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Analysis of the ways for the disposal of gas cleaning dust and sludge at the metallurgical enterprises

Iron and steel industry production is accompanied by generation of large amount of solid industrial residuals. Thus, annual reproduction of solid industrial residuals at the iron and steel enterprises of the Ural region comprises over 120 million tons. The basic processes for industrial residuals disposal and recycling have been considered and the simplest and most promising process, such as briquetting, has been emphasized. Recycling of iron and zinc containing dust and sludge from EAF gas cleaning systems into steelmaking processes is the most perspective solution to the problem of their disposal up to date; furthermore, it does not require a high capital expenditure and processing costs. Preference should be given to a common and reliable option for recycling of iron and zinc containing dust and sludge into the steelmaking processes in the form of slag-forming and metal charge (oxide and carbon) briquettes.

Keywords: *disposal, cleaning, Zn-containing wastes, solid residuals, dust, sludge, slag-forming briquettes, oxide-carbon briquettes.*

Iron and steel industry production is accompanied by generation of large amount of solid industrial residuals. Thus, annual reproduction of solid industrial residuals at the iron and steel enterprises of the Ural region comprises over 120 million tons, the South Urals accounted for 75% of them. At present time, 4 billion tons of industrial residuals, that can be recycled, have been already collected in the Chelyabinsk region. It is known that about 100–120 billion tons of solid industrial residuals are already stored on the territory of the Russian Federation, and annually 5–7 billion tonnes are additionally generated. Only 2 billion tonnes per year (mainly slag) are currently reused. For a variety of reasons, small and fine industrial residuals (especially gas cleaning dust and sludge) are utilized unsatisfactorily and they are collected in the dumps, sludge collectors and chambers. The latter is followed not only by the loss of valuable raw materials for both its own primary metallurgical production and for the other industries, but also leads to the withdrawal of large areas from circulation, environmental pollution and consequently to the additional economic losses (more than $ 100 / t of residuals, according to foreign sources).

The recycling of dust and sludge from gas cleaning units in the electric arc furnaces (EAF) is especially acute with the advanced development of electric steel production in the world. The reason is in the high content of zinc (up to 30 % or more), that does not enable to use them in sinter and pellets production for pig iron smelting in a blast furnace. In Russia, all EAF dust is currently being collected in the dumps and sludge collectors. The position abroad is somewhat better. But, in general, the effective solution for the dust disposal has not been found yet.

At present, more than 7 million tonnes of dust are generated annually in the world in steel smelting in electric arc furnaces. About 1 million tonnes is generated annually only in the EU countries and about 70% from this amount have been sent to the dumps lately. It is true that the situation for several countries is quite different in this area, due to the various requirements and standards for the dust emission into the environment, availability of space for its disposal, taxation and other economic aspects. So, already in 1996 the share of recycled dust in Austria, Germany and the Benelux countries exceeded 80%. At present time, thanks to the EU environmental policy, the amount of recycled dust reaches 100% in the Benelux countries and 98% in Germany [1].

At the same time, the removal of zinc from dust and sludge is complex, expensive and not always effective task. The reason for this is that zinc generally occurs in the form of hard recovering compounds: ferrites, silicates, sulphates and sulphides. The following methods for zinc removal from iron dust and sludge, are known or have been tested up to date such as gravitational, pyrometallurgical, metallurgical and hydrometallurgical methods.

Pyrometallurgical methods are widely used in the process of zinc removal from dust and sludge. These methods combine the processes of reduction of solid carbonaceous material (such as coal, coke) with the sublimation of metallic zinc, lead and other volatile impurities (the analogue of the Waelz process in non-ferrous metallurgy) [2]. The advantage of pyrometallurgical methods for zinc removal from dust and sludge at steelmaking shops of metallurgical enterprises is a high degree of lead and zinc removal (up to 75–90%) with the simultaneous production of metallized Fe-containing product in the iron and steel production. But they have also large disadvantages, such as complexity of the technological scheme and dust collection systems and, as a consequence, large capital expenditures; high energy consumption and processing costs; high pyrophoricity (to the spontaneous ignition) of the resulting metallized product (sponge iron); possibility of environmental pollution.

Thereby, in most cases, pyrometallurgical processes of zinc removal from dust and sludge are unprofitable and exist due to the allocation of funds aimed to the environmental protection. According to the statistics of Hamburger Stahlwerke (one of the largest steel companies), preliminary zinc removal of a dust ton, accompanied with production of crude zinc concentrate (up to 32% Zn), costs 100 Euros. Therefore, even in Japan 40% of EAF dust containing iron and zinc is subjected to detoxification and used for reclamation [3].

