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Analysis on the grinding quality of palm oil fibers by using combined grinding equipment

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Abstract. As known, Malaysia is the second largest palm oil producer worldwide after Indonesia, therefore indicating the abundance of its wastes within the country. The plantation would be seen to increase to at least 5.2 million ha by 2020, and the waste generation would be 50-70 times the plantation. However, the efficiency of bulk density is reduced. This is one of the main reasons of the initiation of this size reduction/ grinding research. With appropriate parameters, grinding will be seen to be helping in enhancing the inter-particle bindings, subsequently increasing the quality of final products. This paper focuses on the grinding quality involving palm oil wastes by using the Scanning Electron Microscope (SEM). The samples would first be ground to powder at varying grinding speed and finally got the randomly chosen particles measured to obtain the size range. The grinding speed was manipulated from 15 Hz to 40 Hz. From the data obtained, it was found the particles fineness increased with increasing grinding speed. In general, the size ranged from 45 μm to about 600 μm, where the finest was recorded at the speed of 40 Hz. It was also found that the binding was not so encouraging at very low speeds. Therefore, the optimum grinding speed for oil palm residues lied in the range of 25 Hz to 30 Hz. However, there were still limitations to be overcome if the accuracy of the image clarity is to be enhanced.

1. Introduction

As to produce a good quality of densified product, grinding process is necessary. Grinding is the process designated to reduce particle size prior to subsequent processing. The rationale of size reduction is none other than to transform biomass materials into a form which optimizes handling, storage, transportation as well as conversion [1]. Some of the known parameters to have direct influence on the quality of grinded product include moisture content, type of equipment utilised, as well as rotary speed (rpm) [2].From studies, biomass has been proven as one of the most promising alternative energies in Malaysia due to its sustainability and environmental friendliness [3]. Then, it was found that the largest biomass source in Malaysia is oil palm since Malaysia is the second largest palm oil producer worldwide after Indonesia [4, 5] This is simply because 14.9 % out of 32.9 million ha land available in Malaysia is used for agricultural activities, where 34.16 % is oil palm [6]. As summarized by [7], there were 400 ha of oil palm plantation back in 1920, then rose to 4.06 million ha in 2009, and expected to expand to 5.2 million ha by 2020. A hectare of oil palm plantation is capable of producing 50-70 tonnes of waste and thus, electricity generation would be able to be generated from those wastes. The resulting yearly energy potential is projected to be at an amount of 800 GWh [8] while the capacity potential would be 1300 MW [9].However, the quality of grinding has to be preserved in order to maximise the efficiency of conversion into fuel source. For instance, the ground biomass powder could be combusted to produce syngas, also known as producer gas. This type of gas results in a better efficiency of 30-40 % when used in internal combustion engines, as compared to the conventional combustion Rankine cycle biomass power plants which have the efficiency of at most 25 % [10].Therefore, this paper will be aiming at determining the functionality of a grinding machine through verification of Scanning Electron Microscope (SEM) outcomes. Its magnifications would enable the extent of internal bonding of lignin for instance within the particles to be determined [11]. The higher the extent of the bindings, the better the resulting strength and other properties would be. The bonding could be achieved through a good extent of particle fineness besides uniformness, at appropriate moisture content. A good grinding facility will have to be able to produce particles with desired uniform shape and size.

2. Experimental set up

In this paper, the material involved is palm oil stem and palm oil fibers (empty fruit bunches-EFB).The standard operating procedures cover two major parts, grinding and scanning.

