Extracting unburnt coal from black coal fly ash

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ABSTRACT

Black-coal fly ash from Kosice Power Plant in Slovakia contains between 22 and 25% of unburnt coal, which is, strictly speaking, a useful component. Studying optimal separation methods of unburnt coal from the examined sample of fly ash, three methods of dry mechanical screening on sieves, counterflow air classification, dry and wet gravity separation and flotation have been verified. The combination of dry mechanical screening and flotation appears to be the most efficient, through the application of which we retrieved coal concentrate with ash content below 10%, which is applicable in the process of power generation in power plants.

Keywords: fly ash, unburnt coal, separation methods

1 INTRODUCTION

Fly ash is the finest fraction of waste from combustion of fossil fuels, which gets intercepted in the thermal power plant separators. Out of the total volume of power-engineering waste from fossil fuel combustion it forms approximately 80%. In fact, fly ash is a heterogeneous material formed by morphologically different particles with various physical, chemical, mineralogical and technological properties, which are affected by both the quality of combusted coal and the technological process of own combustion.

Many types of fly ash are used untreated in a limited number of production technologies, especially in the building industry. On the other hand, fly ash often contains a range of useful components, as stated in Table 9, whose world-wide utilization does not exceed even 10 % of the overall production of this waste.

More economical and complex utilization of fly ash could be achieved through benefication methods focusing on the concentration and retrieval of the individual useful components. The objective of our research was to verify the possibility to separate the useful component of **unburnt coal** and thus increase the efficiency of utilization of the power-producing potential of the examined fossil fuel.

The research dealt with black coal fly ash from a heating plant supplying heat for the city of Kosice (Slovak Republic, Europe).

Useful component	Separation methods	Utilization methods
unburnt coal	sizing, flotation	power generation
cenospheres	sizing	filling agents, etc.
Fe-minerals: magnetite, maghemite, hematite	electromagnetic separation	Fe production, medium solids for gravity separation
Ti minerals: perovskite, rutile, ilmenite, ilmenorutile	electromagnetic separation, flotation, biohydrometallurgy	Ti production
Al minerals: boehmite, hydrargillite	bio and hydrometallurgy	Al production
Al-Si minerals: zeolite group	not stated	production of sorbents
Si minerals: quartz, cristobalite	not stated	Currently, separation and separate utilization is economically unacceptable
Ca minerals: anhydrite, gypsum	not stated	production of building materials
amorphous phase	partial concentration possible by gravity methods, hydrothermal alternation	production of synthetic zeolites, building materials
Trace elements	hydrometallurgy	e.g. production of Ge, etc.

Table 1. An overview of useful components contained in fly ash, methods of their separation and utilization.

2 MATERIAL AND METHODS

2.1 Characteristics of the examined fly ash

Grain-size and chemical composition in terms of distribution of majority constituents into the grain-size classes of fly ash.

Sample	Grain size [mm]	Mass yield [%]	Ignition loss [%]	SiO_2 [%]	Al_2O_3 [%]	Fe_2O_3 [%]
KOSICE	over 0,5	0,9	15,8	48,1	15,3	8,9
	0,1-0,5	13,7	35,5	38,0	11,4	5,7
	0,04-0,1	62,8	23,5	40,3	13,4	10,4
	-0,04	22,6	15,7	27,5	20,9	13,2

Table 2. Distribution of the majority elements in the grain-size classes of the examined sample of black coal fly ash.

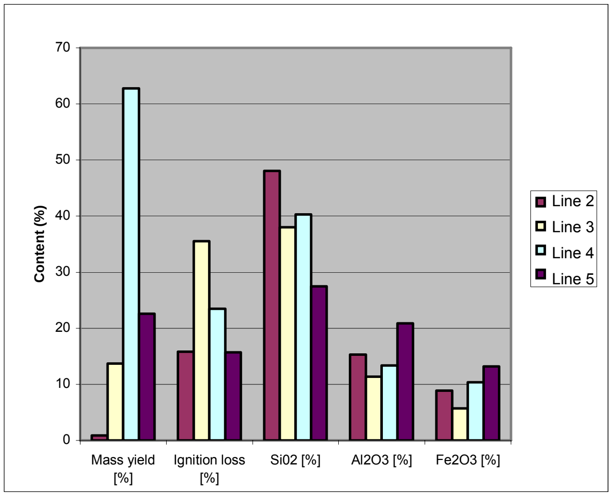
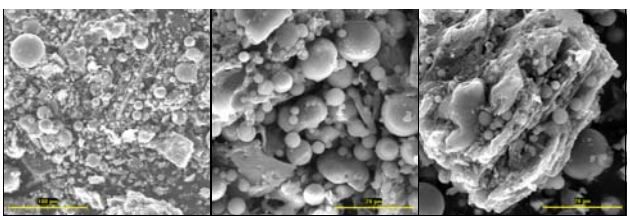


