Pig-iron and ferroalloys production in oxygen reactor.

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ABSTRACT

A new aggregate, oxygen reactor, has been constructed and patented at the Electrometallurgy of Steel and Ferroalloys Department of Moscow Steel and Alloys Institute (MISA). This method allows to produce pig-iron and ferroalloys with essential saving of materials and energy.

The process has been successfully tested in laboratory conditions and in an industrial scale furnace (Serov metallurgical plant) at the production of pig-iron, high carbon ferromanganese, high carbon ferrochromium, low silicon ferrosilicon, ferronickel, siliconickel (18% Si, 4% Ni), vanadium alloying iron (5% V).

The application of this process gives decreasing of the cost of production: in case of pig-iron 20-30%; for the blast furnace ferroalloys 30-40%; for the energy-intensive electrothermic ferroalloys from 30 up to 70%.

INTRODUCTION

The well known traditional methods of pig iron and ferroalloys production can be characterized by the high consumption of coke in blast furnaces or electricity in electric arc furnaces.

A new economical method has been developed and patented. This method allows saving of energy and material sources.

EXPERIMENTAL RESULTS AND DISCUSSION

According to a developed method the process is performed in the oxygen reactor (fig.1). It is represented by the lined cylinder with the following reactionary zones: liquid metal and slag; coke bed zone with the oxygen centers of the lower lances; zone of post-combustion of carbon monoxide. Carbon is burned down in flow of oxygen with formation of carbon monoxide. This reaction provides a part of the heat necessary for the reduction processes. Carbon monoxide reacts with oxygen forming carbon dioxide. This reaction takes place under the arch space of the furnace with the injection of oxygen through the additional top lances. These take place under raw materials inside the furnace. This reaction gives additional heat necessary for the reduction and metal formation processes. The raw materials come to the furnace through the holes in the arch.

The key of the process is post-combustion of carbon monoxide above a layer of solid coke bed. It ensures a full use of carbon materials calorific ability inside an aggregate. Besides that the presence of coke bed creates reduction conditions which allow production of pig-iron and most common ferroalloys. The coke bed protects the metal from re-oxidation by gaseous oxygen.

The described method was used for the production of standard carbon ferroalloys of manganese, chromium, vanadium, nickel, silicon as well as silicochrome, siliconickel, siliconickelchrome, manganese-vanadium complex ferroalloys and pig-iron. The experiments were carried out under laboratory conditions and in an industrial scale furnace.

Thermal performance of the reactor was checked using a pilot oxygen reactor with inside diameter of 400 mm. Carbon ferronickel, ferrochrome and pig-iron were successfully melted without application of an additional power source.

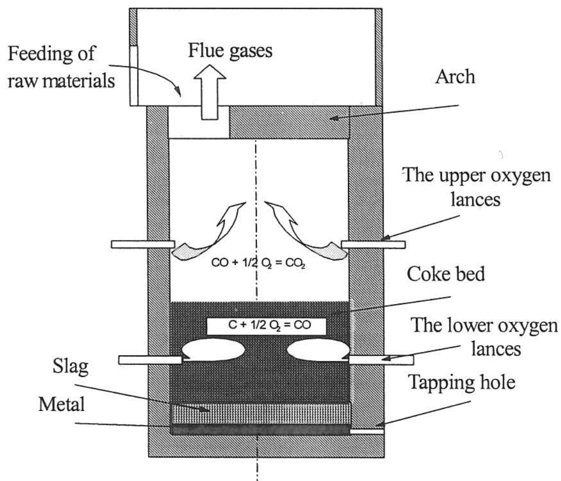

Fig.1. The scheme of the oxygen reactor.

For the ferronickel production the following materials were used: oxidized nickel ore from Ural region (Ni - 0.8-1.2%, Fe - 13-15%, SiO_2 - 46-47%, Al_2O_3 - 4-12%, CaO - 1%, Cr_2O_3 - 1-1.1%, S - 0.02%, P_2O_5 - 0.04%). The obtained metal had the composition: Ni - 7.36%, C - 2.55%, Cr - 1.2%, Mn - traces, Si - 1.17 %, S - 0.014 %, P - 0.04 %. The nickel in slag dump is not detected. FeO content - 1.32%. Basicity of slag - 1.1.