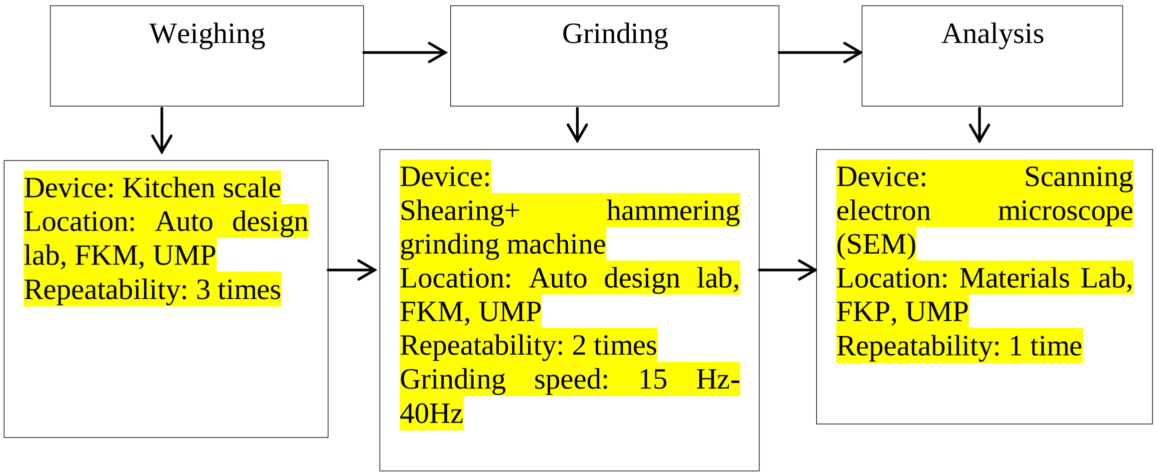

Figure 1. SOP for palm oil biomass.

Firstly, each sample would be weighed using a kitchen scale for three times, at the precision of 1 g. The average weight was then calculated and recorded in a datasheet. The weighing session was necessary to determine the load to be involved in the subsequent grinding process. The load included in the experiment was 5 g each.This particular process was performed using the combined grinding (shearing + hammering) equipment available in the Auto Design Laboratory, Faculty of Mechanical Engineering. In the process, samples would be ground to varying particle sizes through the manipulation of grinding speed, controlled through an inverter. The speeds used in the palm oil waste samples ranged from 15 Hz to 40 Hz, at an interval of 5 Hz. Each of the grinding speeds was repeated twice to allow better results consistency. The samples were first fed into the sampling pipe, then pushed to the blades by using the push piston. After shearing, the samples were allowed to be hammered into finer particles for 30 s. Then, the collection was conducted. All the resulting particles at the specimen collector were placed into either a plastic bag or a container. The machine would be cleaned after each session of grinding to avoid contamination.

3. Analysis

After grinding, the samples were sent for SEM analysis. The analysis focused on the particle sizes randomly chosen at each grinding speed. For the SEM analysis, the preliminary studies involving the palm oil stems were conducted in Central Lab located at Universiti Malaysia Pahang Gambang campus. On the other hand, the SEM for the EFB fibers ground at different grinding speeds were

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conducted in the Engineering Materials Laboratory, Faculty of Manufacturing Engineering, after the facility was made available in the Pekan campus. As there were limitations to the facility in terms of material conductivity, each sample could only be conducted once. However, the multiple images captured for each sample shall be adequate for analysis. Table 1 shows the equipment used for each process where their respective purpose was highlighted.

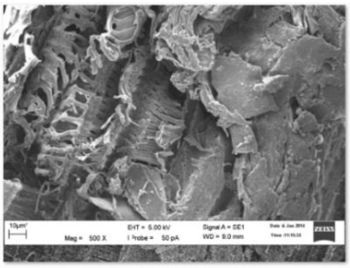
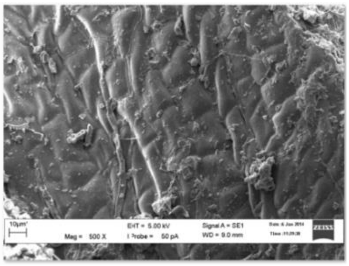
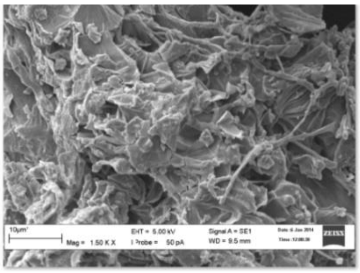
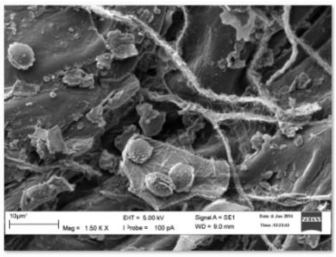
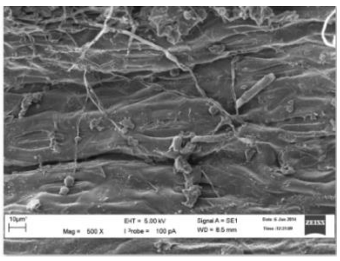
Table 1. Equipment used for each process with their purpose.

