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Table of Contents

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The Mass Time Burning Model of Coconut Shell Charcoal Briquettes

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Keywords: Coconut Shell Charcoal Briquette, Burning Test, Density Test, Mass Time Burning Model, Charcoal Quality

Abstract. Burning Test and Density Test are common to be applied in Coconut Shell Charcoal Briquette for stopping drying process and predict its quality. Before the oven is turned off, the quality person conducted burning test to certify the quality of the briquette. In order to understand the relation of both test and the quality of the briquette, a research on the burning test and density model was applied. Three different conditions of the briquettes were chosen, they are wet, half-dry, and dry. Mathematical models based on burning test of the charcoal briquette were developed. The results show that burning test can provide indicators of different conditions of the coconut shell charcoal briquettes clearly in addition to common general tests such as density and durability. A dry briquette has fully exponential pattern of the left mass during 225 minutes combustion. The half-dry has combination of exponential, linear, and exponential pattern for respective times of 0 – 45', 45 – 120', and 120 – 225'. The wet briquette has similar patterns with shorter linear. The dry briquette can provide longer burning time than other.

Introduction

Briquettes of biomass and its derivatives are considered to be promising clean energy. Mostly the briquettes are produced from biowaste such as husk [1], sawdust[2], stray [3], etc. Therefore, the emission goes to its bioresources[4]. The biomass as the raw material for briquette is considered to be zero emission because the carbon comes from photosynthesis. For the reason, biomass briquette is considered to be clean solid fuel.

During the production, drying as the process of reducing moisture content is significant in energy consumption for briquetting. Conventional drying using solar energy needs time reaching 5 days, even it consumes less fuel than other drying methods [5]. Fuel based drying consume a lot of energy for heating or other drying methods [6]. The trade-off of the drying methods issues stopping drying process as important moment for controlling the briquettes production.

In mass production, burning test is applied to determine the drying stop of the coconut shell charcoal briquette production [7]. The quality control person (QP) stops the drying after burning test conducted and fits the required condition according the experience of the QP. Usually, the QP checked the ash formation during the burning. Good quality briquette has to be able to burn more than 150 minutes, release no smoke, and leave the white ash without any crack. On the other hand, a simple proximity test is also conducted to check the quality of the briquette. It is density test which is related to its mass. The checker just use balance for doing the test. The test assumes homogenous briquettes size, and the relation between moisture content and density. However, the density has less significant differences while the briquette almost dry [7]. The situation implies that a briquette is not always good even the density target reached.

Relation of moisture content and combustion character is important in quality of the briquette. Generally, it is reported that moisture content affects the briquette calorific value [8]. However, the relation of the drying condition and its combustion has not studied yet. The visual phenomena of the relation is always identified by QC person during drying briquette.

A study of mathematical model of the briquette combustion in different moisture content is proposed in order to find the connection of the moisture content and the combustion the briquette. Clear relation of the combustion time and moisture content can be applied for controlling the briquette application. The study is presented in 4 parts including introduction. This part shows the reason of the study. The second part is the method of study which exposes the way the data collected. The next part is the Results and Discussion trying to explain the combustion test phenomena and the briquette quality. The final part is the Conclusion.

Method of Study

The study is the interpretation of the burning briquette data especially its mass. The briquette mass data were collected from experiment of burning briquettes in open space. At the same time, the left mass of the briquettes was measured during the combustion. The pattern of the left mass during the burning is interpretated according to normalized burn rate (NBR) of the solid combustion as shown in [9], [10].

Data collection

The collected data are masses of the premium briquettes during the burning time. The briquettes are product of a company located in Klaten, Central Java. The briquettes have cubic shape of 2.6 cm in dimensions. The average weight of wet, half-dry, and dry briquettes are 18.94 grams, 17.30 grams, and 16,64 grams, respectively. The briquettes were burnt on ceramic containers and measured its mass every 15 minutes. The data were collected for 225 minutes.

The data were collected from 10 briquettes for every condition. There are 3 conditions of the briquettes, they are wet briquettes, half-dry briquettes, and the dry briquettes. The wet briquettes are the briquettes after compaction process. They do not go for drying yet. The half-dry briquettes are the briquettes which have been dried half of its general drying time. They were taken from the oven after 30 hours drying. The dry briquettes are the briquettes finished the drying process. Usually, the briquettes have stayed in the oven for 60 hours.

