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Experimental Investigation of Microstructure and Mechanical Properties of Aluminium Hybrid Composite Reinforced with Rice Husk and Fly Ash

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Abstract: *The application spectrum of low-cost material reinforced metal matrix composites is growing rapidly in various engineering fields due to their superior mechanical properties. In the present study aluminium alloy is reinforced with locally available inexpensive rice husk ash (RHA) and fly ash (FA) for developing a new hybrid composite material. A rice husk ash and fly ash particles of 5, 10 and 15% each by weight are added to develop metal matrix composites using liquid metal processing route. The surface morphology was studied using scanning electron microscope. The mechanical properties such as tensile strength, hardness and percentage elongations were studied for the all-test specimens.*

Keywords*: Hybrid Composite Material, Aluminium Composite, Rice Husk, Fly Ash, Mechanical Properties, Electron Microscope.*

I. INTRODUCTION

A composite is a material that consists of constituents produced via a physical combination of pre-existing ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties. A composite is a material made with several different constituents intimately bonded. The reinforcement may be in the form of whiskers, particles, plates, rods, etc. The matrix may be metallic, resinous, ceramic or organic. The constituents of a composite do not dissolve or merge completely into each other but act in concert. This yields endless possibilities with infinite combinations, hence making it an 'evergreen' field of study [1]. Now a days the particulate reinforced Aluminum matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast Aluminum matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. In composite materials, controlled distribution of one or more reinforcement materials in a continuous metal matrix phase is possible [1].

Particle-reinforced metal matrix composites (MMCs) can be manufactured and formed by conventional metal methods. Several researchers have developed methods to describe the strength of particle-reinforced MMCs. The strength of a particle-reinforced MMC is found to be related to the volume fraction and diameter of the particles from the micromechanics approach. The yield strength of particle-reinforced MMCs is much higher than the result predicted by continuum mechanics theories. This incremental increase of the yield strength is due to the much higher dislocation density and smaller sub grain size in the matrix than in the unreinforced alloy with hard particles dispersed in a relatively ductile matrix [6].

II. LITERATURE REVIEW

S. D. Saravanan et al.[1] studied the properties of the AlSi10Mg /RHA composite and found that the Tensile Strength, Compression Strength and Hardness of the metal matrix composite increases and ductility gets decrease with increase in the weight fraction of rice husk ash.

S. Sarkar S. et al. [2] concluded that the Ultimate tensile strength has improved whereas ductility has decreased with increase in fly ash content to Al-Si and Al-Mg alloys.

H.C. Anilkumar et al. [3] found that the stir casting method used to prepare the composites could produce uniform distribution of the reinforced fly ash particles. The Tensile Strength, Compression Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The enhancement in the mechanical properties can be well attributed to the high dislocation density.

Satish D et al.[4] conducted "Assessment of Concrete Strength using Fly ash and Rice husk ash" and they concluded that rice husk when burned produced amount of silica (more than 80%). For this reason, it provides excellent thermal insulation. The workability of RHA concrete has been found to decrease but FA increases the workability of concrete. Compressive strength increases with the increase in the percentage of Fly ash and Rice Husk Ash up to replacement.

D. Siva Prasad et al. [5] concluded the hardness of A356.2/RHA composites increases with increase in rice husk ash content. Incorporation of rice husk ash particles in aluminium matrix can lead to the production of low-cost aluminium composites with improved hardness and strength.

III. PROCESSING OF METAL MATRIX COMPOSITES

In general the most common manufacturing MMC technologies are divided primarily into two main parts: primary and the secondary. The primary processing is the composite production by combining ingredient materials (powdered metal and loose ceramic particles, or molten metal and fiber performs), but not necessarily to final shape or final microstructure and the secondary processing is the step which obviously follows primary processing, and its aim is to alter the shape and microstructure of the material (shape casting, forging, extrusion, heat treatment, machining). Secondary processing can change the constituents (phase, shape) of the composite. So, MMCs can be made by different ways:

a. Powder Metallurgy
b. Diffusion Bonding
c. Stir Casting
d. Squeeze Casting
e. Compo Casting

