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Production and Characterization of Rice Husk Ash-Silicon Carbide Reinforced Al1100 Aluminium Alloy Hybrid Composites

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Abstract: **-- Aluminium Matrix Composites (AMCS) are light weight, high-strength materials with potential applications in areas such as automobiles, aerospace, defence, engineering and other industries. Stir casting route is the most promising one for synthesizing discontinuous reinforcement aluminium matrix composites because of its relative simplicity and easy adaptability with all shape casting process used in metal casting industry. The objective of developing aluminium alloy based metal matrix hybrid composites using stir casting is to study their mechanical properties. Hybridization of metal matrix composites is the introduction of more than one type/kind, size and shape of reinforcement during processing of composites. The advantages of one type of reinforcement could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design. The liquid metallurgy route (stir casting technique) was successfully adopted in the preparation of aluminium alloy, magnesium (3 wt%) is added to achieve good wettability and hybrid composites containing 3, 6, 9, 12 and 15 wt% of SiC particles and constant 3 wt% of rice husk ash. There is an effort to understand the microstructure study of the cast hybrid composites including particle distribution and defects like porosity in order to correlate with the observed mechanical properties measured in terms of hardness and tensile properties.**

Keywords: AMCS, Al 1100; Hybrid composite; Rice Husk Ash; SIC.

I. INTRODUCTION

Many of our modern day technology require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics and polymeric materials. This is especially true for materials that are needed for aerospace, underwater and transportation applications. During the past few years, material design has shifted emphasis to pursue light weight, environment friendliness, low cost, quality, higher service temperature, higher elastic modulus, improved wear resistance and performance [1-5]. Hybridization of metal matrix composites is the introduction of more than one type/kind, size and shape of reinforcement during processing of composites. It is carried out to obtain synergistic properties of different reinforcements and matrix used, which may not be realized in monolithic alloy or in conventional monocomposites [6-9]. Hybridization of monocomposites with second reinforcement i.e. introduction of more than one reinforcements simultaneously during processing, can be carried out by most of the conventional monocomposites fabrication techniques [10]. The primary composite processing techniques, such as, stir casting, infiltration process, spray deposition process, in-situ and powder metallurgy techniques can be used [11].

Stir casting route is the most promising one for synthesizing discontinuous reinforcement aluminium matrix composites because of its relative simplicity and easy adaptability with all shape casting process used in metal casting industry. This method involves producing a melt of the selected matrix material, followed by the introduction of the reinforcing materials in to the melt and obtaining a suitable dispersion through stirring [12]. Hybridization of metal matrix composites is carried out to obtain synergistic properties of different reinforcements and matrix used, which may not be realized in monolithic alloy or in conventional monocomposites [13-17].

The present study involves synthesis of hybrid composites by adding constant wt% of rice husk ash (RHA) and different wt% of silicon carbide (SiC) particles in to molten aluminium alloy during stirring. The objective of developing hybrid composites in this study by stir casting is to study their potential applications in structural components and the mechanical properties of these composites is, therefore, essential for the present study. There is an effort to understand the microstructure of the composites including particle distribution and defects like porosity, in order to correlate with the observed

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mechanical properties measured in terms of hardness and tensile properties.

II. EXPERIMENTAL METHODOLOGY

Al 1100 of 99.674% purity and commercial magnesium of 99.92% purity is used as the matrix for the synthesis of particle reinforced metal matrix composites. The molten Al 1100 was alloyed with magnesium since it promotes wetting between the molten alloy and the oxide particles. Silicon Carbide (SiC) of average size 25-30 µm and Rice Husk Ash (RHA) of average size 0.5-5µm are used as the reinforcements.

