International Conference On DESIGN AND MANUFACTURING, IConDM 2013

Effect of Mechanical Properties on Rice Husk Ash Reinforced Aluminum alloy (AlSi10Mg) Matrix Composites.

S.D.Saravanan\textsuperscript{a*}, M.Senthil Kumar\textsuperscript{b}

\textsuperscript{a}Research Scholar, Department of Mechanical Engineering, P.S.G College of Technology, Coimbatore-641004, India.
\textsuperscript{b}Assistant Professor, Department of Mechanical Engineering, P.S.G College of Technology, Coimbatore-641004, India.

Abstract

The application spectrum of low cost material reinforced metal matrix composites is growing rapidly in various engineering fields. In this way, present study indicates the possibilities of reinforcing aluminium alloy (AlSi10Mg) with locally available inexpensive rice husk ash for developing a new material. A rice husk ash particle of 3, 6, 9 & 12 \% by weight were used to develop metal matrix composites using a liquid metallurgy route. The surface morphology was studied using scanning electron microscope for analyze the distribution of RHA particles. The mechanical properties such as tensile strength, compressive strength, hardness and percentage elongations are studied for reinforced RHA composites. The results reveal that the percentage reinforcement of RHA will increase ultimate tensile strength, compressive strength and harness of the composite.

© 2013 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license. Selection and peer-review under responsibility of the organizing and review committee of IConDM 2013

Keywords- Aluminium Alloy (AlSi10Mg); Rice Husk Ash; Mechanical Properties; Scanning Electron Microscope;

* Corresponding author. Tel.: +91-98655-26818;
E-mail address: sdssaravan@gmail.com.
1. Introduction

Today’s the world has been looking for the maximum optimization as possible in every field. Engineering is not an exception. Engineers are looking for creating the extreme best from the best. During these developments some way or the other much affected is the environment. 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 in the past few decades. Aluminum alloys reinforced with ceramic particles exhibit superior mechanical properties to unreinforced Al alloys and hence are candidate for engineering applications.

Now the most of the research work carried out to develop composites using various recycled wastes [1,2], especially in developing composites using most environmentally friendly agro-wastes (lignocellulosic materials) as reinforcing fillers. Among them, Rice Husk Ash (RHA) is an agriculture waste by product abundantly available. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). For every 1000 kgs of paddy milled, about 220 kgs (22 %) of husk is produced, and when this husk is burnt in the boilers, about 55 kgs (25 %) of RHA is generated. It is estimated that about 70 million tons of RHA is produced annually worldwide [6].

This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. This ensures the researcher for effective utilization of this agricultural waste. Therefore the environment is protected from these wastes. The recent research studies reported that RHA in turn contains around 85% - 90% 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, Si3N4, elemental Si and Mg2Si [8].

The present research is focused to utilize the rice husk ash [8-13] by dispersing it into the aluminium to produce matrix composites through stir cast route on the lines of [14]. The various weight fractions of rice husk particles are considered in the study. Experiments have been conducted to assess the mechanical behavior of the rice husk ash ceramic composites. Further microscopic studies were conducted to establish the wear mechanisms and transition from one mechanism to another using the Scanning Electron Microscope (SEM).

2. Material and Experimental Procedure

2.1. Matrix material

For experimental investigation, AlSi10Mg aluminium 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 and is used for cast parts with thin walls and complex geometry. The alloying elements silicon and magnesium leads to high strength and hardness. The components made with AlSi10Mg alloy are ideal for applications which require a combination of good thermal properties and low weight. It is easily castable and main advantage of this material is preheating is not required before casting or testing.
Table 1. Chemical composition of the matrix alloy

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>Cu</th>
<th>Mg</th>
<th>Si</th>
<th>Fe</th>
<th>Mn</th>
<th>Ni</th>
<th>Zn</th>
<th>Pb</th>
<th>Sn</th>
<th>Ti</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>0.1</td>
<td>0.2</td>
<td>10.0</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.05</td>
<td>0.2</td>
<td>Balance</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
</tr>
</tbody>
</table>

2.2. Reinforcement material

Rice husk is procured from local sources in India (Tamilnadu-Coimbatore), then it was washed with water to remove the dust and dried at room temperature for 1 day. Washed rice husk is then heated to 200°C for 1 hr duration to remove the moisture and organic matter. During this operation, the colour of the husk is changed from yellowish to black because of charring of organic matter. It is then heated to 600°C for 12 h to remove the carbonaceous material. After this operation, once again the colour is changed from black to grayish white (Figure 1). The obtained silica-rich ash (RHA) is used as a reinforcement material for the preparation of composites. The chemical composition of the rice husk ash after the above treatments is given in Table 2.

