Alternative method for stopping the coconut shell charcoal briquette drying process

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Abstract. The drying processes of coconut shell charcoal briquette consist of drying and agglomeration. In industry, the drying process is determined by a quality control person, which creates dependency. The justification was conducted by firing and hardness checking. The firing test consumes a lot of time. An alternative method for determining the stopping drying process is proposed. The method is based on the resistance of the briquette in addition to density. One hundred and fifty cube briquettes of 2,6 cm x 2,6 cm x 2,6 cm in wet, half-dry, and dry conditions were tested for electricity resistance. The results show different resistivity of wet, half-dry, and dry. The dry has a resistivity of 1.82 105 Ω. The others have less than that number by order more than 10. Some doubts were found due to the low resistivity number close to half-dry condition. The density of the doubt was in the type. Therefore, a combination of density and resistance will be used to stop drying, which can be done quickly and out of the dependency of the quality control person.

1 Introduction

Industrial charcoal briquette uses a hot air oven to dry the briquette. Applying a hot air dryer is considered reasonable instead of applying solar heating as the dryer. Solar heating has a drawback of intermittence and time-cost method [1]. Traditional drying also needs more activities for their employees because pre-treatment is needed [2]. Hot air oven uses fewer people and activities to manage the drying and provide a better product. The method has constant and controllable temperature to reach a specific time and process [3]. However, such drying needs fuel to provide heat for the process. Therefore, fuel consumption is a factor that should be considered in drying [4,5]. Generally, more extended drying time means more fuel, affecting production cost, which is the central issue of the industrial business [6,7].

Drying time in a hot air oven still takes two days. The process is controlled to manage the general drying steps and keep the product's quality [8]. These steps should happen in relatively equal time to avoid cracks in the briquette during drying. The drying is stopped when the product meets the criteria justified by a quality control person. The person uses the experience of identifying the time stop of the process. Usually, visual and practical procedures are applied, such as firing to check the crack, breaking the briquette using a

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hammer and scrutinizing its structure. Among the practical tests, firing and checking the crack of the ash is the most time-consuming approach. The briquette needs 3 hours of firing time. The firing process should be done thoroughly. During this test, the oven of the briquette is still running its drying process, meaning fuel consumption.

This experimental work proposes an alternative approach using resistivity criteria to reduce testing time. In a porous solid, the existence of water increases its conductivity. The water allows ionic flow and has dipole polarity. Therefore, the resistivity of the briquette can be applied to predict the water content condition of the briquette as a porous material.

The presentation of the work consists of four parts: introduction, methods, results and discussion, and the conclusion. The introduction shows the rationale of the work. The second part, the methods, reveals the basic theory of the approach, tested material and procedure of the test. Following it, results and discussion are provided to show the data of the work and its mean. Some findings will be provided in the last part of the work.

2 Methods

This section exposes the procedure of the experiment consisting of general procedure, tested briquette as the materials, and the theory of the approach. The theory based on resistivity will be presented in the first part. The material follows the theory about the type of the briquette and the types of the briquette tested during the work. Three conditions of the briquette are used in the test to show the work of the method: wet, half-dry, and dry briquette. The procedure of the tests is presented after the materials.

2.1 Theory

The resistivity of a material informs electrical resistance of The resistivity of a material informs the electrical resistance of the material. The resistivity of a material depends on the atomic structure of the material and its composition. Generally, an ionic material has low resistivity because it allows the electron to move [4]. In solids, Fermi energy is used to identify the conductivity. Low Fermi energy means that a material tends to be a conductor. In addition, the number of charge carriers is also an essential factor of solid conductivity. Mixing porous and liquid material tends to be more conductive when the liquid allows ionic flow. It happens when the liquid is an electrolyte or has an electric dipole that allows an electric field to be amplified in it.

Practically, the electric resistance of a material depends on its length, cross-section and resistivity [9]. It follows equation (1). The R and R_e are the material resistance and its resistivity, respectively. The l and A are the material's length and the cross-section of the measured material in the direction of the electric field.

$$R = \frac{l}{A} R_e \qquad (1)$$

2.2 Material

The measured briquettes are cube-type coconut shell charcoal briquettes produced in Central Java, Indonesia. The dimension of the briquette is 2.6 cm x 2.6 cm 2.6 cm. The dimension allows the resistivity of the briquette to be determined using equation (2). It is composed of 95% coconut shell charcoal powder and 5% cassava starch mixed with 30% weight water and dried in an oven fueled by natural gas at a temperature ranging from room temperature to 100°C.

$$R_e = lR \qquad (2)$$

The briquette has three conditions to be tested, as shown in Table. 1. The first is wet briquette, the briquette just finishing its mould. At that time, it is considered to have saturated water content. The second condition of the briquette is half-dry. It is applied to the briquette after staying in the oven for one day. The final temperature of the oven room is 50 ◦C. The third is the briquette; after it is finished, it is dried and ready for cooling to meet room temperature and packaging. The final temperature of the process is 100 ◦C. Generally, the water content of the dry briquette at the dry condition is 2%. The time to stop drying is determined by the justification of the quality control person after the firing check and the braking check. The method of determining the finish time of drying makes the drying time uncertain.

