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DEVELOPMENT OF CHARGE PELLETIZING TECHNOLOGY BASED ON ELECTRIC ARC FURNACE DUST FOR PYROMETALLURGICAL PROCESSING IN ROTARY KILNS

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New technology is developed for Waelz treatment of electric arc furnace dust with the addition of calcium oxide to a charge. In this case, lead and halides are transferred into distillates. Calcium ferrite and zinc oxide remain in clinker. Clinker is sent for leaching zinc followed by zinc electrolysis from solution. The insoluble residue of calcium ferrite is used in ferrous metallurgy. The efficiency of this technology is determined by the process of charge preparation for loading into a Waelz kiln. In order to provide complete reaction of zinc ferrite with calcium oxide, it is necessary to provide effective component mixing; in order to provide selectivity of halide and lead liberation, reducing distillate volume, a powder mixture is pelletized. Exploratory research is conducted for preparing pellets of a mixture of electric arc furnace dust with lime, and the effect of some binder reagents on pellet strength is demonstrated. The following optimum parameters are determined for charge pelletizing from electric arc furnace dust and calcium-containing flux under conditions of a plate-like granulator: pelletizing duration 15 min; granule moisture content 19–20%. With the use of an intense type mixer-pelletizer, the optimum moisture content is 13–14%, which is connected with the improved conditions for pellet compaction. Comparison of various inorganic and organic additives for mixture granulation shows that the best are additives containing sodium hydrate sulfate, although their optimum consumption is unacceptable for the technology of material pyrometallurgical treatment. The presence in the production mixture of calcium-containing flux makes it possible to use it also as a binding additive for pelletizing calcium hydroxide in the form of an aqueous suspension. Feeding a pelletized mixture of electric arc furnace dust with lime into a Waelz kiln makes it possible to provide effective reaction of charge components in the kiln and to reduce to reduce escape of dust.

Keywords: *electric arc furnace dust, Waelz processing, charge preparation, mixing, pelletizing, calcium oxide, binder.*

Electric arc furnace (EAF) zinc-containing dust is a valuable source for preparing zinc metal [1]. In 2015, of more than 13 million tons of zinc produced in the world 4 million tons were produced by recycling.

About 83% of EAF dust is processed in Waelz kilns (Japan, Turkey, Bulgaria, USA, Germany, etc.). Alternative technology (Ausmelt, Contop, Enviroplast, IBDR-ZIPP, Indutec, MRP, PEL, Plasma-Dust, Primus, etc. [2–4]) has not been used extensively due to the relatively low zinc content in dust and the complexity of utilizing the slag formed in ferrous metallurgy.

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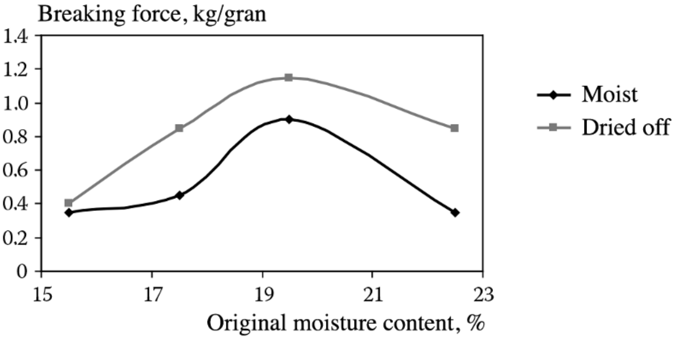

Fig. 1. Effect of pelletizing moisture content on strength (granule breaking force) of moist and dried-off granules 4–5 mm in size.

EAF dust (EAFD) consists predominantly of particles with a size of ~10 μm and has bulk density of 1.1–2.5 g/cm^3 [2]. Processing of dusty material is possible in a Waelz kiln only under prior pelletizing conditions in order to minimize dust escape and contamination of the Waelz oxide obtained with original products. During pelletizing, coke fines and fluxing additive are introduced which provides effective contact of materials during processing in a Waelz kiln. These additives serve as zinc reducing agents [1], and also in order to increase the slag fusibility temperature (its products containing calcium and magnesium oxides [5–8]). For some forms of EAFD, it is effective to use silicon-containing additives and binders (water glass type).