Data Analysis

The briquettes mass during the drying process are averaged and plotted on timeline graphs. Timeline analysis was conducted according to three steps of burning; they are ignition, steady state, and char phases. The ignition phase is the first phase of burning. At this time, the briquettes start to burn. The dimensions of the briquettes are still full. Rate of the burning is very high. The second phase is the steady state which show nearly constant burning rate. The last part is the char phase which shows char burning phase. In this phase, the ashes cover the char burning. It inhibits the oxygen supply. Therefore, the rate is getting slow down.

Comparison of the normalized burning rate, and predicted HHV are applied for every condition. The predicted HHVs are calculated according to percentage of the fixed carbon as the main target of proximity approach. The percentage of the fixed carbon is calculated as the results of equation (1). It is

$$\%FC = (100 - (\%MC + \%Vol + \%Ash)) \tag{1}$$

with $\%MC$, $\%Vol$, and $\%Ash$ are the percentages of moisture content, volatile, and ash, respectively. The $\%MC$, $\%Vol$, and $\%Ash$ are measured according to ASTM standard as mentioned in [4], [11], [12]. The predicted HHV is calculated using equation (2).

$$HHV = \%FC \times 7800 \text{ kcal/kg} \tag{2}$$

Results and Discussions

The basic solid fuel burning model

The plot of the left briquette mass as function of time during the burning is shown in Figure 1. The Figure shows that there are different patterns of briquette mass among the dry, half-dry, and wet briquettes during the burning time. The dry briquette tends to be a single pattern of exponential. The half-dry and the dry briquettes have pattern of three phases. The first and the last phases are exponential. While the second phase has linear trendline. The general pattern of the burning phases is presented in Table 1.

Table 1. The pattern phase of burning

	Phase 1	Phase 2	Phase 3
Wet	Exponential $18.618e^{-0.009t}$	Linear $-0.0671t$	Exponential $49.746e^{-0.015t}$
Half-Dry	Exponential $16.928e^{-0.007t}$	Linear $-0.0717t$	Exponential $22.471e^{-0.11t}$
Dry	Exponential $17.08e^{-0.01t}$		

The functions of the wet briquettes burning rate are $18.618e^{-0.009t}$, $-0.0671t$, and $49.746e^{-0.015t}$ for 1st phase, 2nd phase, and 3rd phase, respectively. The half-dry briquettes have burning rate of $16.928e^{-0.007t}$, $-0.0717t$, and $22.471e^{-0.11t}$ for 1st, 2nd, and third phase, respectively. The dry briquettes have burning function of $17.08e^{-0.01t}$. Time t are in minutes with 0 – 45', 45'-120', and 120'-225' being the 1st, 2nd, and 3rd phases, respectively. The final phase of the briquettes burning tends to be equal burning rate. It explains that the briquettes are already dried in the final phase.