![Figure 1: (a) Raw Rice Husk (b) Carbonize Rice Husk Ash (c) Grounded Carbonized Rice Husk Ash and (d) Combusted Rice Husk Ash (Grayish White)](image)

Table 2. Rice husk ash composition.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>94.04</td>
<td>0.249</td>
<td>0.136</td>
<td>0.622</td>
<td>0.442</td>
<td>0.023</td>
<td>2.49</td>
<td>3.52</td>
</tr>
</tbody>
</table>
3. Experimental Procedure

3.1. 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 °C till the entire alloy in the crucible is melted (Figure 2). The reinforcement particles (RHA) are then preheated to 600°C for three hours before incorporating into the melt. After the molten metal is fully melted, degassing tablets is added to reduce the porosity. 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 up to 2/3 of the height of the molten metal from the bottom of the crucible and the molten metal is stirred at a speed of 500 to 700 rpm. The preheated RHA particles are added into the molten metal at a constant rate of 1-2 gm per stroke. To enhance proper mixing, stirrer speed is gradually increased from 500 to 700 rpm for 10 min duration. The stirring is continued for another 5 min even after the completion of particle feeding. The mixture is poured into the mould which is also preheated to 500 °C for 30 min to obtain the uniform solidification. Similar procedure is repeated for the other weight volume fraction of 6%, 9% and 12% RHA particle reinforcements.

![Stir casting equipment](image)

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

3.2. Testing for Mechanical Property

The tensile tests were conducted on these samples according to ASTM E08 at room temperature, using a universal testing machine (INSTRON). The specimens used were of diameter 12 mm and Gauge length 40 mm, machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. The compression tests were conducted as per ASTM-E9-95. The specimen dimensions are of diameter 15mm and length 20 mm. The hardness was measured using Brinell Hardness Tester at a load of 500 kg for a period of 15 sec in accordance with the ASTM E10.
4. Results and Discussions

4.1. SEM study

The micrographs shown in Figure 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 rice husk ash particles; however no gap is observed between the particle and matrix.

![SEM images of cast Al–RHA MMC’s](image-url)

(a) AlSi10Mg  
(b) AlSi10Mg + 6 % RHA (50-75) μm  
(c) AlSi10Mg + 9 % RHA (50-75) μm  
(d) AlSi10Mg + 12 % RHA (50-75) μm

Fig. 3 SEM image of the cast Al–RHA MMC’s
4.2. Evaluation of mechanical properties

(a) Tensile property
The relation between tensile strength of the fabricated composites with the different weight fractions of rice husk ash particles are shown in figure 4. It can be inferred that the tensile strength increased with an increase in the weight percentage of rice husk ash. Because, the RHA particles act as barriers to the dislocations when taking up the load applied. The similar observation was found in Basavarajappa et al., for fly ash particles. The observed improvement in tensile strength of the composite is attributed to the fact that the filler rice husk ash possesses higher strength by offering more resistance. There was a decrease in the tensile strength of the samples with rice husk ash weight fraction beyond 12 %. It may due to the poor wettability of the reinforcement with the matrix.

(b) Compressive Strength
The variations of compressive strength with addition of Rich husk ash was shown in figure 5. Due incorporation, it was observed that the compressive strength increases with an increase in the weight percentage of rice husk ash particles. This may be due to the hardening of the base alloy by rice husk ash particles.
(c) **Hardness**

The relation between weight percentage of RHA reinforcement and hardness of fabricated MMCs was shown in figure 6. 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. Similar findings were by Radhakrishna et.al, 2007 for SiC particle reinforcements.

![Fig. 6. Variation of Hardness with the weight fraction of rich husk ash.](image)

(d) **Ductility:**

The effect of percentage reinforcement of RHA on percentage elongation of composite was presented in figure 7. It was observed that ductility of the composite decreases with the increase in weight fraction of the rice husk ash. This is due to the increase in hardness of the rice husk ash particles or clustering of the particles. Similar observations were by found Sudarshan et.al & Surappa et.al, for various weight percent of fly ash reinforcement.

![Fig. 7. Variation of Ductility with the weight fraction of rich husk ash.](image)
5. 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 Aluminium Metal-Matrix Composite. It can be successfully used in place of conventional aluminium intensive material.
- The use RHA ash for the production of composites can turn agricultural waste into industrial wealth. This can also solve the problem of storage and disposal of RHA.
- There was 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 effect is increase in interfacial area between the matrix material and the RHA particles leading to increase in strength appreciably.
- The Tensile Strength, Compression Strength and Hardness increases with the increase in the weight fraction and ductility gets decrease with increase in the weight fraction of reinforced rice husk ash.
- It was concluded that the enhancement in the mechanical properties can be well attributed to the high dislocation density. However, for composites with more than 12% weight fraction of rice husk ash particles, the tensile strength was seen to be decreasing.

6. References


