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A novel technique for assessing the coking potential of coals/coal blends for non-recovery coke making process

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HIGHLIGHTS

- ▶ A new coefficient named as Composite Coking Potential (CCP) of coal/coal blend is proposed.
- ▶ CCP is calculated using conventional properties of coking coals, e.g., chemical, rheological and petrographic.
- ▶ CCP value has been correlated with coke quality, namely, coke strength after reaction (CSR).
- ▶ The technique is useful for identifying cheaper coal in a blend.
- ▶ The technique has been validated for commercial non-recovery coke making process.

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ABSTRACT

In an effort to broaden the scope of coal selection, the authors have developed a novel procedure based on a coefficient, named as Composite Coking Potential (CCP). CCP value assesses the suitability of a coal/coal blend for producing coke of desired quality; measured by the parameter coke strength after reaction (CSR). The coking potential takes into account of various properties of the coals and their proportions in a given coal blend and convert them into a single value. This technique is having advantage since each of these parameters represents different aspects of the coking phenomena along with inter dependence of some of these parameters also exists. This makes the coal selection process extremely difficult and in majority of the cases, decision is taken based on experience.

In this investigation, CCP model has been used for selecting the least expensive coal blends which will comply with the minimum coke quality requirements of blast furnace. The study confirms the inter relations between the CCP and the hot strength of coke i.e. CSR. Actual plant data of a non-recovery coke oven have been used for developing and validation of the model. The technique was successfully used in identifying cheaper coals for producing coke with desired quality.

1. Introduction

Coke is the major source of carbon for the operation of blast furnaces. Besides being responsible for producing gas, it also supports the descending burden and provides passages/voids through it for distribution of reducing gas in the furnace. Moreover, the combustion of coke in the lower hearth by the injected blast generates heat for melting of the hot metal. Because of the numerous functions of coke in blast furnace, stringent quality parameters of its physical and chemical properties are required to ensure smooth operation of high productivity in modern blast furnaces.

In general, selection of coals plays a key role in controlling the coke quality. For prediction of coke quality, several mathematical models are available. These models are broadly divided into two groups. The first-type of models focuses on the prediction of cold strength of coke and the second-type of models are on prediction of hot strength. So far, no prediction model has reached universal application in coke making area. However, almost all coking plants have some form of a model based on coal rank, rheological properties, petrology, and ash chemistry.

Some literature reported on prediction of the coke quality based on its petrographic analysis. In one of the attempts, CSR is predicted from coal properties, mean vitrinite reflectance and the inert content [1]. Another study reports that the rank of the coal blend (mean Ro %) should be high for producing coke with high CSR

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[2]. Preceding research work on prediction of coke quality models based on coal properties has also been reported. The pioneering works [3] provided the basis for a definition of coal composition based on the optical properties and the "maceral concept" [4]. This study gave a significant insight on the requirement of optimum ratio of reactive and inert components for making good quality coke. The term "reactives" includes those macerals which soften on heating and bind "inerts" and then resolidifies into a porous, fused, solid carbon material [5,6]. Further, a few coke quality prediction models have also been reported based on US origin [7–9] and Eastern Kentucky coals [10–13].

The quality of coke depends on approximate 70% of the properties of the coals used in the coal blend and about 30% on coke making conditions [14]. The ash content of the coal charge is one of the most important parameter which will influence the coke size with other operating conditions remaining the same [15]. The importance of the coal blend properties as a factor in coke gasification has also been reported [16,17]. Cokemaking conditions, for example, bulk density, coking time, preheating of the charge, etc., minimize some deficiencies in coal properties. The selection of a optimum coal blend with optimum properties is a priority for making good quality coke. The *G*-factor is one of the predicting tools of coke quality. However, the *G*-factor is considered additive property for coal blends. This has a limitation for blends composed of coals whose plastic ranges do not overlap sufficiently [18]. A few reports on the estimation of CSR by the application of the additive rule are not accurate [19–21], while some have claimed that CSR is an additive property [22–24]. The Kobe Steel model is valid for prediction of CSR by means of the Reaction Strength Index (RSI), which is determined differently than the Nippon Steel Corporation (NSC) model. The model, as reported in the review papers [25–27], is based on mean vitrinite reflectance (Ro), Gieseler fluidity expressed as logarithm (base 10), and the ratio of principal basic and acidic components in the coal ash. The fluidity of coal blend controls the bonding process during coke making. It has strong effect on CSR [28–34]. Possibility of predicting the coke quality from the properties of the coals in the blend has been attempted by many researchers [35–48].

