Mechanical Behavior of Aluminum (AlSi10Mg)-RHA Composite

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***Abstract*-Rice Husk Ash (RHA) of three different particle size ranges (50 – 75 µm), (75 – 100µm) and (100 – 150µm) in 3, 6, 9 and 12 % by weight was reinforced with the aluminium alloy using stir cast route. The microstructure and mechanical properties of the fabricated composites were analyzed. The results reveal that the tensile strength, compressive strength and hardness of the aluminum alloy composites decrease with increase in particle size of RHA. But increase in the weight fractions of RHA particles decreases the ductility of the composite. Finally, the wear mechanism was investigated with the worn surface using a scanning electron microscope.**

Keywords- Aluminium Alloy, Agricultural waste; Stir Cast Route, Rice Husk Ash; Mechanical Properties

I INTRODUCTION

Today's world has been looking for the maximum optimization as possible in every field 'and engineering' is not an exception. In the quest for these developments, much affected is the environment. So the development of low cost metal matrix composites reinforced with eco-friendly material has been one of the major innovations in the field of materials to curtail environmental pollution. Aluminum alloys reinforced with particles offer superior mechanical properties compared with unreinforced alloys and hence reinforcements are candidate for engineering applications.

Research efforts have been geared towards the use of recycled wastes as reinforcing fillers to develop composite [1, 2]. Rice Husk Ash (RHA) which is an agriculture waste by-product abundantly available. During milling of paddy about 78 wt.% was received as rice, broken rice and bran while the rest 22 wt.% of paddy was received as husk[3]. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 wt.% organic volatile matter and the balance 25 wt.% of this husk which is converted into ash during the firing process, is known as rice husk ash[4]. For every 1000 kgs of paddy milled, about 220 kgs (22 wt %) of husk is produced , and when this husk is burnt in the boilers , about 55 kgs (25 wt %) of RHA is generated. It is estimated that about 70 million tons of RHA is produced annually worldwide [5, 6].

This RHA is a great threat to the environment, causing damage to the land and the surrounding area in which it is dumped. The need to protect the environment is the basis for this study to ensure the effective utilization of this agricultural waste. The recent research studies reported that RHA in turn contains around 85-90 wt. % amorphous silica [7]. On thermal treatment, the silica converts to crystobalite, which is a crystalline form of silica. However, under controlled burning conditions, amorphous silica with high reactivity, ultra-fine size and large surface area is produced. This micro silica can be a source for preparing advanced materials like SiC, Si_3N_4, elemental Si and Mg_2Si [8].

The present research is focused to utilize the rice husk ash [9-10] by dispersing it into the aluminium matrix through stir cast route to produce composites [11]. The various sizes of rice husk particles are considered in the study. Experiments have been conducted to assess the mechanical behavior of the rice husk ash composites. Further studies are conducted on the composite to predict the wear mechanisms and transition from one mechanism to another using Scanning Electron Microscope (SEM).

II MATERIAL AND EXPERIMENTAL PROCEDURE

A. Matrix material

In this research, aluminium alloy (AlSi10Mg) is used as a matrix material with chemical composition (in wt %) shown in Table 1. AlSi10Mg is extensively used as casting alloy for producing thin walls and complex geometry cast parts. The components made with AlSi10Mg alloy are ideal for engineering applications, which require a combination of good thermal properties and low weight. The main advantage of this material is that the preheating is not required before casting and post production tests.

TABLE 1
Chemical composition of the matrix alloy

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

B. Reinforcement material

Rice husk is procured from local sources in India (Tamilnadu-Coimbatore), washed with water and dried at 26^0C for 24 hrs. Dried rice husk is heated to 250°C for 2 hours to remove the moisture and organic matters[13]. In this process, due to the charring nature of organic matters, the yellow colour of rice husk changed into black colour and then heated to 600°C for 12 hours to remove the carbonaceous material. After completion of this process, the colour again changed from black to grayish white (Fig. 1). The chemical composition of the rice husk ash obtained is shown Table 2.The obtained silica-rich ash (RHA) is thereafter used as a reinforcement material for the preparation of composites. Three different particle size ranges are utilized for this study; namely fine particles (50 -75 µm), medium particle (75-100 µm) and coarse particles (100-150 µm).

