USE AND PROCESSING OF DUST OF DRY GAS CLEANING OF FERROSILICON FURNACES

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ABSTRACT

At "ZFP" PJSC in the shop No.4 8 electric furnaces produce the melting of ferrosilicon.

In 2013, all furnaces were equipped with gas cleaning bag filters. Those gas cleanings can produce flue gas cleaning to meet the requirements of environmental legislation.

At the plant researches of dust were carried out and the work on developing the technology was performed:

- processing of dust in the form of pellets in the ferrosilicon melting;

- use of dust as an antistick coating.

This work is devoted to the study of the physical properties of the dust of dry gas cleanings of closed furnaces on ferrosilicon production and the possibility of their use as an antistick coating.

KEY WORDS: *dust of dry gas cleaning in the ferrosilicon melting, pelletizing, antistick coating*

1. INTRODUCTION

At "Zaporizhzhya Ferroalloy Plant" PJSC in the melting shop №4 8 closed furnaces for production of ferrosilicon alloys are installed. All furnaces are equipped with dry gas cleanings with bag filters, so the recycling of collected dust (production wastes) is a very topical task. Dust generated during the melting of siliceous alloys contains a significant amount of particulate $Si0_2$.

One of the main tasks is to return the dust of dry gas cleanings into production. The best option of production wastes disposal should be considered their return to the technological process. High dispersion and low bulk density do not permit direct use of this dust in the technological process of production without prior preparation.

The use in own production of dust generated during the production of ferrosilicon is limited that necessitates its disposal or use for other purposes.

2. PHYSICAL AND CHEMICAL CHARACTERISTICS OF DUST CAPTURED BY BAG FILTERS FROM FURNACES IN FERROSILICON PRODUCTION

Dust of dry gas cleaning is a fine powder of a light colour with a specific surface which particles have a spherical shape. At temperatures of 1400-1500^{0}C during melting of ferrosilicon in the ore-thermal furnaces in the gas phase thermodynamically stable silicon monoxide, SiO, is present during flow entrainment of hot gases from the high-temperature zone of the furnace and the oxidation to a silicon oxide $Si0_2$ located in the gas stream in powder form takes place. With a sharp decrease in temperature of exhaust gases vapour supersaturation occurs and condensation with spherical particles takes place as well as their dense packing in the process of further collisions. Internal pores of macroparticles obtained in this way are impermeable to nitrogen molecules, and therefore the specific surface of micro-silicieous dust is less than that of Aerosil and amounts to 20-22 m^2/g. Due to the electrostatic forces the particles are kept some distance apart, whereby the bulk density of micro-silicieous dust is extremely small.

The chemical composition of dust generated during ferrosilicon alloys melting is shown in Table 1.

Table 1. Physical and chemical characteristics of the parameters of dust-gas flow and dust captured by bag filters of furnaces in the production of ferrosilicon

Name	Index
1. The bulk density of ferrosilicon dust	0.17 – 0.2 t/m^3
2. The angle of dust repose, degrees: - at rest - in movement	not more than 20 5 – 10
3. Humidity of gas and dust flow from the ferrosilicon melting of charge materials, % by weight of the melted production	18.5 – 18.6
4. Chemical composition of gas and dust flow in the melting of ferrosilicon emitted into the atmosphere,% by weight of the melted production: - carbon dioxide - volatiles – carbon monoxide - sulfur dioxide - nitrogen dioxide	 194.8 – 199 8.3 – 8.5 2.67 – 2.73 0.33 – 0.34 0.23 – 0.24
5. Fractional composition of dust in microns,% < 2 2-2,36 2,36-3,4 3,4-5,4 5,4-8,3 8,3-15,3 15,3-20,0 20,0-46,3	 90.07 1.01 0.86 1.37 1.41 2.66 1.0 1.06
6. Physical properties of the dust: - abrasiveness - explosiveness	 low abrasive explo- sion-proof
7. Chemical composition of the dust: - SiO_2 - Na_2O - MgO - Al_2O_3 - C - S - K_2O - CaO - Fe_2O_3	 86.0-90.0 0.6-0.8 0.8-1.0 0.6-0.8 0.9-1.2 0.2-0.3 1.2-1.4 0.4-0.9 0.4-0.7

The structure of cristobalite type dust is close to the amorphous, well agglomerated, poorly wetted by water.

Content of SiO_2 in the dust up to 90% allows considering it as an amorphous silica fume. Micro silica fume dust is characterized by the following properties:

- high electrical resistance;
- high chemical resistance;
- low thermal conductivity.

