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EFFICIENT TECHNOLOGY FOR REDUCING THE AMOUNT OF ZINC THAT ENTERS BLAST FURNACES WITH THE CHARGE

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One of the consequences of zinc entering blast furnaces as an impurity in the charge materials is that it accumulates in the furnace and forms zincite crusts on the walls of the shaft and the top. A significant amount of zinc circulates inside the furnace. The exact amount is independent of the amount of zinc which enters the furnace with the charge and is instead determined by the properties of the charge materials and the volume and operating regime of the furnace. This has been confirmed by production data obtained from studies conducted on blast furnaces at the Magnitogorsk Metallurgical Combine (MMK) [1–3].

A total of 6–7 tons of zinc has been recovered from blown-out 1370-m^3 blast furnaces characterized by stable operation, while 8–9 tons has been recovered from furnaces that do not run smoothly. Totals of 8–9 and 10–11 tons of zinc have been recovered during the blowing out of 2014-m^3 furnaces in these two cases, respectively. The amount of zinc which can be removed with the use of special technologies also depends on the volume of the furnace. The zinc content of the slags formed during the blowout operation reached 35–55% [1–6].

The coke used in the circulation of zinc in a blast furnace is wasted. Based on the stoichiometry of the reaction, about 0.5 kg of coke is needed to reduce each kilogram of zinc under equilibrium conditions. However, the chemical reactions taking place in blast furnaces are far from equilibrium, and the degree of use of the thermal and chemical energy of the reducing gases $<<1$. According to different reports, from 2 to 12 kg of coke are needed to reduce 1 kg of zinc in a blast furnace [7]. The heat released during the secondary oxidation of zinc makes up for no more than 15–20% of the heat used in its reduction (based on stoichiometric relations).

Assuming that the average mass of zinc circulating in a blast furnace is 8 tons and that there are four circulation cycles, approximate calculations show that excess coke consumption stands at 65,000–350,000 tons per day and 23,000–120,000 tons per year. Excess coke consumption for all of the blast furnaces at the MMK totals 160,000–840,000 tons, i.e., even the minimum amount of coke needed to reduce the circulating zinc is greater than the amount of coke consumed in the production of pig iron in a 1370-m^3 furnace over 4 months.

Together with the periodic formation of zincite crusts – which distort the internal profile of the furnace and the gas flow and disturb the symmetry of the physicochemical processes that take place in the furnace – the excess coke continually needed to maintain the zinc circulation is an equally important reason to introduce measures to reduce the amount of zinc which circulates in blast furnaces [2, 3].

Studies conducted by the Ural Institute of Metals and the MMK consisted of two stages: study of conditions for and methods of removing zinc directly from blast furnaces operating under different regimes; development of effective measures to remove zinc from circulation in the sintering/smelting conversion.

New methods were presented in [2–4, 9–13] for periodically removing zinc from blast furnaces to improve furnace performance indices. Even more effective in improving subsequent furnace operation is blowing furnaces out for class-1 and

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class-2 overhauls and banking furnaces for class-3 overhauls. Half the zinc is removed in the last case, while all of it is removed during the first two types of overhauls.

Class-1 and class-2 overhauls are performed once every few years, while a class-3 overhaul is performed once a year. Thus, the advantage gained from the zinc removal is relatively short-lived compared to the nominal operating time of blast furnaces. Equally beneficial in terms of reducing the amount of circulating zinc is periodic removal of the element with the use of operational methods. In this case, it is necessary to keep zinc from entering the furnace with the sinter, which is made with top dust. In particular, sinter is made with top dust obtained from scrubbers in wet gas-cleaning systems.

Recycling iron-bearing wastes at the factory where they are generated is economically advantageous. However, the sludge from wet gas-cleaning systems is little used due to its high zinc content, and only the coarse fraction of top dust removed in dry scrubbers is employed in sinter production. This approach is essential and is dictated by the fact that the harmful consequences of the recycled zinc may be significantly greater than the advantage gained from substituting recycled factory wastes for unused raw materials. The situation is complicated further by the fact that costs are increased by the need to arrange for the storage of such sludge under environmentally acceptable conditions. In light of this, some of the zinc-bearing sludge now being formed in current production operations at the MMK is periodically used in the sintering-machine charge. From 10 to 40 kg of sludge are used per ton of sinter. The periods during which the sludge is used do not always coincide with the blast-furnace repair schedule. Thus, there may be times when a substantial amount of the recycled sludge will be sent to an operating furnace along with the sludge from a furnace which is under repair. This will disrupt the operation of the first furnace due to the abrupt change in the heat balance of the smelting operation.

The zinc content of the blowout sludge during the study period reached 45–55%. The zinc content remained quite high – 8–10% – even when this sludge was mixed with ordinary sludge (0.4–0.6% Zn). Also, the iron content of the blowout sludge was 15–25%, while the iron content of ordinary sludge ~50%.

