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Insulation Material from Rice Husk Granule

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This research aims to investigate the composition of the rice husk granule (RHG) with high silica content as an insulting material. The ratio of the rice husk ash (RHA) with other supporting material has been varied to produce the RHG with higher silica content. Three RHG samples using 87.09 wt % (Sample A), 87.72 wt % (Sample B), and 88.28 wt % RHA (Sample C) were formulated with other supporting materials. The performance of the RHG samples was analyzed by the scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDX), thermo gravimetric analysis (TGA) and thermal conductivity. The results indicated that the RHG Sample C (88.28 wt % RHA, 9.29 wt % of bentonite and 2.41 wt % exfoliated graphite) with the maximum amount of silica content (86.74 %) showed the desirable properties as insulting material, i.e. with the highest onset temperature (414.15 °C) by the TGA and the lowest thermal conductivity (0.0746 W/m.K).

1. Introduction

Compared to other biomase fuels, approximately 20 %, rice husk has an uncommonly high in ash. It holds 92 % to 95 % silica which has a high absorbant and light in weight. Furthermore, it has a very high surface area. This type of character of rice husk is beneficial for many industrial applications. Bronzeoak (2003) mentions that rice husk can be applied in industrial processes. Those are for steel foundries, manufacture of insulation for houses and refractory bricks. In producing high quality of steel RHA is used especially in producing high quality flat steel.

Other application of rice husk ash includes as an insulator which has good quality of insulating properties which also involves low thermal conductivity, a high melting point, low bulk density and high porosity. Furthermore, rice husk ash can be used as "tundish powder" . This procedure is conducted to insulate the tundish container which can prevent rapid cooling of steel. Furthermore, it ensures equal solidification in casting process. Another function is that RHA can be used as a coating a molten metal in the tundish and in the ladle which becomes a very good insulator in which prevents the rapid cooling metal. (Kumar et al., 2012)

Insulating material with a high melting point but low thermal conductivity is desirable. This study aims to produce an insulating material using rice husk ash, bentonite and exfoliated graphite to enhance the silica content in a composite termed as rice husk granules (RHG). Klatt and Townsend (2002) formulated a composite using rice husk ash (RHA), ceramic clay binder, bran and an exfoliating agent, however the melting points were not high enough (1,000 °C). With low melting points, RHG will be converted to the liquid slag when in contact with the metal at high temperature (Sharika, 2016). Formation of slag became an issue for such material to act as the insulating material in the steel industrial.

Rice is the staple food for billions of people in which it covers 1 % of the earth's surface. Rice paddy is produced around 600,000,000 t annually around the world. Approximately, 20 % of the rice paddy is rice husk with the yearly total production of 120,000,000 t. In countries which rice is the staple food, the processing of rice functions as a waste or discarded by burning them. (Bronzeoak, 2003).

Indonesia is one of the largest world rice producers. The production of rice was 70,850,000 t in 2014 (BPS, 2015). Rice husk consists of about 20 % of the total production (9,730,810 t). The RHA potential was 18 % from the rice husk (1,751,546 t) (Belonio et al., 2008). In this research, the rice husk from the Province of Banten, Indonesia was used. Banten produces about 392,000 t/y of rice husk (Anshar et al., 2016).

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Table 1 shows the composition of the rice husk used in this study. Ash is an important composition, as this value is used to estimate the ash content from the rice husk. Rice husk contains 75-90 % of organic matter including the cellulose, lignin and other minerals such as silica, alkalis and trace elements (Nagar, 2016).