Table 1. The tested briquette conditions.

Type	Drying Time (hours)	Final Temperature
Wet	0	Room temperature
Half-dry	24	50 °C
Dry	48 hours or more	100 °C

2.3 Procedure

The collected briquettes are single-batch briquettes. They were mixed and molded in a single batch. They were also dried in an oven with the same treatment. They were collected on different days due to drying times that meet the conditions shown in Table 1.

The briquettes were collected from some places of the oven trays and placed in airtight containers for transportation and storage. Every briquette type has its container and is coded as shown in Table 2. The airtight containers are also applied to keep the moisture content of the briquette during the measurement. The briquette has three conditions to be tested, as shown in Table. 1. The first is wet briquette, the briquette just finishing its mould. At that time, it is considered to have saturated water content. The second condition of the briquette is half-dry. It is applied to the briquette after staying in the oven for one day. The final temperature of the oven room is 50 ◦C. The third is the briquette; after it is finished, it is dried and ready for cooling to meet room temperature and packaging. The final temperature of the process is 100 ◦C. Generally, the water content of the dry briquette at the dry condition is 2%. The time to stop drying is determined by the justification of the quality control person after the firing check and the braking check. The method of determining the finish time of drying makes the drying time uncertain

Table 2. The tested briquette conditions.

Type	Code	Sample Number
Wet	BS	1 - 50
Half-dry	SK	51 - 100
Dry	KR	101- 150

The resistance measurement was conducted using the two-probe method. The probes provided electric current and were used to measure its voltage digitally. It has a range of 0 –

40 megohm. The reading was conducted when the equipment showed stable results. Before it is used, the battery of the equipment is checked and changed regularly during the process.

The probes were placed on the opposite side of the briquettes. Every briquette had to be measured three times. Such measurement was done to check the homogeneity and isotropic assumption of the briquette. The homogeneity and its isotropic condition show relatively small differences among the probe positions.

The resistance of the briquette was calculated in two steps. First, the resistance results of every briquette were averaged to show the average resistance of the briquette. Then, they were averaged through the briquettes to find the average resistance and resistivity following the equation above (2).

3 Results and discussion

The coming results and discussions show the average resistance, its resistivity and the reason behind the results.

3.1 Resistance of the briquettes

The briquette tends to be isotropic and has homogeneity conditions. The deviations of resistance measurement of each briquette are 5%, 4%, and 5% for the wet, half-dry, and dry briquettes. These inform the homogeneity of each briquette. The measurement was also precise, as the differences among data deviations are slight. The standard deviations of the wet, half-dry, and dry briquettes are 3.3 kΩ, 0.14 MΩ and 0.93 MΩ, respectively. The numbers are 34%, 20%, and 13% of the average resistance of the wet, half-dry, and dry briquettes, respectively. The average resistance and standard deviation of the resistances are presented in Table 3. The resistance ranges of the wet, half-dry, and dry briquettes are 4.76 – 17.82 kΩ, 0.42 – 0.96 MΩ, and 5.52 – 9.37 MΩ, respectively.

Table 3. Resistance of the briquettes and their standard deviations.

Type	Resistance	standard deviations
Wet	8.94 kΩ	3.3 kΩ
Half-dry	0.69 MΩ	0.14 MΩ
Dry	7.01 MΩ	0.93 MΩ

The distribution of the briquette resistances is shown in Fig 1. Some anomalies of the dry briquette happen. They have very low resistances and belong to the half-dry briquette range. It can come from the non-homogeneous condition of the oven. The data were excluded for calculating the average number. These anomalies also confirm the difficulty of determining the stop time of drying. Some briquettes are suspected to be still half-dry.

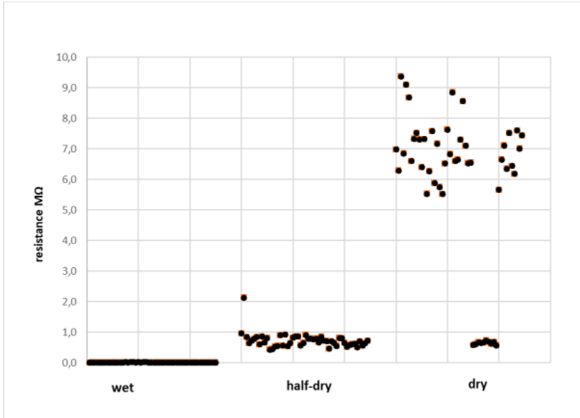

Fig. 1. The resistance distribution of wet, half-dry, and dry briquettes.