In world practice, for charge preparation based on AEFD for pyrometallurgical treatment briquetting [9], pelletizing in plate-like pelletizers [10], and Eirich intensive type mixer-pelletizers are used.

On the basis of studying thermodynamic and kinetic properties of zinc ferrite reaction (more than 50% in the EAFD composition) with calcium oxide, and also processes leading to distillation of zinc, and metal chlorides and fluorides at 600–1100°C, a new Waelz technology has been developed making it possible to remove zinc, chlorine, and fluorine compounds from EAFD, and in this case an increase in the proportion of free ZnO in clinker. After selective leaching of zinc from clinker a product is obtained consisting mainly of $Ca_2Fe_2O_5$, which may be used in ferrous metallurgy.

During the development of the technology, material preparation for calcining was studied: mixing of EAFD with fluxing additive and pellet formation. In particular, the effect of a number of additives on pellet strength and also the strengthening process were studied.

For pelletizing, a mixture was used containing 77% Severstal AEFD, 23% commercial calcium oxide (obtained from limestone firing dust). This ratio was prescribed proceeding from data determined during development of calcining technology.

With respect to grain size composition, the original components contained 92–95% fraction coarser than 0.063 mm. Material for mixing and pelletizing was dried and sinter with a size more than 0.2 mm was broken.

Pelletizing was performed in a plate-like pelletizer (plate diameter 500 mm, side height 50 mm, inclination to the horizontal 42°, plate rotation frequency 14.8 rpm). The last two parameters were determined previously as the optimum for this pelletizer.

A mixture (3 kg in weight) prepared by intense mixing of dry powders was loaded on to the pelletizer plate and sprinkled uniformly by liquid binder for 60 sec, then pelletizing was continued for 5–25 min.

At the end of the pelletizing process, granules were classified on laboratory screens; granules were selected from the samples obtained 4–5 mm in diameter for testing breakage under pressure (breaking force was determined in kilograms for load on a single granule). Testing was performed for freshly prepared granules of this size and the remaining part of the granules was dried at 23–25°C at atmospheric pressure for 20–24 h (to a residual moisture content of 0.5–1.5%), and granule strength in compression was determined during drying.

At initial stage, pellet optimum moisture content was determined by experiment during formation for 15 min. The binder solution used was sodium lignosulfonate with a concentration of 25 mg/liter. Results of the studies are given in Table 1 and Fig. 1.

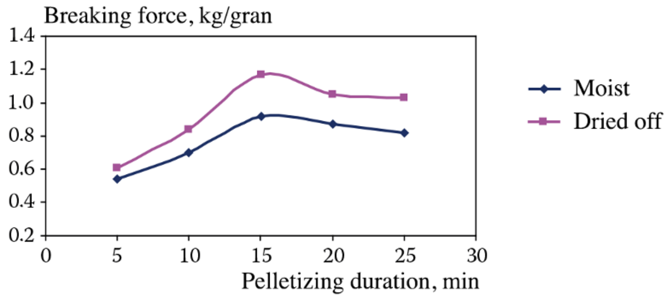

Fig. 2. Effect of prolonged pelletizing on strength (granule breaking force) of moist and dried-off granules 4–5 mm in size.

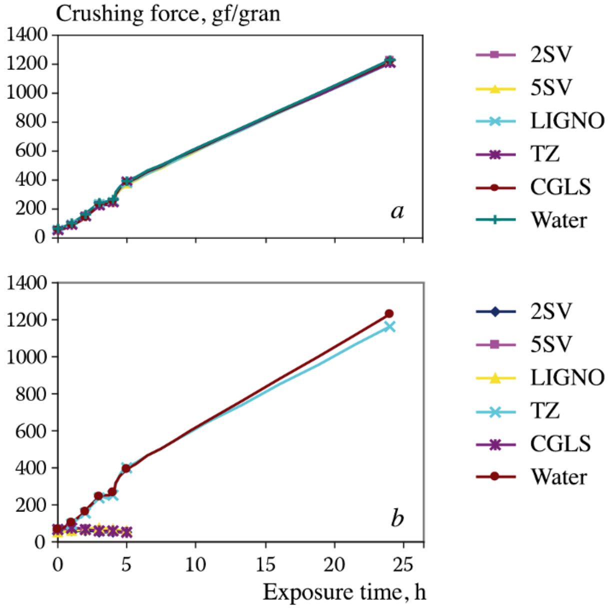

Fig. 4. Change in granule strength (breaking force) with passage of time with addition of different additives in an amount of 5 kg/ton of charge (*a*) and 20 kg/ton of charge (*b*).