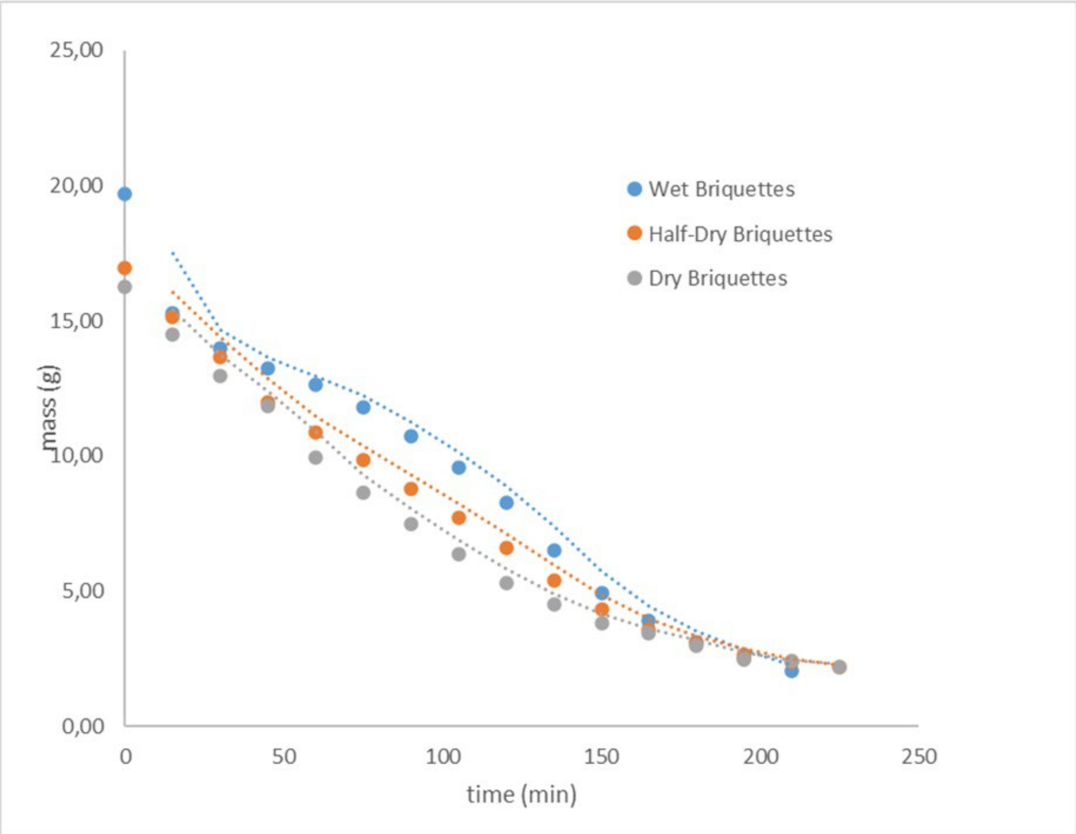

Fig. 1. The general pattern of briquette mass during the burning.

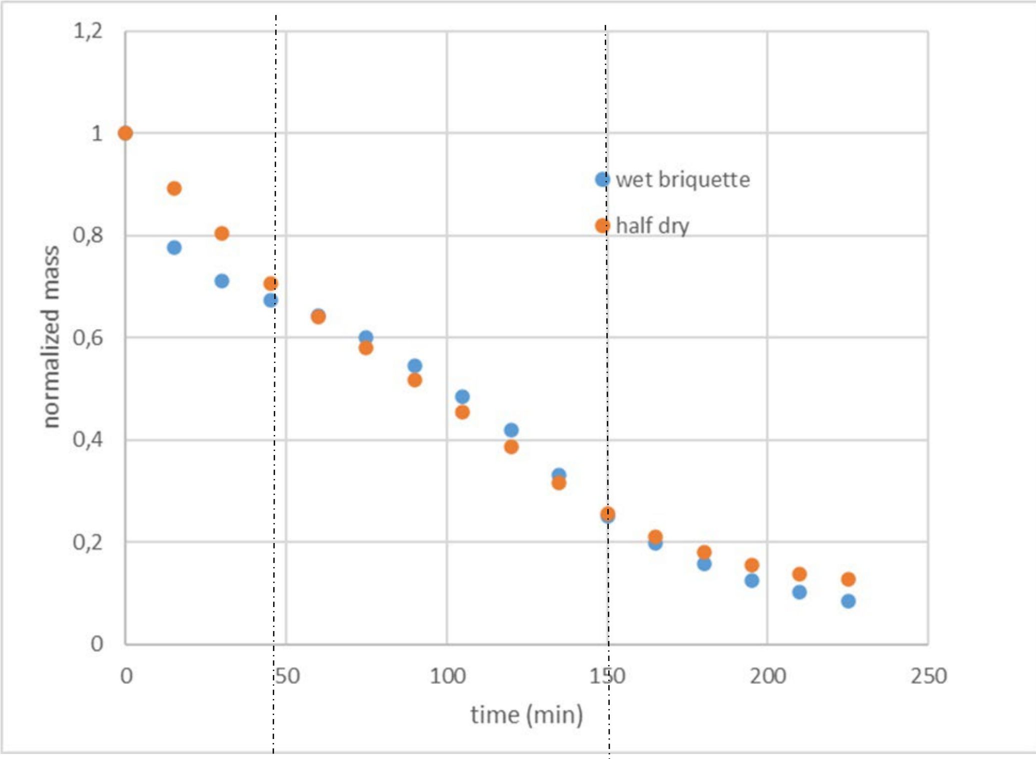

Fig. 2. Three phases of burning; the phases are separated with dashed dotted lines.