IV. CASE STUDY

Effect of Rice Husk ash and Fly ash Reinforcements on Microstructure and Mechanical properties of Aluminium alloy(AlSi10Mg) Matrix Composites[10]A. P. S. V. R. Subrahmanyam, G. Narsaraju and B. Srinivasa Rao

a) Abstract: In the present study aluminium (AlSi10Mg) is reinforced with locally available inexpensive rice husk ash(RHA) and fly ash(FA) for developing a new hybrid composite material. A rice husk ash and fly ash particles of 5, 10 and 15% each by weight are added to develop metal matrix composites using liquid metal processing route. The surface morphology was studied using scanning electron microscope. The mechanical properties such as tensile strength, hardness and percentage elongations were studied for the all-test specimens.

B) Materials: For the present experimental investigation, AlSi10Mg aluminum (6061) alloy was used as a matrix material whose chemical composition (in wt %) is listed in Table 1. AlSi10Mg is a typical casting alloy with good casting properties. Fiber reinforcements rice husk ash and fly ash chemical composition (in wt %) are listed in Table 2 and 3

Table 1. Chemical Composition of the Matrix Alloy (%Wt)

Chemical Composition	Cu	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
%	0.1	10.0-13.0	0.6	0.3-0.7	0.1	0.1	0.1	0.05	0.2	Balance

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Table 2. Chemical Composition of Rice Husk Ash (%Wt)

Chemical Composition	Al_2O_3	Fe_2O_3	CaO	MgO	N_2O	K_20	LOI	SiO_2
%	0.249	0.136	0.622	0.442	0.023	2.49	3.52	94.04

Table 3. Chemical Composition of Fly Ash (%Wt)

Chemical Composition	Al_2O_3	Fe_2O_3	LOI	SiO_2	TiO_2
%	28.44	8.85	1.43	59.96	2.75

c) Composite Preparation:

The sequential procedure followed in the fabrication of hybrid composite is as follows. Heat the AlSi10Mg alloy pieces in the furnace till melts at 7500 C and care is taken to achieve 100% melting. Slag is removed using scum powder to avoid the bad quality of casting. Take less than 5% weight of solid dry hexa-chloro-Methane tablets to degas the molten alloy at a temperature of 780°C. Measure the 15%, 10% and 5% of fly ash (reinforcement) by weight and rice husk ash of 5%, 10% and 15% by weight separately and are pre heated to 4500C-600°C and maintained at the same temperature for about 20 minutes to remove the moisture content. Now start stirring the molten alloy to create a vortex. Add slowly pre heated fly ash 15%, rice husk ash 5% to the molten alloy with temperature maintained at more than 720°C. Add magnesium about 2% of weight to ensure good wettability for all proportions of the reinforcements with continuous stirring at a speed of 350-500 rpm to a time of 6-8 minutes.

Meanwhile preheat the mould to avoid shrinkage of casting material. Then the melted matrix and reinforced particles is poured into the preheated mould and the pouring temperature should be maintained at 680°C. Repeat the same procedure for the other two combinations of the reinforcements (i.e., 10% FA+ 10%RHA and 5% FA+ 15%RHA) by keeping alloy (AlSi10Mg), and magnesium (Mg) as constant in weight. Finally withdraw the specimens from the mould after complete cooling. And confirm the solidification of casting before removing from the mould.

d) Results and Discussion:

Microstructure Analysis:

The micro structure plays an important role for analyzing the distribution of distinct phases in an Aluminium matrix material. The micro structure was studied by using scanning electron microscope and which shows that the phases are near uniformly distributed in the metal matrix. And the SEM Images of the three specimens were as shown below.