It is necessary to do away with the use of blowout sludge in sintering while avoiding disruptions in blast-furnace operation and the operation of the system that transports sludge from the gas-cleaning system to the recyling shop. The key to solving this problem is the installation of a separate container that will allow sludge to be periodically drained from the pipes which connect the Dorr thickeners with the sewage system. Acting as a settling tank, the container will make it possible to separate as many fine zinc particles from the suspension as possible and later remove the thickened zinc-bearing mass.

In the existing system of pipes used for sludge transport at the MMK, the installation of such a container would remove very little ordinary sludge from the flow. Thus, the removal of zinc from the blowout slag of one of the furnaces (No. 1) would require the addition of the normal slag from just two other furnaces (Nos. 2 and 4). The same holds for the blowout slag from furnace No. 6, 7, or 8. Zinc can be removed from blast furnaces Nos. 9 and 10 without the addition of ordinary slag from another furnace, since the slag from these two furnaces can be sent to the Dorr thickeners for the relatively brief period of time required to replace the sludge control valve.

A minimal amount of mixing of ordinary and blowout sludges is needed to prevent a greater loss of iron. The iron in the unmixed ordinary sludge can be returned to the production cycle while a substantial amount of zinc is being recovered. The higher the zinc content of the sludge, the more valuable the sludge is as a raw material for nonferrous metallurgy.

The average zinc content of the sludge obtained in the blowout of blast furnaces during class 1 and 2 overhauls can be kept high if the separate container is used for sludge that contains zinc only from the central part of the upper circulation zone – where the zinc concentration is highest. When the recycling plan specifies the removal of the maximum possible amount of zinc from the sinter, then it may be possible to blow out one furnace while simultaneously removing zinc from another furnace if the wastes from the gas-cleaning system of the latter are normally sent to the Dorr thickeners.

It takes 2.0–2.5 h to remove zinc from the region of the shaft where the concentration of this element is highest. This corresponds to the removal of 1100–1200 m^3 of sludge water from the gas-cleaning system, and that figure also determines the required size of the settlng tank. When the Dorr thickeners are full, some of the water is sent to the circulation loop. Thus, the amount of water that will enter the sludge lines and, thus, the separate container will be smaller than the amount that will enter the gas-cleaning system and the Dorr thickeners. This will allow extra time to remove zinc from the furnace and fill the settling tank.

The existing conditions at the MMK make it relatively easy to link the separate container with the system of sludge lines. The collector of the main line is near (25–30 m) the platform that can be used to install the 1000-m^3 container (at zero elevation). The required reconstruction will involve installing a system of gate valves ahead of the collector. This will switch the sludge flow from the feed line of each Dorr thickener to the special container, with the clarified water then being able to be returned to the main.

The settling tank is rectangular and measures $40 \times 15 \times 1.7$ m^3. Movable partitions were installed inside the tank to separate it into 2–3 successive sections. This was necessary to ensure natural separation of the sludge suspension during the filling of the tank, since the suspension consists of particles of different sizes and densities that will settle after different periods of time. The separation process will be efficient because the particles of zinc oxide comprise the most finely dispersed part of the suspension and – as shown by experience in obtaining samples of sludge – these particles are the last to settle. The first particles that will settle are the heavy and relatively coarse iron-bearing and mineral particles. Thus, the deposit that will accumulate in the first section will have a high iron content relative to the initial value, while the deposits in the succeeding sections will have high contents of zinc. The quality of the deposit as a raw material for the recovery of zinc will be greater becuase some of the components that are harmful to the zinc extraction process will have already been removed [14].

A sharp variation in the composition of the deposits over their height was noted when the Dorr thickener was filled with sludge water obtained from the gas-cleaning system of the blast furnaces that were being blown out. The amount of zinc in the lower layers of the central part of the thickener (where the water enters the unit from the gas-cleaning system) was minimal, and most of these layers consisted of an iron-bearing deposit. Zinc content increased from the lower layers to the upper layers, where the concentration of zinc was 1.5–2.0 times greater than the average [8].

The volume of the first section during the flow of the water is an important factor in the separation process and can be determined experimentally, since no one has had experience in the flotation separation of sludge from the gas-cleaning systems of blast furnaces. The dimensions of the second and third sections – and even the presence of a third section – are less critical.

When the temperature of the water leaving the gas-cleaning system is within the range 60–70°C, the fine particles of zinc oxide form colloids. These colloids break down very slowly, and their complete deposition can take 3–7 days. Their formation causes a significant portion of the zinc (16–20%) to be carried away with the water that spills over the sides of the Dorr thickener. Suspended zinc oxide constantly circulates with the water delivered to the gas-cleaning system when the system operates in a closed cycle. This phenomenon would be a useful factor if the sludge suspension were to be separated in an independent settling tank not connected to the above-described sludge treatment system.