Based on the physical and chemical properties of ferrosilicon dust the following areas of its processing are considered:

- return of dust to the technological process - production of pellets and return to technology;
- in construction;
- as an antistick coating in the metallurgical industry.

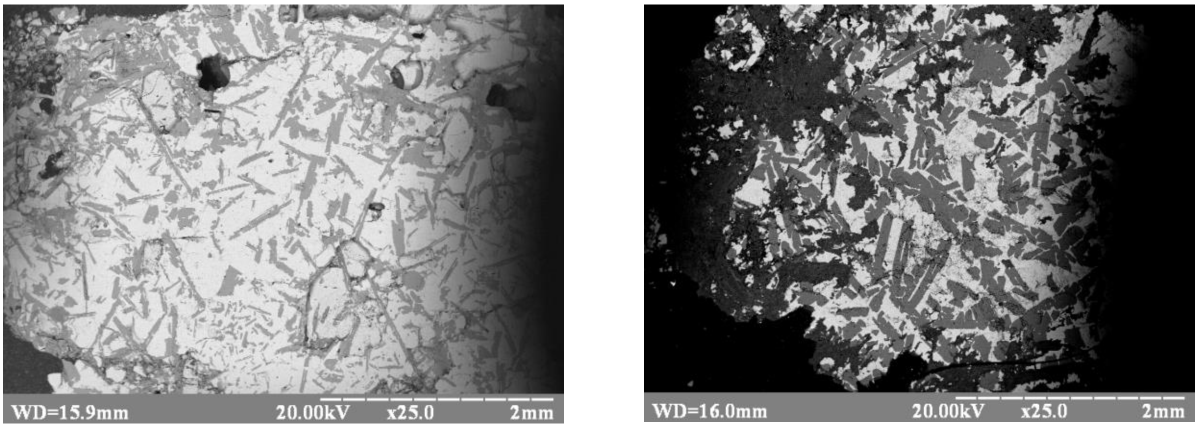
At “ZFP” PJSC all possible directions are developed. Thus, today the most studied question is that involving the dust in technology and the development of an antistick coating for technological facilities. Basic technologies were developed, the issue of implementation is considered.

3. USE OF FERROSILICON DUST AS A REFRACTORY COATING

Traditionally, at “ZFP” PJSC" lime is used as an antistick coating of the molds of casting machines. The molds are treated before each casting, coating layer of mortar is 1 mm. After crushing, the screenings of fractionation are recycled – remelted on furnaces of direct current. An important issue in such processing of the screenings of ferrosilicon was a large segregation in diffuse metal.

For research, samples of ferrosilicon casted during fractionation screenings remelting and casted on the casting machine in the process of ore-thermal melting are taken. Samples were examined with an electron microscope (dust in the package with samples and thin sections made from the thickest part), as well as their phase analysis was performed on the X-ray diffractometer.

Electron microscopic studies have shown that the dust in the package with the sample casted in the process of fractionation screenings remelting except ferrosilicon contains significant amount of compounds based on calcium, potassium and aluminum. Dust in the package with the sample obtained in the casting machine consists of ferrosilicon (alloy of FeSi2 and Si phases) (Figure 1).



a) b)

Figure 1. Structure of the ferroalloys samples obtained by a) remelting of the fractionation screenings; b) ore-thermal melting

Studies of thin sections set different content of $FeSi_2$ and Si phases in the samples (Fig. 1, light - Fe Si_2, dark phase - Si). According to the results of X-ray studies the phase composition of the samples was set which is shown in Table 2.

Table 2. Results of X-ray phase analysis

	Si, %	Fe Si_2, %	SiO_2, %
Layered casting	3	97	-
Casting on casting machine	52	26	13

According to the analysis results, we can conclude that the ferrosilicon ingots obtained during remelting of the fractionation screenings have significant heterogeneity (differences between the results of X-ray and microscopic studies) due to introduction into the technological process of a significant amount of compounds impurities based on calcium.

The obtained result marked the relevance of search for a new technology of an antistick coating of the molds in the melting of ferrosilicon alloys. In the process of metal casting into molds, the place subject to the most considerable wearing is that of the metal stream falling. The main factors of wear is thermal and hydraulic shocks at the impact of the metal stream on the mold (temperature of the ferrosilicon at the time of casting is up to 1600°C). Given these factors, the refractory protective coatings for the molds must meet the following basic requirements:

- high opacity;
- high resistance to fracture and delamination under the influence of the metal stream and high temperatures;
- high fire resistance and heat resistance of the coating layer;
- low thermal conductivity of the coating layer;
- low thermal expansion of the coating layer.

