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# Effects of CSA Reinforcement On Wear Behaviour Of Aluminium Alloy Matrix Composite – A review

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***Abstract* - The application of material metal matrix of low cost composites is increasing rapidly in various fields because of its good mechanical properties. Successes of all industries like automotive, aerospace, marine and electronics applications mainly depend on reducing weight and at the same time increase in life, millage and appearance of their products. It mainly depends on developing new and cost-effective materials that have high weight to strength ratio, bio degradable and at the same affordable. The, composite materials have a steady growth, penetrating and conquering new market condition. Generally composite materials emerge a significant part of the engineered materials market, ranging from day today products to complex applications. Aluminium alloy (LM6) is used as a metal matrix and coconut shell ash (CSA) as reinforcement for developing a new metal matrix composite material. A coconut shell ash 6% by weight is added and an aging process is done at temperature 175°C to develop a metal matrix composite fabricated by stir casting. The wear properties of the composite is studied for all test specimens. Wear properties of the metal matrix composite were studied by performing a dry sliding wear test using pin-on-disc wear tester. The result of the wear test shows that wear rate of composites is higher than the pure alloy.**

***Keywords*: CSA, Wear behaviour, FRP, Hybrid composites, mechanical properties, stir casting.**

## 1.INTRODUCTION

### 1.1 OVERVIEW OF THE COMPOSITES:

The composite materials, plastics and ceramics are the various specially emerging materials. The number of applications of composite materials have grown regularly, penetrating and capture new market conditions. Modern composite materials constitute a significant proportion of the engineered materials market ranging from daily using products to various applications. While composites have already shown its worth as weight-saving components, the current challenge is to make them getting in less cost. The efforts to create an economically usable composite materials have reached invarious innovative manufacturing techniques used in the composites industries now.. It is essential that there be an integrated effort in design, tooling, quality assurance, manufacturing, and management of program for composites to become metals competitive.

The composites industry has started to realize that the commercial use of composites promise to offer much larger business opportunities than the aerospace sector due to the absolute size of the automobile industry. Thus the shift of composite applications from aircraft to other common uses has become important in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high-performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has shown a steady expansion in uses and volume. The increased volume has resulted in an expected cost reduction. High performance FRP can now be found in such diverse used as composite armouring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, blades of windmills , industrial drive shafts, highway bridges beams and even paper roller machine. For certain applications, the use of composites apart from metals has in fact resulted in cost and weight saving. Some examples are engine cascades, welded parts replacement, tubes, containment bands etc. Further, the necessity of composite for construction materials which are less weights and more seismic resistant structures has placed high emphasis on the usage of advanced materials that absorbs the shock & vibration through tailored microstructures. Composites being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity.

### 1.2 STRUCTURE OF COMPOSITES:

A composite material includes two or more physically or chemically distinct or distributed phases, separating them with an interface. Commonly, composite materials consists of a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is harder and stronger. The function of each components is described as:

- Matrix phase

3 The primary phase, having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it.

- Dispersed (reinforcing) phase

The second phase is embedded in the matrix in a discontinuous form. This secondary phase is called the dispersed phase. Dispersed phase is usually stronger than the matrix, therefore it is sometimes called the reinforcing phase. Many of common materials(metal alloys, doped Ceramics and Polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical properties of steel are similar to those of pure iron). The commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide (Al2O3). Silicon Carbide reinforcement increases the tensile strength, hardness and wear resistance of the matrix material. Aluminium Oxide has good compressive strength and wear resistance. Boron Carbide (B4C) is one of the hardest known elements. It has high elastic modulus and fracture toughness. The addition of Boron Carbide in the matrix material increases the hardness but does not improve the wear resistance. Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Zircon is usually used as hybrid reinforcement. It increases the wear resistance significantly. These reinforcements are replaced by cheaper reinforcing elements such as, rise husk, coconut shell, coconut char, fly ash, bagasse, colliery shale groundnut shell, bamboo leaf etc.

