Uncontrolled parameters influence on material and energy consumption for BOF heat

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Abstract
The current article aims at analyzing the impact of uncontrolled parameters (the degree of CO to CO_2 post-combustion, contents of silicon and carbon in iron, heat carrier specific consumption, heat loss of BOF vessel, etc.) on charge materials consumption and energy consumption per a ton of final steel product in BOF production. The research reported has been carried out with mathematical simulation, based on BOF heat and material sheet balances. In this paper, we describe with the analysis how the principal parameters and quality characteristics of the materials, used in BOF heat,

influence the changes in metallic charge consumption and energy consumption per a ton of steel. It is shown that the use of additional agents (contaminated scrap, solid iron, magnesite flux, heat carrier) with the objective to solve current production problems of BOF heat leads to a significant growth of energy consumption as much as up to 42 kg of conventional fuel per ton of steel final product. The scientific novelty of the research is in determining the influence of the uncontrolled factors of BOF heat on initial materials consumption and energy consumption per a ton of steel. The research practical relevance is expressed by the development in BOF heat theory and practice with taking into account the impact of uncontrolled parameters.

Key words: BOF, ENERGY CONSUMPTION, METALLIC CHARGE, STEEL, TECHNOLOGY, CONSUMPTION

Urgency and objective of the research

Ukrainian enterprises of mining and metallurgy sector continue to work under tough conditions, related with the difficulties of their provision with iron ore, metallic scrap, fluxes, and energy carriers. Steel-making shops, however, try to solve the problem of combining high-quality steel production and minimization of production costs by utilizing the existing material stock by trials without any preliminary researches to be carried out. Such an approach to solving the tasks on decrease in materials and energy consumption in steel industry is a kind of dead-end and cannot ensure compatibility of Ukrainian metal products on the global market.

The current research is intended to determine the consumption of initial materials and energy in steel industry, which is to allow revealing the hidden reserves of metal converting process and to develop the directions of energy consumption decrease.

Research methodology

In order to estimate the changes of material and energy consumption per a ton of steel during the metal converting process in BOF, there has been developed a program which allows metallurgists to calculation the BOF heat parameters with the use of present-day approaches to thermodynamics and kinetics of steel-making processes and the results of practical experience of the Ukrainian steel-making shops.

In these calculations the energy consumption is regarded as a key criterion of production energy efficiency and the amount of primary energy consumption is represented in the form of calculations for a kilogram of conventional fuel consumed per a ton of the steel product (kg of conventional fuel / t) embracing both the BOF processing and all the previous stages for receiving the initial materials of a required quality for the heat.

In course of researches, we obtained the data evidencing the impact of uncontrolled or partially controlled parameters of BOF heat (degree of CO to CO_2 post-combustion, carbon content in iron; heat loss of the BOF vessel; the amount of mixer slag; slag contamination in the scrap for the heat; losses at ignition in lime and magnisite flux) on energy consumption in the steel-making process. The BOF heat simulation has been carried out taking into account the following: slag basicity of 3.0 units; 0.18% carbon content in metal for heat correction; steel temperature of 1630 ^{0}C.

Results of the researches conducted

It is common knowledge that the most significant contribution to energy intensity is produced by hot iron. This fact is the reason why the first stage of the researches illustrated in fig. 1-7 has been carried out, providing improvements on BOF heat balance [1-4]. We have analyzed how various parameters influence the consumption of charge metal or the metallic part of the charge during the BOF heat. By metallic part of the charge we mean the conventional composition of initial materials in the Ukrainian BOF practice, that is, liquid pig iron + metallic scrap + metal recovered from slag mucks (hereinafter referred to as contaminated scrap due to high content of slag in it) + solid iron. Additionally, we clearly distinguish in the paper metallic scrap from metallic part of the charge as the former is a narrower notion and is the part of the latter.

According to the data received, the 2% increase in degree of CO to CO_2 post-combustion allows us to have 9.2 kg/t less in iron specific consumption while metallic scrap is to be 8.7 kg/t higher. Moreover, the enhanced post-combustion leads to significant decrease in the specific consumption of metallic part of the BOF charge down to the rate of 2.43 kg/t of final steel, at this, it is worth noting that the lower carbon content of metal (0.04%) leads to less economy on this kind of charge material (fig. 2). This is related to the development of iron oxidation processes at low carbon contents [5-7]. In a similar way, the energy consumption per steel is decreased (fig. 3). Upon that, it is important to note that with the same post-combustion degree it is possible to achieve more appreciable decrease in energy consumption if carbon content of metal is 0.04%. This is explained by the fact that due to iron oxidation, the subsequent increase in heat input of the heat balance is observed, which permits greater amount of prepared steel scrap to be processed.