A. Stir Casting and Its Experimental Setup

About 700 g of commercially pure Al 1100 was melted and superheated to a desired processing temperature in a clay-graphite crucible inside the muffle furnace. Before any addition, the surface of the melt was cleaned by skimming. The weighed amount of powders was added into molten Al 1100 at a processing temperature of 900□C and the rate of addition of particles was controlled at an approximate rate 6-8 g/min. A coated mechanical stirrer was used to disperse the rice husk ash and SiC particles in the melt. The speed of the stirrer was kept constant at 300 rpm. A non-contact type speed sensor was used to measure the stirring speed. The temperature of the melt was measured by using a digital temperature indicator connected to a chromel-alumel thermocouple. During stirring, the temperature of the slurry was maintained within ±10°C of the processing temperature. A magnesium lump of 3 wt% was wrapped by aluminium foil and plunged into the melt-particle slurry after the addition of rice husk ash and SiC particles. When the desired time of the stirring elapsed, reduce the stirrer speed. After completion of processing steps, the graphite stopper at the bottom of the crucible is removed by using the lever to pour the melt-particle slurry into split type graphite coated and preheated permanent steel mould. The mould is kept right below the graphite stopper, the mould containing that cast ingot is allowed to cool in air, in order to achieve better uniformity in distribution of the particles throughout the casting.

Table 1: Nominal composition of the hybrid composite

Designation of hybrid composite	Magnesium (wt%)	Rice husk ash (wt%)	Silicon carbide (wt%)
AM	3	0	0
AMG2S3	3	3	3
AMG2S6	3	3	6
AMG2S9	3	3	9
AMG2S12	3	3	12

Different hybrid composites have been synthesized by adding silicon carbide and rice husk ash powders as given in Table 1 and these hybrid composites have been designated by using the letters AM to indicate Al 1100-Mg (3 wt%) alloy followed by a letter R indicates rice husk ash powder (3 wt% constant in all hybrid composites). The fourth digit S indicates silicon carbide powder, followed by the number indicating the wt% of SiC powder added.

III. RESULTS AND DISCUSSIONS

A. Morphology of SiC and Rice Husk Ash

The size and particle shape of the SiC (average size 25µm - 30µm) and RHA (average size 0.5µm - 5µm) particles in the powder has been observed under SEM and the results are shown in Figure 1 (a) and (b) respectively, it is also observed that smaller and longer particles are irregular in shape.

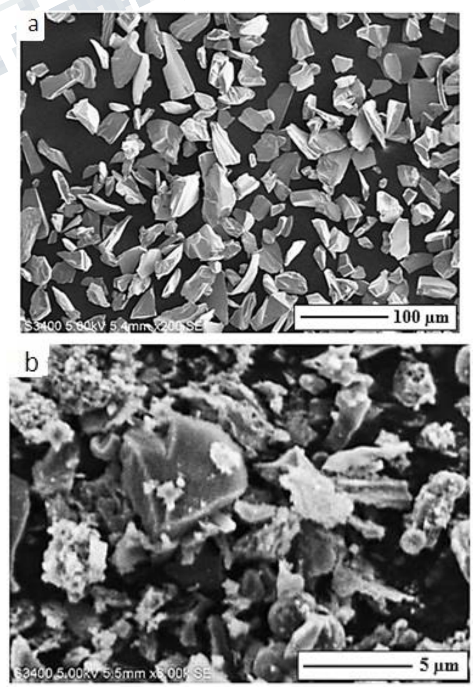

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Fig 1: SEM micrograph showing size and shape of the a) silicon carbide powder and b) RHA Powder used in the synthesis of Al1100 (Mg)-SiC-RHA hybrid composites.

Figure 2 (a) and (b) shows the XRD results of SiC and RHA respectively.

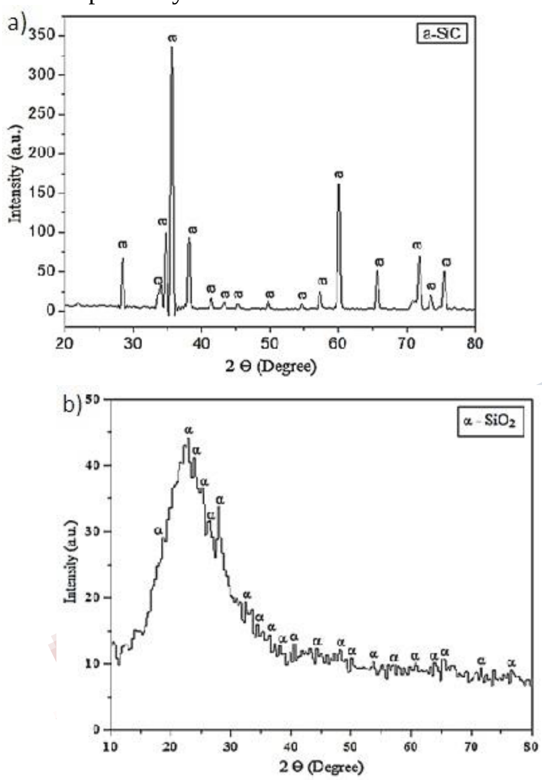

Fig 2: XRD pattern of a) Silicon Carbide particles b) Rice husk ash used in the synthesis of Al1100 (Mg)-SiC-RHA hybrid composites

