Abstract
The iron ore raw materials and coke quality is the basic reserve of improvement of the blast furnace technology. Some of the quality indicators of iron ore raw materials and coke and their influence on the main parameters of a blast furnace smelting are considered in the paper.

Introduction
Coke requirements in a blast furnace smelting are about 40% of costs for the iron production and influence greatly on the coke cost. Therefore essential reducing of the coke requirements at minimization a total energy costs must be considered as the important problem at improvement of the blast furnace technology.

The coke consumption as energy carrier (heat and reducing agent source) can be decreased generally in the two ways. First it can be decreased by using the extensive factors, such as increased iron content of burden; utilization of the direct coke substitutes (natural gas, oil, pulverized coal, reducing gas, including top gas without carbon dioxide); increased blast temperature; utilization high potential heat, etc. Second the coke consumption can be reduced by using the intensive factors, such as increasing of the utilization heat and reducing gas potential as a result of upgrading the iron ore raw materials and coke quality indicators, namely reducibility $\omega_r$, cold and hot strength $B_{+5}$ and $X_{+5}$ respectively.
softening and melting points of raw materials $t_{\text{bm}}$ and $t_{\text{m}}$ respectively, the Coke Reactivity Index (CRI) and the Coke Strength after Reaction (CSR), strength indexes of coke $M_{25}$ and $M_{10}$.

It is also important to note that the limit of improvement of a blast furnace process including the possible minimal coke rate in theory is defined by thermodynamic balance of redox reactions in the separate zones of furnace.

At present time the extensive way of the reducing coke requirements is almost exhausted and there is only one intensive way to reduce the coke rate at the expense of improvement the iron ore raw materials and coke quality.

We use the following approach for the decision of practical problems: the laboratory studies on the experimental equipment with determination of the iron ore raw materials and coke quality indicators; analytical study using mathematical models; trial and industrial tests.

**Quality of iron ore raw materials**

Iron ore raw materials are classified by the following physical properties: high mechanical strength, little crushability and wear ability in the ordinary condition, the minimal decreasing these properties during the heating and reducing, high porosity.

We choose following parameters of quality – the sinter and pellets reducibility and mechanical durability for studying of influence on the blast furnace process efficiency.

Reducibility of a sinter and pellets is the major quality index, which is necessary to take into account at the estimation consumer properties of the prepared iron ore raw materials (1). Reducibility is ability of iron ore material to give oxygen from ferrous oxide to reducing gas with greater or smaller velocity. Its role increases in process of blast furnace improving and the coke rate reduction.

Reducibility is defined as the attitude of weight of the taken
away oxygen to weight of originally connected oxygen expressed in percentage. Reducibility can be certain also as the standardized degree of reduction which usually calculates by a weight loss or by change of a chemical compound of the reduced sample (2).

Reducibility is defined by mineralogy, structure and porosity of agglomerate materials. These factors depend on basicity of sinter which also influences on its reducibility, and this influence has complex character.

Porosity of materials substantially defines its reducibility. Porosity of industrial sinters changes depending on different factors from 25 up to 45 % at a wide range of the pore sizes (3).

Mechanical durability (Russian Federation State Standard 15137–77) (4) is defined in a rotating steel drum with the subsequent definition of test screen structure change. For criterion of durability an output of particles with the fraction content of 0-5 mm (characterizes abrasion resistance) and more 5 mm (characterizes impact durability) is accepted. Durability of materials at reduction defines in accordance with Russian Federation State Standard 19575–74.

**Quality of coke**

It is possible to conclude that the coke chemical and physical properties should meet higher requirements basing on the new operating experience of blast furnaces with the greater specific charge of coal and black oil.

Now the coke reactivity CRI (Coke Reactivity Index) and “hot” durability CSR (Coke Strange after Reaction) are the main physical and chemical properties defined with the conventional method NSC, offered by corporation Nippon Steel.

On the basis of this method the following standards are developed and applied in foreign countries: the British BS 4262–84, the American ASTM D 5341–93 and the project ISO 18894:2006, the Russian State Standard P 50921–2005 (5).