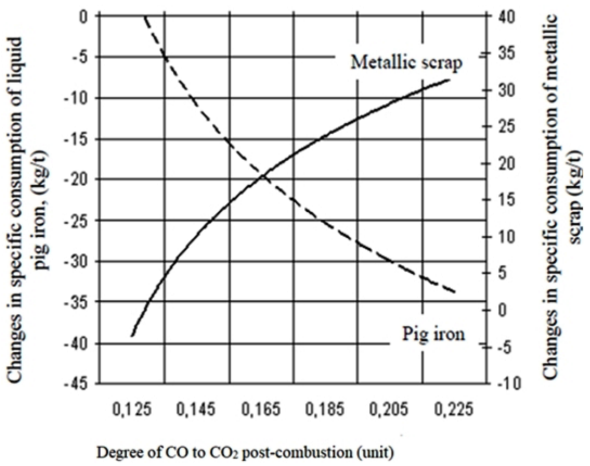

Figure 1. Graph to determine how the degree of CO post-combustion to CO_2 influences the specific consumption of metallic scrap and liquid pig iron

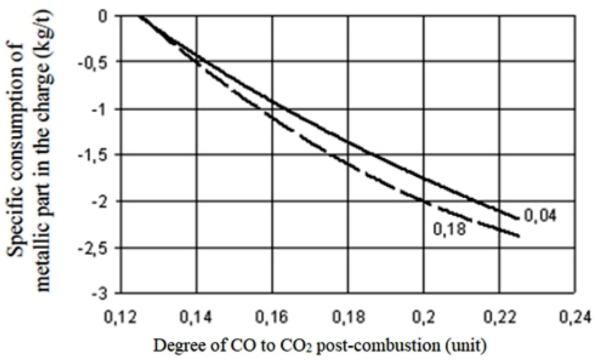

Figure 2. Influence of CO-to-CO_2 post-combustion degree on the specific consumption of metallic part of the charge (figures near the curves identify the carbon content in the metal for BOF charge)

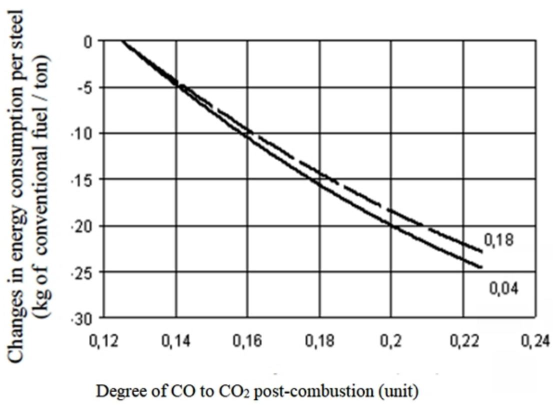

Figure 3. Influence of CO-to-CO_2 post-combustion degree on energy consumption for steel (figures near the curves identify the carbon content in the metal for BOF charge)

Furthermore, in modern BOF practice, there is still no mutually agreed answer on what concentrations of silicon in pig iron are rational and this is quite grounded. The point is that everything in this issue depends on the goals to achieve with the process – economy on materials or economy on energy carriers in the course of steel manufacture. More silicon in pig iron causes the significant increase in consumption of the charge metallic part at marked decrease in energy consumption per steel (Fig. 4). This is related with the increase in the incoming heat in balance and feasibility to increase prepared steel scrap utilization, which are to provide the decrease in energy consumption per steel. However, in this case the growth in the slag amount due to the needs for more lime in such a heat is observed and it causes higher metal loss and respectively makes the consumption of the charge metal higher.