Process	Equipment	Figure	Purpose
Weighing	Kitchen scale (SF-400)		Measuring the weight of samples.
Grinding	Combined grinding machine		Reducing size of samples at manipulated grinding speed and grinding time.
Scanning	Scanning electron microscope (Phenome)		Determining the particle size and extent of bonding at higher magnifications.

4. Results and discussions

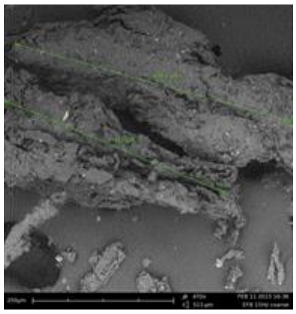
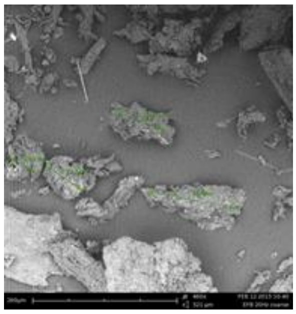
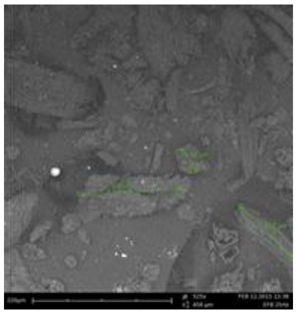
After a specimen was grinded, it would be essential to observe the fineness of the powder or ground specimen. It's simply because too fine or coarse powders would in turn affect the binding effects among the particles and subsequently the strength and durability of the products. Before the analysis on size measurements were performed, the preliminary studies to observe the internal structure were first conducted. In preliminary studies, the material involved was the palm oil stem biomass. However, the specific parameters were not taken into consideration; therefore no relationships could be derived yet. Anyhow, the internal structures especially multiple display of surface structure could be observed clearly and acted as the stepping stone for further analysis. Table 2 portrays the SEM outcomes together with the original ground specimens.

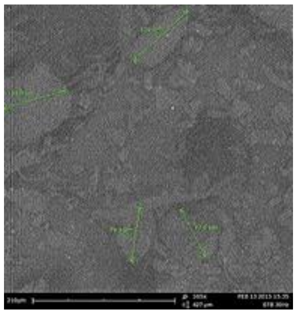
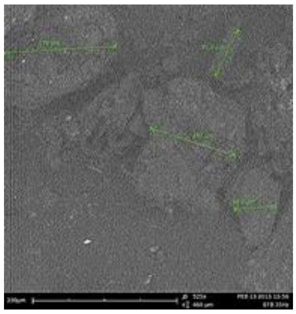
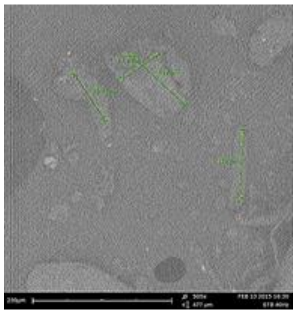
Table 2. Preliminary studies for SEM.

Specimen	**Palm oil stems**		
Sample	**Original figure**	**Magnified figure**	**Observation**
1			The figure shows the structure similar to the shape of DNA, however, without twisting. This would be one of the features preferred as to encourage better binding.
2			The figure portrays the uneven surface structure of the particles, captured at 500x of magnification power.
3			The figure displays the 1500x magnified view of the internal structure of particles with ‘thorny’ feature for binding.
4			At 1500x magnification, the ‘thorny’ feature contained in a prticle could be visible and the feature would aid in the binding between particles.
5			The figure depicts the binding between particles at 500x magnification.

By using the preliminary studies as guidance, it was found that manipulating grinding parameters would bring about different properties, as the binding is closely related to particle size. Therefore, the grinding speed was manipulated, as confirmed by studies in order to figure out the relationship of speed with particle size. The other parameters, i.e. grinding time and load were kept constant at 30 s and 5 g, respectively. For these parameters, only EFB was involved. The outcomes from the subsequent SEM analysis are depicted clearly in table 3.