The normalized burning ratio shows three phases of the burning of the wet and half-dry briquettes. The first phase is the ignition phase. The lost mass is the fastest here. The contact between fuel and oxygen is still optimum. In the condition, the char moves fast. The second part show almost linear line which connects with balance of fuel availability and the oxygen availability. This linear line emphasizes the balance connection. However, the second phase of the wet briquette mentions another factor affecting burning. It is temperature. At the time, the water still exists in wet briquette. It reduces briquette burning rate and releases its water as smoke.

The moisture content and density

The density is getting less sensitive while the briquettes are getting dryer. The difference of moisture content is highly related to density when the briquettes are wet. At this condition, the change of moisture content is positively related to its density. However, when the briquettes are getting dryer, the difference of its density is getting less sensitive. Distributed moisture content can have equal density with limited wet part inside of the briquette. In this case, the briquette has less quality than the distributed moisture content. During the burning, the wet briquette creates smoky briquette and cracks ash. The burning rate of the briquette is higher than distributed moisture one. Generally, half-dry briquette has the wet part in the center of the briquette. The relation of the density, burning rate and moisture content can be seen in Figure 3. The density different of half-dry and dry briquettes is very little. But the different of its burning rate is significant.

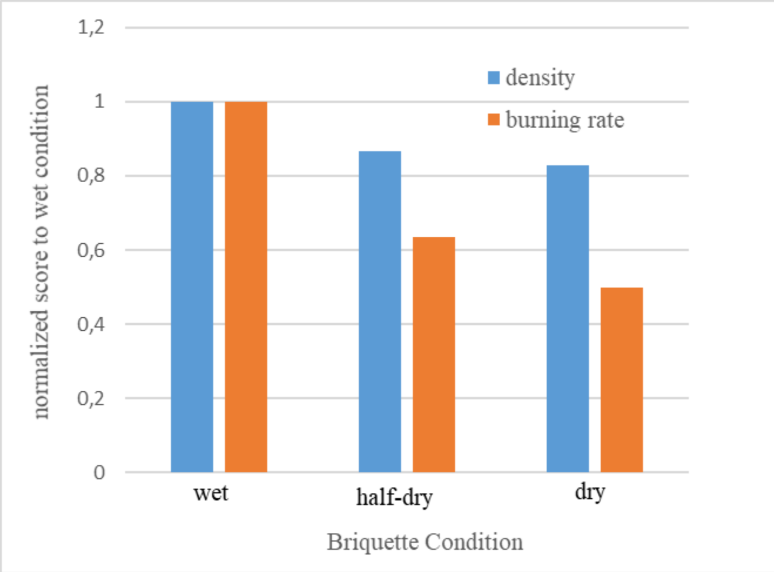

Fig. 3. The normalized density and burning rate according in wet, half-dry, and dry briquette.

The moisture content and calorific value

The calorific value is the most important parameter of the briquette quality. A good quality of briquette tends to have high calorific value. The wet, half-dry and dry briquette HHVs are shown in Table 2. The LHVs of the briquettes will be very different due to moisture content of the briquette condition. The wet briquette contains 10% moisture. The half-dry, and the dry have 6% and 3% moisture content, respectively. The LHV can be calculated from HHV with reducing of evaporation part. The HHVs of the half-dry and dry briquettes fit to the Indonesia briquette quality [11].

Table 2. The high heating value of the briquettes

Condition	HHV (kcal/kg)
Wet	6345
Half-Dry	6934
Dry	7290

Conclusions

The work mentions that burning test which is usually done by the QP is important examination of the briquette production because its usefulness to show the quality of the briquette. The burning test can show different conditions of the briquettes during the drying process. The phenomena of the briquettes during the burning shows the moisture content better than density. It also mentions the calorific value as the main parameter of the briquette quality is significantly predicted through burning test. The test can show phenomena of moisture content inside of the briquettes.

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