Table 1: Composition of rice husk from Banten (Thakuur, 2014)

Property	Range
Hardness (Mohr's scale)	5-6
Ash (%)	22-29
Carbon (%)	≈ 35
Hydrogen (%)	4-5
Oxygen (%)	31-37
Nitrogen (%)	0.23-0.32
Sulphur (%)	0.04-0.08
Moisture	8-9

2. Material and methods

The rice husk was collected from the farms located in Banten Cilegon, Indonesia. The rice husk granules (RHG) were produced based on the method modified from the patents US6342088B1 (Klatt and Townsend, 2002). The method comprised of four parts, i.e. rice husk preparation, calcinations, granulation and analysis. The first step is rice husk preparation include raw material pretreatment and drying process. The following four step process can be seen in Figure 1. Distilled water was used to wash the sample which functions to remove adhering soil and other substances which is easily dissolved. The significant element remained in the suspension in recovered sieve (400 µm) and dried. This took place in an oven in which (Type Scientific, series 200) was adjusted to 110 °C for 24 h. The rice husk gained was calcined at 700 °C in muffle furnace to produce the rice husk ash (RHA). The calcination temperature is a key parameter to define when the slica in the rice husk ash amorphous become crystaline. The RHA was granulated using a pan granulator with the supporting material (S; bentonite and exfoliated graphite) at different composition as shown in Table 2. A dryer was used to dry the rice husk granules at temparature range 100-130 °C.

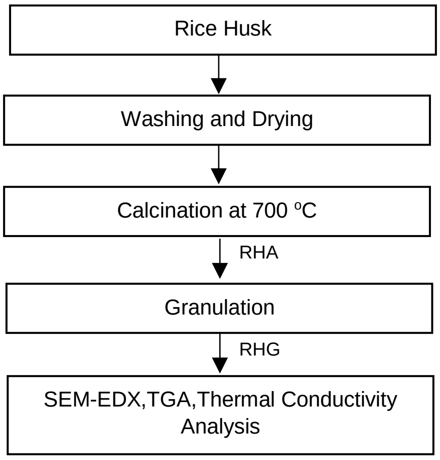

Figure 1: Four-step procedure of RHG Production

Table 2: Different composition and ratio of RHA/S for the production of RHG

Materials	Sample A (wt %)	Sample B (wt %)	Sample C (wt %)
Rice Husk Ash (RHA)	87.09	87.72	88.28
Bentonite (B)	10.24	9.74	9.29
Exfoliated Graphite (EG)	2.66	2.53	2.41
Supporting Material (S=B+EG)	12.9	12.27	11.7
	Sample A	Sample B	Sample C
Ratio of RHA/S	6.74	7.14	7.53

The RHG Samples (A, B, C) were characterized using scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDX), thermo gravimetric analysis (TGA) and thermal conductivity analysis. Electron microscope was used in the SEM process. It produced images of a sample. This process was obtained by using beam of electrons by scanning process. To detect the various signals produced by the sample and to find out the information about the sample's surface topography and composition, it is the interaction of electrons with the atoms that provide these detection and information. Information on the chemistry of individual particles which include size, shape, and surface morphology was provided by the SEMs equipped with energy-dispersive (EDX) or wavelength-disperse spectrometers (Wilis et al., 2002). To support a wide variety of projects and research aims, samples were hand-in for SEM/EDX analysis in large variety of forms. Scanning electron microscopy (SEM) was conducted to observe the morphological features of the as received RHA. Under the secondary electron imaging mode (SEI) at a magnification of 100X, the micrograph was taken (Kingsley et al., 2010). For surface morphology analysis Scanning Electron Microscopy (SEM) was used. This was equipped with and Oxford detector EDX at 20 kV which uses Aztec software for elemental analysis as mentioned by Chantalle et al. (2015).

TGA is a standard method used to determine the mass loss characteristics of the biomass when heated at a prescribed rate. Samples A, B and C were heated from the ambient temperature to 1000 °C at a rate of 10 °C/min. TGA was conducted using a sample pan that was supported by a precision balance. The pan with the sample was heated in a furnace, cooled and the mass loss was recorded during the experiment. The environment in the furnace was maintained by passing an inert gas at 60 ml/min that flowed over the sample and exit through an exhaust (Koo, 2016).

Hossain et al. (2013) argued that Hot Cross-Wire method can be used to determine thermal conductivity of refractories by implementing ASTM C-1113. It is essential to be used to offense refractories in which hot face to cold face thermal gradient show the specific usage of refractory materials. Bird et al. (1960) affirmed that in determining thermal conductivity can be measured through the Fourier's basic balance of linear heat conduction as it is essential for the heat transfer systems in the blocks systems. Thermal conductivity K is not perpetual however it is a utility of temperature gradient with influence to the period of heat flow. Generally, the linearity is a mean of the implementation of ranges values relationship.