Figure 1. Distribution of the monitored elements in power-engineering fly ash of Kosice heating plant; Line 2: +0.5 mm, Line 3: 0.1-0.5mm, Line 4: 0.04 – 0.1mm, Line 5: -0.04 mm.

Morphological properties of the examined fly ash

The powder dispersion of fly ash contains mainly spherical particles (cenospheres) (B), allotriomorphic particles of crystalline constituents of fly ash (A) and porous particles of unburnt coal (C).



A B C

Figure 2. Morphology of fly ash particles.

Phase composition of the examined fly ash

The examined fly ash contained approximately 80% of amorphous material in which especially aluminosilicate vitrain phase prevailed and partly unburnt coal. From the crystalline constituents there were quartz, cristoballite, feldspar, graphite, hematite, magnetite, montmorillonite, bayerite, corundum, and mullite.

The easiest benefication operation is sizing, where in case of polymineral mixtures it is possible, in some cases, to obtain a certain concentrated constituent of fly ash. In the experiments we used the methods of dry mechanical screening on sieves and counterflow air classification on Alpine screens.

To concentrate the unburnt coal, classical froth flotation was also used, applying the collectors of Montanol, Flotalex and depressant (water glass). The experiments were carried out on a laboratory flotation machine VRF-1 with a flotation cell volume of 1l.

Results

Mechanical screening respects only one property of all the fly ash constituents, i.e. particle size. The results of the distribution of the monitored majority elements into the individual grain sizes are given in Table 2 and Figure 1. It is apparent that unburnt coal with approximate 20% mass yield gathers in the material with grain size 0.1-0.5mm, in which the ignition loss is 35.5%.

Air classification

Air classification of polymineral mixtures of various densities of the individual constituents is often accompanied by a partial classification effect. Air classification was applied on the sample of sized fly ash of –0.1mm grain size. The sample contained unburnt coal (ρ = 1.2 g.cm^{-3}), quartz, Fe minerals (maghemite and hematite) (ρ = 4.2-5.3 g.cm^{-3}), and amorphous phase, in which prevailed Si-Al vitrain material in the form of cenospheres (ρ = 0.3-0.8 g.cm^{-3}) and allotriomorphic particles (ρ = 2.6-3.2 g.cm^{-3}). The classification was done under the following conditions: ρ: 0.65 and 1.2 g.cm^{-3} and dividing size: 0.04 and 0.07 mm.

D (mm)	ρ (g.cm^{-3})	Product	Mass yield (%)	Ignition loss (%)	Fe_2O_3 (%)	SiO_2 (%)	Al_2O_3 (%)
0.04	0.65	1	18.00	19.25	8.97	47.28	14.00
		2	82.00	23.74	7.73	40.33	15.00
0.04	1.2	1	24.00	22.16	7.82	45.77	13.87
		2	76.00	22.13	8.61	40.97	15.77
0.07	0.65	1	9.40	16.75	9.04	47.22	14.46
		2	90.60	23.62	7.79	41.68	15.51
0.07	1.2	1	10.00	18.10	8.48	46.59	14.25
		2	90.00	24.30	7.80	40.86	14.88

Table 3. The results of air classification experiments with black coal fly ash.

It is apparent from the results given in Table 3 that in the process of air classification of fly ash, a minimal classification effect was manifested, which is documented by the results of unburnt coal accumulation. What are surprising are the results of Fe contents, where a significantly higher level of concentration was expected. As obvious from the following analyses, displayed in Figures 3 and 4, Fe occurs in the examined fly ash largely in the form of incrustation of various thicknesses on the spherical particles formed by vitrain aluminosilicate mass. The given results also imply that even if there were certain theoretical prerequisites for reaching the classification effect in the process of air classification, practical experiments did not confirm them.

