Removal of Iron-content Magnetic Fraction from Fly Ash after Ecibastuz Coal Burning.

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Abstract.

This work is an extension of the boundaries of a new technology for the integrated processing of the fly ash to produce highly pure alumina and silica with the release of rare and rare-earth metals into a marketable product suitable for their further extraction. It seems efficient to allocate iron in the form of an iron-containing commercial product at the beginning of the technological scheme, which will greatly simplify the technology, reduce material costs and improve the quality of the obtained products. The paper shows the possibility of the separation of iron into an iron-containing product from fly ash after the burning of Ekibastuz coal by magnetic separation. It was found that magnetic separate of the fly ash results in an iron-containing product with a high iron content of up to 50%. A high up to 80% recovery of iron in a commercial iron-containing product is shown. The residual minimum limit of the iron content in the non-magnetic fraction (1.2%) was established. Further processing of such material will significantly improve the technological parameters of the fly ash processing technology and the quality of the resulting commercial products- alumina and silica.

Keywords: Fly ash, Power plants, Magnetic separation, Iron removal.

Introduction.

Despite the negative consequences of a coal burning, it remains one of the main sources of cheap fuel. An analysis of the current state of the coal industry shows an increase in coal consumption in the world's developed countries. Fly ash contains hazardous trace elements (As, B, Cr, Mo, Ni, Se, Sr, V, etc.), which have a significant negative impact on the environment due to the potential leaching by acid rain and groundwater [1, 2, 3]. The volumes of the annual output of fly ash in the developed countries show their huge accumulations, in million tons: India - 112, China - 100, USA - 75, Germany - 40 and Great Britain - 15 [2].

More than 20 thousand square km of land plots have been alienated for storage of fly ash and slag waste from thermal power plants in Russia, on which 1.3–1.5 billion tons of these wastes are located [3].

The problem of accumulation and storage of fly ash is of particular relevance for Kazakhstan, where the development of electricity generation and processing of waste from thermal power plants is one of the main state priorities. The total output of fly ash from coal combustion in the republic is ~19 million tons per year. To date, the amount of fly ash accumulated in dumps is more than 300 million tons [4]. In the large metropolis of Kazakhstan alone, in Almaty, as a result of the operation of three Power Plants, more than 2 million tons of fly ash and slag waste have been accumulated. In just one heating season from coal combustion, about 600 thousand tons of ash waste is added to the accumulated volumes of ash. In the South Kazakhstan region, because of the activities of the Kentau Power Plant, a number of ash dumps were formed, which took huge areas out of land use and have a negative impact on the environment (pollution of soil, air, groundwater).

Understanding that, according to the material composition, fly ash is mainly represented by oxides of SiO_2, Al_2O_3, Fe_2O_3, CaO, where rare and rare earth metals are significantly concentrated [3-7], necessitates the search for new approaches and solutions for using them as an additional source of raw materials, for the purpose of complex extraction of valuable metals from them. The existing methods of fly ash processing [1, 2, 5, 6, 8] make it possible to extract insignificant amounts of valuable elements contained in fly ash and slag waste. At the same time, according to the material composition, fly ash can be considered as an independent complex deposit of ore and non-metallic metals.

The works [9, 10] presents the new technology for the complex processing of fly ash with the production of highly pure alumina and silica with the release of rare and rare earth metals into a commercial product suitable for their further extraction. According to the developed technology, the quality of the products obtained is largely determined by the presence of impurities in them, in particular, the content of iron, the release of which into a commercial product in the form of an iron pigment is provided at the end of the technological scheme, after all the main operations have been carried out. Naturally, the behavior of iron makes a significant contribution to the chemical processes of all initial stages associated with the production of highly pure alumina and silica. In view of the foregoing, the most effective is the separation of iron in the form of an iron-containing commercial product at the beginning of the technological scheme, which will greatly simplify the technology and reduce material costs. The decrease in the iron content in the initial material will significantly affect to the quality of the commercial products according to the technological scheme.

Aim of this paper. In this report, we describe the results of studies of the material composition of the fly ash obtained from the Ekibastuz coal combustion and the extraction of iron from the fly ash by magnetic separation.

Methods.

X-Ray analysis.