Thermal conductivity k is property that can be found in several heat transfer issues. As mention by Robert and Green (2008), it is the heat flow per unit area in line with the temperature that has decrease in the Y distance. While, the constant of proportionality k is identified as thermal conductivity. The transfer rate per unit time (Q) by conduction through the wall can be found if a plan of thickness (∆X) and area (A) support the temperature.

$$Q = -\frac{A.\Delta T}{\Delta X} \tag{1}$$

Below is the formula constructed if the material of the wall is homogeneous and has a thermal conductivity (x) then:

$$Q = -\frac{k.\Delta T}{\Delta X} \tag{2}$$

Q is identified as the amount of heating across the materials, k is identified as the proportionality constant of thermal conductivity, ∆T is identified as the temperature difference at the walls of material and ∆X is the overall thickness of the material.

The thermal conductivity was calculated using the Fourier's equation of the linear heat conduction using the ASTM wire method (Bhatii et al., 2011) as shown in Eq (3).

$$k = -\frac{Q.\Delta X}{A.\Delta T} \tag{3}$$

This equation is used to determine the thermal conductivity in W/m.K of the insulating material each for Sample A, B and C.

3. Results and Discussions

The silica (SiO_2) content of the rice husk granules (RHG) is expected to affect the insulation property. The characteristics of RHG with different composition of silica were evaluated by the SEM-EDX and TGA. The SEM-EDX photographs showing the microstructure of RHG Samples A, B and C are shown in Figure 2, 3, and 4.

Based on Figure 2 to 4, the morphology of Sample C has higher surface area and micro-pore structure than Sample A and B. Figure 4 shows the homogeneity of the material in Sample C. This suggests the higher silica content in the RHG with higher content of RHA (Sample C) and the least concentration of bentonite added as

the supporting material during the mixture process and calcination. During calcination, the porous and morphology can be attributed to the burning out of the organic component in the rice husk. This can be seen in Figure 2 - 4.
The silica contents (SiO_2) in the RHG samples were analyzed by the EDX analysis as shown in Figure 5. Figure 5 shows the effect of RHA/S ratio on the silica content of RHG. The Sample C with the highest ratio of RHA/S has provided the highest silica content (SiO_2, 86.74 %) than Sample A and B. We can assume that the temperature stability of RHG as located on TGA analysis is contributed by silicon content.
Table 3 shows the TGA analyses on the RHG samples as characterized by the onset temperature.

