DISK ROTATION SPEED AND DIAMETER OF IMPACTOR IN DISK MILL ON PARTICLE SIZE DISTRIBUTION FROM RICE HUSK

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Abstract

Researches on material milling have also been well documented. However, these studies have not yet reported on the impactor diameter and disk rotational speed conditions that are suitable milling process. The purpose of this study was to evaluate the effect of impactor diameter and disk rotation speed on the particle size distribution on the disk mill. To test the effect of impactor diameter and disk rotation speed on the disk mill, rice husk was used as the model of destructed material. Inside the disk mill, the impactor was mounted on a disk with the same position of impactor. Impactor diameter was varied to ensure the size reduction profile of rice husk. The process was also done by a certain rotation speed. The results showed that the disk rotation speed and diameter of the impactor affected the particle size distribution. The faster rotation of the disk mill resulted in the more nano-sized particles produced. The larger diameter of the impactor was used, the greater the particle size distribution produced. This influence can be used as a consideration for getting optimum condition for milling process.

Keywords: Disk mill, Disk rotation speed, Impactor diameter, Rice husk, Size distribution.
1. Introduction

Recently, many industries need a crusher or refiner to convert materials from large sizes into smaller sizes. There are various kinds of methods used in crusher machines; one of which is milling process [1]. Material milling apparatus that uses milling works includes disk mill, knife mill, ball mill, and hammer mill [2-6]. But, this study is discussed on disk-milling process.

The disk mill is a milling tool that utilizes a plate as a material milling. The basic principle of disk mill is to mill materials using a rotating disk on a stationary surface [7]. Several process conditions must be considered: type of disk, refiner disk, disk spacing, disk rotation speed [7], the shape of the cutting tool (impactor), and milling conditions [8, 9].

Several studies have reported that the disk mill can be used for various materials. For example, Aman et al. [10] have successfully exfoliated graphite using the disk mill. Exfoliation of graphite produces multilayer graphene. In addition, other studies have succeeded in using a disk mill to milling unwashed biomass in the process of converting sugarcane bagasse to ethanol [11], and milling solids in making cellulosic biofuels [12]. In making cellulose biofuels, disk mill is effective for supporting the production of glucose. Milling of solids can reduce the particle size of solids [13].

One of the solids which can be reduced in particle size is rice husk. Rice husk is an effective model material for milling because its material properties are difficult to be destroyed. When rice husk is destroyed, it is very easy to distinguish since the size-reduced rice husk cannot be agglomerated. The size-reduced rice husk is also easily identified due to its unique physicochemical properties. In addition, rice husk is an agricultural waste from the milling industry which are mostly not reused [14]. Its ability to be easily identified makes rice husk suitable as material for a model in testing the milling process.

Although the milling process using the disk mill has been widely carried out and documented, the effect of the impactor diameter on particle size has not been widely reported. Therefore, the aim of this study was to evaluate the effect of impactor diameter and disk rotation speed on the particle size distribution on the disk mill. This research was conducted using rice husk as a model of milling material. Based on the results of rice husk milling, we can determine the optimum conditions for the milling process using a disk mill.

2. Experimental Method

The method used in this study was divided into two stages, namely (i) milling of materials using a disk mill (E-Scientific Lab, Bandung, Indonesia) and (ii) screening of milling results using sieve test (Rumah Publikasi Indonesia; for measuring size distribution; see reference [15]). Illustration of the disk mill is shown in Fig. 1. Milling in the disk mill was done using an impactor. The impactor used in this study was in the form of small and large square, corresponding to equivalent diameter of 1.3 and 2.4 mm, respectively.

In this study, rice husks (Jaya Makmur Farm Shop, Bandung, Indonesia) were used as a model of milling material. To mill rice husks using a disk mill, rice husks were weighed in about 12 grams. This amount was the optimum mass of material
for milling. Before milling starts, the rotation speed of the disk mill was set. Disk rotation speed used in this study was 600, 1000, and 1500 rpm.

Rice husk (see Fig. 1(1)), then slowly inserted through the hopper (see Fig. 1(3)) into the disk mill that has been put with a certain rotation speed. Milling takes place in a disk mill shown in Fig. 1(4). The process for milling rice husk took 40 minutes. Milled particles as a product of disk milling process (sizes of micro and nanometer) (see Fig. 1(5)) come out through a filter in the disk mill.

Furthermore, the output resulted from milling process was filtered using a mesh filter that has several sizes (48.1, 58, 74, 99.3, 125, 250, 530, 1000, and 2000 μm). Micro and nano rice husk particles from the milling process were successfully separated by a mesh filter based on their specific sizes.