## 2. Inference from literature survey

### 2.1. Aluminium alloy (LM6) matrix composites:

Pushyamitra Mishra, Priti Mishra, R.S.Rana

In this work rice husk ash particles were added to Aluminium alloy (LM6) in quantities of 6% by weight through Stir casting to produce hybrid composite. After the artificial aging process is done at temperature 135oC, 175oC, and 225oC. Based on the observations made in the study, results can be concluded that hardness of both the alloy and composite increases with the aging temperature up to 1750C and then decreases for aging at further high temperature of 225oC.

There is an improvement of around 26.71% and 53.12% in the hardness of alloy and composite respectively at peak ageing temperature (175°C) as compared to cast alloy because of formation of coherent precipitates. The weight loss of LM6 alloy in heat treated condition is less as compared to the cast condition for the same load. The weight loss of composite is less as compared to the alloy at every aging temperature. The weight loss of LM6-6% rice husk ash composite in heat treated condition is less as compared to the cast condition for a constant sand concentration.

**2.2Wear behaviour of Al-Si-Fe / Coconut Shell Ash (CSA) particulate composites:**

In this work wear behaviour of aluminium alloy reinforced with coconut shell ash particles fabricated by stir casting process was investigated. The specimens were produced by keeping the percentage of aluminium alloy and varying the coconut shell ash particles from 3-15 wt% CSA particles. Based on the observations made in the study, the hardness values of the developed composites increased with an increasing percentage of coconut shell particle additions. The coefficient of friction increases with increasing load for the Al-Si-Fe alloy and the composites containing CSA particles. It is observed that, as the applied load increases, the wear rate also increases. This is because, whenever applied load increases, the friction at the contact surface of the material and rotating disc obviously increases. The incorporation of the coconut shell particle in the Al-Si-Fe alloy matrix as a reinforcement increases the wear resistance of the material.

### 2.3 Tribological behaviour of Al-1100 - Coconut Shell Ash (CSA) composite at elevated temperature:

R.Siva Sankara Raju, M.K.Panigrahi, R.I.Ganguly, G.Srinivasa Rao

Wear behaviour of Al-1100 - CSA composites at high temperature is investigated. The composites such as Al-5%CSA, Al-10%CSA and Al-15%CSA are prepared, using stir casting techniques. Based on the observations made in the study, the specific strength of Al-15%CSA alloy composite is enhanced by 70% over Al-1100 base alloy. However, density and elongation of the alloy composite are reduced by 6% and 46% respectively. At 150oC, higher volume fraction of reinforcement in Al-1100 matrix composites have acquired more resistance to wear at all the applied pressure. The wear/wear rate is found to be the least for Al15%CSA composite. Above critical pressure of 8.11N/mm2, Al-1100 and Al15%CSA materials show a sharp increase in the wear, thereby indicating higher wear rate. This is due to change in mechanism of wear when the pressure exceeds a critical value. At ambient temperature, there is a rise in coefficient of friction with increasing pressure. However, for higher temperature, coefficient of friction increases till 6N/mm2 and thereafter decreases.

2.4 Mechanical properties and characterization of zirconium oxide (ZrO2) and coconut shell ash (CSA) reinforced aluminium (Al 6082) matrix hybrid: K.Ravi Kumar, T.Pridhar, V.S.Sree Balaji

This research focuses on the microstructure and mechanical properties while incorporating zirconium oxide and coconut shell ash particles in Al 6082 matrix composites. Zirconium oxide and coconut shell ash particles were varied from 0 to 10% and fabricated by the stir casting process. Based on the observations made in the study, the density of the composites initially decreased and then increased. Density of the composites increased to a maximum of 11.1% compared to the base aluminium alloy. Hardness of the composites decreased while adding 10% coconut shell ash due to the lubrication effect of the fine CSA particles. Addition of $ZrO_2$ in aluminium alloy increased the hardness of composites. Hardness of the composites increased to a maximum of 31.5% compared to that of the aluminium alloy. Increase in addition of zirconium oxide particles increased the strength of the composites initially, while addition of 10% $ZrO_2$ decreased the strength of the composites.