Studies on the resistance of refractory coatings of the molds showed that the main materials used as a binder of the refractory coatings are as follows: a solution of sodium silicate, ethyl silicate, hydrolyzed ethyl silicate, monobasic aluminophosphate ligament, silica sol. The use of colloidal silica sol as the binder shows a dense, smooth refractory coating, keeps well on the surface. In addition, silica sol has the following advantages:

- the possibility of applying as a refractory coating on a heated surface up to 100-300ºC with smooth and dense layer;
- high refractory quality (about 1700 °C);

• sufficiently long storage.

The best properties belong to the refractory coatings of the molds based on silica fume with a silica dioxide content of 90÷ 95%. With temperature increasing, the strength of refractory coating increases due to sintering of the plurality of dispersed particles having a maximum developed surface and the maximum level of free energy.

Dust of dry gas cleanings in the ferrosilicon production (silica fume) is difficult to transport and store directly on the site of metal casting for making an antistick coating. To get more easy-to-use material the method of preparing silica fume suspension is selected - mixing of silica fume with an equal amount of water and suspensionfication using mixing devices. For the provision of chemical and physical stability of the suspension pH value is provided in the range from 4.5 to 5.5.

Refractory coating based on silica fume is produced on the basis of dry gas cleaning dust in the production of ferrosilicon with mass content of SiO_2 from 89% to 92%. Colloidal aqueous solutions for the molds processing were prepared of this dust. Composition of the suspension included 25% of mass fraction of SiO_2, and 75% of mass fraction of H_2O.

Dispersed systems with particles sizes of up to several microns are sedimentation stable due to the fact that in such systems the Brownian motion of particles dominates the force of gravity. The resulting colloidal solution has a low degree of precipitation of finely divided amorphous silica fume - a component which has a grain size less than $5 \cdot 10^{-7}$ m formed a lyophobic colloid component of the suspension, and the particles having a grain size of 10^{-7} - 10^{-5}m are the activated microfiller. When the dust contains less than 84% of SiO_2 there is a decrease in the amount of lyophobic colloidal particles and particles of activated microfiller, that reduces the sedimentation stability and the strength characteristics of the suspension.

To increase the storage time and transportation durability of suspension applying of antistick coating high molecular component was introduced based on starch in an amount of 0,5% of mass fraction of silica. This additive allowed getting the knitting suspension with high sedimentation stability (Figure 2).

Figure 2. Treatment of molds of casting machine by antistick coating based on silicia fume (dust of dry gas cleaning).

The main technological parameters of antistick coating used are shown in Table 3.

Table 3. The main technological parameters of antistick coating used

1	Composition of suspension:	
1.1	Dust of ferrosilicon production, kg	100
1.2	Water, kg	100
2	Suspension density, g/cm3	1,23
3	Temperature of the mold at the moment of the suspension applying, °C	270
4	Layer thickness, mm	0,5

Antistick coating based on ferrosilicon dust was used on troughs of ferrosilicon casting machine. Twenty consecutive set molds were selected after metal casting into molds on casting machine. The temperature of the molds before treatment was 270ºC. Suspension was applied to the surface of troughs with even layer by spray nozzle prior to each casting. The drying up of the mixture in the molds took 10-20 seconds. The rest of the molds were treated with lime according to the technological regime.

Metal casting was carried out uniformly to all of the troughs with the passage of the cooling system. After a metal shakeout the process of retreatment of the same troughs by antiburning-through composition based on ferrosilicon dust took place and metal was casted in them. In the process of evaluating the effectiveness of applying antistick composition 15 consecutive metal castings were carried out. In all cases, the metal in the molds treated with a mixture of a coating based on ferrosilicon dust was not stuck.

The resistance of pilot antistick coating on the mold was estimated. Resistance totalled 2-3 castings, however, due to wearing in a place of metal stream falling the coating for subsequent castings was applied before each casting.

Application of this refractory coating on the inner surface of the molds eliminated the ingots welding. The reduction of wear of the molds bottom part in site of metal stream falling is further noted.

4. RETURN OF FS DUST INTO TECHNOLOGICAL PROCESS IN THE FORM OF PELLETS

The use of dust of the dry gas cleaning in technological process before directly supplying to the furnace without special measures is impossible. The main reasons are the following:

- dusting and removal of fine fractions in the gas cleaning when loading into the furnace;
- reduction of permeability of the throat and as a consequence violation of the furnace operation.

At this, it is possible to use a Si-containing dust in the form of pellets for additional charging in the amount of 50 - 200 kg per 1000 kg of quartzite.

