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Effects of Untreated and Treated Rice Husk Ash (RHA) Addition on Physical Properties of Recycled Aluminium Chip AA7075

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Abstract: The use of low cost metal matrix composites (MMC) is increasing rapidly in various engineering fields because of their better mechanical properties. The effects of recycled aluminium chips AA7075 with untreated rice husk ash (URHA) and treated rice husk ash (TRHA) on physical properties were investigated. Recycled aluminium chip AA7075 was reinforced with untreated and treated rice husk ash i.e., 2.5 wt.%, 5 wt.%, 7.5 wt.%, 10 wt.% and 12.5 wt.%. Density, apparent porosity, water absorption, micro-hardness and microstructures analysis of the metal matrix composites samples were examined in current study. The density for metal matrix composites increase up to 5 wt.% of rice husk ash, and then decreased with increasing mass fraction of rice husk ash. However, the densities for treated rice husk ash slightly higher than untreated rice husk ash. Porosity and water absorption of metal matrix composites were consistently increase at increasing mass fraction of rice husk ash. The hardness of chip AA7075 has improved with increasing the composition of rice husk ash from 53.49 Hv to 65.93 Hv for untreated rice husk ash and 69.56 Hv for treated rice husk ash at addition 10 wt.%. The microstructures of metal matrix composites were found random distribution and non-homogeneous compared to fully chip AA7075.

Keywords: Recycled aluminium chip, rice husk ash, metal matrix composite

1. Introduction

The worldwide generation for primary aluminium has expanded quickly in the past 100 years. The properties of the various aluminium alloys have resulted in aluminium being utilized in various industries such as assorted as food preparation, packaging, transport, architecture, electric transmission and energy generation applications [1]. Many researchers and industrial nowadays research on machining to improve the performance of production, space utilization, and reduced production cost [2-4]. The melting process of recycled aluminium has pollution effects to the environment. Aluminium is the most heavily used nonferrous metals in the world. The high energy requirement for mining and melting aluminium, replacing a part of the aluminium by recycling industrial wastes such as aluminium chips promise low production cost, not harming the environment and saving primary aluminium resources thus satisfying the modern industrial societies aim [5,6].

Due to the expansion of the use of aluminium, waste issue has been one of the many popular issues that have gotten worldwide concerns to develop composites using various recycled wastes especially in developing composites using most environmentally friendly agro-wastes as reinforcing fillers such as bamboo leaf and fly ash. Rice husk (RH) is one of agro-waste material that is generated from rice milling industry that produced huge amount of rice husk during milling

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of paddy. After burning process of RH, husk then is converted into ash during incineration process, known as rice husk ash (RHA) [7]. RH produced higher percentage of silica than other biomass fuels. According to Tiwari et al. [8], rice husk as well as its ash can be used a potential reinforcing agent as the excellent source of silica that can replace other conventional silica sources. Other literatures, like Kenneth et al. [10] (>90% silica), Armesto et al. [11] (87.7% as SiO2), and Houstan [12] (87-97% silica) consistently reported that rice husk ash contains very high silica content.

Based on investigation on aluminium reinforced rice husk ash composites, chemical rice husk ash has a good potential to improve the material behavior of metal matrix composites by appropriate composition of rice husk ash to metal matrix composite compared to non-chemical rice husk ash. Therefore, the recycled aluminium chips reinforced rice husk ash for composite production can change industrial wastes into valuable industrial raw material, where metal matrix composites are beneficial to be used as manufacturing products and thereby, reducing the cost of aluminium products.

2. Material and Method

2.1 Materials

Aluminium block AA7075 with a theoretical density of 2.81 g/cm^3 was used as the metal matrix material where the chemical composition (wt.%) as shown in Table 1.