Due to irregularity and insufficient efficiency of the existing methods for zinc removal from iron and zinc containing dust and sludge, as well as the rapid development of electric steel production and strict environmental requirements, in the 1970-ies the idea and the program for recycling of iron- and zinc-containing dust and sludge into its own production of iron and steel enterprises were proposed and implemented. Steelmaking units are the main object for recycling, where the harmful effect of zinc (as in a blast furnace) is not observed because of the oxidation process.

According to the research of ESM (USA) specialists, recycling of dust from steelmaking shops into own production has the following advantages [4]:

1. Iron removal directly from the dust by the liquid bath, omitting the zinc removal process;
2. Increase of steel yield during melting;
3. Enrichment of newly forming and recovering dust with zinc and other volatile elements (Pb, Cd), that allows it to be used at non-ferrous metallurgy plants;
4. Alloying elements, contained in dust, such as Ni, Cr, V, Mo, Nb, etc. are easily utilized in an electric furnace in the manufacture of alloy steel;
5. Relatively small costs for the dust disposal.

There are two types of dust (sludge) recycling in steelmaking processes:

1. gas-carrier stream injecting into the liquid bath;
2. dust (sludge) loading into the steelmaking unit in the formed pre-agglomerate.

Krupp Edelstahl Profile (KEP) and Forschungsgemeinschaft Eisenhüttenchlacken (Germany), as well as Det Danske Stalvalsev (DDS, Denmark) were the first companies who studied the idea of dust recycling from dry BOF gas cleaning by its injection. Dust was applied to the slag-metal boundary within 10 min (in an amount of 80–150 kg/min) by a gas-carrier stream (dry air under pressure 0.6 MPa) with a special pneumatic unit. Zinc and lead content in the newly recovered dust increased by 1.5–2.0 times per cycle. The average amount of zinc in this dust constituted 40%. On the next stage dust was withdrawn from the furnace system, agglomerated and transported to the non-ferrous metallurgy plants. The balance melting processes showed that all blowing dust zinc was sublimated and recovered again. The dust blowing does not affect on the process of steelmaking in a furnace in no way and practically does not affect on the zinc content in metal and slag. The dust removal is decreased by 30%. In the late 1990ies, recycling of iron- and zinc-containing dust by injection was introduced in the 100-t electric arc furnaces of Steel Co. Sheerness (CARBOFER process, the U.K.,) and in the electric arc furnaces with 140 t capacity by KEP (Germany). Unreliable pneumatic conveying and dust shipment to the metal can be considered as disadvantage of dust recycling by injection [5].

Taking into account the unreliability of the system for dust shipment to the metal by a gas carrier stream, the company Stelko Inc. (Canada, 1993–94) investigated its shipment to the melting unit in the form of agglomerates. 50 thousand tons of dust were recycled in the 150 ton capacity converters at the company's mills in Hilton, while 30 thousand tons of sludge from its own gas cleaning plant were recycled in the 230 ton capacity converters in Lake Erie. Prior to agglomeration, dust and sludge were subjected to briquetting and extruding respectively. Transportation and loading of agglomerated materials did not cause any organizational difficulties. The extruded material was fed into the plant in bags, but the briquettes were transported by the conveyors and charged in different ways: with scrap in the furnace charge or through the upper bunker, before and after iron discharging or together with bulk materials.

To compensate heat losses during pelletizing, carbonaceous blast furnace dust and sludge (17% each of them) and briquettes - coke breakage (22%) were added to the mixture to obtain extruded materials. Under any way of loading the agglomerated materials into the converter, there were no emissions during the melting process. The oxygen level in the furnace hood of gas discharge system remained at a safe level. The sulfur and phosphorus content in metal was in the usual range. Closed-loop recycling of EAF dust was put into practice in the mills of Bethlehem Steel, Babcock and Wilcox, Empire-Detroit Steel, LASCO, ARMCO, where the electric furnace dust is added to the charge in the form of pellets or briquettes. Crucible Steel Company (USA) reuses all the dust that is generated in the electric arc-furnace plant of Midland works. This plant produces alloy steels. Dust recycling facilitates to use the alloying elements present in charge materials more widely [6, 7].

