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Partial briquetting vs direct addition of biomass in coking blends

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HIGHLIGHTS

- Briquettes containing sawdust were used for metallurgical coke preparation.
- Partial briquetting compensates for lower sawdust bulk density.
- Inclusion of coking coal in briquettes helps to integrate sawdust in the coke matrix.
- Additions of 10–15 wt.% of briquettes can be used depending on the base coal.

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ABSTRACT

In this work partial briquetting is employed as a means of biomass densification to allow for biomass inclusion in coking coal blends. The effect of increasing the bulk density was evaluated by comparison with direct addition. Two briquettes of different composition were studied. The influence of the briquettes on the Gieseler plasticity of the coals was determined. It was found that the effect of the binder was not enough to compensate for the decrease in plasticity produced by the inert components of the briquettes. Carbonizations were carried out in a movable wall oven of 17 kg capacity and the quality of the cokes produced was tested by evaluating their mechanical strength, coke reactivity to CO_2 and post-reaction strength. In addition, the porosity and ash chemistry of the cokes was determined and an attempt was made to establish a relation between these results and the quality of the cokes. Coke quality results suggest that 10–15 wt.% of briquettes containing biomass can be included in coking blends.

1. Introduction

There is general concern about the generation of greenhouse gases due to anthropogenic causes such as the use of fossil fuels. The steel industry is a major contributor to CO_2 emissions because of its use of coal [1–3]. On the other hand, the international coal market has experienced considerable volatility in recent years, giving rise to a notorious variability in coal prices and problems related to supply.

The use of additives is a common practice in cokemaking in the search for alternative materials with which to make low-cost coking blends and to improve the coking characteristics of a specific coal blend [4–8]. With these considerations in mind the inclusion of biomass in coking blends has been the subject of a number of recent studies [9–12].

The co-carbonization of coal blends with additives has been observed to modify the coking properties of coals and the quality of the resulting cokes significantly [5,13]. In the present work, the effects of adding alternative raw materials to coking coals have been assessed. The possibility of including materials different from coking coals in coke ovens is of great interest because of the lower cost of these materials and also as a way to overcome the problems related to the shortage of coking coals. In view of the immense importance of the plastic stage on the properties of the final coke, the effect of biomass on coal plastic properties has been investigated by high-temperature small-amplitude oscillatory-shear (SAOS) rheometry and Gieseler plasticity test to determine whether the use of a specific biomass can produce a reduction in coal plastic properties [10,14].

Some research works have already been published on the inclusion of biomass in coking blends [1,11,12] but to our knowledge this is the first study on the use of partial briquetting to allow the inclusion of biomass in coking blends. The procedure is based a combination of two factors: (1) increasing the bulk density of the charge and (2) using the binder present in the briquettes to restore the coal's plastic properties.

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It is generally recognized that coke reactivity and post-reaction strength are the parameters that should be used to determine coke quality. Therefore a study of the reactivity of the biomass will contribute greatly to assess the effect of using biomass as additive on the quality of the coke produced. Biomass-derived chars are more reactive than coal chars. This higher reactivity is thought to derive from their porous structure and the presence of inherent catalytic elements such as K that have a strong catalytic effect [15–18]. When using a highly reactive coke in a blast furnace it is important to bear in mind that lowering the temperature of the thermal reserve zone will decrease the CO/CO_2 ratio and increase the gas utilization ratio. This will result in a lower reducing agent rate which is considered to be an effective method for decreasing the emission of carbon dioxide in steel works [19,20].

The aim of the present work is to study the effect of addition of biomass on the quality of the coke produced from two coking coals of different quality. The effect of densifying the charge on the quality of the coke produced by adding briquettes was compared with the effect of direct addition of the briquette components.

2. Experimental

2.1. Materials and methods

Waste chestnut sawdust (SC1), a non-coking coal of high rank (K) normally used as pulverized injection coal (K), two coking coals (P and M) and coal tar (T) were selected as materials for the experiments. Briquettes were prepared by using a roller press consisting of two rollers rotating in opposite directions at the same speed [21]. The material was squeezed through the gaps between the two rollers. The briquettes obtained had an ellipsoidal shape, with 46 and 42 mm long axes and a weight of around 23 g. Two briquettes with different compositions were produced: B1 and B2. A diagram of the procedure used for making briquettes is presented in Fig. 1.