Table 1 - Chemical composition of AA7075 alloy (mass fraction, wt.%)

Al	Zn	Cu	Si	Cr	Others
87.18	9.49	2.59	0.31	0.28	0.15

Rice husk ash (RHA) obtained from a local industry; Nano Siltech Sdn Bhd, was used as reinforcing agent. Rice husk ash was processed in industry by burning rice husk at temperature 700°C in 2 hour. The untreated rice husk ash (URHA) is the rice husk ash that is directly burnt while treated rice husk ash (TRHA) is rice husk ash that has been mixed with chemical solution prior to the burning process. The chemical composition (wt.%) of each rice husk ash is shown in Table 2 and Table 3, respectively. The characterization of rice husk ash was conducted by using X-ray Fluorescence (XRF).

Table 2 - Chemical composition of URHA (wt %)

SiO_2	C	K_2O	P_2O_5	CaO	MgO	SO_3	Cl	Fe_2O_3	Al_2O_3
87.23	0.11	4.77	3.58	1.74	1.23	0.61	0.15	0.23	0.35

Table 3 - Chemical composition of TRHA (wt %)

SiO_2	C	K_2O	P_2O_5	CaO	MgO	SO_3	Cl	Fe_2O_3	Al_2O_3
87.73	0.08	4.73	3.53	1.53	1.21	0.55	0.13	0.19	0.32

2.2 Sample Preparation

Aluminium chip was produced by high speed computer numerical control (CNC) milling machine, Mazak Nexus 410A-II CNC Mill with feed rate of 1100 mm/min, depth cut of 1 mm and cutting velocity of 345.4 m/min. Milled aluminium was then cleaned through ultrasonic bath apparatus, FRITSCH – ultrasonic cleaner Labarette 17. The duration of the cleaning taken was 1 hour for each batch using an acetone solution (CH_3COCH_3) to remove oil, grease and any impurities. Finally, the drying process was done in an oven for 1 hour at 75ºC to remove the residual acetone from the chip [13-16]. Ball mill was used in preparation of RHA to produce smaller particle size using high impact mill with porcelain jar under wet milling cycles for 10 minutes. Then, sieving process was conducted to separate the particle size of 63µm using vibrator type apparatus, FRITSCH analysette 3 within 30 minutes and amplitude of 1.

The compaction process was conducted using the uniaxial hydraulic press machine, Carver model 3851-0. The aluminium chips were mixed with untreated rice husk ash and treated rice husk ash with the composition as shown in Table 4, and then poured into the mould to shape the sample. The setting of load compaction and holding time of compaction process were 9 tons and 20 minutes, respectively [17,18]. The sintering was controlled under heating rate, time, temperature and atmosphere required for reproducible results. The equipment used during sintering process for sample is tube furnace, and Argon gas as inert gas. The temperature used in this process was referred to the sintering profile as shown in Fig 1. At 300ºC after 30 minutes, the zinc stearate was burned out, and then sintering process started at 552ºC within 60 minutes.

2.3 Sample Analysis and Characterization

The analysis of sample were measured by using Archimedes Principle to measure the density(g/cm^3), porosity (%), and water absorption (%). The analysis of the sample conducted followed the standard ASTM B328 for density and ASTM B962-17 for the porosity and water absorption. The hardness test was conducted using the micro Vickers hardness machine in which the apparatus consists of a hard and accurate head for easing the penetrating in the material. Eight times indentation was taken to each sample to obtain the average hardness, follow the standard ASTM E384. The characterization of sample was conducted using Optical Microscope (OM) to observe the microstructure forms of the samples. The image was captured in lower magnification of 50 times at 100 micron scale.

Table 4 - Sample preparing for mixing process

Reinforcement	Sample Composition
None	Fully chip AA7075
Untreated rice husk ash (URHA)	Chip AA7075 + 2.5% URHA Chip AA7075 + 5.0% URHA Chip AA7075 + 7.5% URHA Chip AA7075 + 10.0% URHA Chip AA7075 + 12.5% URHA
Treated rice husk ash (TRHA)	Chip AA7075 + 2.5% TRHA Chip AA7075 + 5.0% TRHA Chip AA7075 + 7.5% TRHA Chip AA7075 + 10.0% TRHA Chip AA7075 + 12.5% TRHA