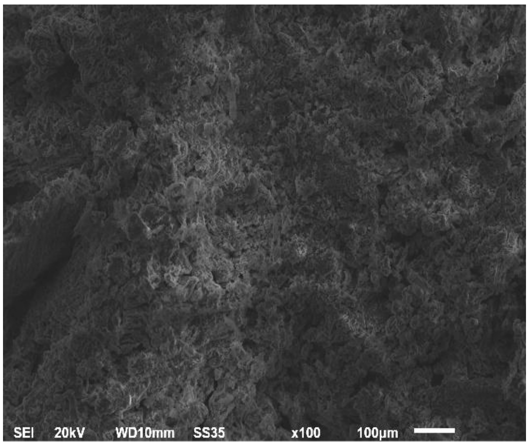

Figure 2:SEM-EDX analysis for Sample A

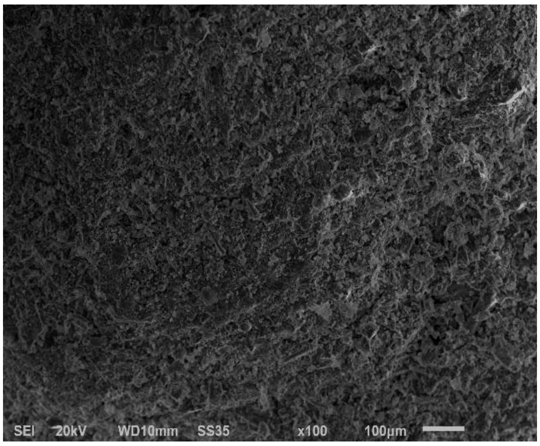

Figure 3: SEM-EDX analysis for Sample B

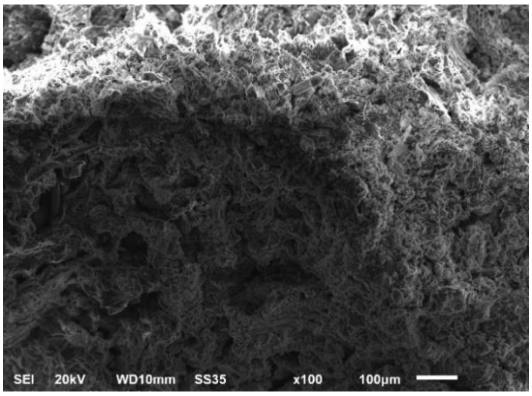

Figure 4: SEM-EDX analysis for Sample C

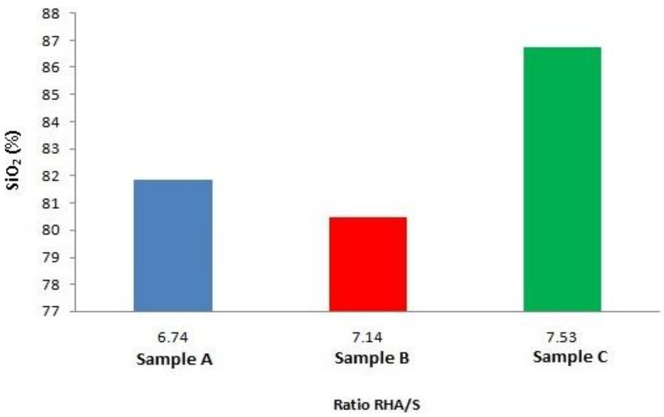

Figure 5: The effect of the ratio of RHA over the supporting material (S; bentonite and exfoliated graphite) in the RHG Samples

Table 3: Onset temperature of the different RHG Samples analyzed by TGA Analysis

Sample	Onset (°C)
RHG Sample A	412.50
RHG Sample B	406.75
RHG Sample C	414.15

The onset value is the first temperature where a material undergoes a reduction of the volatile matter of an element in the form of water and other compounds. Sample C with the highest SiO_2 content showed the highest onset temperature. Previous research on RHG with 52 % of SiO_2 content (Klatt and Townsend, 2002) showed a low melting point of 1,000 °C and a higher tendency of conversion to the liquid slag. The highest melting point for the insulating material containing SiO_2 can be as high as 1,500 °C. All three samples have higher silica content (>80 %), their melting points are expected to be higher.
Table 4 shows the thermal conductivity of the RHG samples. Sample C has the lowest thermal conductivity compared to Samples A and B. A lower value of thermal conductivity (Sample C) is desirable to serve as an insulation material to minimize the heat loss. The values of low thermal conductivity in the process of insulating refractory is assumingly caused by their porous nature, grain boundaries, and other microscopic imperfection.

Table 4: Thermal Conductivity of RHG samples

RHG Sample	Thermal Conductivity	Method (Bhatii, 2011)
Sample A	0.1911 W/m. K	ASTM Hot wire
Sample B	0.1235 W/m. K	ASTM Hot wire
Sample C	0.0746 W/m. K	ASTM Hot wire

4. Conclusions

This study shows a promising formulation of the rice husk granule (RHG) to serve as an insulating material. The RHG Sample C with the composition of 88.28 wt % rice husk ash (RHA), 9.29 wt % of bentonite and 2.41 wt % of exfoliated graphite contained the maximum amount of silica (86.74 %) Sample C provided the highest onset temperature (414.15 °C) and the lowest thermal conductivity (0.0746 W/m.K). These properties are desirable for consideration as isolation material to prevent energy loss. The recycling of rice husk as the insulating material via RHG can minimize the negative environmental impact due to the open dumping of rice husk.

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