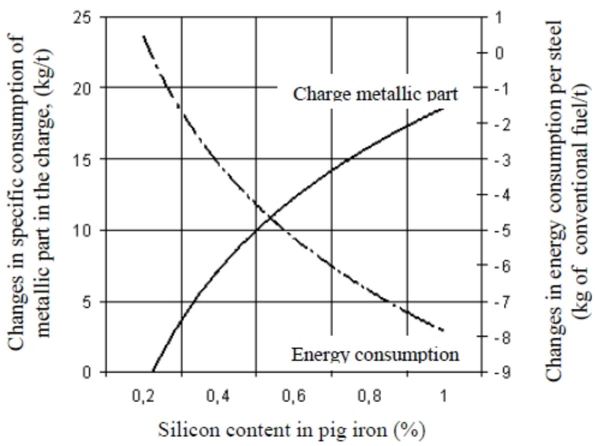

Figure 4. Graph to determine the influence of silicon content in pig iron on consumption changes both in charge metallic part and energy per steel

In figure 5, the results of the analysis on heat simulation with energy carrier (coal of AC grade) are shown; they evidence a small reduction in the consumption of charge metal and pig iron but this is accompanied with a significant growth in energy consumption per steel (up to 2 kg of conventional fuel per one ton of steel).

It may be quite interesting to trace how thermal loss with BOF and carbon content in iron influence the energy consumption per BOF steel. This type of research is also carried out and the data are reported in the graphical form in figures 6 and 7. According to the calculations performed, 1% higher increase in BOF heat losses causes extra energy consumption in the amount of 7 kg per of conventional fuel per a ton of steel, due to the necessity to meet the conditions of the heat balance with higher in pig iron consumption while 0.1% increase in carbon of pig iron allows energy consumption per steel to go down as much as 3.4 kg of conventional fuel per a ton of steel.

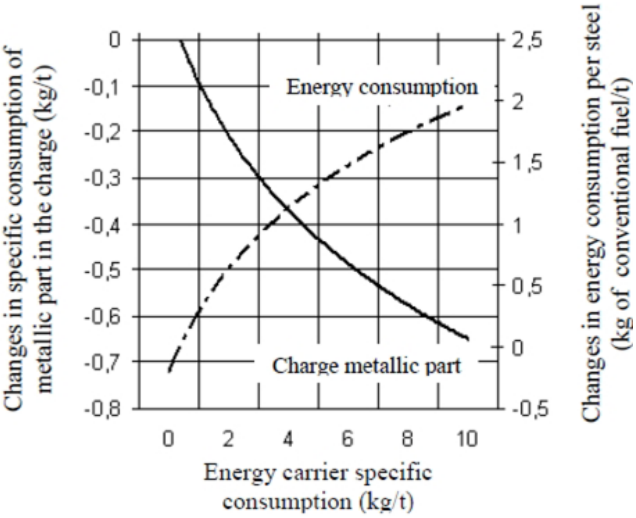

Figure 5. Graph to determine the influence of coal consumption on specific consumption of both metallic charge and energy per steel

The second stage of our research is devoted to the problem how the consumptions of charge constituents influence the changes in specific metallic part consumption and energy consumption per steel (Fig. 8-12).

In case if we substitute prepared steel scrap with contaminated scrap (recovered scrap extracted from slag mucks and reclaimed for the BOF heat), the latter with its slag content influences the melt quality. Fig. 8 and 9 illustrate the data, which show how the consumption of contaminated scrap with its slag affects BOF final metal. Taking into account the fact that energy consumption of contaminated scrap is smaller than that of prepared steel scrap, it is natural to expect the reduction in energy consumption when the steel manufacture. However, the data obtained evidence the appreciable amount of the metallic part consumption and respectively energy consumption per steel.

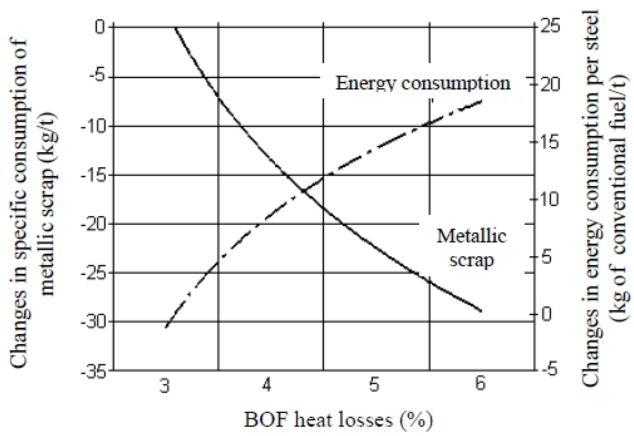

Figure 6. Graph to determine the influence of BOF heat loss on the changes in specific metal scrap consumption and energy consumption per a ton of steel

