On the possibility of a radical decreasing of costs in iron production

Successive economic crises exacerbated to the limit a major problem of ferrous metallurgy – the high production cost of iron and steel. The reason consists in long term invariability of the main technological principle, based on low-reactive lump coke. In the article are discussed advantages of the new carbonaceous reductant - highly reactive lignite coke. By using this agent in direct reduction of iron ore the unit cost for coke and fuel is about 700 rubles ($ 20 USD) per ton of iron. It provides the radical reduction of production cost.

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At international conferences in recent years established a kind of ritual – to devote the first day for forecasts of the Chinese economy development and then on the basis of different scenarios to assess the prospects of metallurgy in other countries. However, in today's economic environment the expectation of the next favorable cycle - it's just self-deception, but in the long term - guaranteed bankruptcy. Problems of ferrous metallurgy primarily consist in exhaustion of the potential of the existing technological foundation, rather than a decrease in the rate of development of the China economy.

In the prospect of the coming decades the determining requirement becomes ***a radical reduction in the cost of production of pig iron***, which can be achieved only through the introduction of innovative technological solutions. It is the only way to deal with crises.

Obviously, any derivatives of iron ore will only get more expensive, due to the objective trend to lower quality ore, rising costs associated with the transfer of mining in remote regions, as well as the steady increase in transportation tariffs. Similarly is the case with coking coal and coke products, respectively. However, the development of civilization is incompatible with unlimited rise of price of the main structural material - steel. Therefore, inevitably must occur the change of leading technological concept.

Once again we turn to coke. Under normal economic conditions, the cost of coke and fuel is for slightly less than half the cost of production of pig iron. The overwhelming majority of metallurgical plants are working using the ***lump, low reactive coke***. If to digress from the construction of concrete devices for known metallurgical processes, the above properties of coke have no economic or technological justification. According to basics of physical chemistry of heterogeneous processes, for maximization of the recovery rate of iron oxides is necessary to use ***highly reactive, fine-grained carbonaceous reducing agent***.

It is ironic, but for a century the metallurgy was developing, ignoring the fundamental principles of heterogeneous chemistry.

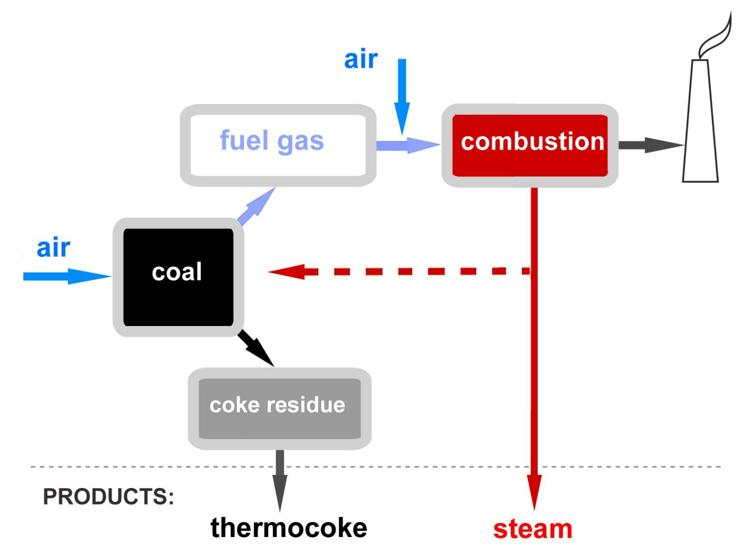
Thus, objectively the ferrous metallurgy needs carbonaceous reducing agent, which has the following main features: a) the high reactivity; b) large specific surface; c) cheapness.

Technology THERMOCOKE®

The above requirements to the carbonaceous reductant fully meets medium temperature coke (thermocoke), producing from lignite as grained material. It has 20 times higher reactivity than classic coke and contains up to 85% of fixed carbon. The cost of its production is approximately equal to the price of 2.5-3 tons of brown coal.

The technology of thermocoke production consists ***in partial gasification of high volatile coals*** (Fig. 1). Optimal raw materials are cheap brown coals of Kansk-Achinsky basin with a low content of ash (A^d = 5-6%) and sulfur (S^d = 0.15%). Industrial stocks of coal amount to hundreds of billion tons.

This technology also can process high volatile bituminous coals (V^{daf}> 35-40%). Moreover, due to the simultaneous effect the gravitational separation is possible to use coal with high ash content.



Pic. 1 Principal scheme of thermocoke production

Partial gasification of coal is carried out in a standard coal firing boiler, which is modified for a mode of parallel coproduction of coke, preserving nominal heat capacity. Crushed coal feeding into the boiler undergoes partial gasification in a fluidized bed with a temperature of 750-800 ° C. The solid residue is cooling in separate cooler. Hot gas products are afterburned with secondary air in the space above fluidized bed, providing rather high heat concentration in this volume. Thus, the boiler combusts predominantly gaseous component of coal and instead of ash waste it produces a second valuable product – lignite coke.

Instead of steam production the products of gasification can be used for other purposes: drying concentrates after enrichment, agglomeration, sintering and calcination a variety of materials used in the metallurgical industry.

Obviously, the scale and scope of use of the new carbonaceous product is determined by its main consumer properties. As an example, we present the characteristics of thermocoke manufactured from lignite of Berezovsky deposit.