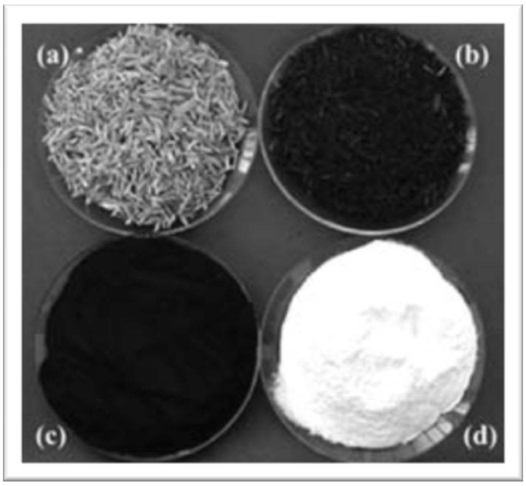


Fig. 1: (a) Raw Rice Husk (b) Carbonize Rice Husk Ash (c) Ground Carbonized Rice Husk Ash and (d) Combusted Rice Husk Ash (Grayish White)

TABLE 2
Rice husk ash composition.

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	LOI
%	94.04	0.249	0.136	0.622	0.442	0.023	2.49	3.52

III EXPERIMENTAL PROCEDURE

A.Specimen Preparation

The synthesis of the metal matrix composite used in the present study is carried out by using the liquid metallurgy route. Initially, Al alloy is charged into the graphite crucible and heated to 800 ºC till the entire alloy in the crucible become molten (Fig. 2). The reinforcement particles (RHA) are then preheated to 600°C for three hours before incorporating into the melt. The molten metal is degassed with 30g of C_2Cl_6 tablets to reduce the porosity[14]. Simultaneously, 1wt% of magnesium is added into the molten melt to enhance the wettability between the rice husk particles and alloy melt. It is noticed that without the addition of magnesium, the particles of rice husk ash are rejected.A stainless steel stirrer is lowered into the molten melt slowly upto 2/3 of the height of the molten metal from the bottom of the crucible and it stirred at 500 rpm. The preheated RHA particles are now added into the molten metal at a constant rate of 1-2 gm per shot by gradually increasing the stirrer speed from 500 to 700 rpm. The stirring action continue for another 5 minutes even after the completion of particle feeding. The mixture is then poured into the mould preheated to 500 ºC for 30 minutes to obtain uniform solidification[16]. Similar procedure is repeated for 6, 9 and 12 wt % RHA particle reinforcements.

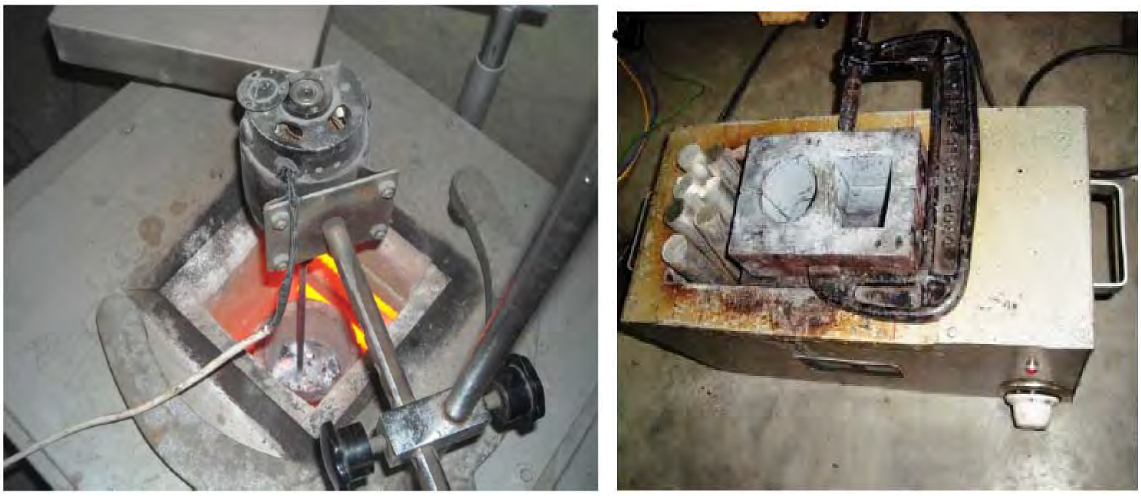


Fig. 2 Stir casting equipment (a) Electrical furnace (b) Preheated permanent mould

