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HEAT LOSSES IN THE COOLING SYSTEM AND CONSUMPTION OF COKE TO COMPENSATE FOR THEM IN BLAST FURNACES OF VARIOUS VOLUMES

A. L. Chaika,[1] **V. V. Lebed',**[2] **K. S. Tsyupa,**[3] **V. Yu. Shostak,**[4]
B. V. Kornilov,[5] **A. A. Zherebetskii,**[6] **and A. A. Sokhatskii**[7]

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Data analysis has been performed concerning the limiting values of heat losses in the cooling system and consumption of coke to compensate for them in the blast furnaces, depending on their volume, technical condition, and smelting technology. It was shown that the consumption of coke to compensate for heat losses may vary from 10 to 55 kg of coke or more per ton of cast iron.

Keywords: blast furnace, cooling, heat losses, coke consumption.

The stages of blast furnace (BF) cooling systems and water management development at the metallurgical plants are associated with the history of enhancement of cast iron smelting, i.e., the use of hot blasting, increase in furnace volume and high top pressure, oxygen enrichment of hot blasting, and injection of fuel additives into the hearth [1–4].

Currently, the amount of heat losses with cooling water reaches 10 to 50 MW depending on the BF volume [4–6]. This item of heat balance of the smelting process is one of the most significant at the present level of blast-furnace process development when designing technical and technological measures to reduce the consumption of coke [7, 8].

As a result of analyzing multiple examinations of blast furnaces conducted by the experts of the Institute of Ferrous Metallurgy under the guidance of A. V. Borodulin, as well as research studies and audits, the authors have discovered that the amount of heat losses is an integral parameter characterizing the efficiency of furnace design and smelting technology from the perspective of reduction in coke consumption, increase in furnace campaign duration, and advantages of large volume BF [4–8].

The conducted studies have shown that the absolute value of heat losses, first of all, depends on the furnace volume. However, depending on furnace design, technical condition, radial distribution of gas flow, and the amount of produced cast iron, furnace heat losses may differ by more than twice (Fig. 1). The consumption of coke required to compensate for heat losses may vary from 10 to 55 kg of coke and more per 1 ton of cast iron [4–8].

Z. I. Nekrasov Institute of Ferrous Metallurgy, National Academy of Sciences of Ukraine, Dnepr, Ukraine.
[1] E-mail: chaykadp@gmail.com.
[2] E-mail: vitalii.lebid@gmail.com.
[3] E-mail: t.kirill.90@gmail.com.
[4] E-mail: shostak.vu@gmail.com.
[5] E-mail: balesan2209@gmail.com.
[6] E-mail: anton.zherebetskiy@gmail.com.
[7] E-mail: sokhatskyaa@ukr.net.

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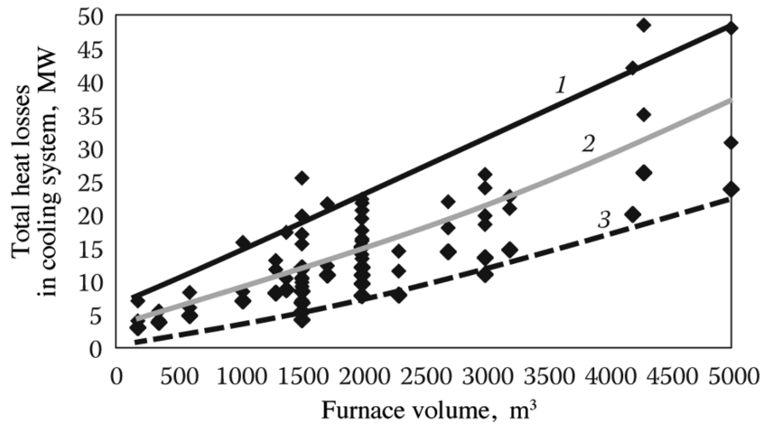

Fig. 1. Total heat losses of BF cooling system depending on its usable volume: 1 – maximum; 2 – medium; 3 – minimum.

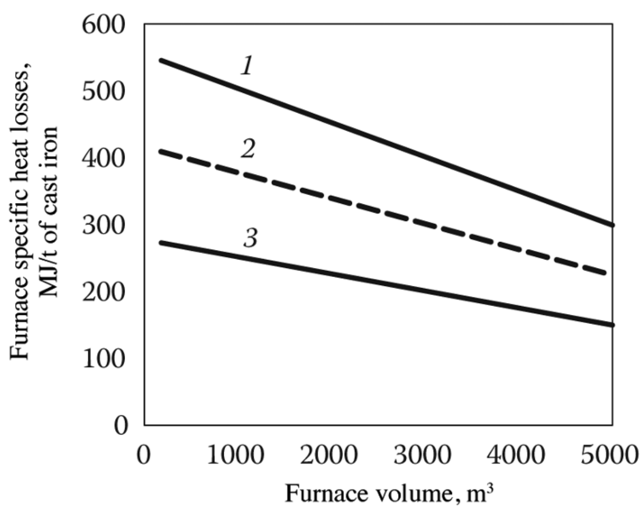

Fig. 2. BF specific heat losses depending on usable and capacity: 1 – 1.5 t/m^3; 2 – 2.0 t/m^3; 3 – 3.0 t/m^3.