The elemental and phase composition of the products were carried out using a D8 Advance analyzer (Bruker), α-Cu, tube voltage 40 kV, current 40 mA. Processing of the obtained data of diffraction patterns and calculation of inter-planar distances were carried out using the EVA software. The interpretation of samples and the search for phases were carried out using the Search/match program using the PDF-2 Powder Diffraction Data Base.

In order to clarify and obtain reliable results of the phase composition of the initial fly ash and the products of the experiments, an additional X-ray diffraction analysis was carried out on an automated DRON-3 diffractometer with CuKa - radiation, β-filter. Conditions for shooting diffraction patterns: U=35 kV; I=20 mA; shooting θ-2θ; detector - 2 deg/min. X-ray diffraction analysis on a semi-quantitative basis was performed using diffraction patterns of powder samples using the method of equal weights and artificial mixtures. The quantitative ratios of the crystalline phases were determined. The interpretation of the diffraction patterns was carried out using the data from the ICDD file cabinet: the PDF2 (Powder Diffraction File) database of powder diffraction data and the diffraction patterns of minerals free of impurities. Content the main phases was calculated.

Magnetic separation.

The magnetic separation of ash was carried out using a 25T-SE tubular magnetic analyzer (Fig. 1).

Fig. 1. Tubular magnetic analyzer 25T-SE

The 25T-SE analyzer consists of a core and windings of a closed electromagnetic system with tapered pole pieces between which, with the help of an electric motor and a crank mechanism, a glass tube rotates and reciprocates. The essence of the experiments was as follows. Wash water is fed into the tube and the flow rate is regulated by the installed drain through the product removal hose. The water level in the tube is maintained above the pole pieces. A milled fly ash sample (20 gr.) was moistened in a glass (total fly ash sample was 500 gr) gradually poured into the tube through the receiving device and washed out of the glass with a pear. In this case, the drain hose was directed to a container for collecting the non-magnetic fraction.

The magnetic fraction at the intensity of the electromagnetic system set by the current was attracted to the walls of the tube at the poles. The complex movement of the tube facilitated the separated of the non-magnetic particles from the magnetic particles. The analysis was continued until clean wastewater was obtained at the bottom of the tube. Upon completion, the drain hose was transferred to a container for collecting the magnetic fraction, and the current supply to the electromagnetic system was turned off. The water supply was stopped after the complete the magnetic fraction washing off. The water was decanted. The resulting products (magnetic and non-magnetic fractions) were settled and after drying, were subjected to weighing and further complex studies of the material composition.

Materials.

The elemental composition of the initial fly ash is shown in Table 1.

Table 1. The elemental composition of the initial fly ash.

	Content, mass. %									
	O	Na	Mg	Al	Si	K	Ca	Ti	Mn	Fe
The fly ash after Ekibastuz coal combustion	47.1	0.6	0.5	14.1	27.2	1.9	2.5	0.7	0.2	5.3

The diffraction patterns of the initial fly ash and the results of semi-quantitative X-ray phase analysis of crystalline phases of the fly ash are shown in Fig. 2 and in Table 2.