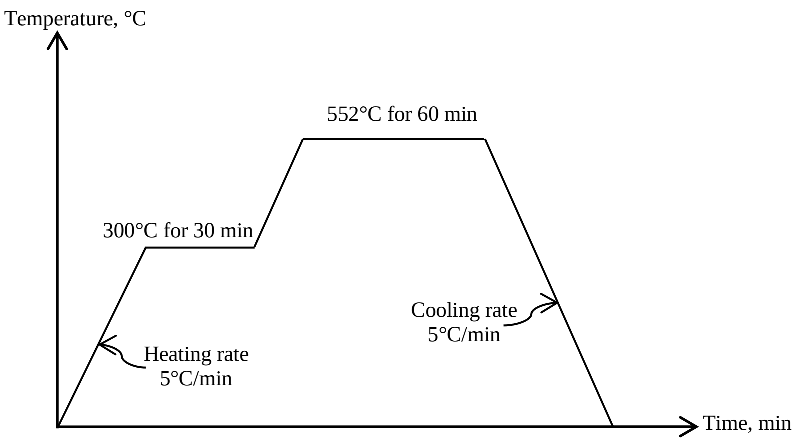


Fig. 1 - Sintering profile

3. Results and Discussion

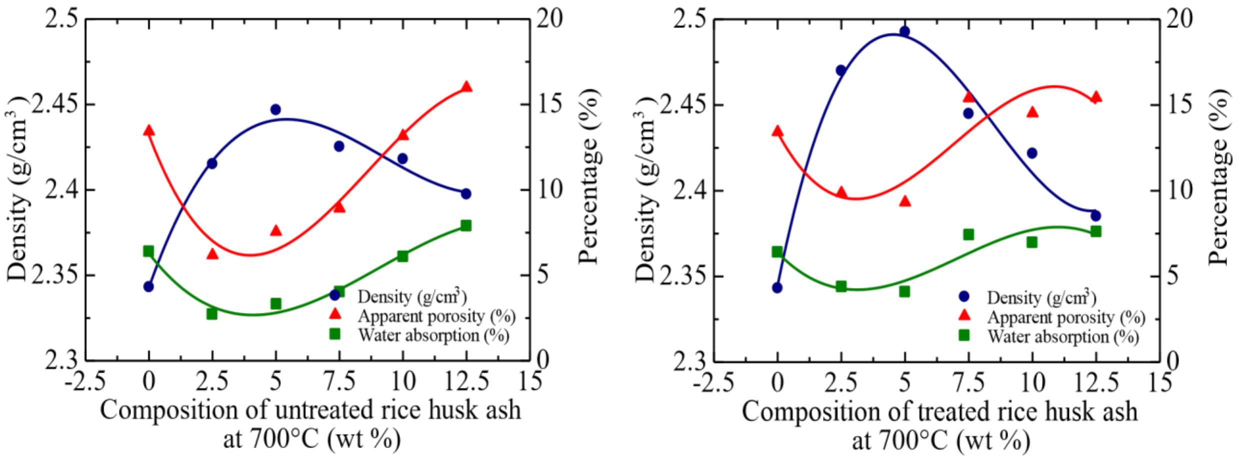
3.1 Density, Apparent Porosity and Water Absorption

The relationship between the density, apparent porosity and water absorption of metal matrix composites samples with different composition of chips and types of rice husk ash (untreated and treated) were identified through Archimedes technique as shown in Fig 2. The density of metal matrix composites rapidly increased at increasing the composition of rice husk ash up to 5 wt.%. However, the density of metal matrix composites was decreased after it was reinforced for more than 5 wt % of rice husk ash. As the density decreased, the porosity was increased due to the weak bonding of the reinforced particle [19,24].

The effect of rice husk ash as reinforced has improved the density of metal matrix composites, however, the effect between untreated and treated rice husk ash seems similar. Apparent porosity and water absorption shows that untreated metal matrix composites has consistent increment percentage compared to treated metal matrix composites. The percentage of porosity can be relate to the composition of rice husk ash were the carbon content for untreated rice husk ash is slightly higher than treated rice husk ash, whereby its affected the process of compaction and sintering of metal matrix samples.