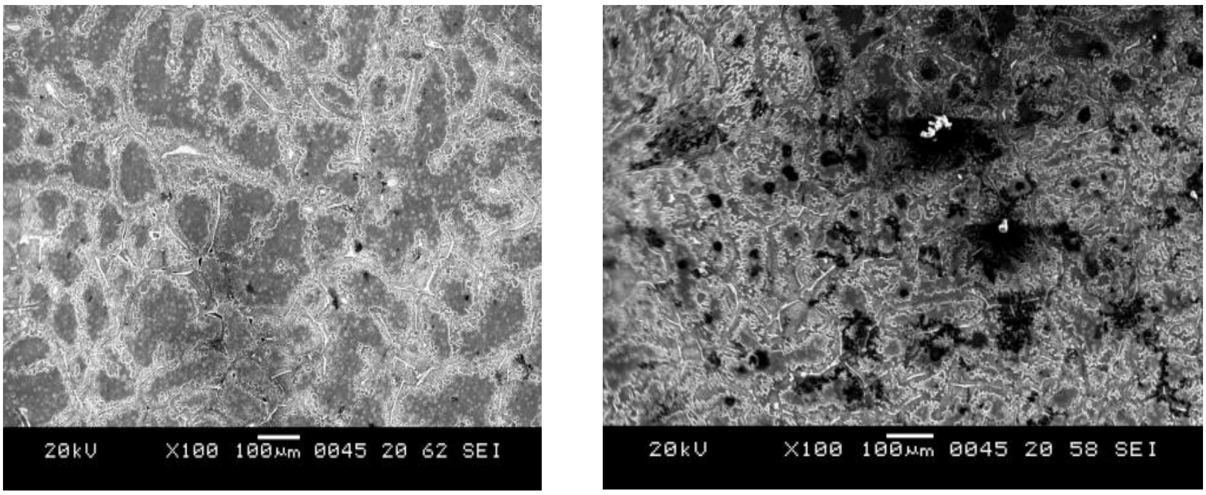
B. Specimen Testing

Tensile tests are conducted on the samples according to ASTM E8-95 at room temperature, using a universal testing machine (INSTRON). The specimens used are of diameter 12.5mm and Gauge length 62.5 mm, machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. Compression tests are carried out as per ASTM-E9-95.The sample used are of diameter 15mm and length 20 mm machined from cast composites. According to ASTM E10, the Brinnel hardness tests are conducted [15]. The microstructure of the Al/RHA composite is examined using JSM-6610LV Scanning electron microscope (SEM).