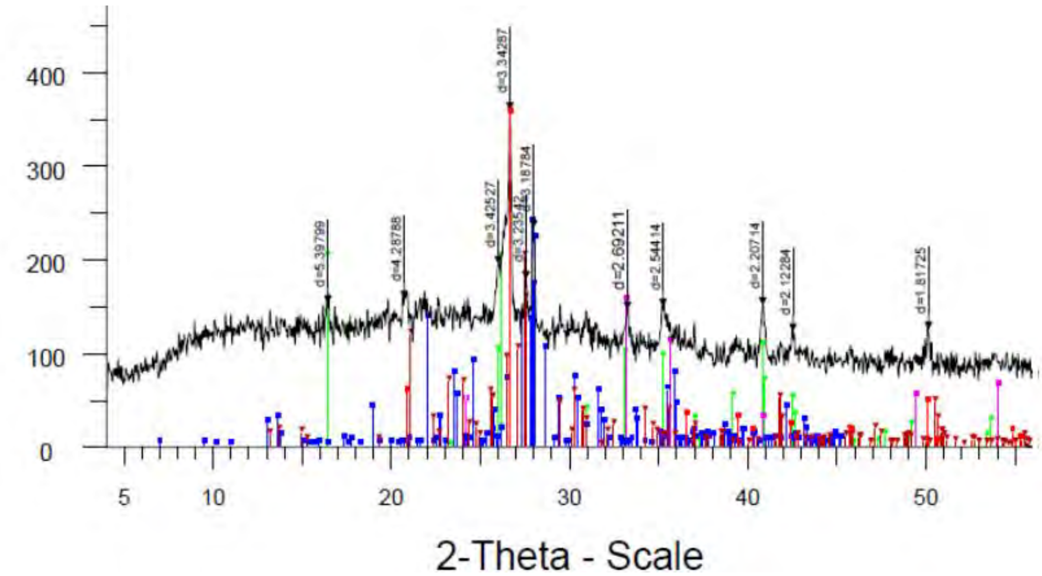

Fig. 2. The diffraction patterns of the initial fly ash.

- Mullite, - Quartz, - Hematite, - Anorthite, - Microcline.

Table 2. Phase analysis of crystalline phases of the fly ash.

Phase		Content, mass %
Mullite	$Al_{4.984}Si_{1.016}O_{9.508}$	21.8
Quartz	SiO_2	36.6
Hematite	Fe_2O_3	1.6

Anorthite	$Ca(Al_2Si_2O_8)$	15.2
Microcline	$(K_{.95}Na_{.05})AlSi_3O_8$	18.8
Magnetite	Fe_3O_4	6.1

Results and Discussion.

Removal of iron-content magnetic fraction from fly ash.

Magnetite content in the fly ash is equal 6%. The method of magnetic separation was used to fly ash separated to the magnetic fraction and non-magnetic fraction. This method widely used in metallurgy [11, 12].

The initial weight of fly ash was 500 g. After magnetic separation, 46.1 gr. of the magnetic fraction was obtained and 453.9 g of the non-magnetic fraction were obtained.

Magnetic fraction of the fly ash.

The composition of the magnetic fraction is presented in Table 3.

Table 3. The composition of the magnetic fraction.

Content, mass %									
O	Mg	Al	Si	P	K	Ca	Ti	Mn	Fe
32.4	1.4	2.9	2.8	0.1	1.1	0.9	0.4	2.4	47.6

The diffraction patterns of the magnetic fraction and the results of semi-quantitative X-ray phase analysis of crystalline phases of the magnetic fraction are shown in Fig. 3 and in Table 4.

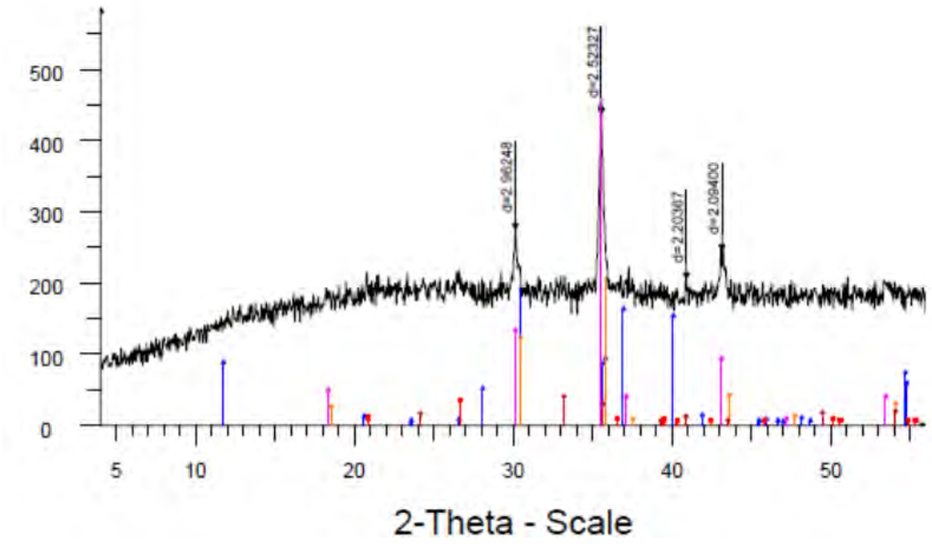

Fig. 3. The diffraction patterns of the magnetic fraction.

— - Magnetite, — - Calcium-Phosphorus oxide, — - Magnesium-Aluminum-Iron oxide, — - Hematite, — - Quartz.

Table 4. Phase analysis of crystalline phases of the magnetic fraction.