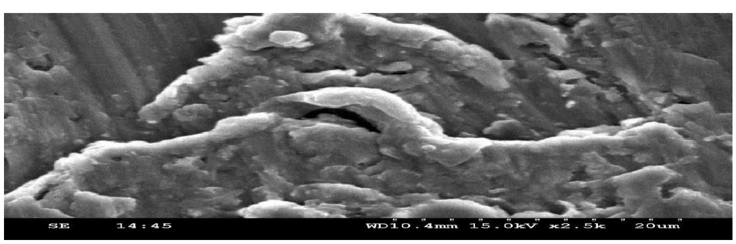

Figure IV (a) AlSi10Mg +15% FA+5% RHA

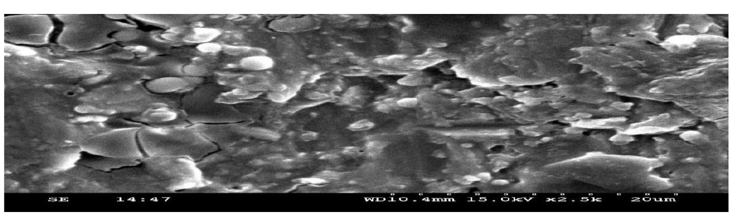

Figure IV (b) AlSi10Mg + 10% RHA +10% FA

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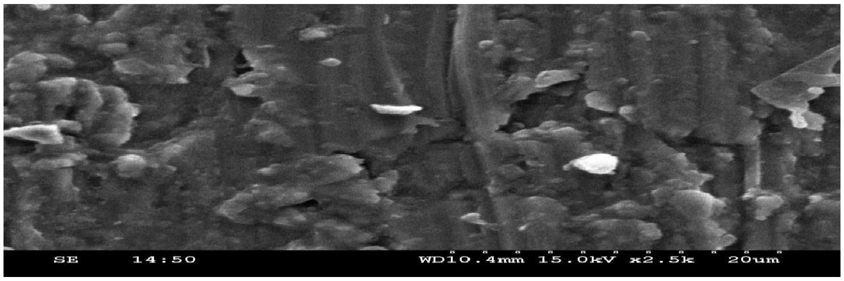

Figure IV (c) AlSi10Mg + 15% RHA +5% FA

The SEM micrographs of Al-Si10Mg/Rice Husk Ash/Fly Ash hybrid composites are shown in Figure IV.(a) to IV.(c). From the Figure IV.(a) the fly ash is more as depicted in the form of hollow spheroids. Whereas Rice husk ash in the form of flakes. The reinforcements Rice husk ash and Fly ash are not uniformly distributed due to improper bonding between reinforcements and matrix alloy. From the image 4.4.1(c) the Rice husk ash is more in the form of flakes and Fly ash in the hollow spheroids is less. In this case the rice husk ash particles are agglomerated on the sides of the composite and dominating fly ash particles this is due to the poor wettability. In this case Figure IV. (b) it can observe that the Fly ash (hollow spheroids form) and Rice husk ash (Flakes form) are uniformly distributed when the two reinforcements each of 10% weight are added to matrix alloy are tightly packed due to the surface formed by the combination of reinforcements with the matrix alloy, which ensures good mechanical properties of the resultant hybrid composite (AlSi10Mg + 10% RHA +10% FA).

Hardness Test (BHN):

The hardness test results are shown in the below graph for all composite specimens.

