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FLOTATION OF SLOVAK FLY ASHES

For using energetical fly ashes in the civil engineering it is necessary to reduce their combustible substance residue (csr) content. The fly ashes in the quantity of about 1 Mt were being sedimented during 26 years in a sludge bed. The average content of the csr is around 32%. For removing the csr the flotation was used. The optimization of the flotation conditions for certain contents of the csr is described in the paper.

INTRODUCTION

Fly ashes, the waste of the power production industry, are utilized world wide but only from 1 to 40% of them is used commercially. The utilization of the fly ashes in the civil engineering applications, the largest potential consumer, is limited due to the presence of the non-burnt coal particles also called combustible substance residue (csr). The aim of this study is to determine basic parameters of the flotation, the consumption of the collector during flotation as well as the kinetics of flotation to produce products with reduced amount of csr which meet standards set up by potential users of the fly ashes.

EXPERIMENTAL

The samples of fly ashes were taken from a sludge bed consisting of several layers. The upper layer was 60 cm thick and the average content of csr was 31%. The middle layer was 50 cm thick and its csr content was 37%, while the lower layer, 45 cm thick, contained 25%. The average concentration of csr in the sludge was 32.7%.

The csr was determined by the loss by ignition (lbi) method. The csr content in different size fractions of all three samples as well as in the fresh fly ashes is given in Table 1. The residual concentration of the Flotacol NX collector was determined by the permanganate and dichromate methods as the demand for oxygen in mg O_2/dm^3.

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Table 1. Particle size analysis of black coal fly ash and the content of csr in different fractions

Fraction mm		Upper layer		Middle layer	
		Weight yield %	csr content (by l.b.i.) %	Weight yield %	csr content (by l.b.i.) %
	+0.315	0.06	30.60	1.65	65.12
0.25	−0.315	0.18	45.35	1.23	73.48
0.15	−0.25	1.48	67.61	5.11	74.61
0.10	−0.15	7.33	72.76	12.27	75.58
0.09	−0.10	8.62	70.87	7.66	64.43
0.071	−0.09	3.08	57.64	4.45	44.52
0.056	−0.071	2.40	50.56	5.44	50.39
0.040	−0.056	6.65	44.70	9.22	33.37
	−0.004	70.20	18.00	52.97	17.16
Feed:		100.00	31.14	100.00	37.10
Fraction mm		Lower layer		Fresh fly ash	
		Weight yield %	csr content (by l.b.i.) %	Weight yield %	csr content (by l.b.i.) %
	+0.315	0.08	50.79	0.08	73.36
0.25	−0.315	0.08	57.24	0.23	76.39
0.15	−0.25	0.92	70.76	2.81	73.33
0.10	−0.15	5.16	76.28	5.95	70.43
0.09	−0.10	3.58	66.19	2.75	55.84
0.071	−0.09	3.58	52.12	5.21	52.69
0.056	−0.071	5.41	55.96	2.07	39.20
0.040	−0.056	7.98	31.51	6.18	29.46
	−0.004	73.21	14.85	74.72	13.90
Feed:		100.00	25.32	100.00	23.28

RESULTS AND DISCUSSION

The Slovak standards (STN 72 2060–70) require, depending on application, either 0.5, 2, 3, 4, 5, 6, 7, or no more than 10% of csr in the products containing combustible material. To meet these standards, physical separation methods, for instance screening, can successfully be used if the content of the csr is only 2–5% higher than it is permitted by the standards. For example the brown coal fly ash containing 5.6% csr become a usefull product after removal of the coarse (+0.63 mm) fraction. The oversized product contains 40.3% csr at the weight yield 7.5% and recovery equal to 54%, while the undersized product contains only 2.8% csr at the weight yield equal to 92.5% and 46%

recovery (Michalíková et al. 1993). In the case of the investigated fly ashes, which were produced by burning black coal, the screening alone was not sufficient to remove the csr. Therefore, flotation was chosen as the most promising method of separation. After evaluation of different collectors available for flotation of the combustible substances from the fly ashes the non-ionic collector FLOTACOL NX (FNX) was selected. It consists of 15–30% weight percent of OXO-HE foamer and 70–85% weight percent of K 315 mineral oil. Besides good collectibility it is also cheap and its residual concentration in the flotation products is low. The latter feature is very desired from the environmental point of view.