## 2.5 Mechanical properties of coconut shell ash reinforced aluminium metal matrix composites:

Poornesh Mangalore, Akash, Akash Ulvekar, Abhiram, Joy Sanjay, and Advaith

In this study In the present study, an effort was made to produce a new class of aluminium based metal matrix composites by reinforcing coconut shell ash particles and graphite particles into the Al 7079 alloy using liquid metallurgy technique or stir casting process with bottom pouring provision. The composite specimens were effectively produced using stir casting technique with bottom pouring at a melting temperature of 750±20°C, stirring speed of 600 rpm and a holding time of 5 minutes. Based on the observations made in the study, the increase of the reinforcing particles (CSA) on to the matrix (Al 7079) the hardness of the produced samples increases in a considerable amount. The major elements in the coconut shell ash particles are SiO and MgO which are ceramic in nature and have a high hardness inherent in them. These hard ceramic particles tend to absorb the load applied during the test therefore reducing the probability of large deformation on the surface.The density of the composites in addition to impact energy of the composites decreased linearly with the addition of the reinforcing particles because of the inbuilt properties of the particulate reinforcement.

## 2.6 Mechanical and tribological behaviour of aluminium Al6061 - CSA composite using stir casting pellet method :

P.Lakshmikanthan, Dr.B.Prabu

This work is focused on synthesis and determination of mechanical and tribological properties of aluminium alloy Al6061 - Coconut Shell Ash (CSA) metal matrix composite synthesized by stir casting - pellet method. Using this method, varied weight percentage 3%, 6%, 9%, 12% and 15% of CSA particles are successfully introduced in the aluminium alloy to produce different mixtures of composites. Based on the observations made in the study, 6% CSA reinforced composite has the maximum tensile strength , maximum hardness, maximum wear. The reason for the initial increase in the tensile strength and hardness and initial decrease in wear at lower % of CSA (up to 6%) in the composites may be due to the fact that CSA particles act as barriers to the dislocations when load is applied and also the presence of ceramic particles and metal oxides in the reinforcement. The coefficient of friction and friction force of the composites increases gradually with the increase in amount of reinforcement.

## 2.7 Optimization of tribological behaviour on Al - Coconut Shell Ash composite at elevated temperature :

R Siva Sankara Raju, M K Panigrahi, R I Ganguly, G Srinivasa Rao

In this study, determine the tribological behaviour of composite at elevated temperature i.e. 50 - 150oC. The aluminium matrix composite (AMC) are prepared with a combo casting route by volume of reinforcement of coconut shell ash (CSA) such as 5, 10 and 15%. Based on the observations made in the study,mechanical properties of composites such as tensile strength and hardness have been increased. Similarly, elongation and density decreased with increasing volume of CSA in Al composite. Temperature has the highest influence on wear rate and coefficient of friction in the wear behaviour of Al - CSA composite followed by sliding velocity and sliding distance. Optimal wear behavioral conditions, such as temperature (50oC), sliding velocity (0.5m/s), and distance (1000 m), can be used to achieve the maximum wear rate and coefficient of friction Al - CSA composites.

## 3.MANUFACTURING TECHNIQUES

Different processing methods such as stir casting, powder metallurgy and squeeze casting, etc., have been attempted and discussed to synthesize dual particles reinforced aluminium matrix composites (AMCs).

### 3.1 STIR CASTING :

The simplest flexible and most economical attractive class of route of metal matrix composite production is to simply stir and mix the liquid metal with solid ceramic particles (Reinforcing materials) and then allow the mixture to solidify. This technique involves inclusion of ceramic particulate into molten metal and allowing the mixture to solidify. The simplest and most commercially used techniques are known as vortex techniques or stir casting techniques. Another variant of stir casting process is compo-casting. Here, ceramic particles are added into the alloy in the semisolid state.

