On the possibility of carbonaceous dust waste use of prebaked anode production in silicon metallurgy

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Abstract. During the prebaked anodes production used in aluminium electrometallurgy a considerable amount of fine-dispersed waste with a carbon content of more than 90% is formed. Analytical studies of the waste properties such as chemical, particle size analysis, moisture content and some others have been conducted. Electro-paramagnetic resonance (EPR) method was used to study the structures of charcoal, oil coke and a sample of carbon-containing dust from mixing and pressing compartment of aspiration equipment. EPR results showed that the studied sample is similar in structure to natural traditional reductants (its EPR spectrum has a pronounced narrow Gaussian signal). This indirectly shows its satisfactory reactivity and can be recommended as an additive (in pelletized form) to the charge for the silicon production.

1. Introduction

The process of silicon technology in electric furnaces and the process operation depend on the use of different carbonaceous reducing agents or carbonaceous reductants (CR). The dominant requirements applicable to them are low ash level, high reactivity (R), high specific electrical resistivity (SER) and low cost [1–3].

Nowadays at ZAO SILICON UC RUSAL charcoal, oil coke, mineral carbon from different deposits (Kazakhstan, Colombia) and woodchips (as a desintegrator) have wide spread occurrence as CR.

Charcoal is one of the best carbonaceous materials complying with the requirements of crystalline silicon production technique. However, considering its insufficiency and high cost it is necessary to search for new carbonaceous reductants able to partially substitute some traditional reductants in order to cut down prices for the finished product.

JSC “RUSAL Sayanogorsk” is the third largest aluminium smelter in the UC RUSAL structure. The plant uses the technique of baths equipped with prebaked anodes (PA) [4] and has a workshop producing electrodes. Producing PA, a great amount of finely dispersed carbon-containing waste is formed, that, in turn, has a negative influence on the ecology near the enterprise.

The present research is aimed at the study of the properties of the given type of technogeneous raw stock.

2. Research materials

At present electrode production at aluminium smelters is an independent multistep works with a branched transport and technology structure. Thus, electrode production workshop of JSC “RUSAL
Sayanogorsk” consists of three departments: Green Anode Plant (GAP), green anode baking area (BA) and anode assembly area (AAA).

The multistep process of PA production includes some procedures like grinding, breakage, sizing, mixing, stub-end cleaning and etc. During the steps there is a large amount of dust partially captured by gas-cleaning plant. The dust partly precipitates in the production unit place:

1. GAP dust from dust exhausting plants;
2. GAP dust from plant cleaning;
3. BA dust from pot tending machines;
4. BA dust from coke filling unit cleaning;
5. BA dust from dust exhausting plants;
6. AAA dust from a barreling machine;
7. AAA dust from dust exhausting plants;
8. AAA dust from stubs and spoiled units fr. -0.5 mm breaking;
9. AAA dust from stubs shot blasting.

Practically, all waste, except the dust from dust exhausting plants of Green Anode Plant, is not used in the production again and stockpiled on the landfill.

3. Study results

The tests of the study specimens according to the size grade were carried out with the help of a lazer particle-size analyzer, Analysette 22 NanoTecplus (Fritsch, Germany). The device tests particle size in a liquid fluid. As test specimens have poor wettability, the suspension of dust and surface-active substances was prepared for measuring.

The results of the granulometric composition of the test specimens of the bake furnace dust are presented in the form of the figures with an integral curve and differential distribution as well as tables. The table of the size grade distribution consists of two main columns: size (µm) and size yield (%). The particle size is represented in the form of the size grade from 0 µm to the indicated number, i.e. if the size is 40 µm and the size yield is 99.3 %, it means that the particles of the size less than 40 µm make 99.3 %. From the table of the size grade distribution one can conclude what is prevailing in the size grade. For example, if the size yield is 90 % and the size is 26.4 µm, this means that 90 % of the probe has the size less than 26.4 µm.

The example of the granulometric composition study of GAP dust from dust exhausting plants is shown in Table 1 and 2 as well as Figure 1.