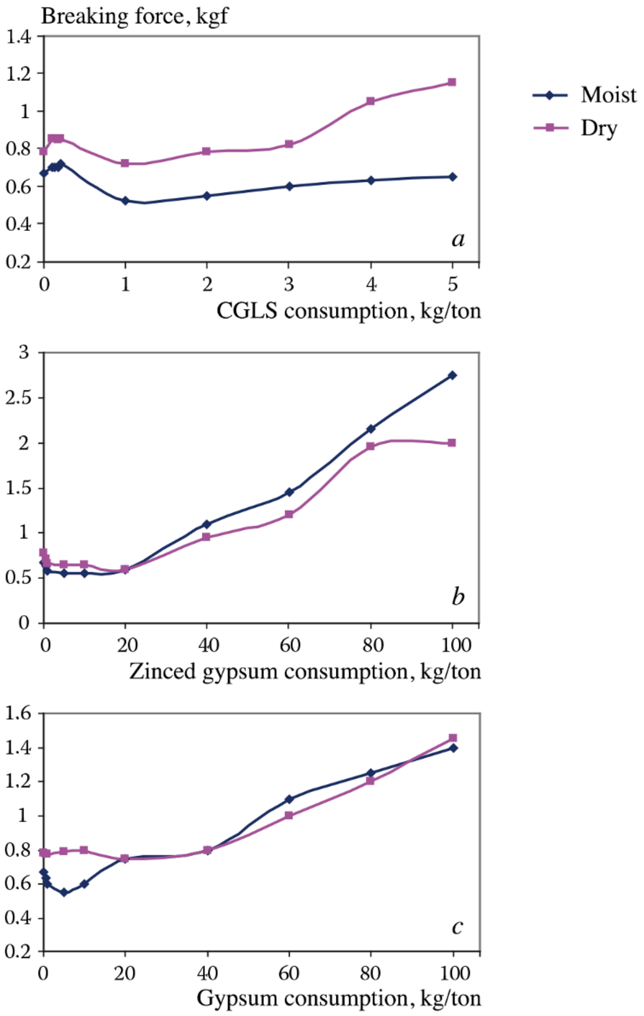

Fig. 3. Dependence of strength (granule breaking force) of moist and dried granules of a mixture of EAF dust with lime on binder consumption: *a*) CGLS in solution; *b*) zinced gypsum in suspension; *c*) calcium sulfate hydrate in suspension.

The optimum moisture content (~20%) for pellets was determined from the results of the studies for pelletizing conditions in a plate-like pelletizer. The optimum pelletizing duration was also determined with respect to the strength of moist (19–20%) granules and those dried under the conditions indicated (Fig. 2).

On the basis of the data obtained, optimum pelletizing duration was determined, i.e., ~15 min.

In the course of subsequent studies, the optimum form and consumption of binder additive was determined in order to prepare quite strong granules. The binder used was the well-known sodium lignosulfonate (CGLS, in the form of solutions of different concentration); suspensions containing calcium sulfate and zinc hydrosulfate, i.e., “zinc gypsum” (prepared with neutralization of a zinc sulfate solution by calcium oxide); suspension of calcium hydrate sulfate.

The change in strength of moist and dry granules with concentration of the added sodium lignosulfonate (in units of its consumption for one ton of charge), consumption (for dry weight) “zinced gypsum,” and calcium hydrate sulfate is shown in Fig. 3.