The resistivity of the briquettes following equation (2) is presented in Table 4. The wet briquette has the highest conductivity, while the dry has the lowest conductivity. It confirms the assumption that the water content of the porous briquette affects its conductivity. The conductivity numbers are below the amorphous and graphite conductivities. The amorphous and graphite have conductivities of 1.25 – 2 103 S-1/m and 2 – 3 105 S-1/m [10], respectively

Table 4. Resistivity and the conductivity of the briquettes.

Type	Resistivity (MΩm)	Conductivity (S^{-1}/m)
Wet	2.33 10^{-4}	4.30 10^{-2}
Half-dry	1.8 10^{-2}	5.55 10^{-5}
Dry	1.82 10^{-1}	5.49 10^{-6}

3.2 Mass and density

The mass distribution of wet, half-dry, and dry conditions is mentioned in Fig. 2. The figure shows that the dry briquettes have less density. The briquette density was affected by the water content of the briquette. The more water content of the briquette, the higher the density. The wet briquettes have average mass and density of 21.46 g and 1221 kg/m^3, respectively. The half-dry and dry have a density less than water. The half-dry and dry densities in respective sequences are 988 kg/m^3 and 925 kg/m^3.

However, Fig. 2 shows that it is not suggested to differentiate the half-dry and dry briquettes based on the mass and density, even though technically, the half-dry and dry have different densities. The half-dry and dry density standard deviations are 18.7 kg/m^3 and 16.4 kg/m^3 respectively. The difference is less than three times the deviation standard on both sides.

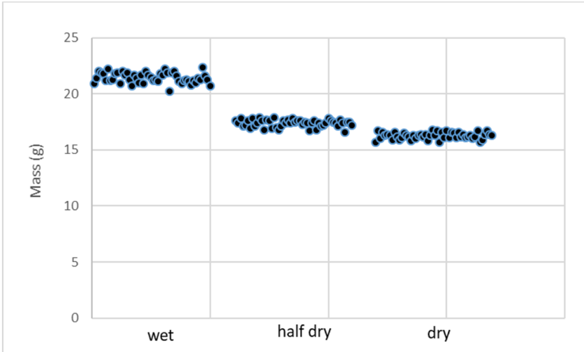

Fig. 2. The mass distribution of wet, half-dry, and dry briquettes.

3.3 Combination of resistivity and density

The dry briquette resistivity has a clear difference with half dry. For the cube briquette of 2.6 cm x 2.6 cm x 2.6 cm, the resistance difference is more than 6 MΩ and the resistivity difference by 10^5 Ωm as shown in Tables 3 and 4. However, the data of resistance at the dry condition has some anomalies that show the difficulty of determination of the drying stop. Some resistivity of briquettes categorized dry by the Quality Control Person were still half-dry type, as mentioned in Fig. 1.

The density difference between half-dry and dry is not as big as the resistivity difference. The density difference can be seen in Fig. 2. The resistivity difference is mentioned in Fig. 1. However, there were no anomalies in the density data. All of the data are very close to each other. Both categories have precise results, but they are close.

A combination of resistivity and density can be complemented to stop the drying process in the oven. The resistivity provides a clear difference between half-dry and dry briquettes, but some anomalies still exist. The density difference between half-dry and dry briquettes is still being determined but is very consistent. Density can be applied to ensure the situation in a condition of doubt due to resistivity anomalies. The resistivity test can be done quickly as the standard measurement for wood, pulp, food, grain, etc [4]. The strategy is applicable for determining whether to stop the drying process. The resistivity of the coconut shell charcoal briquette is about 1.82 10-1 MΩm. For the cube charcoal briquette of 2.6 x 2.6 x 2.6 cm3, the resistance of the dry is 7.01 MΩ. The density of the briquette is 925 kg/m3.

Resistance measurement and density can be done fast. To measure the resistance, people can use an ohmmeter. The density can be measured using sensitive mass balance and calipers. The method is faster than the current method using combusting, which takes 3 hours. Applying the method can reduce drying time, eliminating the 3 hours of combustion.

4 Conclusions

The wet, half-dry and dry briquettes have different resistivity and density. The resistivity of the briquette combined with its density can be applied to justify the stop time of drying in a fast way. Resistance of cube briquette should be in the order of MΩ. When there is doubt due to low resistance, checking the density can help ensure that the dry density should be 925 kg/m^3. The method improves the time determination of stop drying.

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