The ferrochrome melt was conducted with use of chromium ore from Ural as well: Cr_2O_3 - 38.4%, FeO - 18.3%, SiO_2 - 4.9%, Al_2O_3 - 15%, CaO - 1.4%, MgO - 16.2%, P - 0.023%. The obtained metal had a composition close to that of charge-chromium: Cr - 39.27%, C - 6.9%, Si - 2.07-2.82%, S - 0.24%, P - 0.046%. Slag had the following composition: Cr_2O_3-7.1%, SiO_2 - 33.92%, Al_2O_3 - 13.84%, CaO - 15.20%, MgO - 16.04%, Fe_2O_3 - 3.43%, P_2O_5 - 0.027%.

The test of the process on a reactor of an industrial scale with inside diameter of 1200 mm and height of 17 м has confirmed functionality of the process and its economical efficiency.

The total oxygen flow rate in the industrial scale experiment was limited by the possibilities of the oxygen station of the Serov metallurgical plant. It was about 500 $м^3$/hour. This condition limited the productivity of the reactor. It was about 0,2-0,3 t/hour*m^2 for ferroalloys production.

After ignition of the first portion of coke the blowing of oxygen through the lower and top lances began smoothly increased. Simultaneously the additional coke was added for the formation of the coke bed. The raw materials mixture was fed by a skip technique under the arch of the furnace after reaching an expected calculated temperature. Before this time the relation of the top and lower oxygen flow was changed according to mass-heat balance calculations. The ore-coal briquettes with an organic binder were used as a raw material blend. In addition to that the coke with size fraction of 20-50 mm was used with briquettes for the restoration of burning down coke bed. A moment for the feeding of the next portion of a blend was determined by measuring the temperature under the arch (according to the preliminary calculations it should be equal to 1800°C) and from calculated raw materials level inside the furnace.

From calculation of mass-heat balances it follows that the total consumption of carbon materials for the realization of the process decreases compared to the traditional processes. The thin layer of coke bed and input of reduction materials to ore-coal briquettes (or unburned pellets) makes it possible to replace a greater part of the coke by coal. The carbon consumption was as follows: for the pig-iron production - 500 kg/t (coke - 200 kg/t, coal in a composition of briquettes of 300 kg /t) instead of 600 kg of coke /t in the blast furnace. A melt of ferromanganese - approximately 700 kg/t (coke - 300 kg/t, coal in a composition of briquettes of 400 kg/t) against 1900 kg/t in the blast furnace. A melt of ferrochrome - coke consumption was 1000 kg/t against 3000 kg/t in the blast furnace.

The consumption of oxygen at production of pig-iron was 670 $м^3$/t; ferromanganese - 824 $м^3$/t; ferrochrome - 1300 $м^3$/t.

Calculated temperature of flue gases was equal to 1800°C. It gives high waste of heat with flue gases - 24% from total heat of the process for pig-iron production and 30-40% for ferroalloys production. Even without heat recovery from the flue gases the process looks promising. The CO post-combusting inside the reactor compensates all losses of heat.

The preliminary estimation shows the utilization of just 30% of flue gases heat completely ensures for the electric power development necessary for the oxygen production for realization of the process.

The given process is a new and has no analogues in production of pig-iron and ferroalloys. Simplicity of reactor construction is the special attractiveness of this process. It gives a possibility for rather simple reconstruction of classical metallurgical aggregates such as the blast furnace, cupola, open-hearth furnace or electric arc furnace to the oxygen reactor.