Reactionary ability of coke is a parameter of intensity of
interaction of coke carbon with carbon dioxide in standard conditions of test (temperature of coke heating is above 1100°C), and is defined by the general coal burden ash level (6) and coal burden grade composition (7). Final (working) value of coke reactivity is formed inside of the furnace at interaction of coke with pairs and a dust of a shaft atmosphere.

The range of requirements to parameters of quality of coke at foreign and domestic factories is wide enough, however for the majority коксохимических factories recommended parameter CRI is within the limits of 20–30 %.

The measurements on the coke various types have shown that predictably its “hot” durability of coke greatly raises at the reactivity decreasing. Low reactivity defines decrease of a degree of development of iron direct reduction reactions that reduces the charge of coke carbon as the heat-carrier and a reducer.

The parameter CSR is also defined since the equation of connection between CRI and CSR has close correlation.

Influence of the iron ore raw materials and coke quality on the parameters of a blast furnace operation

The calculations for a blast furnace № 9 of the “Magnitogorsky metallurgical works” are made by means of balance logic-statistical model (8). For a basis the base variant of work of the furnace for 2009 year is taken: productivity of the furnace, tons pig-iron/day – 4488; the charge of coke, kg/tons of pig-iron – 437.61. Variants of influence of change of reducibility (from 69.46 up to 94.46 %) and durability (from 65.13 up to 90.13 %) on the blast furnace process technical and economic parameters are calculated.
Figure 1. Influence of reducibility (1) and durability (2) on the coke rate (---), blast furnace productivity (- - -)

Predictably there is a known alternative between these two metallurgical iron ore material characteristics: if the attention to the question on the maximal productivity achievement of a blast furnace is given, it can achieve by increase of “cold” durability value and, on the contrary, if there is a necessity for decrease of coke rate as a priority there will be a problem of increase in the burden reducibility (with other things being equal). It is recommended to apply the iron ore materials with parameters of reducibility and “cold” durability above 80 % (Fig. 1) for reception of optimum values of productivity of the furnace and the coke rate.

Also the coke of “Ural Steel” was investigated. The average metallurgical characteristics of coke, weights %: ash value – 12.1; humidity – 4.6; sulfur content– 0.51; the volatile matter – 1.1. For the coke reactivity definition the experiences with sizes of coke about 20 mm on the installation corresponding requirements are made.
For a basis the base variant of work of a blast furnace № 3 of “Ural Steel” for 2009 year is taken. Accounting characteristics of the furnace is taken: useful bulk of the furnace, m$^3$ – 1513; the charge of coke, kg/tons of pig-iron – 480.60; the iron ore materials charge, kg/tons of pig-iron – 1694.80; an outlay of top gas, m$^3$/tons pig-iron – 1283.20; an outlay of slag, kg/tons of pig-iron – 411; basicity of slag CaO/SiO$_2$ – 1.08; the content of sulfur S in pig-iron, % – 0.017.

The value of coke reactivity varied from 28 to 45 % (Fig. 2) for calculation of productivity and the coke rate dependences in a blast furnace. The productivity of a blast furnace has decreased on 234.1 tons pig-iron/day (9.44 %) at the coke reactivity increase by 17 %, the coke rate has increased for 55.02 kg/tons of pig-iron (11.48 %) for the mentioned conditions, i.e. on 1 % of coke reactivity increase productivity decreases on 0.555 %, the coke rate increases for 0.675 %.

**Conclusion**

Thus influence of such iron ore materials characteristics as reducibility and “cold” durability, coke reactivity on a blast furnace efficiency is shown by means of balance logic-statistical model of blast furnace process.

At the arrangement of priorities of improvement of this or that blast furnace technical and economic parameter it is necessary to consider that the optimal results of productivity and the coke rate it is possible to reach by iron ore material application with parameters of reducibility and “cold” durability above 80 %.

It is obvious that decrease in value of the coke reactivity is economically expedient and will allow improving blast furnace efficiency. Also improvement of technology of reception of coke with reactivity low parameters is expedient.
Figure 2. Influence of coke reactivity on the blast furnace productivity (1) and coke rate (2)

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References


