A New Lining Material for Aluminum Electrolysis Cells that Can be Recycled

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Abstract

The paper discusses several technical, environmental and economic problems related to lining materials used in aluminum reduction cells, including the possibility to re-cycle them. The paper suggests that lignite semi-coke be used instead of conventional thermal insulation materials and refractory bricks. It also discusses the method of preparation of such a material and the results of laboratory studies of the properties of the material. The paper describes the equipment and technology used to apply this new lining material; it discusses original compacting equipment that can be used for un-shaped refractory materials. Also, the barrier layer properties are given. Moreover, the authors describe the concept of the cell that uses the new lining material, including the results of industrial pilot tests of such a cell. Furthermore, the paper discusses the results of an autopsy of an 887-day-old cell, in which lignite semi-coke was used. It was found out that 80% of the new lining material can be re-used, which improves both the environmental safety and economic efficiency of the process of aluminum production.

Keywords: Cell lining materials; electrolysis cells; lignite semi-coke for cell lining; cell lining material recycling.

1. Introduction

The world's amount of SPL in the existing dumps is several tens of millions of tonnes and it increases by 1.7 million tonnes annually [1]. About 30 % of this material is spent aluminosilicate refractory and insulating materials. A significant number of publications cover different methods to dispose and recycle such materials [2 - 5]. However, so far, the value of the regenerated product has not exceeded the cost of processing, and there is no cost-effective and environmentally friendly solution of this problem, yet.

One of the possible solutions is the use of lignite semi-coke as an insulation and, partially, refractory material, including its subsequent recycling. At an industrial level, lignite semi-coke is produced by the oxidizing carbonization of low-ash, low-sulfur coal in the boiler, including fluidized bed combustion at temperatures of 700 -8 00 °C [6]. This allows generating flammable gases and a solid product with a low volatile content. This paper contains the results of studying the possibility of using lignite semi-coke as a lining material of the cathode in the aluminum reduction cell.

2. Experimental

With the help of optical microscopy, electron microscopy, and integrated thermal analyses, lignite semi-coke was investigated; both in its initial state and after 30 months of cell operation. An EVO 50 Carl Zeiss electron microscope (Germany) and an INCA 350 energy-analyzer (UK) were used. The diffraction pattern was recorded with a PW1800 Philips X-ray diffractometer. Phase identification and quantitative X-ray phase (diffraction) analyses of the samples taken were made with the help of an information retrieval system for X-ray phase identification [7] and a database of X-ray references of inorganic phases and minerals [8], including 115 thousand standards. The content of cyanides was determined in a specialized environmental lab (TsLATI) as per the methodology used by the State Environmental Monitoring Authority (PND F 16.1:2:2.2:2.3:3.70-10), by means of a photometric method with the use of pyridine and barbituric acid [9].

The integrated thermal analysis of the samples was conducted by means of using STA 449 Jupiter (NETZSCH), a thermal analyzer that simultaneously measures mass changes (TG) and heat flows (differential scanning calorimetry) and is combined with QMS 403 Aeolos (NETZSCH), a quadrupole mass spectrometer that analyzes gases released during the process of heating samples. Samples were heated from 40 °C to 1 000 ° C, at a rate of 10 °C/min, in the air, as per a temperature program. The quadrupole mass spectrometer (electron ionization) was connected to the STA 449 Jupiter via a gas line that feeds gases at a constant temperature of 230 °C. The data obtained by using the mass spectrometer were combined, on a software basis, with the data from the STA 449 Jupiter. In order to estimate the thermal conductivity of un-shaped materials, a method of non-stationary heat control was used, as per GOST 30256-94 by means of using a MIT-1 cylindrical probe. Thermal properties (at different temperatures) were determined by using LFA 457 (NETZSCH) (a laser flash method). For the studies, semi-coke samples were used. They were placed in a special cell, which excluded any access of oxygen. Chemical resistance was determined both to sodium and to the combined effect of aluminum, sodium and the bath. Research on the combined effect of the above aggressive components was carried out according to the methodology proposed by Tabereaux [10].

2.1. Laboratory testing

Lignite semi-coke was used as a test material. Semi-coke was produced as per the TERMOKOKS-KS technology, which provides for partial gasification of coal in a fluidized bed at temperatures of 750 – 800 °C in order to remove moisture and volatiles. The product of pyrolysis of the Berezovsky MK-1 lignite – the semi-coke – has a dull gray or blackish color and a highly porous structure. The studies showed that more than 90 % of the mass of the initial lignite semi-coke was in a substantially amorphous state. The semi-coke's characteristics are given in Tables 1 - 3.

Table 1. Granulometry of lignite semi-coke.

Parameter	Value
Granulometry (%) by class (mm):	
> 1	10.5
1 - 0.315	51.1
0.315 - 0.2	16.1
0.2 - 0.1	16.7
0.1 - 0.063	1.1
0.063 - 0.056	1.8
< 0.056	2.7

Table 2. Technical properties of sample of lignite semi-coke.

Parameter	Value
Moisture (%)	3.7
Ash (%)	9.9
VMC (%)	6.0

In contrast to the existing processes, the proposed approach is simple and accessible; given the low cost and the possibility of recycling, this approach is also highly efficient from an economic point of view. Using a new un-shaped material – the lignite semi-coke – opens the door to the mechanization and automation of the process of assembling and disassembling cathodes, including a significant reduction in labor costs and time, and, in the meantime, the improvement of the quality of the process of lining. This allows a highly efficient use of the material.

4. Conclusions

1. It has been shown that lignite semi-coke may be used as a lining material for the under-cathode area of the cell.
2. It has been found that, after 889 days of operation, up to 80 % of the initial semi-coke used as a lining material may be subjected to recycling, and the remaining part may be burned at temperatures above 600 ° C.
3. The autopsy of the 2 331-day-old cell shows that the mixture of lignite semi-coke and powder-like aluminosilicate provides for quite a low (0.4 %) level of cyanides in the spent monolithic material.
4. The technology, which uses lignite semi-coke, allows having an economic effect by virtue of the following: reduction of the cost of lining materials; reduction of labor costs during installation; reduction of the amount of waste; and the reduction of fees for the storage of waste (possibility to recycle).

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6. References

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