3.2 Microhardness

The hardness test is the resistance of a material to localized deformation that was applied from indentation, cutting, scratching and bending. Fig 3 illustrates the relationship of hardness between various composition and different type of rice husk ash. It has been found that the hardness for both untreated and treated rice husk ash increases with increasing composition of rice husk ash content, where it had improved the hardness of metal matrix composites. The hardness reaches 65.93 Hv for untreated rice husk ash addition and 69.56 Hv for treated rice husk ash addition compared to fully chip AA7075 with 53.49 Hv. It indicates that the hardness of metal matrix composites was dependent to composition of rice husk ash. It also shows that treated rice husk ash improved the hardness of metal matrix composites higher than untreated rice husk ash. However, Saravanan et al., and Tiwari et al., reported that the composition of silica by rice husk ash that increased to more than 10 wt % was seen decreasing the hardness of material due to insufficient bonding between matrix and reinforced material [9,20].



(a) **(b)**

Fig. 2 - The graph of density (g/cm^3), apparent porosity (%) and water absorption (%) with the increasing composition of; (a) untreated rice husk ash (wt.%), (b) treated rice husk ash (wt.%)

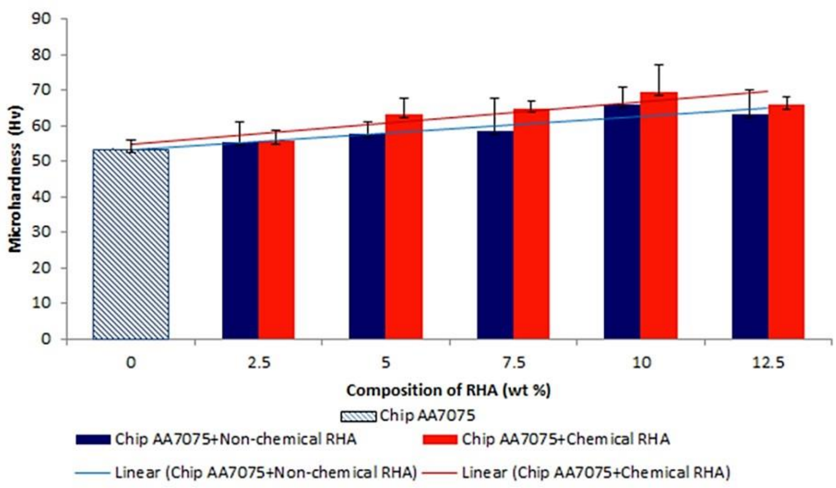


Fig. 3 - Microhardness (Hv) with the increasing of different RHA (wt.%)

3.3 Microstructure Analysis

The micrographs shown in Fig 4 are the microstructure of recycled aluminium chip AA7075 reinforced with untreated rice husk ash and treated rice husk ash at 5 wt.% and 10 wt.%. The microstructures of the sintered samples were captured using optical microscope (OM). Fig 4 – (a) represents fully chip AA7075 that can be seen to have larger shape forming on the surface. When rice husk ash was added gradually and mixed with the chips, it can be seen that the shape becomes smaller as indicated in Figs 4 – (b-e). Fig 4 – (b) and (c) shows the chips AA7075 that gradually mixed with untreated rice husk ash at 5 wt.% and 10 wt.%. While Fig 4 – (d) and (e) shows the chips that gradually mixed with treated rice husk ash at 5 wt.% and 10 wt.%. The rice husk ash filled up the gaps of AA7075 aluminium chips and it covered the pores to form a good surface on the sample. Increasing the porosity from physical tests was correlated directly with an increase in the irregularity of pore shape. The irregularity of AA7075 chip sizes resulted in the higher porosity and random pore shapes as shown in Fig 4 – (c) and (e). As more powder particles were added into the sample, it resulted in high pores formation, and more spherical pore shape [22-24].