TABLE 1. Determination of Optimum Pellet Moisture Content

Calculated moisture content, %	Breaking force for granules 4–5 mm in size, kg		Fraction content (mm) in pelletized material, %				Notes
	moist	dry	+10 mm	–10+5 mm	–5+4 mm	–4 mm	
15–16	0.35	0.4	6	7	38	49	Large amount of wet dust, and also small pellets
17–18	0.45	0.85	10	14	35	41	Main part – small pellets, dusty component present
19–21	0.9	1.15	13	29	32	26	Main part regular shaped pellets, diam. 3–5 mm
22–23	0.35	0.85	22	41	24	13	Large amount of large pellets with increased moisture content
24–25	–	–	–	–	–	–	Mushy mixture not amenable to pelletizing

It is seen from data in Fig. 3 that addition of gypsum (hydrate) is effective, although the required pellet strength (more than 1 kg per granule) is only achieved with a consumption of more than 60 kg/ton. For "zinced gypsum," the minimum consumption is 40 kg/ton.

The high binder consumption dilutes a charge with respect to zinc content, and in the case of using "zinced gypsum" it is saturated with sulfate that during pyrometallurgical treatment leads to an increase in SO_2 discharge and a requirement for additional gas cleaning. For the same reason, zinc sulfate solution was not considered as a binder, whose high effective action is confirmed for a charge based on zinc cake.

It is efficient to use organic binders such as sodium lignosulfate. Similar materials (for example addition of 3–4% sulfite-yeast mash) are also used during pelletizing zinc raw material before melting in short-drum furnaces [11].

In the next series of tests, several organic binders were used, including various reagents for forming refractory materials produced by Poliplast Company (trade names, 2SV, 5SV, LIGNO, and TZ).

Reagents were mixed with a charge in dry form and sprinkled with water during pelletizing. This technology has been proved for mixing and pelletizing a charge in an Eirich rapid mixer-pelletizer, where liquid may be fed during mixing. Dispensing of reagents was 1–20 kg/ton of charge. Moisture content of the granules obtained was 20–21%. Testing of granules (fraction 5–7 mm) for crushing was performed through equal time intervals during air drying.

The following results were obtained:

1) with reagent dispensed in an amount of 1–5 kg/ton, the pellet strength hardly differed from that when pelletizing without reagent; over days the breaking strength of pellets increased uniformly from 0.05–0.06 kg to 1.2 kg (see Fig. 4), and pellets lost moisture content to 1.2–1.7% (Fig. 4*a*);

2) with reagent dispensed in an amount of 10–20 kg/ton, the majority of organic additives facilitated a reduction in pellet strength and their breakage after 24 h. The exception is TZ additive, although with its use there is almost no difference in granule strength pelletized with or without reagent (Fig. 4*b*).

The results of studying the effect of mixture moisture content and pelletizing duration showed the extreme nature of the dependences obtained. With pelletizing in a plate-like pelletizer, a specific amount of capillary moisture collects in areas of contact between particles forming rings (collars) not communicating with each other [12]. With an increase in moisture content, there is an increase in the amount of "collars" in zones of close particle contact, and the area of the water-free surface between particles, and correspondingly the overall surface tension force. During subsequent material saturation with moisture, its "collars" join with each other and the area of water surface and surface tension force are reduced.

The effect on granule strength of process duration may be explained by the fact that during mechanical action there is granule compaction, contact of powder particles, and also water film viscosity between particles increases. However, during compaction "collars" merge and there is liberation of excess moisture between particles. Therefore, an increase in granule formation duration leads to some strength reduction.

It has been established that in order to strengthen pellets of a charge based on EAFD with lime pelletizing technology is required with prior mixing of a moist charge, and in this case maximum use of lime properties as a binder is necessary: part of the lime is fed during mixing in the form of milk of lime or slurry with a moisture content of 80–90%. During a study of charge composition, with addition to EAFD of 30% hydrated lime 18–20.8% moisture is added, which is entirely suitable for pelletizing in a plate-like granulator.

With the use for pelletizing of a rapid type mixer-pelletizer, the optimum moisture content will be lower. This is connected with a change in granule formation mechanism. Lump formation of loose finely dispersed materials in a plate-like granulator mainly occurs by rolling fine particles (10–500 μm) into coarser granules (1–1.5 mm). With an increase in lump size, their density increases, and excess moisture emerges at the surface and new particles of material stick to it.