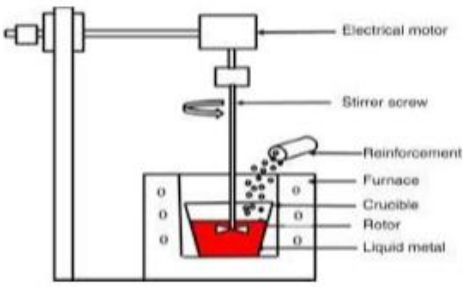


**Fig: STIR CASTING**

**4. MATERIALS USED :**

- **LM6 aluminium alloy**
- **Coconut shell ash**

**4.1 LM6 ALUMINIUM ALLOY :**

LM6 is a corrosion resistant aluminum casting alloy with average durability and strength, and with high impact strength and ductility. Applications: general, electrical, marine, intricate shaped castings, and building cladding panels. Aluminium alloys of this and similar compositions are rather difficult to machine, due to their tendency to drag and to the rapid tool wear caused by their high Silicon content. Chemical composition (in wt %) of this aluminium alloy is listed in Table 4.1. Mechanical properties of LM6 aluminium alloy is listed in Table 4.2

**Table 4.1 : Composition of LM6**

| **Element** | **LM6** |
|---|---|
| Cu | 0.15 |
| Mg | 0.10 |
| Si | 12.50 |
| Fe | 0.60 |
| Mn | 0.55 |
| Ni | 0.10 |
| Zn | 0.15 |
| Pb | 0.10 |
| Ti | 0.20 |
| Al | Rest |

Table 4.2 : Mechanical properties of LM6 aluminium alloy

| | Mechanical Properties | | |
|---|---|---|---|
| Process | Tensile Strength | Elongation | Brinell Hardness |
| Sand casting | 160 – 190 | 5 | 50 – 55 |
| Pressure Die Casting | 280 | 2 - 5 | 55 – 60 |
| Gravity Die Casting | 190 – 230 | 7 | 55 – 60 |

4.2 COCONUT SHELL ASH :

Coconut shell is an agricultural waste. The coconut shell in the form of ash is a material which can be used as a substitute for cement. The research indicates that the materials rich in amorphous silica can be used as partial replacement of cement. Use of such material can lead to increased compressive and flexural strength. Chemical composition (in wt %) of Coconut shell ash is listed in Table 4.3.

**Table 4.3 : Composition of CSA**

| Constituents | % of Wt. |
|---|---|
| Fixed C | 4 – 6 |
| $SiO_2$ | 36 – 40 |
| $Fe_2O_3$ | 8 – 9 |
| $Al_2O_3$ | 23 – 25 |
| MgO | 2 – 3 |
| CaO | 3 – 5 |
| $K_2O$ | 0.7 – 0.9 |
| Remain | LOI |

**Fig :Coconut Shell Ash**

PREPARATION OF Al-CSA COMPOSITE :

Aluminium alloy (grade LM6) is procured from Balaji Aluminium Cast Alloy, Chennai, Tamilnadu. The metal matrix composite that was used in the study was produced at Met Mech Engineers, Ashok nagar, Chennai. For the present experimental investigation, aluminum alloy LM6 was used as a matrix material and coconut shell ash as reinforcement.