In the present study, a new method based on a coefficient, named as Composite Coking Potential (CCP), has been proposed for assessing the suitability of a coal as well as a blend for making coke of acceptable properties. For broadening the scope of the study, wide ranges of coking coals were chosen for developing the model. The model takes into account the various coking properties of the coals of a given blend to calculate the CCP value of the blend. The model has been used in developing, a correlation between CCP and CSR of coke. The technique is being used in selecting cheaper coals for producing coke with CSR > 65% for non-recovery coke making process at Tata Steel.

2. Experimental

The coals used in the study were characterized through physical, chemical, rheological and petrographic analysis (Table 1). After characterization of individual coals, CCP values were calculated with the help of the model developed. Total 169 coal blends were used for developing and validating this model. In the present investigation, the test work has been carried out in two stages, namely, laboratory scale and plant scale. After successful completion of laboratory trials, coal blends were recommended for plant trials.

2.1. Carbonization tests at laboratory scale

For the laboratory tests, the coals/coal blends were charged into an electrically heated 7 kg Carbolite oven (370 mm length, 115 mm width and 305 mm height) and then carbonized at a temperature of about 1000 °C. The bulk density and coking time of the coal charge was maintained at 800 kg/m^3 (dry basis) and 5 h respectively. The heating rate and crushing fineness of the coals/coal blends were kept identical for all the tests.

2.2. Carbonization trials at plant scale

Different coals collected from the coal yard were fed with the help of a conveyor belt into the identified blending bunkers. After collection of the coals in the required proportions, the blended coal was passed through the coal crusher and crushed to the extent so that 90 (±2)% coals were below 3.2 mm. The moisture content of the blend was maintained in the range of 10–12%. The crushed coal was then charged into the stamping press mold for the formation of coal cake. The coal cake was stamped with three layers in the hydraulic stamping machine. The stamped coal cake density was around 1050–1080 kg/m^3 (on wet basis), the weight of one coal cake (13,000 mm length, 3400 mm width and 1000–1025 mm height) was approximately fifty tones and the coking time was 64.5 h. The coal cake was then charged into the identified oven with the help of the pushing-cum-charging machine. The pushing was done at the normal operation schedule and quenched with water.

During trial the following precautions were taken to maintain standard test condition: (a) the blending ratio was continuously monitored through PLC to ensure the accurate percentage of each coal; (b) the coal tower (which receives blended coal) was emptied and cleaned before each experiment and; (c) the ovens, in which the experiments were done, were carefully selected to ensure set test conditions. Based on the plant trials results, coal blend was selected for implementation in the plant.

2.3. Coke quality

The coke samples from the plant were collected from wharf (trialed coal blends) and also collected through auto sampler (implemented coal blends). The CRI and CSR of the collected coke samples were assessed by the testing procedure developed by the Nippon Steel Corporation (NSC) method.

3. Coefficient of Composite Coking Potential (CCP)

Coking Potential (CP) of coal depends on its individual properties which is important of coke making to produce good coke. In an effort to broaden the scope of coal selection, the authors have developed a novel procedure based on a coefficient, named as Composite Coking Potential (CCP). CCP model has been used for selecting cheap coal blends that would still comply with the minimum coke quality requirements of blast furnaces. The CCP index takes into account the various properties of the coals and their proportions in a given coal blend. This methodology is necessary since each of these parameters represents different aspects of the coking phenomena with its varying importance. Some of these parameters also have interdependencies.

3.1. Development of CCP model

CCP is a combination of statistical and mathematical methods that are useful for selection of coals. In this technique, the main objective is to optimize the proportion of prime hard coking coal (HCC) in a coal blend that is influenced by various coking properties. The calculation of CCP is based on the interpolation of the range of selected properties which is used in this model. Experiments are performed with the variety of coal and subsequent