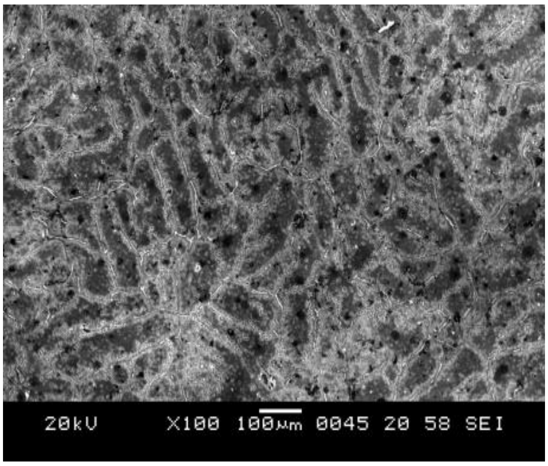
IV. RESULTS AND DISCUSSIONS

A. SEM study

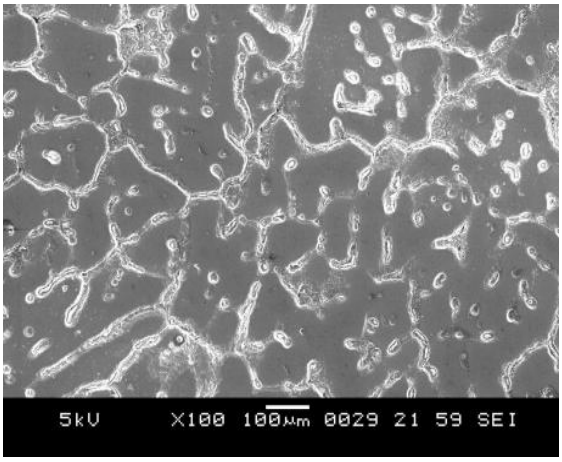
The distribution studies of RHA in the matrix are examined using scanning electron microscope. The micrographs shown in Fig. 3 depict the microstructure of as- cast Al and RHA reinforced Aluminium alloy. A uniform distribution of rice husk ash particles without voids and discontinuities can be observed from these micrographs along with good bonding between matrix material and RHA; however, no gap is observed between the particle and matrix. This observed result is due to the heating of RHA particulates prior to dispersion and the addition of magnesium in small quantities during stirring which improved wettability between matrix and RHA particles.



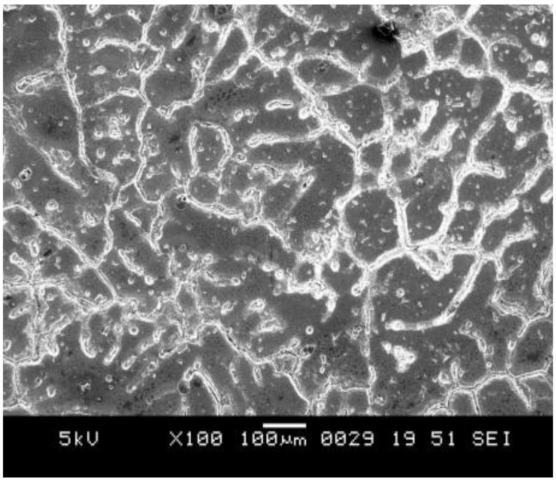
(a) AlSi10Mg (b)AlSi10Mg + 9 % RHA (50-**75)** µm



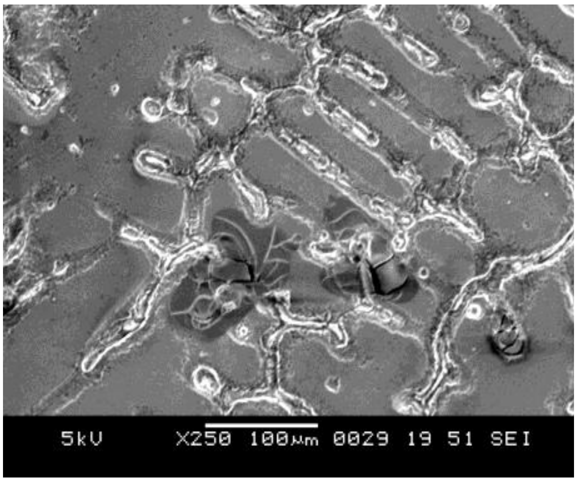
(c) AlSi10Mg +12 % RHA (50-**75)** µm



(d**)** AlSi10Mg + 9 % RHA (75-100) µm



(e)AlSi10Mg +12 % RHA (75-100) µm



(f) AlSi10Mg +12 % RHA (100-125) µm

Fig. 3 SEM image of the cast Al–RHA MMC's

B. Evaluation of mechanical properties

1. Tensile property

The Tensile Strength variations of the composites with the different weight fractions of RHA particles are shown in Figure 4. The tensile strength increase with an increase in wt % RHA. The RHA particles act as barriers to dislocations motion when taking up the applied load in a similar form as found by Basavarajappa et al.,[11]. The hard RHA particles obstruct the advancing dislocation front, thereby strengthening the matrix. However, as the size of the RHA particles increase, there is decline in tensile strength. Good bonding of smaller size RHA particles with the matrix is the reason for this behavior. The improvement in tensile strength of the composite is attributed to the fact that the filler RHA posses higher strength.

