ECONOMIC BENEFITS OF RAW MATERIALS REDUCIBILITY TESTING

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Abstract

The paper deals with economic possibilities of reducibility tests carried out in Laboratory of high temperature properties testing of raw materials in Centre ENET at VŠB – Technical University of Ostrava. The reducibility tests are aimed at testing of iron ore, sinter, pellets and other mixtures of raw materials for metallurgical industry. The reducibility might be an indicator in task of specific coke consumption. The paper discusses economic interpretation of reducibility tests in the field of decrease in specific coke consumption.

Keywords: reducibility, specific coke consumption, iron-making

1. INTRODUCTION

There are several possibilities how to decrease in energy demands of iron-making technology such as pulverized coal injection into blast furnace or higher temperatures of wind heaters. These technologies relate to high costs. The injection of alternative fuels such as pulverized coal, oil, waste gases requires special installation for blast furnace tuyeres, which is demand on high investments [1]. The operation of wind heaters under higher temperatures is financial demanding, too [2, 3]. The study of blast furnace feedstock reducibility seems to be the most economical way how to optimize the blast furnace process for decrease in fuel coke consumption. It does not relate to high investments into constructions. It works just with the operation data and iron ore characteristics serving for the interpretation of savings in specific coke consumption.

The study of reducibility has had a long tradition. The first laboratory of blast furnace feedstock properties in the Czech Republic was founded in the department of metallurgical research in iron works at Vitkovice. Ore and agglomerate’s reducibility as well as coke reactivity were tested. The laboratory of blast furnace raw materials as blast furnace research were later displaced by a newly – established Research Institution of ferrous metallurgy in Dobra.

In the 1970s, the theoretical research in mathematic modelling of direct and indirect reduction begun. A mathematical model of indirect reduction describing oxygen circulation between ore feedstock and reductive gas along the isothermal zone of blast furnace shaft was designed. The model included a version for the shaft and for firm bed in the furnace retort for reducibility tests. The variant for the shaft related to numerical solution of differential equations, while differential equations for reducibility tests were written in formulas. The established procedure for calculation enabled to predict coke consumption for pig iron production according to laboratory tests of blast furnace feedstock without advanced definitions of top gas composition.

1.1 Laboratory for testing of high temperature properties of raw materials

Nowadays, the study of reducibility is carried on with Laboratory for research in high temperature properties of materials (LVVVS)that was found within Centre ENET, one of research workplaces of VSB-Technical University of Ostrava specialized in research of energy units for alternative energy sources. The new laboratory is equipped by RF 33/TV/RDI provided by DASFOS v.o.s. Ostrava (Fig. 1). The device for reducibility determination measures the depletion in weight of iron ore sample in the laboratory furnace
heated for the temperature of isothermal zone in blast furnace shaft at 950 °C. The depletion generally is caused by oxygen elimination from ferrous oxides by reductive gas. The depletion of sample weight is continuously recorded until the grade of reduction is 65%. The reduction velocity is counted according to the relation \( \frac{O_2}{Fe} - 0.9 \). The reduction grade is counted according to (1): [5]

\[
R_t = \left( \frac{w_1}{w_2} \cdot \frac{m_t - m_1}{m_0} \cdot 100 \right) \cdot 100
\]  

(1)

- \( m_o \) weight of sample [g]
- \( m_1 \) weight of sample just before the test [g]
- \( m_t \) weight of sample after the reduction [g]
- \( w_1 \) content of FeO [%]
- \( w_2 \) content of Fe [%]

The device determines essential technological properties of iron ore lumps, pellets and sinter which is used as blast furnace feedstock. It is especially aimed at the determination of reducibility and disintegration. The device simulates the process of non-direct reduction in blast furnace. The materials properties are possible to determine by standards ISO such as ISO 4695:2007, ISO 7215:2007, ISO 4696-1:2007, 4696-2:2007. The non-standard tests differing in gases amount, grain size of samples or sample weight are also available to carry out. The simulations take part in the environment of technological gases such as - CO, \( CO_2 \), \( H_2 \) and \( N_2 \). In Fig. 2, 3 are metallurgical materials after the reduction processed by ISO 4695:2007.

Fig 2 Metallurgical pellets after reduction by ISO 4695:2007

3. MODELS FOR BLAST FURNACE OPTIMIZATION

The measured depletion in oxygen of iron ore during the reduction process is not the only one result of the experiments. The experimental values are processed in an extensive system of mathematical models which interprets the values according the specific blast furnace conditions and predict specific coke consumption (practically achievable minimal consumption) and other important parameters of technological process.
The result of evaluation by mentioned models is a diagram in Fig. 3 which clearly presents the position of labor point to the limits for keeping all the functions of fuel (coke) in blast furnace. The diagram sums up calculations and results of the whole system of models. According to the diagram, it is possible to carry out technological analysis of efficiency of technological measurements for decrease in fuel demands of iron-making. Generally, the analytical and simulating system presents mathematical models which enable objective evaluation of heat and reductive blast furnaces operation and at the same time, determine reserves for further decrease in specific coke consumption. Beside evaluating and analytical purposes, they are possible to use for various prognostic calculation providing essential quantitative orientation in supposed changes of iron-making technology.[6,]

![Diagram showing relation between reduction degree and carbon coke consumption](image)

**Fig. 3 Relation between reduction degree and carbon coke consumption**

### 3.1 Discussion

As it results from the diagram, the correct relation between direct and non-direct reduction relates to the decrease in coke consumption. The calculations show quite significant savings of coke. In the metallurgical company, the decrease in reduction degree from 0.35 to 0.28 results in savings of coke. The blast furnace operation presented in the diagram (Fig.5) after the optimization of reductive processes reaches savings about 30 kg of carbon, which is about 35 kg of coke. For todays’ prices of coke it means about 213 CZ per ton of pig iron. As in the metallurgical company, the annual iron production per one blast furnace is about 1 mil. tons, the coke savings reach 200 mil. CZK per year. It is a significant amount which grows with amount of blast furnaces in the company.
4. CONCLUSION

The study of iron-making materials reducibility presents a promising way how to affect on blast furnace technology. The knowledge about the blast furnace feedstock reducibility is very important for optimization of blast furnace operation. The reducibility as it is one of the basic properties of iron ore and other metallurgical materials, shows possible relation between reductive processes in the blast furnace shaft. As it has been presented in example of a Czech metallurgical company, the optimized relation relates to significant savings in coke consumption. The reducibility of blast furnace feedstock is possible to use for prediction of coke properties.

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LITERATURE


