



# Value addition of coal fines and sawdust to briquettes using molasses as a binder



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## ABSTRACT

In this study, the co-briquetting of coal fines saw dust and molasses as a binder is explored as an option for value addition of the wastes generated in the various industries. The effect of the saw dust concentration and the molasses concentration was investigated through measuring the briquette's calorific value, fixed carbon, compressive strength and shatter index. Addition of  $\text{Ca}(\text{OH})_2$  was done to effect removal of sulphur from the briquette. Measurements of the briquettes physicochemical properties such as moisture content, ash content and sulphur content were measured using the standard methods. As the saw dust and the molasses concentration increased, the calorific value, fixed carbon and compressive strength increased by 16%, 8% and 50% respectively. Whereas, the shatter index decreased by 146% as the saw dust and the molasses concentration increased in relation to the coal fines. Addition of the saw dust and the molasses are therefore critical in the production of a high quality coal-saw dust-molasses briquette which does not shatter.

## 1. Introduction

The usage of briquettes as an alternative source of solid fuel for several applications in boilers and industrial use is having increased attention. (Wang et al., 2014, 2016). In South Africa alone, the coal mining and processing process generates about 10 million tons of waste in the form of coal fines that can be a source of pollution to the environment if not properly managed (Venter and Naude, 2015; Ibeto et al., 2016). Coal fines being of particulate nature if inhaled have potential to cause pneumoconiosis and other health related conditions; furthermore these contain high sulphur which results in acid rain. On the other hand, there are several initiatives on the briquetting of these coal fines that have been explored so that they become a source of solid fuel (Kim et al., 2001; Venter and Naude, 2015).

The stand-alone briquettes from coal alone have been reported to be highly brittle and easily shattered due to the nature of the coal fines as they cannot easily agglomerate (Kwong et al., 2007). Previous studies have reported that waste biomass and binders can actually be introduced as part of the briquette composition so as to increase the strength and calorific value as well the strength of the briquette (Zakari

et al., 2013). Binders such as starch, molasses and coal tar have been used for enhancing the characteristics of the briquettes (Zakari et al., 2013; Sen et al., 2016). Introduction of biomass and binders in the coal fines during briquetting have also resulted in a briquette with a lower attrition index and increase the compressive strength (Tosun, 2007). The addition of additives like  $\text{Ca}(\text{OH})_2$  and  $\text{CaCO}_3$  have been proposed by several studies so as to remove sulphur contaminants the biomass briquettes (Singh et al., 2009). This study therefore proposed to use coal fines with a combination of saw dust and molasses as a binder especially with the addition of  $\text{Ca}(\text{OH})_2$  as a desulphurizing additive so as to come up with a high quality briquette for application as a solid fuel at domestic and industrial level.

## 2. Materials and methods

### 2.1. Materials

Coal fines with particle size of  $\leq 2$  mm were used for briquetting and this particle size was achieved through sieving. A manual briquetting machine with a hydraulic pressure of 5 MPa was used to make

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rectangular briquettes with briquettes size of 30 mm × 25 mm X 15 mm. Briquetting was done at standard pressure and hot temperature of 250 °C. Pulverized coal fines were mixed with saw dust for ratios ranging from 5 to 25 wt %. Molasses, which is a waste product in the sugar manufacturing industry was used as a binder in the ratios ranging from 0 to 8 wt %. A desulphurizing agent, Ca (OH)<sub>2</sub> with 99% purity was added at 5 wt % of the coal-saw dust briquettes so as to minimize environmental pollution. A bomb calorimeter model XRIA was used for determination of the briquette calorific value. An AND moisture analyser was used for the briquette moisture content analysis. Experiments were repeated 3 times and the average values were used to plot the graphs. The obtained data had standard deviations within 5%.

## 2.2. Methods

A sample containing 2 kg of the mixture of coal fines saw dust and molasses was used during briquetting. The proximate analysis of the coal-saw dust-molasses briquette was analysed according to the ASTM D3172 standard methodology. The moisture content (MC) was determined by heating the briquette at 105 °C for 3 min. The briquettes volatile matter (VM) was determined at 925 °C for 7 min in a furnace. The fixed carbon (FC) was determined by heating the briquette at 800 °C for 3 h. The ash content (AC) was then calculated as the difference in the total MC, VC and FC as indicated in Equation (1).

$$AC (\%) = MC (\%) - VC (\%) - FC (\%) \quad (1)$$

The shatter index of the briquettes was determined by dropping them thrice at metal base at a height of 2m. The amount of briquette that remained was used to measure the index of the briquette breakability. The weight loss as a percentage of the briquette was expressed as a percentage of the initial mass of the briquette remaining. The shatter resistance was therefore calculated by subtracting the percentage weight loss from 100%. The percentage weight loss is calculated in accordance to Equation (2):

$$\% \text{ Weight loss} = \frac{W_1 - W_2}{W_1} \quad (2)$$

Where  $W_1$  is the weight of the briquette before shattering and  $W_2$  is the weight of the briquette after shattering in grams.