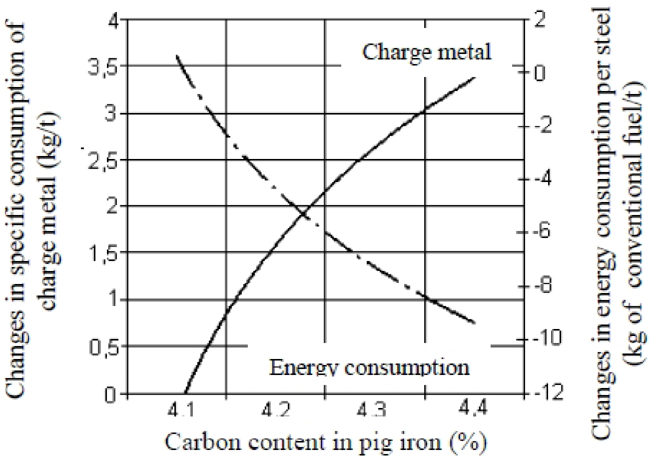

Figure 7. Graph to determine the influence of the carbon content in pig iron on changes in specific consumption of metallic charge and energy consumption per a ton of steel

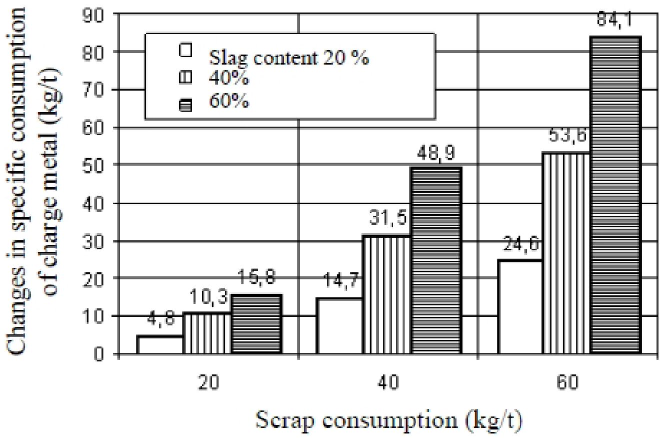

Figure 8. Influence of contaminated scrap consumption and its slag percentages on specific consumption of the metallic charge

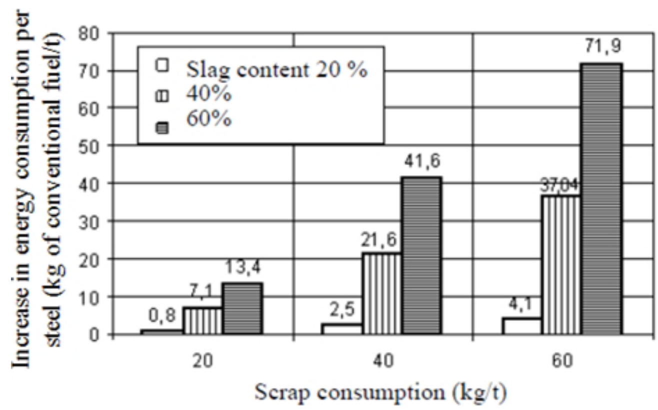

Figure 9. Influence of contaminated scrap consumption and its slag percentages on extra energy consumption per one ton of steel

The shortage of prepared steel scrap makes metallurgists apply solid iron within the charge in the BOF shops. The simulation analysis on BOF heat practice (Fig. 10) has shown that the use of solid iron causes the increase in consumption of the charge metallic part and fluxes, which consequently leads to the applicable increase in the energy consumption per one ton of steel. Here, it is worth mentioning that iron in the charge improves BOF heat balance to a certain extent since with the consumption rate of 10 kg of solid iron per one ton of steel we can observe the decrease in liquid iron consumption as much as 0.7-0.9 kg/t.