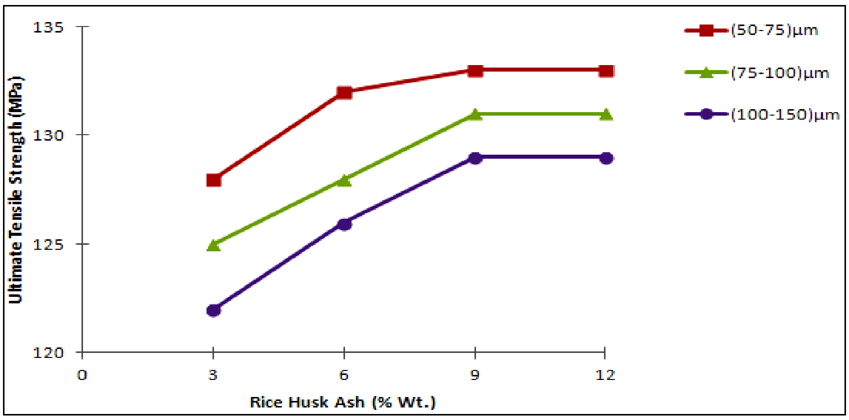


Fig.4. Tensile strength behaviour of Aluminum-Rice Husk Ash composite

2. Compressive Strength

The variation of compressive strength with addition of Rich husk ash is shown in Figure 5. The compressive strength is high for smaller particle size of rice husk ash and it increase with increase in the wt % RHA particles. This may be due to the hardening of the base alloy by RHA particles. However, decrease in compressive strength occurs as the size of the RHA particles increase.

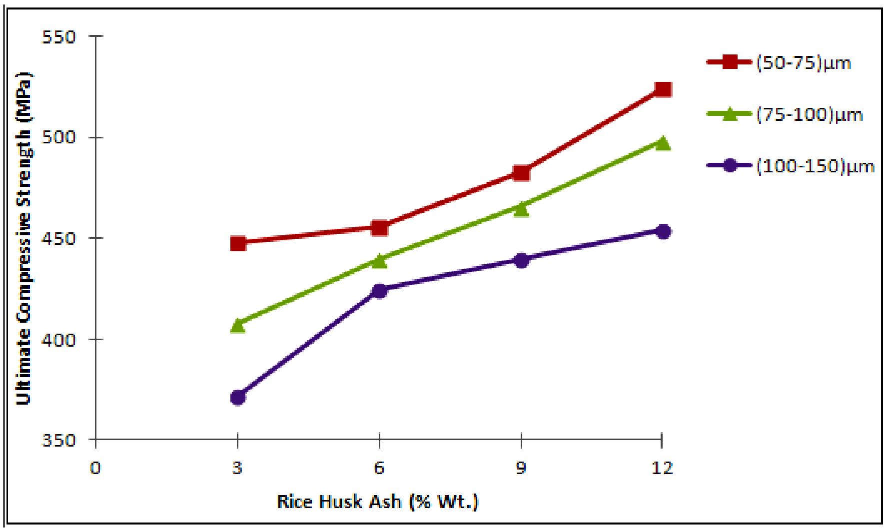


Fig. 5. Compressive strength behaviour of Aluminum-Rice Husk Ash composite.

3. Hardness

The relation between weight percentage of RHA reinforcement and hardness of fabricated MMCs is shown in Figure 6. The hardness of the composite linearly increase with increase in weight fraction of RHA particles occasion by increment in surface area of the matrix with reduction in grain sizes. The presence of such hard and large surface area offers more resistance to plastic deformation which leads to increase hardness. Similar findings is reported by Ramachandra et.al, [13] for SiC particle reinforcements.