Recycling of dust and sludge containing iron into the iron and steel industry in the form of agglomerates can be put into practice by producing slag-forming and metal charge (carbon and oxide) materials on their basis. The first materials can radically improve the process of slag formation. Slag-forming materials with complex composition in the formed briquettes were successfully tested in due time in the open-hearth and two-bath furnaces (Magnitogorsk Iron and Steel Works (MMK), Dneprovsky Integrated Iron and Steel Works named after Dzerzhinsky and Azovstal Iron & Steel Works) and in the basic oxygen converter process (EVRAZ-DMZ Petrovskogo and Arcelor-Mittal Kryvyi Rih). The investigation carried out in the late 1990ies in Volgograd State Technical University and pilot melting in the electric arc furnaces of Red October Volgograd Steel Works and the Byelorussian Steel Works showed that the oxide-coal briquettes can be effectively used in electric steelmaking as alternate materials for iron and steel scrap [8].

Both slag-forming and oxide-carbon preliminarily agglomerated materials with required composition can be produced only by briquetting. The creation of original and effective technology to produce a wide variety of briquettes, including slag-forming and oxide-carbon, from various materials and waste fines resulted from the long-term work at the Chair of Iron and Sreel Metallurgy of Nosovov Magnitogorsk State Technical University. The technology was tested on the punching presses of refractory production of MMK, as well as on the punching and roller presses of the briquetting department of blast-furnace plant and refractory production of BMC OJSC.

Conclusions

1. Recycling of iron and zinc containing dust and sludge from EAF gas cleaning systems into steelmaking processes is the most perspective solution to the problem of their disposal up to date; furthermore, it does not require a high capital expenditure and processing costs.

2. Preference should be given to a common and reliable option for recycling of iron and zinc containing dust and sludge into the steelmaking processes in the form of slag-forming and metal charge (oxide and carbon) briquettes.

REFERENCES

1. Stovichenko A. P., Kampina L. V., Proydak Yu. S. et al. Protsessy utilizatsii pyli staleplavilnogo proizvodstva. Chast 1. Vysokoproizvoditelnye promyshlennye protsessy pererabotki pyli i drugikh zhelezosoderzhashchikh otkhodov (The recycling processes of steelmaking dust. Part 1: High-performance industrial processes for dust and other iron containing residuals processing). *Elektrometallurgiya* = Electrometallurgy. 2010. No. 1. P. 32.
2. Abdeyev M. A. Veltsevanie tsink–svinetssoderzhashchikh materialov. Uchebnik (Waelz process of zinc and lead containing materials. Textbook). Moscow. *Metallurgiya* = Metallurgy. 1985. 120 P.
3. Vozhdayev V. P. Utilizatsiya zhelezosoderzhashchey pyli elektrodugovoy pechi i umenshenie vrednykh vybrosov. (The disposal of iron containing dust from arc furnace and reduction of harmful emissions. Magnitogorsk. *KTsPK «Personal»* = CCPT "Personnel". 2009. 77 p.
4. Shalimov A. G. Retsirkulyatsiya otkhodov chernoy metallurgii (Recycling of iron and steel industry residuals). *Novosti chernoy metallurgii za rubezhom* = News of ferrous metallurgy abroad. 2000. No. 3. P. 53–55.
5. Lopukhov G. A. Poluchenie bolee kachestvennoy pyli v dugovykh pechakh firmami «Krupp» i «DDS» (Obtaining the higher quality dust in arc furnaces of Krupp and DDS). *Novosti chernoy metallurgii za rubezhom* = News of ferrous metallurgy abroad). 1997. No. 2. P. 59–63.
6. Vishkarev A. F. Retsikling pyley i shlamov v konverternykh tsekhakh (Recycling of dusts and sludges in converter shops). *Novosti chernoy metallurgii za rubezhom* = News of ferrous metallurgy abroad). 1996. No. 3. P. 70–72.
7. Kokorin V. N., Grigoryev A. A., Kokorin N. V. et al. Promyshlennyy retsikling promyshlennykh otkhodov. Uchebnoye posobiye (Industrial recycling of industrial residuals. Textbook). Ulyanovsk. UlGTU (Ulyanovsk State Technical University). 2005. 42 p.
8. Godansky N. A. Opyt ispolzovaniya zhelezouglerodosoderzhashchikh briketov v elektrostaleplavilnom proizvodstve (The experience in the use of iron containing briquettes in electric furnace steelmaking). *Metallurg* = Metallurgist. 2003. No. 1. P. 43–45.