Fig. 1. Illustration of disk mill, (1) input, (2) input material before milling, (3) hopper, (4) disk mill, (5) output, and (6) output material after milling.

3. Results and Discussion

3.1. Optimum time of milling using disk mill

Figure 2 shows the particle size distribution resulting from disk-milling rice husk using a disk speed of 1500 rpm. Milling was carried out with varying milling times, which is 5, 10, 20, 30, 40, and 50 minutes. The curve shows the relationship between final particle diameter and the intensity of the particles. The resulting particle diameter reached 2000 μm.

Based on the analysis results, milling for 5 minutes has a smaller particle size distribution than the particle size distribution resulting from milling for 10 minutes. Similarly, on the next minutes up to 50 minutes. Particle size distribution increases with increasing milling time. In Fig. 2, the narrow particle size distribution has increased dramatically at the milling time from 5 to 10 minutes. However, the increases in particle size distribution began to be constant at 10 to 20 minutes. After
milling rice husk up to 40 minutes, there is no significant increases in particle size distribution. Based on these results, the optimum time was selected for evaluating milling process at 40 minutes.

![Particle size distribution graph](image)

**Fig. 2. Particle size distribution obtained after different time to milling rice husks using disk mill.**

### 3.2. Particle size distribution

Figure 3 shows the particle size distribution of rice husks from milling using a disk mill. The particle size distribution changed with increasing rotation speeds. In this study, we limited the rotation speed to only 1500 rpm.

Based on the analysis results, the higher rotation speed produces higher particle intensity. As shown in Figs. 3(a) and (b), the particle size with a rotation speed of 600 rpm has the broadest distribution. Particle size intensity increased when using 1000 and 1500 rpm. This is because milling with a high disk rotational speed can increase the higher pressure. Consequently, the drive of the disk speed to the material to collide with the wall can be stronger. This causes the material that is destroyed into micro and nano sized particles to be more and more produced.

Figures 3(a) and (b) show the particle size distribution in the milling process using large square and small square impactors, respectively. The diameter of the large square impactor is 2.4 cm, while the diameter of the small square impactor is equal to 1.3 cm. Based on the analysis results, the particle size distribution in the milling process using a large square impactor is relatively larger compared to using a small square impactor for each spin speed. This is confirmed from the maximum peak on each curve. In Fig. 3(a) with a disk rotation speed of 1500 rpm, the maximum peak is higher than the maximum peak speed of 1500 rpm in Fig. 3(b). So, it can be obtained even at speeds of 600 and 100 rpm.

The difference in the particle size distribution is due to the influence of different impactor diameters. The greater impactor diameter can allow the greater particle size distribution. The large impactor diameter causes the destruction area of rice husk on the disk mill to be even greater. When a large diameter impactor was used, more rice husk can be ground, making that the process of rice husk milling becomes more effective and the resulting particle size distribution gets better.
3.3. Milling mechanism of disk mill

To confirm the phenomena regarding the milling process, Fig. 4 shows the mechanism during disk mill process. In the disk milling apparatus, each disk has several impactors that have identical shape and size.

Initially, the rice husk was inserted into the disk-milling apparatus (see Fig. 4(1)). After the disk mill is started, the disk has been rotated at a certain speed (see Fig. 4(2)). Impactor on the disk can dredge the rice husk in the disk mill. Rice husk that is dredged by the impactor is pushed and hit to the milling wall, causing the rice husk to break into pieces (see Figs. 4(3) and (4)). Parts of the broken rice husk fall to the surface of the center of the milling reactor (see Fig. 4(5)). However, some of the other rice husk are pushed back by the impactor to get more collision again with the wall, which causes the rice husk to get more experiences for fracturing into smaller-sized particles. This rotation and collision occur repeatedly until the rice husk in the disk mill was destroyed into micro and nano sized particles (See Fig. 4(6)).

Fig. 4. The illustration of milling mechanism of disk mill.
4. Conclusion

The effect of disk rotation speed and diameter of the impactor on the rice husk size distribution has been evaluated. The milling process for each process condition is carried out in relatively the same milling time, so the results can be compared easily. The results showed that the disk rotation speed and diameter of the impactor can affect the milling results. The higher speed of rotation leads to the narrow size distribution. Further, it can create nano-sized particles in the product. The greater diameter of the impactor allows the narrow size distribution obtained. Since the use of different process conditions can allow different production result, this study is important to predict and further design as well as scale up milling process.

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