Design and Fabrication of a Simple Laboratory Ball Mill for Powder Coconut Shell Preparation as Raw Material of Biochar

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Abstract. Biochar is one of the progressive material used for many application in pharmaceutical food, chemical and electrochemical industry. To manufacture the biochar, one of the main obstacle is derived from the preparation process and characteristics of the biochar source. Coconut shell is one of the abundant material usually used as biochar source. However, the coconut shell have a hard-shell which is practically is not easy to process it manually. Therefore, in this study we design and fabricate a simple and low cost ball mill. The goals of this research is to customize the coconut shell powder as technical grade for biochar source using a laboratory ball mill. The laboratory ball mill consist of a steel bowl, steel ball and a vibrator. The fabricated ball mill was tested to 1 mm, 10 mm and 1-10 mm of coconut shell chips for three series of testing to evaluate the grinding capability and reproducibility. For 30 minutes of testing, the ball mill has produce the powder coconut shell about (26.07 ± 1.2) %; (22.69 ± 1.58) % and (16.24 ± 0.52) % respectively for 1 mm, 10 mm and 1-10 mm of coconut shell chips. The high reproducibility of the ball mill show that it has potential for powder coconut shell preparation machine.

1. Introduction

Ball mill is one of grinding tools used to produce a fine powder material, dispersing and blending the materials which is commonly used in metallurgy and nanotechnology [1]. Typically ball mill consist of a grinding jar and balls as grinding media. The jar shaped of a bowl or a tube made of steel or ceramic. The jar can vibrate on its center or rotated around an axis [2-3].

The ball mill principle is to reduce the material size due to the collision of the ball and the material and transfer of kinetic energy. The material size reduction influenced by characteristics of the material, mass of the grinding media and the speed of the mill [3].

In this study, it is a challenging to grind the coconut shell because of its hard-shell and high carbon content which is frequently used as biochar source [4-5]. We use various size of the parent coconut shell to evaluate the grinding capability. Also, we study the reproducibility of the ball mill by employing of three series of testing.
2. Design
The design of laboratory ball mill is given in Figure 1. As described earlier, the ball mill consist of two components: the grinding jar and the grinding media. All of the component is connected to the vibrator to operate. The grinding jar has a lid which function as a feeder for coconut shell inlet.

In order to achieve the powder particle size, the ball mill should fulfill the specification as shown in table 1. The grinding jar have the form of a bowl which is made of a steel (Bowl SG225) with diameter of 15 cm. The steel bowl is filled up by a ball (SP-30) with diameter of 3 cm. The ball mill is operated by a vibrator machine of ¼ HP with frequency of 50 Hz.

| Specification       | Description                                      |
|---------------------|--------------------------------------------------|
| Grinding jar        | Bowl SG225, diameter of 15 cm                    |
| Grinding media      | A ball SP-30, diameter of 3 cm                   |
| Vibrator machine    | ¼ HP (three phase), frequency 50 Hz              |

3. Testing
The as-fabricated ball mill subsequently tested to the coconut shell by using a procedural as explained in the flowchart (Figure 2). First, the coconut shell is manually crush into chips of 1-10 mm. The various size of chips is fed to the ball mill about 30 minute. The ball mill is operated by turning on the vibrator. Along the process the grinding lid is closed. The resulted coconut shell is sieving using mesh of 20, 25 and 40. Finally the milled coconut shell is weighing to classify the product. Here, we classified the powder coconut shell for coconut shell with particle size less than 420 μm (0.42 mm). Other higher particle size are categories as granular form.
Figure 2. Flowchart of ball mill testing.

4. Results and discussion
Realization of the proposed design of the ball mill is shown in Figure 3. The ball mill has a simple architecture and user friendly. This ball mill can be used for other biomass sources. The size of the steel ball can adjust the size of the chosen precursor.

![A laboratory ball mill](image)

The produced milled coconut shell are demonstrated in Figure 4-6. For the testing, we use about 100 gram of coconut shell chips. All of the figure (4-6) show that the produced coconut shell chips are less distributed in powder form. Majority of the milled coconut shell are still in granular form (700-840 μm) for 30 minutes of milling.

In figure 4, it is clear that the particle size distribution of the 1 mm of coconut shell chips which is in powder form is more numerous (26.07 ± 1.2) % than the granular with particle size of 420-700 μm which is about 23.06 ± 0.76) %. In addition, the majority of the particle size of 700-840 μm is about (50.70 ± 1.7) %.
Figure 4. Particle size distribution of 1 mm of coconut shell chips.

Figure 5. Particle size distribution of 10 mm of coconut shell chips.

Figure 5 represent the particle size distribution of 10 mm of coconut shell chips. The minority of particle size distribution is in contrary to that of the 1 mm of the coconut shell (Figure 4) where is the minority particle size is distributed in powder form $(22.69 \pm 1.58)\%$. The other granular form of particle size of $420-700 \, \mu m$ is about $(29.15 \pm 1.92)\%$ and the highest distributed particle size of $700-840$ is weighing in $(38.13 \pm 2.45)\%$. 
Figure 6. Particle size distribution of 1-10 mm of coconut shell chips.

Particle size distribution of 1-10 mm of coconut shell chips as shown in figure 6 have a poor particle size in form of powder (16.24 ± 0.52) %. Anyhow, this number is better than the granular in size of 420-700 which is about (12.92 ± 0.07) %. The majority of the coconut shell is in form of granular with particle size of 700-840 μm (70.84 ± 0.49) %. This result show that the ball mill cannot work properly to grind the heterogeneous particle.

Based on the results, it is shown that grinding mechanism is dominantly happened through cleavage of particle with slow impact which produce fragment of size of 50-80 % of the size of initial coconut shell chips [3]. In other hand, the size reduction in form of powder has easily occurred on the initial particle size of 1 mm as demonstrated in Figure 4 and 6. As consequence, to produce more the powder, it needs intense impact by increasing the speed of the ball mill and using small initial particle.

5. Conclusions

We have designed and fabricated the simple laboratory ball mill for coconut shell grinding tools to produce powder coconut shell. The testing procedural show that the ball mill is effectively work for coconut shell with small initial size of 1 mm with result of powder coconut shell about (26.07 ± 1.2) %. The ball mill has good reproducibility for three series of testing along 30 minutes operation.

Acknowledgments

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References

[1] Zhang D 2004 Progress in Materials Science 49.
[2] Mankosa M, Adel G and Yoon R 1986 Powder technology 49 (1).
[3] Monov V, Sokolov B and Stoenchev S 2003 Cybernetics and Information Technologies 12 (2).
[4] Su W, Zhou L and Zhou Y 2003 Carbon 41.
[5] Das D, Samal D and Meikap 2015 J. Chem. Eng. Process Technol. 5 (6).