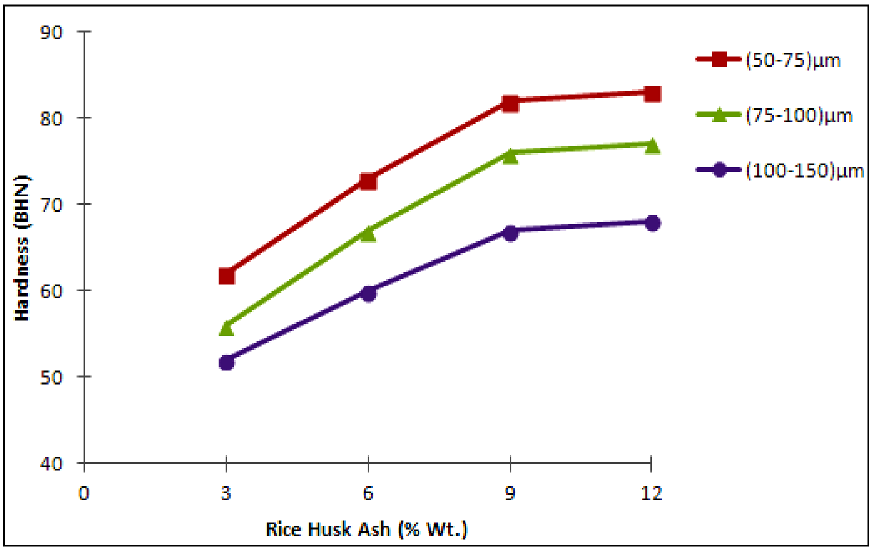


Fig. 6. Hardness behaviour of Aluminum-Rice Husk Ash composite.

4. Ductility:

The effect of percentage reinforcement of RHA on percentage elongation of composite is presented in Figure 7. The ductility of the composite decreases with increase in weight fraction of RHA. This is due to the increase in hardness of the rice husk ash particles or clustering of the particles. Similar observations are stated by Surappa et.al, [15] for various weight percent of fly ash reinforcement.

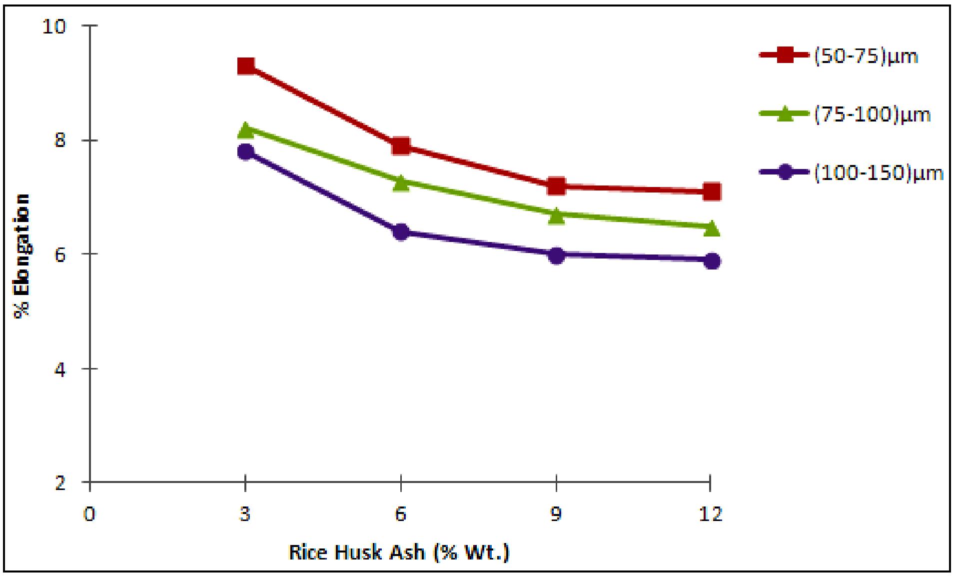


Fig. 7. Ductility behaviour of Aluminum-Rice Husk Ash composite

V. CONCLUSIONS

The conclusions drawn from the present investigation are as follows:

- Rice Husk Ash, the agricultural waste generated from milling paddy can be successfully used as a reinforcing material to produce Metal-Matrix Composite (MMC) component in aluminium matrix. Thus the use RHA ash for the production of composites can turn agricultural waste into industrial wealth and inevitably solve the problem of storage and disposal of RHA.
- There is good dispersibility of RHA particles in aluminium matrix which improves the hardness of the matrix material and also the tensile behavior of the composite. The result of this is increase in interfacial area between the matrix material and the RHA particles leading to increase in strength appreciably.
- It was found that tensile strength, compression strength and hardness increases with the increase in the weight fractions of rice husk ash and decreases with increase in particle size of the rice husk ash.
- The ductility of the composite decreases with increase in the weight fraction of reinforcement and also decreases with increase in its particle size.
- The enhancement in the mechanical properties can be well attributed to the high dislocation density. However, for composites with more than 12 wt % of RHA particles exhibits poor wettability.

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