Table 3. SEM analysis for EFB at different grinding speeds.

Specimen	**Empty fruit bunches (EFB) fibers**			
Grinding speed (Hz)	**Before grinding**	**After grinding**	**Size (µm approx.)**	**Magnified figure**
15			98-480	
20			54-565	
25			44-400	

30			77-340	
35			52-331	
40			90-214	

As seen in table 3, grinding at different grinding speeds resulted in a variety of particle size. The size of the particles was measured using Scanning Electron Microscope. At high resolution and magnification, the bonding between the particles could be verified. From the analysis, the relationship between the grinding speed and particle size could be derived. The trend was that as the grinding speed increased, the particle fineness also experienced increment, implying the production of finer particles. The relationship was that the particle was proportional with the grinding speed, as shown in equation (1).

$$\text{Particle size} \ \alpha \ \text{Grinding speed} \quad (1)$$

In general, the particle sizes ranged from 45 μm to about 600 μm, at the grinding speed ranging from 15 Hz to 40 Hz. The lowest size of about 45 μm was achieved at the grinding speed of 25 Hz, in the case of EFB. Each of the grinding speed was conducted twice and the SEM once due to machine limitation.

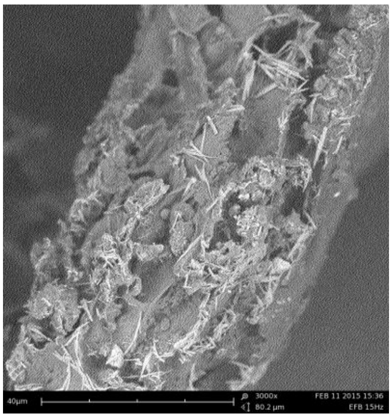


Figure 2. A magnified photo to show binding of particles.

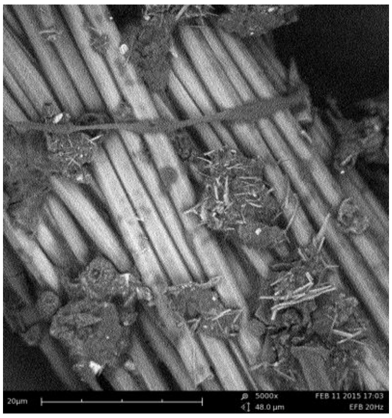


Figure 3. Binding performance at 20Hz.

As depicted in figures 2 and 3, the bonding between particles was shown clearly. Of course, from studies, the better the binding, the better the quality of the final products formed. From a lower magnification, the bonding looked encouraging even at low speeds. However, when the magnifications were further increased, it was proven the bindings were not so encouraging at low grinding speeds, as proven in Figure 3. The speeds identified were 15 Hz and 20 Hz. Thus, it could be concluded the optimum grinding speed to produce a good quality of oil palm wastes powder specifically for EFB would be at 25-35 Hz. However, as the tested specimens were chosen at random and due to the limitation of the equipment used for analysis, the accuracy was reduced. This was due to only clearly seen images were captured and measured, indicating forced negligence on ultra-fine particles which were normally not visible clearly even at high resolutions.

5. Conclusions

From the study, it was found that the newly designed grinding machine with strong cutting blades equipped with the functions of shearing and hammering, helped in producing fine particles with features for good binding. The ‘thorny’ feature was verified through SEM, as shown in the result section. As expected, the particle fineness increased with increasing grinding speed, manipulated at an interval of 5 Hz. The particle sizes ranged from 45 μm to about 600 μm, where the coarsest particle was recorded at the grinding speed of 20Hz and the finest at 40Hz. However, there were recorded limitations of the device which subsequently reduced the results accuracy. The bindings at 15Hz and

20 Hz were recorded to be below than par when they were broken, subsequently reducing the quality of final product formed, in terms of strength in particular. In future, analysis involving SEM shall be applied with appropriate coating as to increase the accuracy and clarity of images. Otherwise, the particle size analysis shall be performed using some other device that could result in high accuracy outcomes. Also, in future studies, the experimentations would involve more variety of samples which are abundant within the country such as rice residues as well as food residues. Then, the relationship between the grinding parameters with resulting particle size could be explored further.

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