To meet the requirements of ferrosilicon alloys melting technology in closed furnaces requires such preparation of the starting material which provides its supply into the furnace without destroying with formation of dust and fines. The most suitable way to prepare dust of dry gas cleanings to reprocessing is pelletizing with a moisture content in the pellets up to 20%. The optimum size of the pellets to ensure normal operation of the furnace is 25-30 mm, with a density:

- wet 0.88 - 0.92 kg/m^3;
- partially dried 0.72 - 0.75 kg/m^3.

"ZFP" PJSC was the pilot producer of the pellets of Si-containing dust from the ferrosilicon melting. As the core of the pelletizing were used the screenings of coke and quartzite fractionation. Trial production of pellets was made on existing equipment of pelletizing area.

Pelletizing was performed by balling on a pan granulator. In the production process for the day, drying up in the air, the pellets gained mechanical strength. As the core pellets obtaining the screenings of charge materials such as coke and quartzite were used. Fractional composition of coke screenings is 1 ÷ 10mm, quartzite screenings - 0 ÷ 15mm.

The resulting pellets of the dust of dry gas cleaning in the ferrosilicon production with a core of coke screenings have a circular shape with a diameter of 10 ÷ 25 mm. Pellets with a core of quartzite screenings were obtained in two forms: round with a diameter of 10 ÷ 25 mm and of irregular shape following the shape of the core.

In the production of pellets in the mixer cap 0,04m^3 of material for use as the core of pelletizing, dust of the dry gas cleaning was given 4 times more in volume ratio and water was fed. In the production, the additional binder was not used. The resulting wet pellets have sufficient mechanical strength and appearance is shown in Figure 3.

a)

b)

Figure 3: The pellets of dust of dry gas cleaning in the production of ferrosilicon with the core of pelletizing a) coke screenings with fr. 0 ÷ 10 mm; b) quartzite screening with fr. 0 ÷ 15 mm

Working time of pelletizer (at a given weight) until the pellets were obtained was 15 min. The next 20 min. the drying process in a pelletizer cap was carried out. Humidity of wet pellets with a quartzite core was 8.1%, with a coke core - 13.6%.

Drying of the pellets in a muffle furnace at 200 °C within 5 and 15 minutes has improved the strength characteristics. At the same time, indexes of moisture of the material after drying within 15 minutes showed the importance of appropriate moisture of source material given by the pelletizing core (Table 4).

Table 4. Humidity pellets

Material parameters	Humidity of pellets with the core of pelletizing of coke with fr. 0 ÷ 10 mm,%	Humidity of pellets with the core of pelletizing of quartzite with fr. 0 ÷ 15 mm%
Wet pellets	13,6 %	8,1 %
Drying 5 min., T=200 ºC	11,5 %	6,1 %
Drying 15 min., T=200 ºC	9,3 %	1,4 %

Pellets with a core of quartzite screenings are irregularly shaped and represented by bulk material of quartzite with fraction of 10 ÷ 15 mm, covered with 2 ÷ 3 mm layer of compacted dust (Figure 4). Durability of this coating decreased during drying, and local signs of coating exfoliation.

Figure 4: The pellets with the core of quartzite pelletizing, after drying

To determine the thermal stability three samples of pellets were selected and heat treatment in a muffle furnaces at three temperature regimes of 500 °C and 800 °C was performed. Wet and dried pellets were subject to heat treatment at a temperature of 200 °C for 5 and 15 minutes. Heat treatment is performed without smooth heating of material.

Destruction of pellets is observed at heating up to 800 °C. Pellets with core of coke fines in the total mass showed a higher resistance to high temperature exposure. Destruction of pellet with a quartzite core occurs when the size of the original quartzite exceeds 10 mm - cracking and delamination of 2 ÷ 3 mm of coating due to the difference in thermal expansion coefficient. Pellets with the quartzite core with fraction of 0-10 mm have sufficient thermal stability to ensure their submission to the reaction zone of the furnace. However, in the production of ferrosilicon the screenings of quartzite must first be cleared of clay constituents present in the fine fraction. This fact reduces the economic component when using this material in the process of ferrosilicon melting.

5. CONCLUSION

In this paper the physical properties of the dust of dry gas cleanings of closed furnaces on ferrosilicon production and the possibility of its use as an antistick coating were considered.

The researches of dust were carried at the plant out and the work on developing the technology is performed:

- processing of dust in the form of pellets in the melting of ferrosilicon;
- use of dust as an antiburning-through covering.

Estimated resistance of pilot antistick coating on the mold was 2-3 castings, however, due to wearing in a place of metal stream falling the applying of coating for subsequent castings was performed before each casting.

Application of the present refractory coating on the inner surface of the molds eliminated the ingots welding. The reduction of wear of the molds bottom part in site of metal stream falling is further noted that characterizes this antistick coating as an acceptable for production.

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