Phase		Content, mass %
Magnetite	Fe_3O_4	67.3
Calcium-Phosphorus oxide	Ca_4P_2O	14.1
Magnesium-Aluminum-Iron oxide	$MgAl_{0.8}Fe_{1.2}O_4$	12.8
Hematite	Fe_2O_3	3.1
Quartz	SiO_2	2.7

Non-magnetic fraction of the fly ash.

The composition of the non-magnetic fraction is presented in Table 5.

Table 5. The composition of the non-magnetic fraction.

Content, mass %									
O	Na	Mg	Al	Si	P	K	Ca	Ti	Fe
49.7	0.7	0.4	14.6	29.2	0.2	1.7	2.0	0.3	1.3

The diffraction patterns of the non-magnetic fraction and the results of semi-quantitative X-ray phase analysis of crystalline phases of the non-magnetic fraction are shown in Fig. 4 and in Table 6.

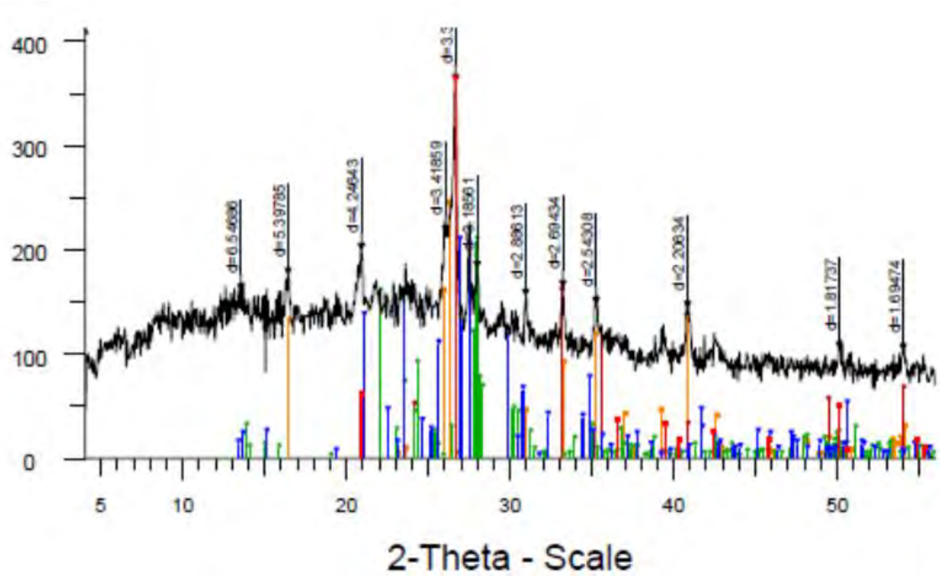

Fig. 3. The diffraction patterns of the magnetic fraction.

- Quartz, - Mullite, - Hematite - Albit, - Microcline.

Table 4. Phase analysis of crystalline phases of the non-magnetic fraction.

Phase		Content, mass %
Quartz	SiO_2	30.19
Mullite	$(Al_{2.5}Si_{1.5})O_{9.75}$	21.90
Hematite	Fe_2O_3	1.55
Albit	$Na(AlSi_3O_8)$	16.70
Microcline	$(K_{.95}Na_{.05})AlSi_3O_8$	11.90
Anortite	$Ca(Al_2Si_2O_8)$	17.60
Magnetite	Fe_3O_4	0.16

Basic elements distribution between magnetic fraction and non-magnetic fraction are presented in the Table 5.

Table 5. Basic elements distribution between magnetic fraction and non-magnetic fraction.

	Distribution, %			
	Aluminum	Silicon	Calcium	Iron
Magnetic fraction	2	3	1	80

Non-magnetic fraction	98	97	99	20

Conclusions.

Possibility of removing iron from the fly ash by magnetic separation with the magnetic fraction (~50% iron) production at the initial stage of the fly ash treatment process [9, 10] was presented. The resulting iron-containing product can be used in ferrous metallurgy.

Iron extraction to the magnetic fraction product was 80%. Aluminum and silicon losses with magnetic fraction product were 2% and 3% accordingly.

The residual content of iron in the non-magnetic fraction was equal ~1%. Further processing of such material will significantly improve the technological performance of the fly ash processing technology [9, 10] and the quality of the resulting commercial products - alumina and silica.

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