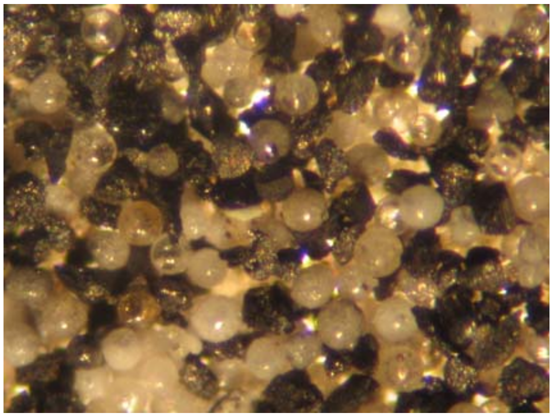


Figure 3. Oversize fraction of air classification with the division of d=0.04 mm and dividing density of 0.650 g.m^{-2}.

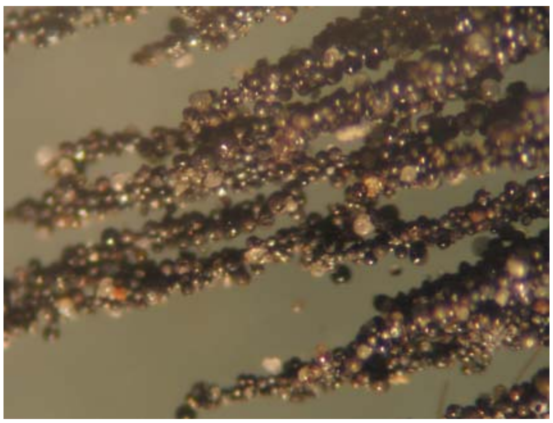


Figure 4. Agglomeration of magnetic particles in the magnetic lines of force from the product in Figure 3.

Flotation

The flotation experiments were carried out with the samples of examined fly ash with grain size of 0.1-0.5mm, -0.1mm and deslimed fraction of –0.02-0.1mm. For flotation we selected two classical flotation regimes making use of a collector and a depressant of aluminosilicate constituents of fly ash material. The flotation experiments were implemented under the following conditions: pulp density 100g/l, collector dose (Flotalex, Montanol) 500g/t, and an alternative dose of depressant (Na_2SiO_3) 2000g/t in the form of 1% solution. Froth products - concentrates of unburnt coal were fractionally sampled after 5 min (K1), 5-10 min (K2), and 10-15 min (K3). The final product after 15 minutes of flotation was final tailings.

The flotation process was as follows: 1/- agitation of water glass and the sample for 2 min, 2/- admixture of collector (agitation for 1 min) 3/- flotation for 5 minutes and concentrate sampling + admixture of collector in the dose of 500g/t, 4/- flotation for 5 minutes and concentrate sampling + admixture of collector in the dose of 500g/t, 5/- flotation for 5 minutes and concentrate sampling + admixture of collector in the dose of 500g/t, 6/- filtration of the froth and final product + drying + weighing + determination of ash content.

The results of the individual flotation exams in terms of ash yield are given in Figures 5, 6, and 7.

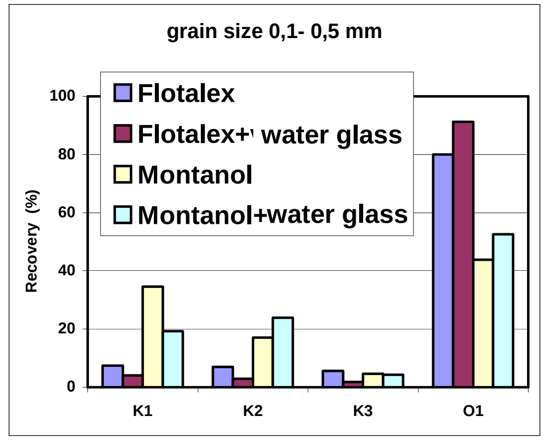


Figure 5. The results of fly ash flotation, grain size 0.1-0.5 mm.

