experimental set up was shown in Figure 3.10. The same was in schematic view was shown in figure. The disc was ground to a smooth surface finish and renewed for each test. The wear test specimens were prepared from the alloy and composite castings in the dimensions of 6 mm ø and 30 mm length. Prior to testing, the test samples were polished with emery paper and cleaned in acetone, dried and then weighed using an electronic balance (Model: Sartorius Research R 200 D Germany) with a resolution of 0.1 mg. The samples were placed on the wear disc and the sliding wear tests were carried out at various loads, time and sliding distance. The test was conducted in a load range of 0.5 – 1.5 kgf (4.9 – 14.7 N) at a sliding velocity of 2.0 m/s and at sliding distance of 1.2 – 3.6 km. After each test, the specimens were removed, cleaned in acetone and weighed with an electronic balance within an accuracy of 0.1 mg. For each load, the volume loss from the surface of each specimen was determined as a function of sliding distance and applied load. The wear rate (K) was defined as the volume loss (V), divided by the sliding distance (L). Hence, the volumetric wear rate (K) was calculated from the weight loss measurement and expressed in terms of mm^3/km.

The friction force (F) was continuously monitored during the wear test for determining the coefficient of friction (μ). The friction force was measured for each pass and then averaged over the total number of passes for each wear test. The average value of coefficient of fricition (μ**)** of composite was calculated from the following expression :$\mu = F_f / F_n$

where: F_f is the average fricition force and F_n is applied load

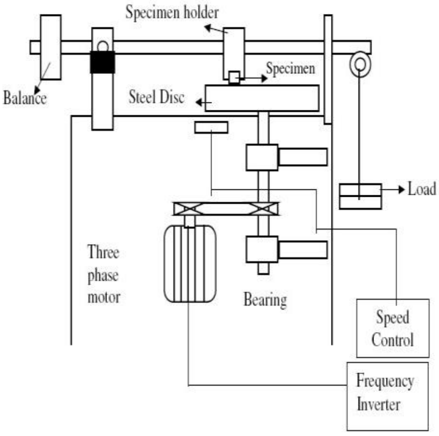


Figure 2.6 Pin-on-disc wear tester (Model: Ducom TR- 20 LE)

3 RESULTS AND DISCUSSIONS

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fibre includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. The main objective of this work is to prepare a Metal Matrix Composite using coconut shell ash as reinforcement and Aluminum zinc alloy A356 as matrix material and to study its density, porosity, hardness and wear studies.

3.1 Density and Porosity Studies:

The average theoretical and measured density values of the A356 alloy and its respective composites were given in table 3.1 It was observed that the addition of Coconut Ash particles into the A356 alloy matrix significantly decreases the density of the resultant composites in compare to the base alloy.

Table 3.1 Theoretical and measured densities of A356 alloy and A356-

S. No	Specimen	Density (g/cm^3)	
		Theoretical	Measured
1.	A 356 alloy	2.81	2.81
2.	AA356 alloy – 5% Coconut Ash composite	2.78	2.76
3.	A 356 alloy - 10% Coconut Ash composite	2.69	2.66

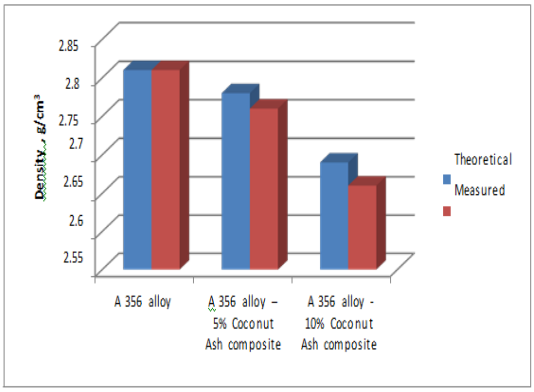


Figure 3.1 Density variation with weight fractions of reinforcement.

The density of the composites decreases with increasing the percentages of Coconut Ash particulates, as shown in Figure 4.1. With 10% Coconut Ash, the density of composite decreased to 2.69 g/cm^3 compared to the density of the alloy 2.81 g/cm^3. The measured densities, however, were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing Coconut Ash content. This can be attributed to the increase in porosity with Coconut Ash content and is shown in the Figure4.2

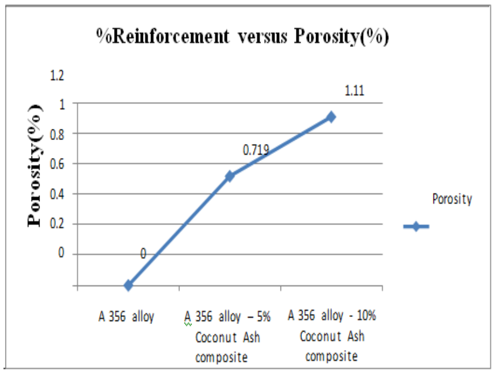


Figure 3.2 Porosity (%) variations of composites

3.2 HARDNESS STUDIES

The hardness of a material is a physical parameter indicating the ability of resisting local plastic deformation the hardness values of the A356 alloy and Coconut Ash particles reinforced composites. The hardness was increased from 104 VHN for A356 alloy to 168 VHN for composite which is shown in Figure 3.3. This could be due to the presence of Coconut Ash particulates which consists of majority of the alumina and silica which are hard in nature.