For blast ferroalloys the decreasing of the cost price is mainly achieved by the reducing of carbon materials consumption by approximately three times and the partial replacement of coke by coal. In cases of electric furnace ferroalloys the value of a drop of the cost price depends on the price of electricity. The benefit of this new process compared to the classical method increases with increasing of the electrical energy in a structure of ferroalloy cost price. For example, for high-carbon ferromanganese and ferrochrome it is possible to predict a drop of the cost price by 40-50%, for power-consuming ferrosilicon - by 50-70%. This is because the production of heat by the using of electric power is more expensive than from by burning of coke in oxygen and especially coal (fig.2, 3). Fig.2 demonstrates the dependence of cost for the heat produced by different methods. As can be seen the electricity gives the lowest price for 1000 MJ if its price less than 0,01 \$/kWh only. A comparison of prime cost for ferrosilicon production (20% Si) in oxygen reactor and in electric arc furnace presented in fig.3 depending on the price for electricity. It is visible that oxygen reactor is more economical method. Besides from economical point of view the electric arc furnace can not be used for low silicon ferroalloys production if the price for electricity more than 0,04 \$/kWh.

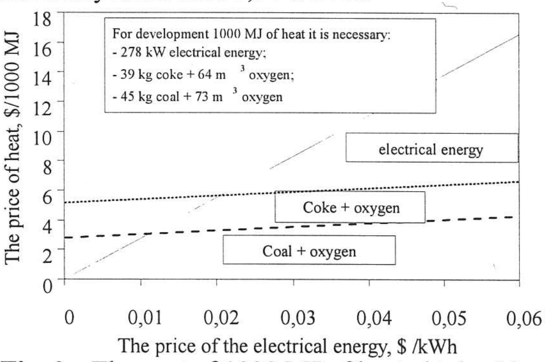

Fig. 2. The cost of 1000 MJ of heat obtained by different sources

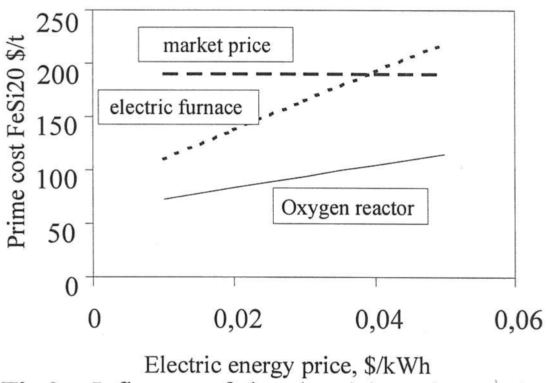

Fig.3. Influence of the electricity price on the cost of ferrosilicon (FeSi20) produced by various ways.

On the basis of laboratory and industrial experiments the mathematical model of the oxygen reactor is developed. The model works in real-time mode. The adequacy of the model was checked against data from the oxygen reactor on Serovsky metallurgical plant. The outcome of the simulation showed satisfactory agreement with the available experimental data.

The offered process can be used for effective reduction of copper and nickel ores, for production of alloying composition from slime, dusts and other scrap from metallurgical industry, for which other economical ways of processing, probably, are not present. Taking into account a universality of the process and its profitability in a combination with low capital investment it is possible to assume that this process will take a more broad application in ferrous metallurgy.

CONCLUSIONS

1. It was described a new energy and resources saving way for pig-iron and ferroalloys production in a reactor of a new type. A melt of pig-iron the coke consumption was 200 kg/t, coal – 300 kg/t, oxygen flow rate – 670 m^3/t. A production of ferroalloys (manganese, silicon and chromium) the coke consumption was equal to 300 kg/t, coal - 400 kg/t, average oxygen flow rate - 1000 $м^3$/t.
2. The method was investigated in a laboratory and successfully tested on Serovsky metallurgical plant in pilot and industrial scale oxygen reactors to produce pig-iron, ferronickel, ferrochrome, vanadium alloying composition and siliconickel.
3. The mathematical model of the oxygen reactor is offered. The developed model works in real-time mode and it is suitable for simulation of processes in the described reactor.

ACKNOWLEDGMENT

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References:

1. Way of pig-iron and ferroalloys production. The patent of Russian Federation - № 2109817. Dates of priority - October 16, 1997. The authors: V.A.Grygorian, A.V.Pavlov, E.F. Vegman, A.E.Semin, V.A.Shcherbakov. Patentee: Moscow Steel and Alloys Institute.