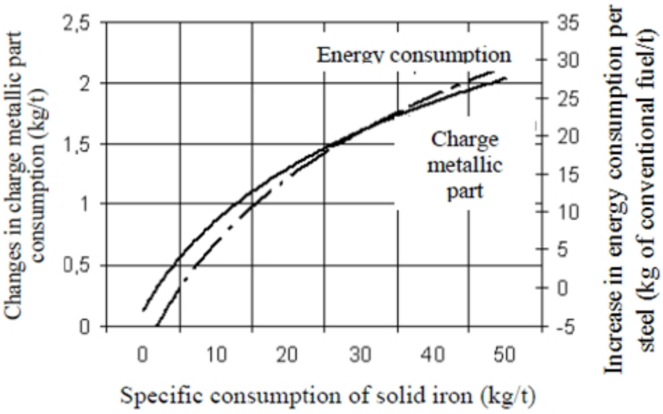

Figure 10. Graph to illustrate how solid iron consumption influences the consumption of metal charge and energy consumption per a ton of steel

The data on the influences in terms of quality and flux consumption for BOF heat are given in Fig. 11-14. The research has revealed that the increase in losses during lime and magnesite flux calcinations causes the growth of the metallic charge specific consumption and energy consumption per a ton of steel. Here, it is necessary to note that energy consumptions per lime and magnesite flux are assumed as constants for the calculations and the variations due to variants in $CaCO_3$ and $MgCO_3$ contents are not considered.

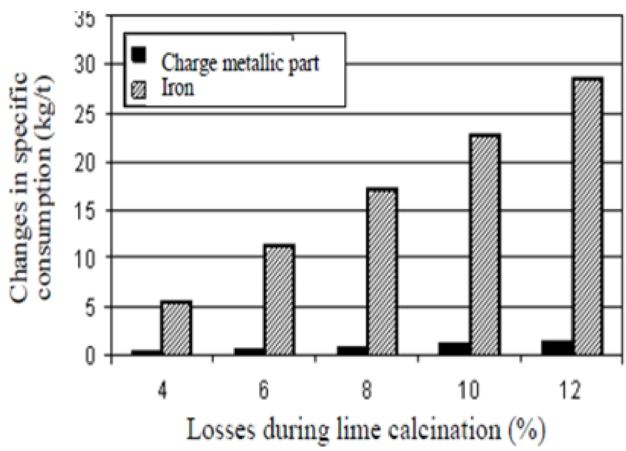

Figure 11. The influence of growth in losses during lime calcination on changes in iron specific consumption and metallic charge specific consumption

Based on the research performed, the bar diagram has been developed (Fig. 15) to show the average values of changes in energy consumption per a ton of steel and those in the metallic part of the charge for the variety of BOF production technologies, which are applied at Ukrainian metallurgical enterprises.

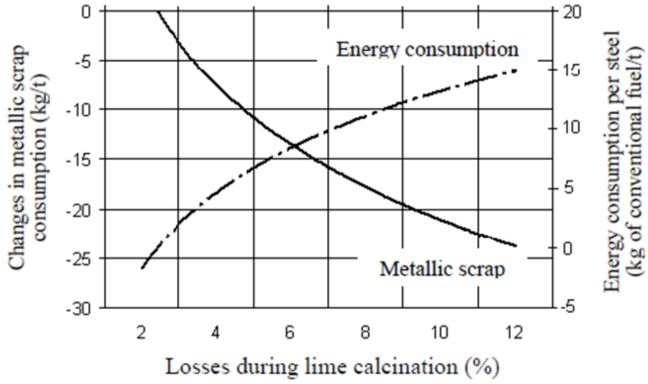

Figure 12. Graph to determine the influence of growth in losses during lime calcination on changes in metallic scrap specific consumption and energy consumption per a ton of steel

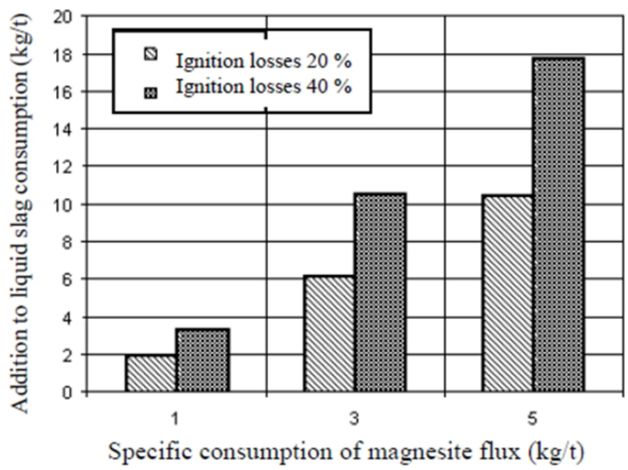

Figure 13. Influence of consumption and loss increase during magnesite flux calcinations on the changes in iron specific consumption