W_t = 1-5%	S^{dry} < 0.2%	Q_i^r = 28-30 MJ/kg
A^{dry} = 8-9%	C^{daf} = 90-94%	Reactivity with CO_2 = 8.0 $cm^3/g \cdot s$
V^{daf} = 7-8%	ρ_{bulk} = 500 kg/m^3	HGI = 68.5
C_{fix} = 82-85%	Specific electrical resistance $1.37 \cdot 10^3$ Om·cm	

Parallel gravitational enrichment. When using coal with increased ash content in the fluidized bed occurs gravity separation. A more heavy mineral part of the coal (rock) removed from the bottom of the reactor. For example, when processing dropout after enrichment of subbituminous coal with initial ash content 20-24% the manufactured thermocoke has 13-15%.

<u>Economic indicators.</u> In the parallel production of coke and thermal energy unit capital cost per 1 MJ of both of products is dramatically lower, and production efficiency is several times higher than in the classical coal fired energetics. For example, by processing 4 tons of lignite ($Q_i^r \approx$ 15.5 MJ / kg) we can get 1 ton of coke ($Q_i^r \approx$ 29.3 MJ / kg) and about 25 GJ of hot water or steam. Since all operating costs offset by the sale of thermal energy the production costs of thermocoke is mainly determined by the cost of raw coal. According to a feasibility study fulfilled in 2014, after modernization of the existing coal thermal power station in Krasnoyarsk production cost of thermocoke will be 1358 RUR / t (excluding VAT), i.e. not more than 40 USD / t . Unit consumption of lignite - 2.3 t / t thermocoke and coal price - 505 rubles / t (near 14 USD/t). Return of investment for modification of existing power station is not more than 3 years.

Environmental performance. Since in the boiler mostly burned fuel gas with a small admixture of themocoke dust removing from the fluidized bed, the result is a radical reduction of controlled emissions compared to conventional coal-fired boilers. Technology, in fact, has no ash waste, since the ash contained in coal goes into the coke product. This fact eliminates the need to create a huge slag heaps. Thus, the environmental indicators of coal-fired boiler unit approach the relevant indicators of the gas-fired boiler. Since the products of combustion are attributed on heat production, the second product – coke, produced with ***zero emissions*** into the environment.

Briquetted carbonaceous reductant

Currently used metallurgical technologies are oriented mainly on the use of classical lump coke. Key features of this material: a) high cold and hot strength; b) a low reactivity. As a compromise with the existing metallurgy thermocoke can be briquetted (extruded) to obtain a molded product of any size. If the strength requirements can be satisfied by the selection of optimal binder, the reactivity of molded thermocoke reduced insignificantly. Accordingly, the scope of use of this product is limited mainly by electrometallurgy, primarily by ferroalloys production. To date, our company has gained sufficient experience in producing briquettes with high strength and continues improvement in product quality by testing pilot batches of briquettes at the plants for ferroalloys and polycrystalline silicon production. For the latter application the iron content in thermocoke is decreasing by its pre magnetic separation.

Grained carbonaceous reductant

The stage of thermocoke briquetting is redundant, both from a position of physical chemistry of pyrometallurgy and economic standpoint. The greatest interest is the direct use of fine-grained carbonaceous reductant having high reactivity.

In traditional metallurgy highly reactive thermocoke – perfect fuel for injecting into the blast furnace. Successful industrial tests with blowing of lignite char (significantly lower quality compared with thermocoke) were held in 1971 at the West Siberian Metallurgical plant on the blast furnace of 2000 m^3.

Today the most effective reducing agent for direct reduction of iron ore is produced from natural gas. Unfortunately, this type of raw material has a limited geographic availability and rather high price. Alternatives are some brands of energetic coal. But, their benefit is limited only by cheapness in comparison with the classic coke. According to results of testing in 2010, the company Hares Engineering (Japan) endorsed the use of thermocoke in DRI technology ITmk3.

In Russia, a modified version of the Japanese technology develops company ITEM (Irkutsk). In 2012, their specialists also successfully tested thermocoke manufactured from lignite of Berezovsky deposit and noted a number of positive features of this reducing agent compared to coal: primarily, high content of fixed carbon, high reactivity and low cost in terms of carbon. Positive factor of this technology is the reduced requirement for the content of harmful impurities in the iron ore concentrate. And nevertheless it ensures high quality of the final product. For example, the iron produced from concentrate of Kovdor dressing mill (company "Eurochem") and thermocoke of Berezovsky lignite contains more than 95% Fe, about 3% carbon and satisfies all the requirements for the characteristics of the pig iron. The specific consumption of thermocoke is 0.45 t / t of pig iron.

Economy of ironmaking based on Thermocoke.

In 2014, together with company ITEM was performed feasibility study for construction of industrial plant for the production of 1 million tons / year of iron nuggets. As the reducing agent used fine-grained thermocoke, produced on the coal-fired thermal power station after a slight its modification. Specific capital cost is near 8 thousand rubles (about 200 USD) per 1 ton of iron nuggets. Unit costs for coke is near 700 rubles/ton pig iron (~ 20 USD / t). For comparison: in blast furnace technology this parameter is about 4000 rubles/ton pig iron (~ 110 USD / t).

Additional economic effect is achieved by introducing into the general flow chart the unit for thermocoke production instead of gasification unit. Generating during partial gasification gas can be used for heating of reduction furnace. In economic terms, this would eliminate the use of coal (300 rubles/t iron) for production of combustible gas. Capital expenditures on construction of coal gasification unit and block of carbonization (partial gasification) are roughly comparable.

Thus, the use of lignite coke in DRI technology provides a radical reduction in prime cost of production of pig iron, which in principle is unattainable under the domain of production based on classic coke.