Physical Properties and Hardness of Treated Amorphous Silica as Reinforcement of AA7075 Recycled Aluminum Chip

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Abstract. Solid state recycling techniques of waste aluminum materials without melting the material is a process that consumed less energy consumption. The reuses of waste materials such as aluminum scrap and rice husk ash lead to the friendly environmentally and low cost of production. Physical properties and hardness of treated amorphous silica as reinforcement of AA7075 recycled aluminum chip were investigated. Recycled aluminum sample AA7075 reinforced treated amorphous silica by rice husk ash was prepared by the technique of powder metallurgy (PM) owing of reduced energy consumption and operating cost in comparison with conventional cast-recycling. The presence of silica exists in rice husk ash obtained after through chemical treatment and burning process of rice husk at temperatures of 700°C for 2 hours. The effect of aluminum recycled chip with rice husk ash composite with composition of 2.5 wt.%, 5 wt.%, 7.5 wt.%, 10 wt.% and 12.5 wt.%, on physical properties and hardness were investigated. Based on investigation to AA7075 recycled aluminum chip reinforced treated amorphous silica by rice husk ash, the porosity and water absorption of composite of metal matrix is increase with increasing of composition of treated rice husk ash as the density shows decrease when the treated rice husk ash is added up to 5 wt.%. The addition of treated rice husk ash has improve the hardness of composite of metal matrix from 53.49 Hv of 100 wt.% of AA7075 recycled aluminum chip to 69.53 Hv of composite of metal matrix at 10 wt.% of composition of treated rice husk ash. Based on this research, treated amorphous silica as reinforcement has enhance the physical properties and hardness of recycled aluminum chip sample in composition up to 10 wt.% of treated amorphous silica.

1. Introduction
Aluminum metal is a very light material with a specific weight of 2.7 gm/cm³, heavily nonferrous metals used in the world and it is about third most abundant element in the earth’s crust [1,2]. Waste material has becomes major issue as it’s produced in manufacturing industry as aluminum scrap. Aluminum scrap obtained as secondary aluminum promise environmentally friendly and low cost of production than the cost production by conventional methods [3-5].

During the production of products, after the machining process, different sizes and types of chips are generated [6]. Conventional recycling leads oxidation loss of metals and also increases labor and energy costs, only 5 percent of the energy needed for ore aluminium production to be recycled [3]. Consequently secondary aluminum in many countries has been accepted.
Rice husk and its ash are used as a potential reinforcement additive to replace conventional forms of silica as a major source [7]. Crystalline silica was obtained at burning temperature of 1100°C and 1200°C, while silica was observed at burning temperatures of 900°C and 1000°C in transitional phase amorphous to crystalline and silica were remains in amorphous phase at burning temperatures of 700°C and 800°C [8-10].

Based on the study of AA7075, the composite material of the composite of metal matrix can be improved with an addition amorphous silica with appropriate composition treated amorphous silica to composite of metal matrix. Thus, silica produced by rice husk is excellent natural source that can be able to replace conventional silica sources, where agricultural waste can be change into beneficial agricultural raw material.

2. Experimental Material and Procedure

2.1. Aluminum Matrix Material

The matrix material used in this study is aluminum AA7075 alloy. The theoretical density of material is 2.81 g/cm³ where the element composition of aluminum AA7075 alloy (wt.%) is shown in Table 1.

| Element | Composition (wt.%) |
|---------|-------------------|
| Al      | 87.18             |
| Zn      | 9.49              |
| Cu      | 2.59              |
| Si      | 0.31              |
| Cr      | 0.28              |
| Others  | 0.15              |

2.2. Reinforced Material

Rice husk obtained from industry of rice husk company, Nano Siltech Sdn Bhd, was used as reinforcing agent. The rice husk was burned at 700°C using chemical treatment (hydrochloric acid) to fasten the burning process (amorphous phase). The chemical element composition (wt.%) of treated amorphous silica obtained by x-ray fluorescence analysis (XRF test) as shown in Table 2.

| Element | Composition (wt %) |
|---------|--------------------|
| SiO₂    | 87.52              |
| C       | 0.11               |
| K₂O     | 4.83               |
| P₂O₅    | 3.52               |
| CaO     | 1.44               |
| MgO     | 1.28               |
| SO₃     | 0.54               |
| Cl      | 0.13               |
| Fe₂O₃   | 0.39               |
| Al₂O₃   | 0.24               |

2.3. Chips AA7075 Preparation

The high-speed CNC milling machine Mazak Nexus 410A-II CNC Mill produced the aluminum chip at 1100 mm/min feed rate, 1 mm depth cut and 345.4 m/min cutting velocity. FRITSCH – ultrasonic cleaner Labarette 17 was then used to clean the milled aluminum. The cleaning time used for the treatment of grease, oil and impurities was 1 hour with an acetone solution (CH₃COCH₃). Finally, it was used to dry the residual acetone from the chip by using a drying oven in 1 hour at 75°C [11-14].

2.4. Rice Husk Ash Preparation

In preparing rice husk ash, the ball mill was used to generate smaller particle size by using porcelain jar for 10 minutes under wet milling cycles. FRITSCH analysette 3 vibrator apparatus was used to perform sieving process with duration of 30 minutes for separating the particle size of 63μm.