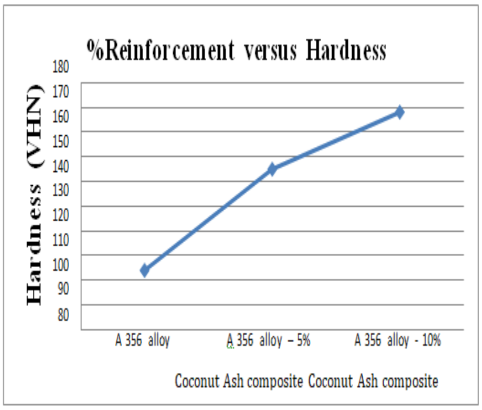
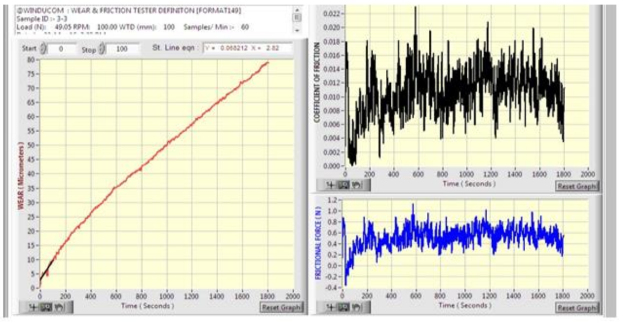


Figure 3.3 Hardness variations of composites

3.3 WEAR STUDIES:

Table 4 shows the sliding wear behaviour of A356 alloy and A356 alloy- 5 and 10 wt. % Coconut ash particulate composites. The normal load applied was 0.5 Kgf. The wear test was conducted for a period of 15 min at a sliding speed of 640 rpm on a steel disc with 120 mm track diameter and the track velocity was 2.0 m/sec. In all the results it was evident that the resistances to wear increases with increasing Coconut ash particulate content. With increasing Coconut ash particulate content, the amount of particle present strengthens the matrix and hence more wear resistance was observed. The MMCs with lower weight fractions of Coconut ash particulate underwent large wears, and the wear increased almost linearly with time. The base metal exhibits higher wear, and the MMCs with 10% coconut ash showed lower wear. The presence of Coconut ash particulate particles in A356 alloy matrix might be reason for the lower wear losses for composites compare to base alloy. The sliding wear behavior of base alloy and MMCs for various normal loads of 1.0 kgf and 1.5 kgf was shown in figure 3.3. The amount of wear increases with increasing normal load. With increasing normal load, MMCs underwent a transition from mild to severe wear.



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Sample ID :- 3-3
Load (N): 49.05 RPM: 100.00 WTD (mm): 100 Samples/ Min :- 60

Start 0 Stop 100 St. Line eqn : Y = 0.068212 X + 2.82

Figure 3.3 Sliding wear behavior with load

Table 3.2 Sliding wear behavior with % Reinforcement

Material	Load in kg	Time in minutes	Wear rate(microns)	Friction Factor(N)	Run
5% Reinforcement	0.5	5	110	0.7	1
5% Reinforcement	1	10	140	0.2	2
5% Reinforcement	2	15	175	0.1	3
10% Reinforcement	0.5	10	96	0.5	2
10% Reinforcement	1	15	122	0.8	3
10% Reinforcement	2	5	160	5.1	1

CONCLUSION

In the present work detailed investigation was carried out on the coconut shell ash reinforced A356 composites. The investigation includes manufacturing of composites through stir casting technique and evaluation of mechanical properties like density, porosity, hardness and wear properties according to the experimental plan. The following conclusions can be drawn from the present investigation. A356/Coconut Ashcomposites were produced by stir casting route successfully.

The density of the composites decreases with increasing the percentages of Coconut Ash particulates compared to the density of the alloy 2.81 g/cm^3.

The measured densities were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing Coconut Ash content. This can be attributed to the increase in porosity with Coconut Ash content.

The hardness of the composites increased with increasing the amount of Coconut Ash than the base alloy.

The base metal exhibits higher wear, and the MMCs with 10% coconut ash showed lower wear. The presence of Coconut ash particulate particles in A356 alloy matrix might be reason for the lower wear losses for composites compare to base alloy.

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