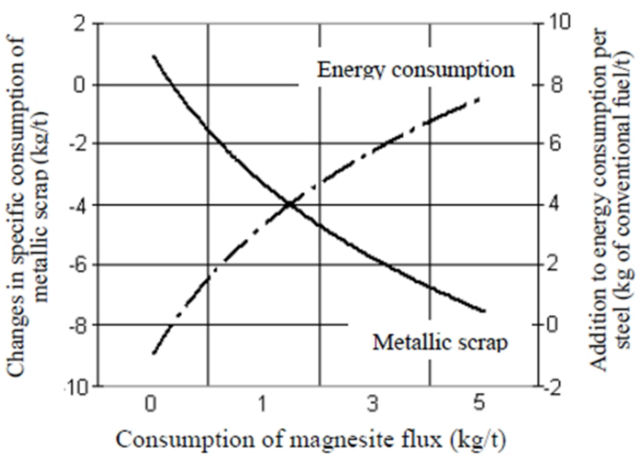

Figure 14. Graph to determine the magnesite flux consumption on the changes in metallic scrap specific consumption and energy consumption per a ton of steel

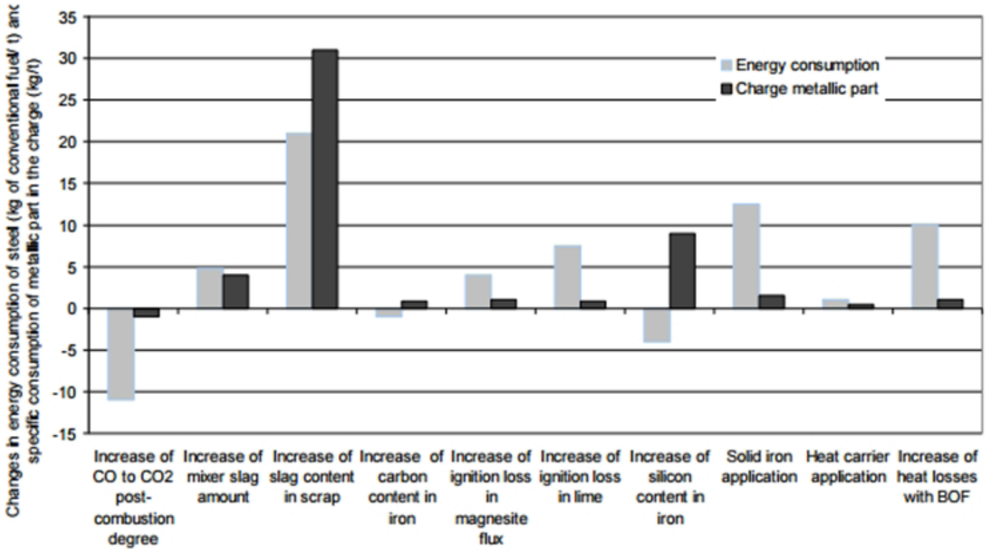

Figure 15. Average values of changes in energy consumption per a ton of steel and values of changes in charge metallic part consumption

Conclusions

The conducted research allows us to define the influence of the currently applied technologies and quality characteristics of the BOF heat materials on the changes in values of energy consumption per a ton of steel and the consumption values of metallic part in BOF charge. The received data show that the use of the additional agents in BOF heat (such as contaminated scrap, solid iron, magnesite flux, heat carrier) for the solution of the current production problems leads to a significant growth of energy consumption per one ton of steel, which could reach the amount of up to 42 kg of conventional fuel/ t. Upon that, we can also observe the increase in consumption of metallic part of the charge, which has the especially powerful influence on BOF production and economical indicators.

From the standpoint of decrease in energy consumption, the most attractive are those process engineering solutions that foresee as a priority the aim of achieving increase in post-combustion of CO to CO_2 within BOF vessel volume. It should be noted that the increase in silicon and carbon contents in iron also provide the decrease in energy consumption per a ton of steel.

Therefore, the present day of BOF production is featured with diversity of technologies and materials, applied in the course of converting metal that mostly leads to growth of energy consumption per liquid steel. That is why the problem of decrease in material and energy consumption in BOF production should be solved through the removal of the additional agents from the BOF heat and development of steel production schemes with respect to conditions of product range, materials and facilities of a certain steel-maker.

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