4. Conclusion

Rice husk as well its ash can be used as a potential reinforcing agent to produce metal matrix composite. It is one of excellent source of silica and can be able to replace other conventional silica source. The use rice husk ash for the production of composites can turn agricultural waste into industrial wealth. This also solves the problem of storage and disposal of rice. The hardness of metal matrix composites was increased at increasing composition of rice husk ash. The metal matrix composites for fully chip AA7075 has improved from 53.49 Hv to 65.93 Hv for untreated rice husk ash and 69.56 Hv for treated rice husk ash at addition 10 wt.%. The enhancement in the physical properties can be well attributed to produce better material. If percentage of rice husk ash increases beyond a certain limit (12% above) its effect were minimized due to poor wettability with aluminium chips. Finally, it has been concluded that treated rice husk ash has the better potential to be excellent reinforcing agent compared to untreated rice husk ash.

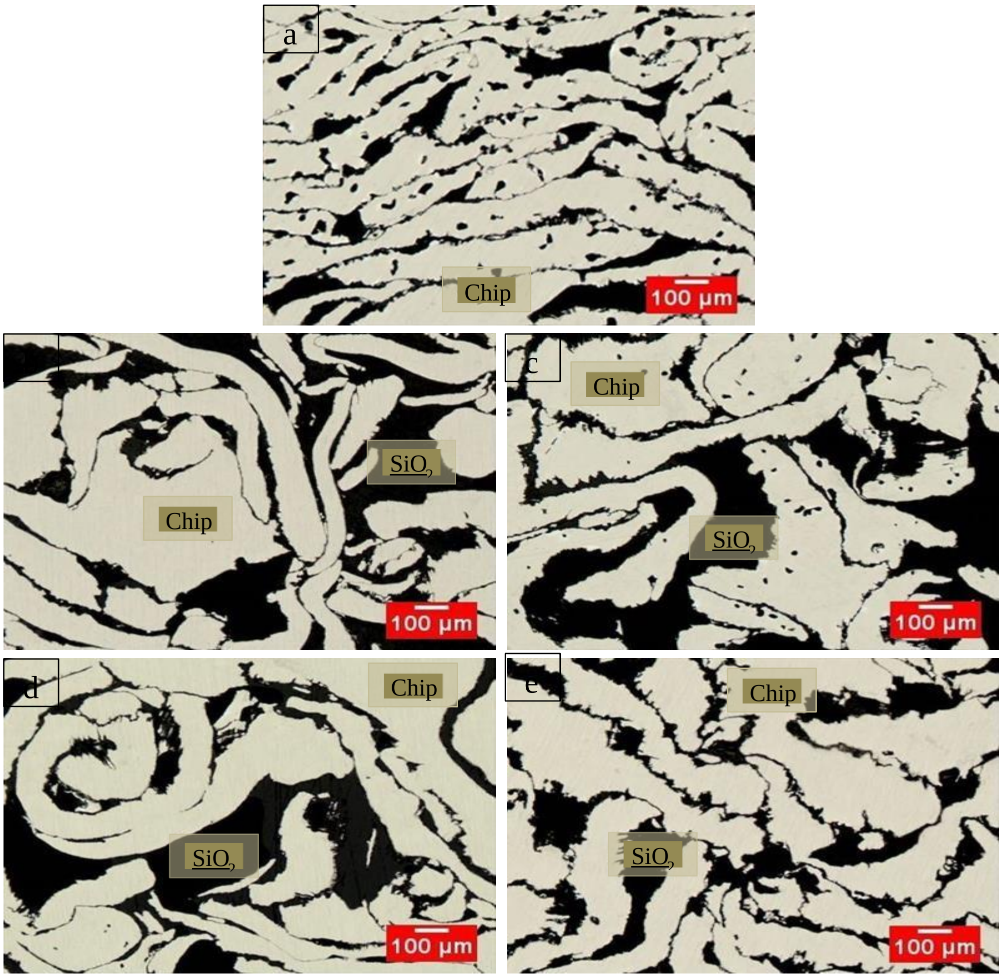


Fig. 4 - Microstructures of (a) fully chip AA7075; (b) Chip AA7075+5 wt.% URHA; (c) Chip AA7075+10 wt.% URHA; (d) Chip AA7075+5 wt.% TRHA; (e) Chip AA7075+10 wt.% TRHA

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