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Statistical assessment of coal charge effect on metallurgical coke quality

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Abstract The paper studies coke quality. Blast furnace technique has been interested in iron ore charge; meanwhile coke was not studied because, in previous conditions, it seemed to be good enough. Nowadays, requirements for blast furnace coke has risen, especially, requirements for coke reactivity. The level of reactivity parameter is determined primarily by the composition and properties of coal mixtures for coking. The paper deals with a statistical analysis of the tightness and characteristics of the relationship between selected properties of coal mixture and coke reactivity. Software Statgraphic using both simple linear regression and multiple linear regressions was used for the calculations. Obtained regression equations provide a statistically significant prediction of the reactivity of coke, or its strength after reduction of CO_2, and, thus, their subsequent management by change in composition and properties of coal mixture. There were determined indexes CSR/CRI for coke. Fifty – four results were acquired in the experimental parts where correlation between index CRI and coal components were studied. For linear regression the determinant was 55.0204%, between parameters CRI – Inertinit 21.5873%. For regression between CRI and coal components it was 31.03%. For multiple linear regression between CRI and 3 feedstock components determinant was 34.0691%. The final correlation has shown the decrease in final coke reactivity for higher ash, higher content of volatile combustible in coal increases the total coke reactivity and higher amount of inertinit in coal increases the reactivity. Generally, coke quality is significantly affected by coal processing, carbonization and maceral content of coal mixture.

Key words – coke, blast furnace, statistical assessment

1. Introduction

The conventional route for making steel consists of sintering or palletisation plants, coke ovens, blast furnaces, and basic oxygen furnaces (LEGEMZA J. et al. 2010, BARICOVÁ D, DEMETER P. 2010).The principle involved in blast furnace ironmaking is the thermochemical reduction of iron oxide ore by coke into liquid iron. Unwanted materials are removed in the form of liquid slag by addition of suitable fluxes (KONSTANCIAK A. 2010, PUSTĚJOVSKÁ P., BROŽOVÁ S., JURSOVÁ S. 2010). Raw materials are changed from blast furnace top and hot air is sent up from the bottom resulting in these thermo-chemical reactions. Coal in the form of coke dominates the blast furnace process. Necessary coke properties are commonly known but the quantification of individual data relates closely to the economy of preparing the coal mixture and its constituents. In blast furnace department, the decrease of total costs of production is possible mainly by decrease of the costs of fuel (STAN T. MADZIEJ. 2010).

The specific coke consumption varies from various kinds of blast furnaces and different processing conditions. In ironmaking industry there is a huge range of methods for coke quality testing (ICE B. RIDSECKI. 2011) such as Coke Reactivity Index – CRI in standard gaseous conditions and CSR index – Coke Strength after reaction with CO2. For coke of high quality there is CRI index low and CSR index high (ULANOVSKII M. L. 2010). In case coke reacts excessively with blast furnace gases including increasing rate of CO2, coke is degraded into smaller pieces. An excessive coke degradation results in the decrease of air permeability in blast furnace, the decrease of blast furnace efficiency and blast furnace blockage by coke pieces. There is a narrow relationship between CRI index and reflection of vinitrit in coal. The choice of coal and the composition of coal mixture are main factors affecting coke properties (BILÍK J., PUSTĚJOVSKÁ P., BROŽOVÁ S., JURSOVÁ S. 2012).

2. Experiment

Testing of CRI and CSR index was carried out according to the standardized method NSS (Nippon Steel Corporation) (see Fig. 1) (PUSTĚJOVSKÁ P., JURSOVÁ S., BROŽOVÁ S. 2013).

Fig. 1. Testing furnace

The coke is sieved after the experiment and coke up 10 mm is weighed. CSR and CSR indexes are calculated according the equations below:

$$CRI = \frac{m_1 - m_2}{m_1} \cdot 100 \qquad (1)$$

$$CSR = \frac{m_3}{m_2} \cdot 100(2)$$

where:

m_1 – coke weight before reaction [g],

m_2 – coke weight after oxidation [g],

m_3 – weight of coke up 10 mm after drum desting [g].

3. Results

For statistical computations, CRI index was used as a characteristic parameter of coke; ash content (Ad), volatile combustible (Vdaf) and maceral content expressed ratio of inertinit in coal mass as further important parameters of coke quality. Statistical methods were used to study the character of statistical relationship between input parameters of coal and output parameters of coke. The calculations were carried out by software Statgraphic.

For the first statistical relationship between both, output coke quality parameters CRI and CSR were studied. Determination coefficient is 55.0204% and model equatation CRI 59.6914 – 0.46583 CSR. Linear regression of both parameters shows statistically important correlation coefficient characterized by nonlinear relationship in equatation of regression. It is depicted in Fig. 2.

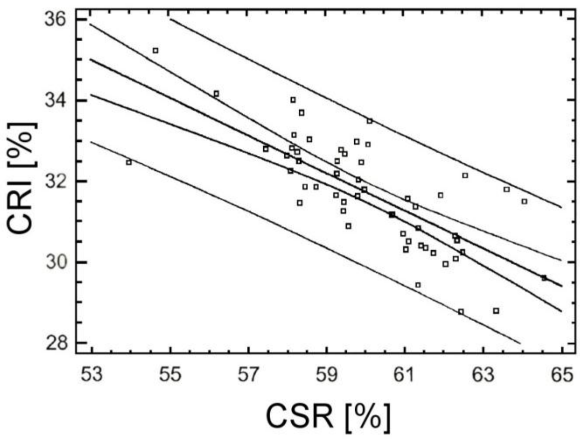

Fig. 2. Regression relationship between CRI and CSR

The results show rather tight statistical relationship between both parameters. The equation describes it mathematically; the sign of variable shows nonlinear relationship of both parameters, coke of high strength after reaction has lower reactivity and contrary.

Linear regression between parameters CRI and Inertinit is described by determination coefficient

21.5873% and model equation 26.8075 + 0.186131. Their statistical relationship is depicted in fig. 3.

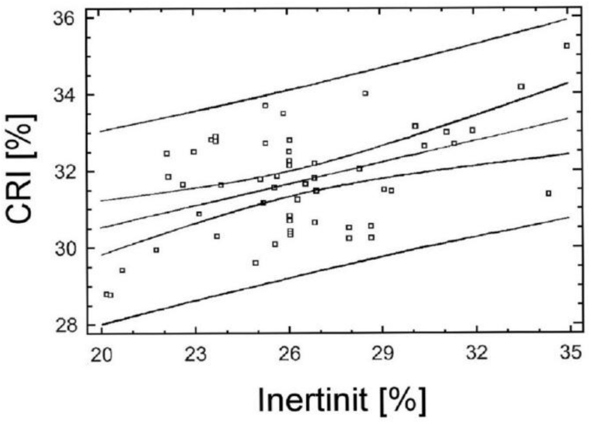

Fig. 3. Regression relationship between Intertinit and CRI

4. Conclusions

From resulting correlations it arises that higher ash content in coal decreases resulting coke reactivity. Higher content of volatile combustible in coal increases resulting coke reactivity. Higher inertinit ratio in coal increases resulting reactivity. Generally, coke quality is affected by grade of coal treatment, coalification and maceral composition of coal mixture.

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