The SiC and RHA powder has been examined for their X-ray diffraction (XRD) pattern using X-ray diffractometer in the two theta range of 10-80° and 5-80° respectively, using CuKα radiation target and nickel filter, step size and dwell time were suitably adjusted. This was used for identification of various phases with the help of inorganic JCPDS (joint committee on powder diffraction standards) x-ray diffraction data card which shows the SiC and RHA particles are fairly pure.

B. Microstructure Studies on Hybrid Composites

Figure 3 shows SEM micrographs of different hybrid cast composites (a) AMRS3, (b) AMRS6, (c) AMRS9, (d) AMRS12 and (e) AMRS15 respectively, which reveal similar phase but their weight fraction varies depending upon the amount of rice husk ash and silicon carbide particles additions. The hybrid composite AMRS15 has more distributed phase than AMRS3. In general, porosity (dark spots not clearly visible due to uneven surface) in the composites increases with increasing in addition of rice husk ash and silicon carbide particles. This is often attributed to attachment of particles with bubble during processing. This attachment takes place during particle transfer by stirring. It may also happen during solidification as the dissolved gases start nucleating on the heterogeneous surface of particles. Often these bubbles are not able to float out rapidly due to increased density because of attached particles and get entrapped during solidification, enhancing porosity in cast composites. Thus, porosity increases with increasing addition of Rice husk ash and Silicon Carbide particles in cast hybrid composites.

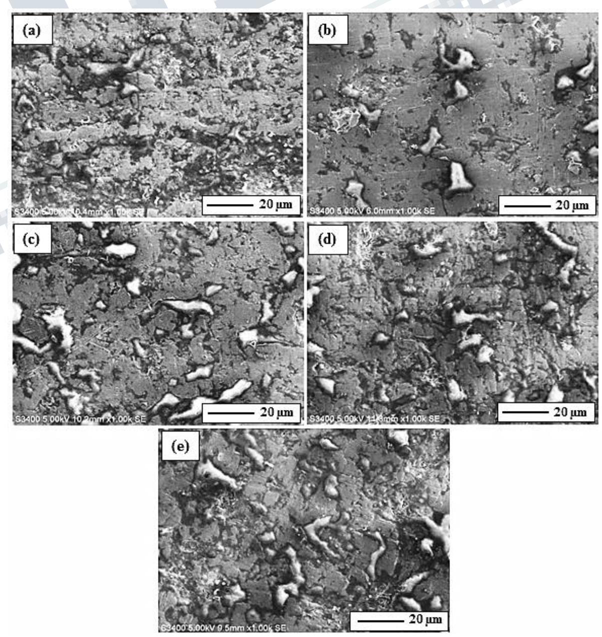

Fig 3: SEM micrographs of different hybrid cast composites developed by constant 3 wt% of Rice husk ash and increasing wt% of SiC particles designated as (a) AMRS3, (b) AMRS6, (c) AMRS9, (d) AMRS12, and (e) AMRS15 respectively

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The particle distribution in the hybrid composites, developed by the addition of Rice husk ash (3 wt% constant) and silicon carbide particles, shows almost individual particles and no significant clustering in hybrid composites AMRS3 and AMRS6 respectively. As the weight percentage of Silicon Carbide particles increases significant clustering of particles is observed.

C. Hardness of Hybrid Composites

The hardness of the cast hybrid composites increases with increasing addition of silicon carbide particles to the base alloy up to 9 wt% of silicon carbide particles. The hardness decreases for AMRS12 and AMRS15 may be due to increased porosity and poor interface bonding between matrix and reinforcement particles as observed in Figure 4.