The calorific value of the briquettes was determined using the bomb calorimeter. The coal-saw dust-molasses briquette was analysed for the sulphur content using the Eschka methodology (ASTM, 1992). The relative density of the briquette was calculated in accordance to Equation (3).

$$\text{Relative density} \left( \frac{\text{kg}}{\text{m}^3} \right) = \left( \frac{M_b (\text{kg})}{V_b (\text{m}^3)} \right) \quad (3)$$

Where  $M_b$  is the mass of the dried briquette and  $V_b$  is the volume of the briquettes.

The saw dust, coal fines and molasses binder were mixed in the desired ratio to come up with a mixture which was fed into the hot pressing briquetting machine. A schematic representation of the coal-saw dust-molasses briquetting process is shown in Fig. 1.

Response surfaces graphs in Excel were used to schematically represent the effect of changing the saw dust and molasses composition on the coal-saw dust-molasses briquette's physicochemical parameters.

## 3. Results and discussion

The effects of the saw dust and molasses binder concentration on the coal-saw dust-molasses briquette various properties are discussed in detail below. The initial coal-saw dust-molasses mixture had a sulphur content of around 500 ppm before the briquetting with Ca (OH)<sub>2</sub> as a desulphurizing agent. After the hot pressing briquetting at 250 °C, the sulphur content significantly reduced to 0.1–0.2 ppm. The Ca(OH)<sub>2</sub> reacted with the sulphur to produce calcium hydroxide and water

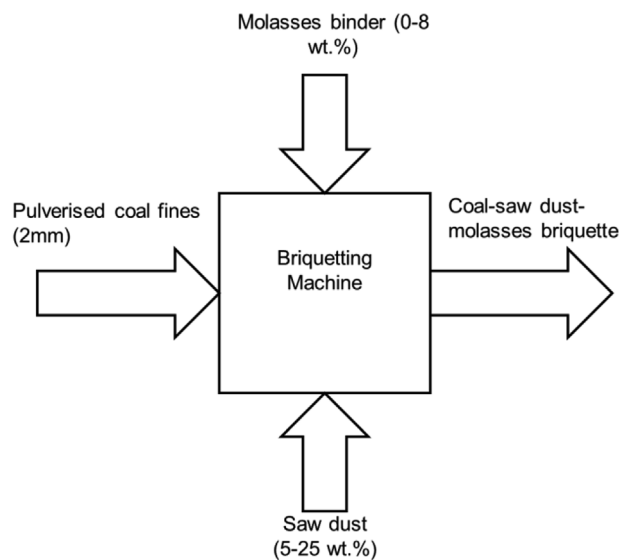


Fig. 1. Briquetting process for the coal fines-saw dust-molasses briquette.

which formed part of the fillers for the briquettes. The reaction is indicated in Equation (4).



### 3.1. Effect of saw dust and binder concentration on calorific value

The calorific value of the briquette gives the indication of the intensity of the heating value. High calorific values are required in high quality briquettes so as to harness as much energy as possible from the briquettes. In this study, as the molasses binder concentration increased to 8 %wt., the briquettes calorific value increased and on the other hand, as the saw dust compost increased from 5 wt % to 25 wt %, the caloric value also significantly increased (Fig. 2). Highest calorific values of 25–26 MJ/kg were observed when the molasses binder concentration was 8 wt % and the saw dust concentration was 25 wt %. High binder and saw dust concentration resulted in increased interlocking bonds with the coal fines resulting in a briquettes that has a high heating value due to the additional strength provided by the combined effect of the high saw dust and binder concentration (Blesa et al., 2003; Sen et al., 2016). The calorific values obtained for the briquettes were in the same range as lumpy coal, which is 23–25 MJ/kg, therefore making them have the same application as lumpy coal such as application in boilers.

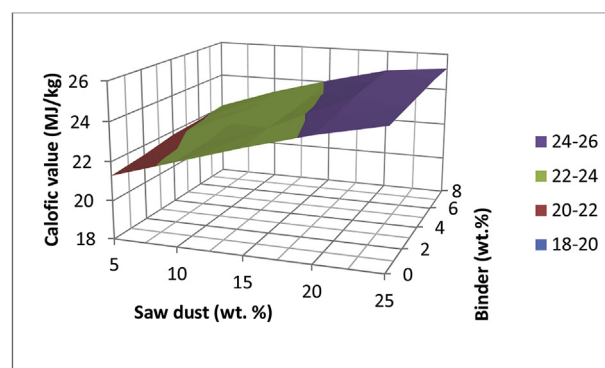


Fig. 2. Effect of saw dust and molasses concentration on the briquette calorific value.

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