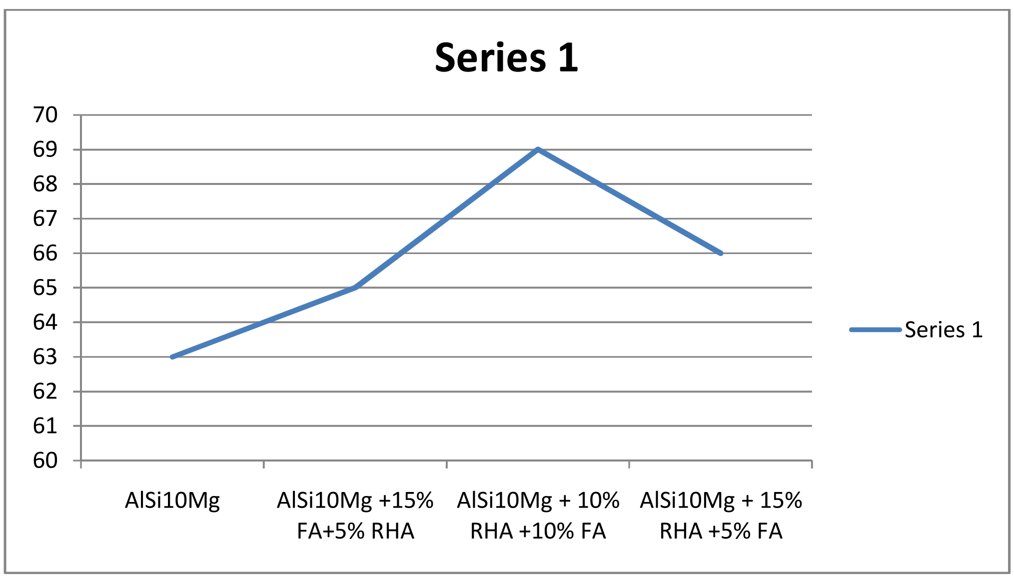

Figure IV (d) Hardness Test Graph

It was observed that the hardness of the composite linearly increasing with the increase in weight fraction of the rice husk ash particles. This occurs due to increases in surface area of the matrix and thus the grain sizes are reduced. The presence of such hard surface area offers more resistance to plastic deformation which leads to increase hardness. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, fly ash as filler in Al casting reduces cost, decreases density and increase hardness. The reinforcement's fly ash and rice husk ash each of 10% weight showed maximum hardness.

e) Conclusions:

The major conclusions of the present study on microstructure and mechanical properties of the Rice Husk ash and Fly Ash reinforced AlSi10Mg hybrid metal matrix composites are summarized below.

1. The micro structures revealed that reinforcements in 10% each by wt. are distributed uniformly and tightly packed when compared to other combinations of reinforcements probably due to the surface formed by reinforcement combination with the matrix alloy.
2. The tensile strength of the composite is found to be decreased when rice husk ash is increased and is maximum when fly ash and rice husk ash are taken each of 10% weight.
3. The Hardness of MMC increased with increased % of RHA and decreased with increased % of Fly ash.
4. One of the major requirements for uniform distribution of particles in the melt is its wettability. The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement, due to this problem the strength decreases after certain limit. From this problem we can overcome by adding small amount of Magnesium and by pre heating the composites and the die.

V. CURRENT STATE OF APPLICATIONS OF ALMMCS IN VARIOUS INDUSTRIES

i. AlMMCs in innovative light-weight designs
ii. Automotive industry
iii. Aerospace and aircraft industry
iv. Rail transport
v. Marine transport
vi. Building and construction industry
vii. High-temperature applications
viii. Automotive industry
ix. Applications in aerospace and aircraft industry
x. Electronic packaging and thermal management
xi. Packaging and containerization
xii. Electrical transmission
xiii. Sports and recreation

VI. FUTURE SCOPE

Currently, the design of high performance-low-cost components is receiving much attention from material researchers. The same can be attained by the consideration of industrial and agro-waste materials as green reinforcements in aluminum matrix composites. The disposal of these materials faces environment related problems. Therefore, recycling of these waste materials by converting it into green material is a focus of the current research. Due to environment friendliness, energy efficiency and cost-effectiveness, these materials exhibit good market potential as a reinforcement material for composites. Fly ash, rice husk, red mud, palm oil fuel ash (POFA), palm oil clinker (POC), rice husks, coconut husk and sugarcane bagasse are some of the waste materials that have potential to be utilized in construction and automotive industries.

Vast researches have been conducted and developments are still advancing for successful utilization of waste materials as partial reinforcement in composites. The present study shows that the HAMCs offer unique combination of mechanical and physical properties, which are scarcely attainable with the use of ceramic reinforced composites. The HAMCs could be applied in the design of components for automobiles, aircrafts, marine structures and facilities, defence assemblies, sports and recreation among many others. The notable advantages of HAMCs are the relatively low cost, lightweight and higher strength to weight ratio in comparison ceramic reinforced composites. However, the investigations regarding wear properties of these composites needs to be carried out under different parametric conditions since very limited literature corresponding to wear of such composites is available.

Finally, it can be said that there is an immense potential, scope and opportunities for the researchers in the field of prediction and improvement of characteristics of the HAMCs.

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