Proximate analyses were performed following the ISO562 and ISO1171 standard procedures for the volatile matter and ash content, respectively. An elemental analysis was carried out using a LECO CHN-2000 for C, H and N, a LECO S-144 DR for sulphur and a LECO VTF-900 for the direct determination of oxygen. The inorganic matter composition of each sample was analysed by X-ray fluorescence (XRF) in a SRS 3000 Bruker spectrometer in accordance with the ASTM D4326-04 standard procedure.

2.2. Assessment of coal thermoplastic properties

The thermoplastic properties of the base coal and of the blends containing 2, 5, 10 and 15 wt.% of each briquette were measured by means of the Gieseler test (ASTM D2639-74). The Gieseler fluidity of the briquettes was also measured. A 5 g sample with a size <0.425 mm was heated while a constant torque was applied to a stirrer placed in the crucible containing the coal charge. The parameters measured by this test were: (i) softening temperature, T_s; (ii) the temperature of maximum fluidity, T_f; (iii) resolidification temperature, T_r; (iv) plastic range, $T_r - Ts$, which is defined as the difference between the resolidification and softening temperatures; and (v) maximum fluidity, MF, expressed as dial divisions per minute (ddpm).

2.3. Carbonization experiments and coke quality evaluation

Carbonization tests were carried out in a movable wall oven of approximately 17 kg capacity (MWO17) [8]. The dimensions of the oven are 250 mm L × 165 mm W × 790 mm H. A load cell was mounted on the movable wall to measure the force exerted on the wall during carbonization. A programmable controller was used to control the oven temperature. The temperature at the centre of the coal charge was monitored by means of a thermocouple connected to a computer. The coal was charged when the oven had reached 1100 °C. The temperature of the wall was kept constant throughout the test. The coke was pushed out 15 min after the centre of the charge had reached 950 °C. The coking time lasted approximately 3.5 h. The moisture of the charge was fixed at 5 wt.%. The carbonizations were carried out in two ways: (1) by means of a partial briquetting procedure in which a mixture of the coal and a percentage of the briquettes was carbonized in the carbonization oven and (2) by direct addition where a mixture of the coal and the corresponding percentages of briquette components (binder, biomass, non-coking coal, coking coal) were directly added. Special care was taken with direct addition to ensure the homogeneity of the mixture to be carbonized. The following nomenclature was used: B1 and B2 represent partial briquetting procedure and B1D and B2D direct addition of the components of briquettes B1 and B2 respectively.

The cold mechanical strength of the cokes produced was assessed by the JIS test (JIS K2151 standard procedure). After the test the coke was sieved and the DI150/15 index was calculated from the amount of coke with a particle size greater than 15 mm. The coke reactivity and mechanical strength after reaction were assessed by means of the NSC test (ASTM D5341 standard procedure). Two indices were derived from this test i.e. the CRI index which represents the loss of weight of a 200 g sample of coke with size between 19–22.4 mm after reaction with CO_2 at 1100 °C for two hours and the CSR index which represents the percentage of partially-reacted coke that remains on the 9.5 mm sieve after 600 revolutions in a standardized drum. The relationship between the

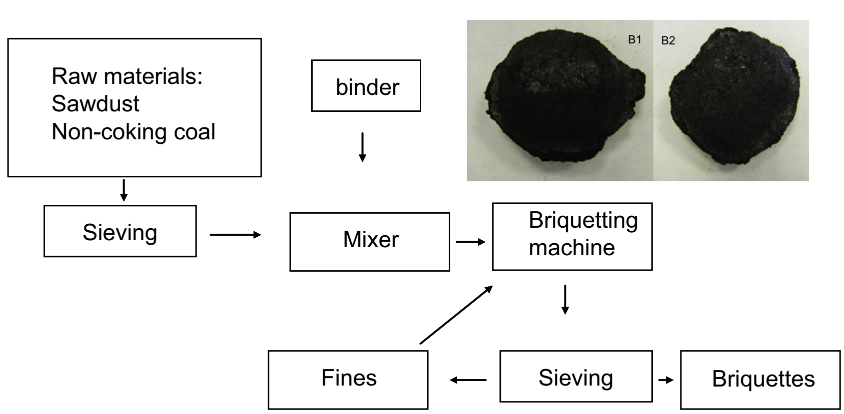

Fig. 1. Diagram of the procedure used to produce briquettes and photograph of briquettes obtained.