As the furnace volume increases, so does the absolute value of heat losses, while its specific value per 1 ton of smelted cast iron decreases (Fig. 2). Hence, an increase in furnace volume is the main factor, which, under other equal conditions, allows reducing BF specific heat losses and, respectively, the consumption of coke required to compensate for them.

The second most significant factor affecting the compensation of coke consumption to cover for heat losses is the yield of smelted cast iron from 1 m^3 of usable volume of the furnace: the higher it is, the lower the specific heat losses and consumption of coke required for their compensation (see Figs. 2, 3).

To calculate coke consumption (K_{loss}, kg/t of cast iron) required to compensate for heat losses (Q_{loss}, MW) based on the heat balance of blast furnace smelting, the following relationship has been established [4, 9]:

$$K_{\text{loss}} \cong \frac{100}{Q_B^P \cdot C_c} \cdot \frac{Q_{\text{loss}} \cdot 3600}{\eta_C \cdot P} \cdot 1000, \quad (1)$$

where Q_B^P = 33,900 kJ/kg – total heat of combustion of coke-contained carbon; C_c – carbon content in coke, %;

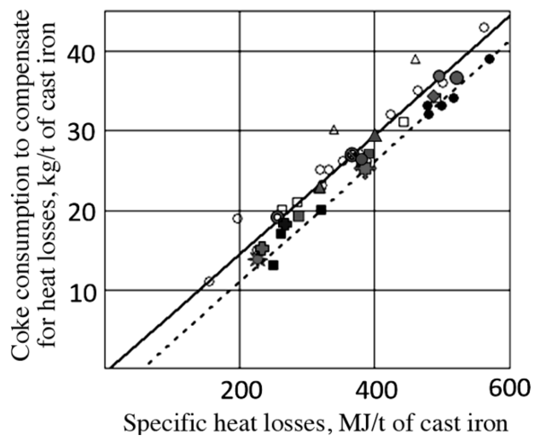

Fig. 3. Relationship between coke consumption (K_{loss}) per 1 ton of cast iron to compensate for heat losses and specific heat losses for BF with the usable volume from 1000 to 5000 m^3.

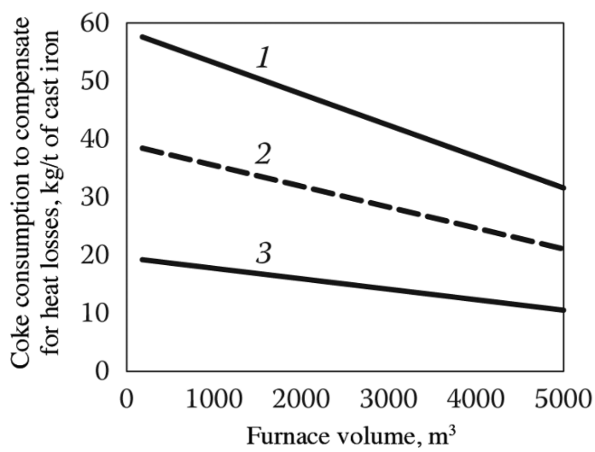

Fig. 4. Variation of coke consumption to compensate for heat losses depending on the usable furnace volume: 1 – minimum; 2 – medium; and 3 – maximum coke consumption.

P – furnace capacity, t/h; η_C – thermal power parameter (fuel heat-availability factor), which accounts for fuel combustion to form CO and the fraction of CO heat to melt and reduce cast iron (for normally operating furnace: $\eta_C = 0.45–0.5$) [1, 4, 9].

By generalizing the heat loss study results based on more than 40 BF across Ukraine and Russia, it became possible to determine the limiting values of coke consumption to compensate for heat losses depending on the furnace volume (Fig. 4).

The obtained range characterizes the amount of potential coke savings reserve due to an increase in furnace volume, reconstruction of the cooling system and lining, as well as technological measures to organize centralized gas distribution, reduction of lining wear, and furnace cooling system.