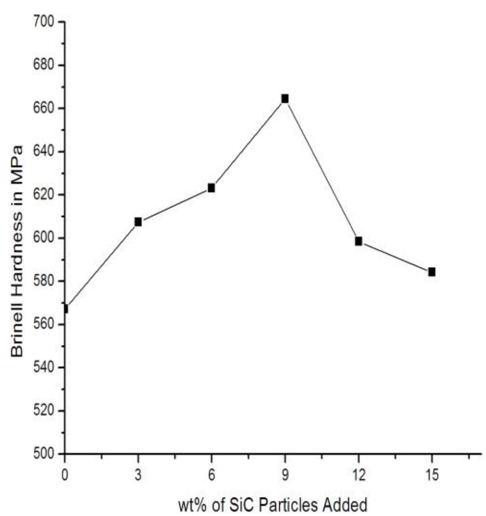

Fig 4: Variation of average Brinell hardness in cast hybrid composites developed by constant 3 wt% of Rice husk ash and 3, 6, 9, 12 and 15 wt% of SiC particles designated as AM, AMRS3, AMRS6, AMRS9, AMRS12 and AMRS15 respectively

D. Tensile Properties of Hybrid Composites

The variation of yield strength, tensile strength and percentage of elongation in the cast hybrid composites developed by addition of 3, 6, 9, 12 and 15 wt% of SiC and keeping rice husk ash 3 wt% constant is as shown in Figure 5.

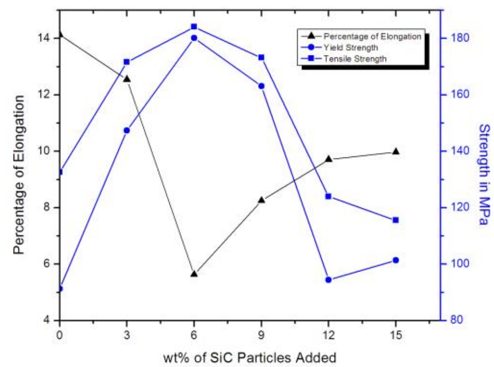

Fig 5: Variation of yield strength, tensile strength and percentage elongation in composites developed by by addition of RHA and SiC powder

In the composites percentage of elongation decreases with increase in wt% of SiC powder addition up to 6 wt% of SiC particles, further increasing in addition of SiC powder shows improvement in the percentage elongation. The tensile strength increases with increasing the addition of SiC particles up to 6 wt% in the cast composites, tensile strength decreases with further increase in wt% of SiC particles. The yield strength increases with increasing the addition of SiC particles up to 6 wt% in cast composites, yield strength decreases with further increase in wt% of SiC particles.

CONCLUSION

Cast composites have been synthesized by addition of the desired amount of silicon carbide and rice husk ash particles in to the molten Al 1100-Mg alloy fallowed by stir casting in permanent mould. The influence of increasing the wt% of SiC particles addition (3 wt% Rice husk ash kept constant) on evolution of cast microstructure and their impact on the mechanical properties of the resulting hybrid composites has been investigated.

1. The liquid metallurgy route (stir casting technique) was successfully adopted in the preparation of hybrid composites containing 3, 6, 9, 12 and 15 wt% of SiC particles and constant 3 wt% of rice husk ash.
2. XRD and SEM/EDAX analysis shows the SiC particles are fairly pure and the shape of the SiC particles are irregular and sharp edged. The Rice husk ash was

amorphous form and irregular in shape.

3. The microstructure of the hybrid composite shows that particles are mostly occurring individually although there are some clusters of two or three particles observed at composite with higher content of SiC.

4. The hardness of the cast hybrid composite increases with increasing the addition of SiC up to 9 wt% (constant 3 wt% of rice husk ash) and thereafter hardness decreases.

5. There is increasing yield strength and tensile strength in hybrid composite developed with increasing addition of SiC powder up to 9 wt% (constant 3 wt% of Rice husk ash) beyond this addition impairs yield strength and tensile strength.

6. The cast hybrid composite developed form 6 wt% of SiC particles and 3 wt% rice husk ash exhibited good yield strength of 180.2 MPa, tensile strength of 184.1 MPa and percentage elongation of 5.63.

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