2.5. Mixing and Compaction Process

A machine of uniaxial hydraulic press in Carver model 3851-0, was used to compact the samples. The preparation of mixing samples as shown in Table 3. The aluminum chips AA7075 were then mixed with treated amorphous silica, and then shaped to the mold. The sample is in cylindrical shape with size of 10 mm height and 14 mm diameter. The load compaction and compaction duration were set at 9 tonnes and 20 minutes, respectively [15,16]. The die surface was cleaned with lubricants for easy removal of the samples, by spraying the surface.
Table 3. Composition of treated amorphous silica and aluminum AA7075 chip

| Composites | Composition                                      |
|------------|--------------------------------------------------|
| A          | 100% AA7075 chip                                 |
| B          | 97.5% AA7075 chip + 2.5% treated amorphous silica|
| C          | 95.0% AA7075 chip + 5% treated amorphous silica  |
| D          | 92.5% AA7075 chip + 7.5% treated amorphous silica|
| E          | 90.0% AA7075 chip + 10% treated amorphous silica |
| F          | 87.5% AA7075 chip + 12.5% treated amorphous silica|

2.6. Sintering Process
Tube furnace is used for sintering process under inert gas (Argon gas) control. The heating rate, temperature and time were controlled for reproducible results. The sintering profile shown in Figure 1 was the temperature used to performed this process [10,15]. The zinc stearate was burned out at 300ºC after 30 minutes and the sintering procedure began within 60 minutes at 552ºC.

![Figure 1. The sintering profile](image)

2.7. Physical Test and Hardness Test
The physical test consists of density, porosity and water absorption of composite of metal matrix is measured with Archimedes Principle which is using an electronic balance, Mettler Toledo German. The analysis testing was conducted followed by standard ASTM B328 for density and ASTM B962-17 for porosity.

Hardness test was conducted using Vickers method followed by standard ASTM E-384. Vikers hardness test machine equipped with a diamond indenter to measure the hardness. The measurements were performed with eight indenters to take the average.

3. Results and Discussion

3.1. Physical Properties
Archimedes method has been used to identify the relationship of physical properties between the density, apparent porosity and water absorption of composite of metal matrix at different composition of treated amorphous silica. Table 4 shows the results of density, porosity and water absorption for composite of metal matrix and Figure 2 shows the graph of density, porosity and water absorption for composite of metal matrix sample.
Table 4. Physical test.

| Composites | Density (g/cm³) | Porosity (%) | Water absorption (%) |
|------------|----------------|--------------|----------------------|
| A          | 2.34           | 13.4215      | 6.4071               |
| B          | 2.47           | 9.8659       | 4.4146               |
| C          | 2.49           | 9.3247       | 4.1098               |
| D          | 2.44           | 15.3990      | 7.4164               |
| E          | 2.42           | 14.5194      | 6.9874               |
| F          | 2.38           | 15.4281      | 7.6196               |

Figure 2. Graph of physical test.

Figure 2 observed that the density of composite of metal matrix were increase steadily by up to 5 wt.% at the composition of treated amorphous silica. The density of composite of metal matrix were decreased after being reinforced by more than 5 wt % of treated amorphous silica. It is certain that the density of composite of metal matrix was significantly dependent on the composition of treated amorphous silica. Meanwhile, the apparent porosity and water absorption were increase to the increasing in composition of treated amorphous silica. It can be concluded that the higher the addition composition of treated amorphous silica, the higher the pore formed.

3.2. Microhardness

The hardness of material was performed on the material surface using the Vickers hardness machine at small load of 1 N, as it is consists of a hard and precise head for easing the penetration into the sample material. The average of hardness was taken with eight times of indentation into each sample.

Figure 3 shows the relationship between hardness and different compositions of treated amorphous silica. It has been found that the hardness increases with an increasing mass fraction of the treated amorphous silica content, improving the hardness of the composite metal matrix. The hardness of composite of metal matrix has improved from 53.49 Hv of fully AA7075 recycled aluminum chip to 69.53 Hv of composite of metal matrix. The hardness reaches 69.52 Hv at 10 wt % of treated amorphous silica and it is higher than hardness of untreated amorphous silica that reaches 65.93 Hv at 10 wt % [10]. However, Saravanan et al., and Tiwari et al., reported that the hardness of matrix material reduced with silica composition due to poor bonding of the matrix and poor wettability of reinforcing rice husk material with aluminum material when the addition of silica were more than 12 wt.% [7,17].

Table 5. Microhardness data

| Composites | Microhardness (Hv) | Std. dev. |
|------------|--------------------|-----------|
| A          | 53.4905            | 3.43413   |
| B          | 55.8036            | 2.77232   |
| C          | 63.2777            | 4.25264   |
| D          | 64.5604            | 2.47375   |
| E          | 69.5261            | 4.41494   |
| F          | 65.7145            | 2.22012   |

Figure 3. Microhardness (Hv) at different composition of treated amorphous silica (wt.%)
4. Summary
In conclusion, the summarized of current study is as follows:
1. Rice husk, industrial residue from paddy milling, which are containing high amount of silica can be used as aluminum matrix composites reinforcing agent.
2. Industrial wastes become economic resources if rice husks are used to produce composites. This also solves the issue of rice husk problem of storage and disposal waste.
3. The density of composite metal matrix has been risen to 5 wt% of treated amorphous silica and then reduced by enhanced mass fraction of treated amorphous silica. The porosity of composite metal matrix increase at increasing composition of treated amorphous silica.
4. The hardness of composite of metal matrix was seen to be decreased with composite more than 12.5 wt% of treated amorphous silica by rice husk ash.

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