In 2014–2017, based on the technical specifications developed by the Institute of Ferrous Metallurgy (National Academy of Sciences of Ukraine), all furnaces of the blast-furnace shop of PJSC "Zaporozhstal" were equipped with the automated control systems to monitor the total heat losses in their cooling systems (ACS "Heat losses"), and three of them were equipped with the automated control systems to monitor shaft and crucible lining erosion (ACS "Shaft" and ACS "Hearth"), which allowed controlling and quantitatively estimate

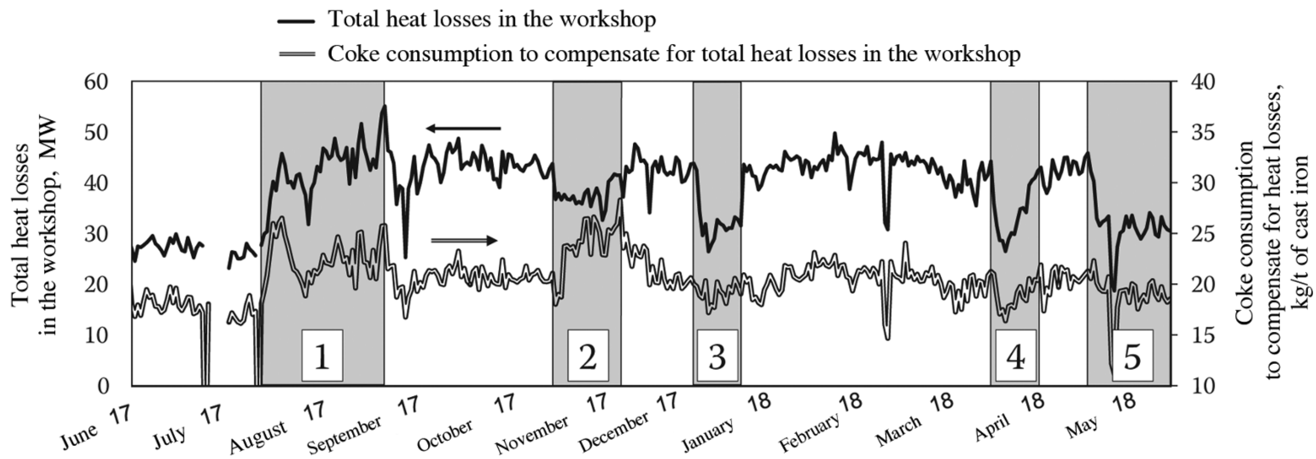

Fig. 5. Dynamics of total heat losses and coke consumption to compensate for them in the blast furnace workshop of PJSC "Zaporozhstal": 1 – starting-up and achieving BF-3 design parameters; 2 – BF-2 shutdown; 3 – BF-4 shutdown; 4 – BF-3 shutdowns and slow run; 5 – BF-5 shutdown.

the effect of technology and design solutions on heat losses and coke consumption to compensate for them in blast-furnace processes (Fig. 5).

The results of the heat losses automated control system operation and instrument measurements showed that the consumption of coke after the general overhaul (restoration) of the furnaces decreases by 8 to 26 kg/t of cast iron depending on the furnace condition after blowing-out and implementing changes to the lining and cooling system designs. For example, sprayed castable lining in the lower part of the shaft gets almost completely destroyed within the first six months from the startup, which leads to an increase in heat losses of the furnace with cast-iron coolers by 13 MW, and increase in coke consumption to compensate for such losses – by 26 kg/t of cast iron in comparison with silicon carbide refractory lining built into the vertical copper cooler [6].

According to the study data obtained in the blast-furnace shop of PJSC "Zaporozhstal", an increase in heat losses by 1 MW leads, on average, to an increase in skip coke consumption by ≈ 2.5 kg/t of cast iron, or by ≈ 0.7%.

CONCLUSIONS

The consumption of coke to compensate for heat losses in the cooling system of blast furnaces may vary from 10 to 55 kg of coke and more per 1 ton of cast iron depending on the volume, design and technical condition of the furnaces, as well as loading and smelting technologies.

The main directions for using the system of automated control and accounting for the total heat losses in the cooling system of blast furnaces are the following:

– determining deviations in external heat losses exceeding the limits of permissible values and norms;

– determining standard coke consumption rates considering heat losses in blast furnaces;

– justifying furnace restoration overhauls and increasing the volume of furnaces under construction;

– accounting for the amount of external heat losses and coke consumption to cover them when calculating technical and economic characteristics of furnace performance;

– using the information supplied by the system to assess the efficiency of the selected operating mode and search of a reserve of reducing coke consumption and fuel equivalent for cast iron smelting, increase in duration of furnace campaign;

– using the information on heat losses deviations to uncover “discrepancies” in furnace operation.

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