The aluminium alloy composites are prepared in a bottom pouring furnace, using stir casting method. The LM6 aluminium alloy pieces are heated in the furnace till they melt at 750oC and care is taken to achieve 100% melting. Measure the coconut shell ash of 6% by weight separately and are preheated to 450oC - 460oC and maintained at the same temperature for about 20 minutes to remove the moisture content. Add slowly preheated coconut shell ash 6% to the molten alloy with temperature maintained at more than 720oC. The reinforcements are added with continuous stirring at a speed of 350-500 rpm to a time of 6-8 minutes. Then the melted matrix and reinforced particles are poured into the preheated mould and the pouring temperature should be maintained at 6800C. The specimen of LM6-Coconut Shell Ash composite was heat treated in a muffle furnace to compare the properties in aged and as cast condition. In the first step the specimen was heated to a temperature of 520 ± 50oC in a muffle furnace for a duration of 1 hour. Finally withdraw the specimen from the mould after the complete cooling process. In the first step the specimens were heated to a temperature of 520±50oC in a muffle furnace for a duration of 1 hour. This was done to completely dissolve the solute elements in Al solid solution. In the second stage the solution treated specimens were rapidly cooled into oil to prevent the precipitation of the solute elements. At last the Al-6%CSA composite reheated to 175oC for 5 hours and then allowed it to cool in air to improve the strength and hardness of the material. Three independent metals are cast as

- Al-LM6 alloy
- Al-6%CSA
- Heat treated Al-6%CSA

WEAR TEST :

A pin-on-disc test apparatus was used to investigate the wear characteristics of the composites as per ASTM standards. The initial weight of the samples was measured using a single pan electromagnetic weighing machine with an accuracy of 0.01 g. During the test, the pin is pressed against the rotating disc. The wear test was conducted with a constant velocity and load of 2.0 m/s and 30 N respectively. The sliding distance for this wear test is 500 m. The results of the wear rate of samples are shown in fig . The coefficient of friction of the specimens was calculated by the below stated formula. Coefficient of friction = Friction force / applied load

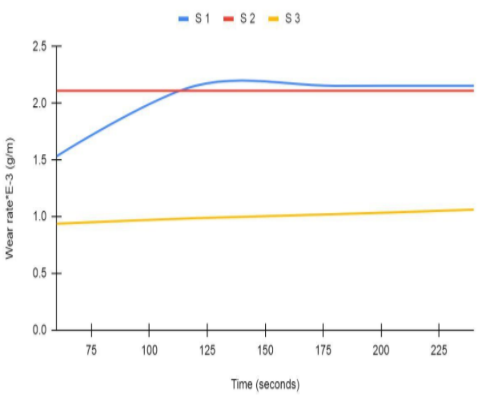


Fig : Variation of wear rate

From Figure it was observed that the wear rate of pure LM6 aluminium alloy is higher than the composites. The wear rate of the specimen 3 suddenly decreases which is solution treated and participation hardened. In the specimen 2 composite, a higher fraction of the matrix (i.e. softer phase in the composite) is exposed to rubbing action. Softer phase undergoes a plastic deformation which is helped at a higher temperature. The coconut shell ash particles composite exhibited the higher wear resistance. This behaviour can be attributed to the presence of CSA particles on the counter surface, which acts as a transfer layer and effective barriers to prevent large scale fragmentation of Al-Si-Fe (LM-6) matrix. The addition of hard ceramic particles improves resistance to seizure. The coconut shell ash particle allows considerable thermal softening effects without having adverse effects on the wear behaviour. The addition of CSA particles restricts the flow or deformation of the matrix material.

CONCLUSIONS

The following conclusions are arrived from review study. The mechanical properties of the composites are enhanced with a higher percentage of reinforcement content. Mechanical properties of the composite mainly depend on the hardness of the matrix and the reinforcement. Stir casting method is a very low cost fabrication method and more suitable for mass production. Stir casting route is a widely used fabrication method which compares to the other fabrication method.

- Stir casting methods improved the strength of the composite and also increased the distribution of particles in the matrix.
- It is observed that wear resistance of heat treated composite is higher than the pure alloy and non heat treated composite.
- The incorporation of the coconut shell ash particles in the LM-6 alloy matrix as a reinforcement increases the wear resistance of the material.

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