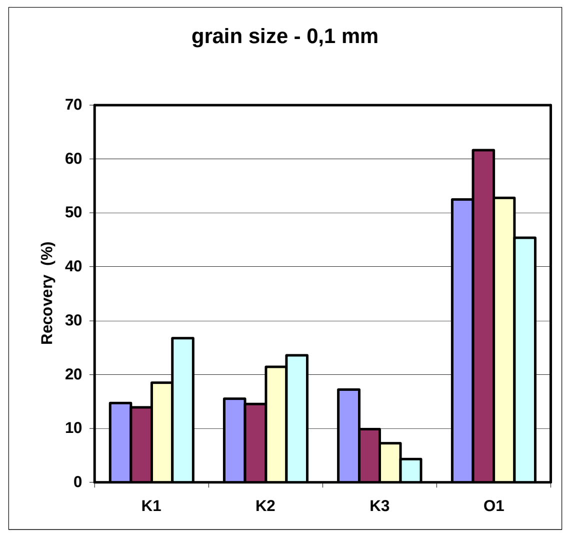


Figure 6. The results of fly ash flotations, grain size -0.1 mm.

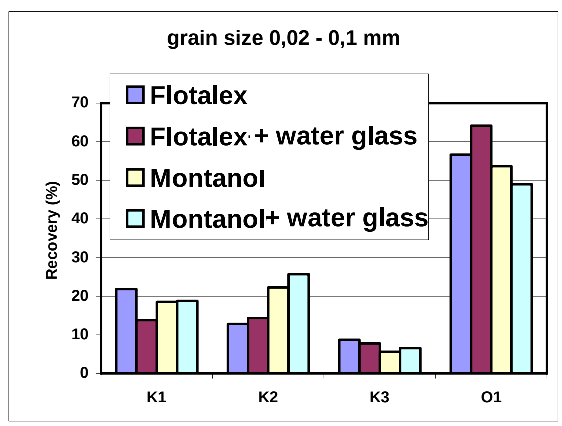


Figure 7. The results of fly ash flotation, grain size 0.02-0.1 mm.

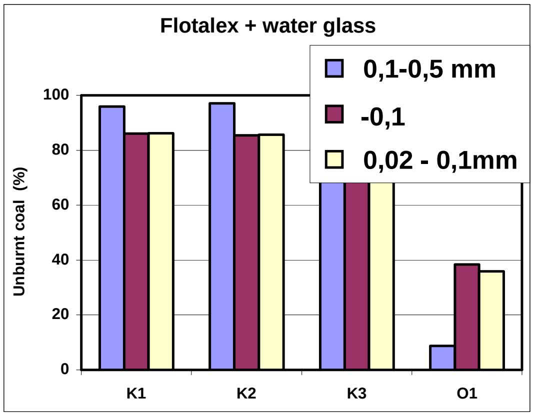


Figure 8. The best results of fly ash flotation, according to the individual fractions.

The results of the individual flotation tests in terms of ash yield are given in Figures 5, 6, and 7. The best results of flotation of the individual floated samples in terms of unburnt coal yield, See Table 4 and Figure 8, confirm that the best and also practically significant results were obtained in the flotation of material of 0.1-0.5mm grain size using Flotalex collector and depressant. The content of unburnt coal in tailings was 8.75 %, which makes the material useful for the building industry. However, the ash content in the concentrate was 16.3% and therefore, refining flotation was applied, which provided unburnt coal concentrate with ash content of 9.8%.

Floated material	**Products of flotation**			
	K1	**K2**	**K3**	**O**
	0,1-0,5 mm			
ε unburnt coal (%)	**95.92**	**97.09**	**98.23**	**8.75**
	– 0,1mm			
ε unburnt coal (%)	86.07	85.43	90.11	38.38
	0,02-0,1 mm			
ε unburnt coal (%)	86.2	85.63	92.25	35.92

Table 4. The best results of flotation tests of the individual fly ash grain size fractions.

3 CONCLUSION

The presented results of experiments confirmed that there is a potential retrieval of coal concentrates utilizable as secondary power-producing material provided that the examined fly ash is treated applying combined processes of dry mechanical screening and following flotation of sizing product of 0.1-0.5 mm grain size, in which unburnt coal accumulates. The possible fly ash treatment shall increase the level of the power-producing potential of coal and thus decrease the volume of produced waste.

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