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Original Article

Investigations on mechanical properties of aluminum hybrid composites

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ABSTRACT

A double stir casting process was used to fabricate aluminum composites reinforced with various volume fractions of 2, 4, 6, and 8 wt% RHA and SiC particulates in equal proportions. Properties such as hardness, density, porosity and mechanical behavior of the unreinforced and Al/x%RHA/x%SiC ($x = 2$, 4, 6, and 8 wt%) reinforced hybrid composites were examined. Scanning electron microscope (model JSM-6610LV) was used to study the microstructural characterization of the composites. It was observed that the hardness and porosity of the hybrid composite increased with increasing reinforcement volume fraction and density decreased with increasing particle content. It was also observed that the UTS and yield strength increase with an increase in the percent weight fraction of the reinforcement particles, whereas elongation decreases with the increase in reinforcement. The increase in strength of the hybrid composites is probably due to the increase in dislocation density. A systematic study of the base alloy and composites was done using the Brinell hardness measurement and the corresponding age hardening curves were obtained. It was observed that in comparison to that of the base aluminum alloy, the precipitation kinetics of the composites were accelerated by adding the reinforcement. This effectively reduced the time for obtaining the maximum hardness by the aging heat treatment.

1. Introduction

Composite materials are a mixture or a combination of two or more constituents differing in form and/or material composition and that are essentially insoluble in each other. Both constituents maintain their identity as they do not dissolve or melt in each other, and act in such a way that a new material results whose properties are better than the sum of their constituents. The incorporation of several different types of ceramic particulates into a single matrix has led to the development of hybrid composites. Also, using a hybrid composite that contains two or more types of particulates, the advantages of one type of particulates could complement to what is lacking in the other [1].

Nowadays, the use of agro/industrial wastes as a secondary reinforcement in the fabrication of composites is gaining more importance. The advantages of using these wastes are production of low cost by-products, reduction in the cost of aluminum products [2], readily available with less cost,

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and often lower densities in comparison with most technical ceramics (boron carbide and alumina). Many researches have reported the potentials and limitations of the use of wastes as reinforcements [3,4]. Prasad and Krishna [5] reported that the tribological properties of low-cost composites developed with the use of rice husk ash (RHA) have been increased along with some increase in mechanical properties. Prasad [6] investigated the damping behavior of the composites with rice husk ash as reinforcement and the results indicate the increase in damping capacity with the increase in particulate content. The increase in damping capacity has been attributed to several mechanisms such as thermoelastic damping, intrinsic damping, and interfacial damping. Several authors studied different properties of hybrid composites with graphite as reinforcement. Suresha [7] studied wear characteristics of hybrid aluminum matrix composites reinforced with graphite and silicon carbide particulates and found that hybrid composites exhibit better mechanical properties and wear characteristics. Jinfeng Leng et al. [8] studied the machinability of SiC/Gr/Al hybrid composites and their results showed that the presence of flake graphite particle acted as solid lubrication and promoted chip formation during cutting, resulting in an improved machinability. Alaneme et al. [9] studied the characterization and mechanical behavior of RHA reinforced hybrid composites and concluded that RHA has great promise to serve as a complementing reinforcement for the development of low cost products. Rice husk ash contains a quality of high surface area silica, which has been purified by chemical leaching and fluidization furnace. Mishra et al. [10] discuss the method of preparation of silicon and its purification procedure with rice husk ash. Rodriguez de Sensale [11] studied the strength development of concrete with rice husk ash. RHA is a highly pozzolanic material. The non-crystalline silica and high specific surface area of the RHA are responsible for its high pozzolanic reactivity. In the present work, an attempt was made to fabricate aluminum hybrid composites with silicon carbide (SiC) and agro waste RHA as reinforcements. Properties such as density, porosity, aging, and mechanical behavior were investigated and the related mechanisms have been discussed and presented.

2. Materials and method

2.1. Matrix material

In the present study, A356.2 with the theoretic density of 2760 kg/m^3 was used as a matrix material. The chemical composition of the matrix material is given in Table 1. RHA particulates with an average size of 25 μm and SiC particulates with an average size of 35 μm were used as reinforcement materials. The chemical composition of RHA is given in Table 2. Magnesium was selected as a wetting agent to improve wettability between the matrix and the reinforcements during production of the hybrid composites.

Table 1 – Chemical composition of A356.2 Al Alloy matrix.

Si	Fe	Cu	Mn	Mg	Zn	Ni	Ti
6.5–7.5	0.15	0.03	0.10	0.4	0.07	0.05	0.1

2.2. Pretreatment of RHA

Before incorporating the rice husk ash particulates into the molten metal, RHA was pretreated to RHA to free it from inorganic matter and carbonaceous material. The RHA particulates were thoroughly washed with water to remove the dust and dried at room temperature for 1 day. The rice husk was then heated to 200 °C for 1 h to remove the moisture. It was then heated to 600 °C for 12 h to remove the carbonaceous material. After this operation, its color changed from black to grayish white. The silica-rich ash, thus obtained, was used as a reinforcement material in the preparation of composites.

2.3. Preparation of hybrid composites

The aluminum alloy was charged into the graphite crucible and heated to 750 °C till the entire metal in the crucible was melted. The reinforcement particles RHA and SiC were preheated to 700–800 °C for 1 h before incorporation into the melt to remove moisture. After the molten metal was fully melted, degassing tablet was added to reduce the porosity. Simultaneously, 1% by weight magnesium was added to the melt to enhance the wettability between the matrix and the reinforcements. A stirrer made up of stainless steel was lowered into the melt slowly to stir the molten metal at a speed of 700 rpm. The speed of the stirrer can be controlled by means of a regulator provided on the furnace. The preheated SiC particles were added into the molten metal at a constant rate during the stirring. Stirring was continued for another 5–10 min even after the completion of particle feeding. After this stage the Al/SiC composite slurry was allowed to maintain at 700 °C for 10 min without stirring. The composite slurry was then heated to 750 °C and preheated RHA particulates were poured at a constant rate and the stirring was continued for 20 min. The mixture was poured into the mold (prepared for tensile test specimens) which was also preheated to 500 °C for 30 min to obtain uniform solidification. Using this double stir casting process, 2, 4, 6 and 8% by weight of equal proportions of RHA/SiC particle-reinforced hybrid composites were produced.

Table 2 – Chemical composition of RHA.

Constituent	Silica	Graphite	Calcium oxide	Magnesium oxide	Potassium oxide	Ferric oxide
%	90.23	4.77	1.58	0.53	0.39	0.21