After all of the zinc has settled, the clarified water is sent back to the main and the deposit is removed from the tank. The latter task can be accomplished with the use of a ladle-type elevator or heavy-duty pumps. The iron-bearing part of the deposit can be returned to the metallurgical production cycle.

In order to be able to separate blowout sludge from ordinary sludge by using an independent settling tank, the temperature of the air must be 2–3°C. At lower temperatures, the water in the settling tank will cool and freeze over a period of days, leading to cracking of the tank. To make the above-described integrated technology as efficient as possible, it is best if the repairs to the blast furnaces are scheduled so as to conform to the technology's requirements.

Thus, the method described here for separating blast-furnace sludges makes it possible to do the following:

• improve the technical-economic indices of blast-furnace smelting and stabilize furnace operation;

• make use of zinc-bearing metallurgical waste products with miminal impact on the smelting operation. The technology also allows certain operating procedures to be used on blast furnaces to plan for the eventual removal of zinc from the furnaces in accordance with a set schedule;

• remove just the blowout sludge with an iron content of 15–25% from the sintering-machine charge (instead of all such sludge generated during the overhaul of a blast furnace), since it is unsuited for use as an iron-bearing raw material. The iron-bearing part of the separated sludge could also be returned to the metallurgical production cycle;

• avoid large expenditures on the anti-pollution measures that would otherwise be needed for the storage of high-zinc sludge.

Rough calculations show that 70–90 tons of sludge could removed each year from the flow of materials used in sinter production. The projected savings in the blast-furnace shop alone due to the periodic reduction in the amount of zinc circulating in the furnaces and the permanent elimination of some zinc from the production process total at least seven million rubles a year.

REFERENCES

1. Yu. P. Shchukin, I. E. Kosachenko, V. I. Sedinkin, et al. "Relationship between the formation of zincite crusts and blast-furnace smelting practice," *Stal'*, No. 4, 13–15 (1994).
2. V. I. Sedinkin, *The Accumulation of Zinc in Blast Furnaces and the Development of a Technology for Its Removal: Engineering Sciences Candidate Dissertation.* Magnitogorsk (1998).
3. Yu. P. Shchukin, V. S. Novikov, B. A. Marsuverskii, et al., "Main law governing the behavior of zinc in blast furnaces," *Stal'*, No. 2, 5–9 (1992).
4. Yu. P. Shchukin, V. I. Sedinkin, I. E. Kosachenko, et al., "Results of commercial trials of new methods of removing zinc from blast furnaces at the MMK," in: *Third International Congress of Blast-Furnace Operators: Summary of Documents.* Novokuznetsk (1995).
5. Yu. P. Shchukin, V. I. Sedinkin, V. A. Gostenin, et al., "Results of the introduction of a new technology for removing zinc from the blast furnace," *Stal'*, No. 3, 11–13 (1997).
6. Yu. P. Shchukin, V. V. Filippov, V. S. Rudin, et al., "Effect of the regime used to process smelting products on blast-furnace operating parameters and zinc accumulation inside the furnace," *ibid*., No. 6, 3–6 (1998).
7. V. V. Kaporulin, G. I. Urbanovich, E. V. Nevmerzhitskii, et al., "The problem of zinc in blast-furnace smelting," *ibid*., No. 11, 9–15 (1984).
8. Yu. P. Shchukin, V. I. Sedinkin, and S. N. Nefedov, "Removing high-zinc blast-furnace sludge from the production cycle," *ibid*., No. 11, 13–17 (1999).
9. Yu. P. Shchukin, A. A. Deryabin, V. I. Sedinkin, et al., Russian Patent No. 2025491, MKI C21B 5/00, "Method for blast-furnace smelting of a zinc-bearing charge," *Byull. NTI*, No. 24, 6 (1994).
10. Yu. P. Shchukin, A. A. Deryabin, V. I. Sedinkin, et al., Russian Patent No. 2058394, MKI C21B 5/00, "Method for blast-furnace smelting of zinc-bearing charges," *Byull. NTI*, No. 11, 12 (1996).
11. Yu. P. Shchukin, A. A. Deryabin, V. I. Sedinkin, et al., Russian Patent No. 2058393, MKI C21B 5/00, "Method for blast-furnace smelting of charges based on iron ore," *Byull. NTI*, No. 11, 10 (1994).
12. Yu. P. Shchukin, A. A. Deryabin, V. I. Sedinkin, et al., Russian Patent No. 2078830, MKI C21B 5/00, "Method for blast-furnace smelting of zinc-bearing charges based on iron ore," *Byull. NTI*, No. 13, 6 (1997).
13. V. I. Sedinkin, V. A. Gostenin, Yu. P. Shchukin, et al., Russian Patent No. 2074893, MKI C21B 5/00, "Method for blast-furnace smelting of zinc-bearing charges," *Byull. NTI*, No. 7, 11 (1997).
14. D. M. Chizhikov, *The Metallurgy of Nonferrous Heavy Metals* [in Russian], Izd. AN SSSR, Moscow–Leningrad (1948).