GAP dust from dust exhausting plants (Specimen 1) has size of -50 µm (figure 1, table 1), and 90 % is grade of -26.4 µm (table 2).
The most part of finely dispersed carbon-containing waste of the three departments of the electrode production workshop (Green Anode Plant, green anode baking area, anode assembly area) is represented by the fraction of -100 µm, that creates a problem of the further direct use of the materials [5]. However, their main value is high content of carbon (more than 90 %) and low ash level of some specimens (0.29-1.35 %):

No. 1 – 0.53 %; No. 2 – 0.45 %; No. 3 – 6.03 %;
No. 4 – 3.58 %; No. 5 – 0.29 %; No. 6 – 61.71 %;
No. 7 – 1.20 %; No. 8 – 1.35 %; No. 9 – 31.33 %.

The ash content of the specimens was rated according to GOST 22692-77. The essence of the method is in ashing of the specimen of the tested material in a muffle furnace and baking of the ash residue to the fixed mass at temperature of (850±20) °C.

The chemical composition of ash residue was analyzed with the help of a wavelength-dispersive spectrometer, S8 TIGER (Bruker, Germany), using X-ray fluorescence spectroscopy, table 3.

The carried out researches identifying the chemical composition of the ash residue of the carbonaceous dust specimens do not demonstrate considerable contrasts to the component analysis. Moreover, the largest amount of ferric oxide is registered in the specimen of GAP dust from the workshop cleaning, that can be indicative of the availability of some contaminating impurities of inorganic nature (metallic dust and etc.).

Table 1. Specimen 1 particle distribution by size grade.

| Size, µm | Average | Measuring number |
|----------|---------|------------------|
| 0.3      | 0.2     | 0.2 0.2 0.2 0.2 0.2 |
| 0.5      | 0.6     | 0.5 0.6 0.6 0.6 0.6 |
| 1        | 1.8     | 1.6 1.9 1.9 1.9 1.9 |
| 10       | 40.1    | 44.4 41.3 39.2 38.2 37.4 |
| 20       | 76      | 78.6 77 75.5 74.8 74.1 |
| 30       | 94.4    | 95.1 94.7 94.3 94 93.7 |
| 40       | 99.3    | 99.4 99.4 99.3 99.3 99.2 |
| 50       | 100     | 100 100 100 100 100 |

Table 2. Specimen 1 particle distribution by size yield.

| Size yield, % | Average | Measuring number |
|---------------|---------|------------------|
| 5             | 1.8     | 1.8 1.7 1.7 1.7 1.8 1.8 |
| 10            | 2.7     | 2.6 2.7 2.7 2.7 2.8 2.9 |
| 20            | 4.9     | 4.4 4.7 4.9 5.1 5.3 |
| 30            | 7.4     | 6.5 7.1 7.6 7.8 8 |
| 40            | 10      | 8.9 9.7 10.2 10.5 10.7 |
| 50            | 12.5    | 11.4 12.2 12.8 13 13.2 |
| 60            | 15.2    | 14.1 14.8 15.4 15.6 15.9 |
| 70            | 18      | 17 17.7 18.2 18.5 18.7 |
| 80            | 21.4    | 20.5 21.1 21.6 21.9 22.1 |
| 90            | 26.4    | 25.5 26.1 26.6 26.8 27.1 |
| 95            | 30.6    | 29.9 30.3 30.7 30.9 31.2 |
| 98            | 35.3    | 34.4 34.9 35.4 35.6 36 |
| 100           | 51.1    | 51.1 51.1 51.1 51.1 51.1 |
4. Conclusion
The carried out analyses by EPR method demonstrate that the specimens of carbonaceous GAP dust from dust exhausting plants are similar to the structure of natural CR, that indirectly indicates their satisfactory reactivity worth and they can be used as addition agents to the traditional reducing agents in silicon metallurgy. The specimen of GAP dust from the workshop cleaning has slightly worse results from the viewpoint of structure and activity. However, for more complete information it is necessary to conduct some supplementary investigations. Besides, to use the data of the carbonaceous dust waste in silicon production it is essential to apply the methods of their preliminary balling [10].
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