Moist finely dispersed materials exhibit a clearly defined capacity for arbitrary aggregation even after application of insignificant mechanical forces. Lump formation occurs in the case when the aggregates formed are subjected to action less in magnitude than for breaking their structure.

Intense mechanical action created by a rapidly moving mixer tool (10–22 m/sec) leads to partial breakage of aggregates and liberation of capillary moisture included within them, and the lumping–breaking cycle is repeated many times. As a result of this, within the material densely packed aggregates remain resistant to breaking loads with a minimum amount of capillary moisture within them (volumetric charge weight increases by a factor of 1.5–2). Excess moisture may be used in the presence of unwetted particles, or leads to breakage of air layers between liquid "collars." In the last case, surface tension forces cease to hold particles and there is granulate breakage with preparation of a uniform slurry mix.

In practice, the optimum granule moisture content obtained with a rapid mixer is 13–14%. It may be obtained by controlling the feed to a charge of dry and moist hydrated lime.

Conclusion. Pelletizing of EAF dust for charging into a Waelz kiln makes it possible to:

1) provide maximum contact between zinc ferrite particles within the dust composition and calcium oxide added to it;

2) prevent dust escape from original with provision of a low yield of volatiles (4–5% of a loaded charge) concentrating lead (up to 25%), alkali metals, and chlorine.

REFERENCES

1. A. M. Pan'shin, L. I. Leont'ev, P. A. Kozlov, et al., "Technology for treating OAO Severstal electric arc furnace dust at the OAO ChTsZ Waelz-complex," *Ekol. Prom. Rossii*, No. 11, 4–6 (2012).
2. P. J. W. K. de Buzin, N. C. Heck, and A. C. F. Vilela, "EAF dust: An overview on the influences of physical, chemical and mineral features in its recycling and waste incorporation routes," *J. MRT*., 10/002 (2016).
3. J. Czhernecki, E. Stos, and J. Botor, "Technology of EAF dusts treatment in rotary furnaces," *Proc. EMS* (2003), pp. 465–479.
4. B. M. Heegard, M. Swartling, and M. Imris, "Submerged plasma technology and work within Zn/Pb recovery," *Proc. of Lead–Zinc Conf. Pb–Zn 2015*, Dusseldorf, Germany, Vol. 2, pp. 807–816.
5. P. A. Kozlov, *The Waelz Process*, Ore and Metals Publ. House, Moscow (2003).
6. M. A. Abdeev, A. V. Kolesnikov, and N. N. Ushakov, *Waelz Treatment of Zinc-Lead-Containing Materials*, Metallurgiya, Moscow (1985).
7. P. A. Kozlov, A. M. Pan'shin, L. I. Leon'tev, et al., Patent 2507280 RF, IPC C22B19/38, "Method for treating zinc-containing metallurgical waste," subm. 07.23.2012, publ. 02.20.2014.
8. E. N. Nenashev, S. Yu. Odegov, S. P. Korostelev, et al., Patent 2450065 RF, IPC C22B7/02, "Method for processing metallurgical production dust," subm. 07.23.2010, publ. 01.27.2012.
9. P. J. W. K. de Buzin, N. C. Heck. L. A. H. Schneider, et al., "Study of carbothermic reduction of self-reducing briquettes of EAF dust and iron scale for use electric steelmaking," *Proc. 66th Congr. ABM* (2011), pp. 1268–1279.
10. S. Wegscheider, S. Steinlechner, C. Pichler, et al., "Innovative treatment of electric arc furnace dust," *Selected Papers from the 3rd Edition of Int. Conf. on Wastes: Solutions, Treatments and Opportunities WASTES 2015*, Viana Do Castelo, Portugal, Sept. 14–16, 2015, CRC Press (2015), p. 378.

11. A. V. Klimov, S. G. Melamud, A. V. Poluyakhtov, and D. S. Binder, “Preparation of lead dust and cake for pyrometallurgical treatment,” *Tsvet. Met.*, No. 10, 66–70 (2014).
12. E. A. Isaev and I. E. Chernetskaya, *Granule Formation: Theory and Experiment: Monograph*, Yugo-Zap. Gos. Univ., Kursk (2015).