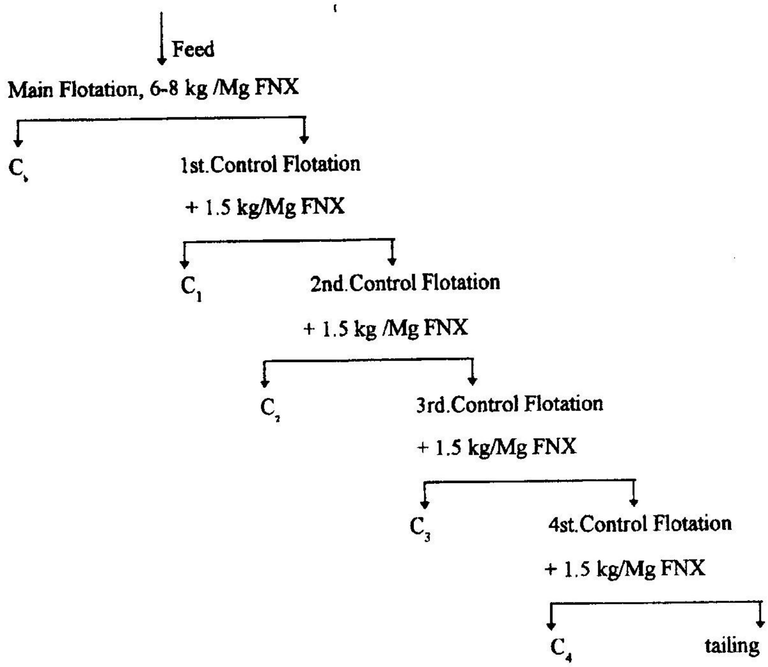


Fig. 1. The flowsheet of flotation tests

The flotation tests were carried out according to the flowsheet shown in Fig. 1. The amount of the collector required for a complete flotation of the csr in the sample for the investigated samples was between 6 and 14 kg/Mg. The results of flotation for the sample taken from the lower layer of the sludge bed are given in Table 2. According to Table 2 the first 6–8 kg/Mg dose of the collector provides concentrates with the yield of 30–40% and the csr content between 64 and 72%. During testing it was noticed that slime particles coating the unburnt coal prevented the adsorption of the collector prohibiting some csr particles from floating.

To learn about the kinetics of fly ashes flotation a new series of tests were carried out according to the flowsheet shown in Fig. 2.

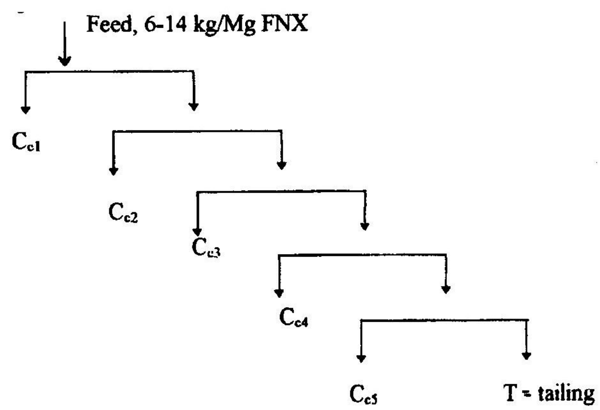
Table 2. Results of flotation of Slovak black coal fly ashes

Concentrates	Quantity of collector %	Weight yield of concentrate %	Content of the csr in tailing %
C_b	57	31.1	18.3
C_1	11	7.9	13.0
C_2	11	6.8	7.5
C_3	11	5.9	1.9
C_4	11	4.1	0.2

The collector was added to the agitated pulp in one dose. The results for the sample taken from the lower layer of the sludge are shown in Table 3. The results of flotation can be described by the following empirical equation

$$C = C_0 \exp(-0.45t)\,, \tag{1}$$

where t denotes time of flotation, c_0 is the content of the csr in the feed, and c_n is the content of the csr in the flotation fly ash waste (tailing) while C is the content of csr in the tailing at given time t.



The concentrate collected after:
the 1st minute of flotation C_{c1}
the 2nd minute of flotation C_{c2}
the 3rd minute of flotation C_{c3}
the 5th minute of flotation C_{c4}
the 10th minute of flotation C_{c5}

Fig. 2. Flowsheet of flotation to determine the kinetics of flotation

The values of C for different samples of the fly ashes (characterized by C_0) as a function of time of flotation are given in Table 4. The values of C_1–C_4, representing the values of the csr content in the tailing after appropriate time of flotation, which were calculated from Eq. 1, are also given in the table. For comparison purpose the values of csr required by the Slovak standard in the form of C_n values are also given in Table 4. It results from the table that to achieve first standard with C_n = 10% the whole sample needed only 2.45 min of flotation while to achieve the standard with C_n = 0.5% up to 9.2 min of flotation is needed. The change of the csr with time of flotation in the tailing for initial content of csr equal to 35% is given in Fig. 3.

Table 3. Kinetics of fly ash flotation for sample taken from the lower layer of the sludge bed

Flotation time min	Weight yield %		Content of csr %	Recovery of csr %
	F	100.00	26.88	100.00
1	C_1	22.65	75.37	63.51
2	C_2	11.13	71.24	29.50
3	C_3	3.24	40.47	4.88
5	C_4	0.87	11.06	0.36
10	C_5	0.55	3.56	0.07
	T	61.56	0.73	1.68

Table 4. Theoretical dependence of the content of csr in the chamber product (tailing) on the time of flotation

t min	C_n %	C_1	C_2	C_3	C_4
0.0		C_0= 34.34	C_0= 38.18	C_0 = 26.88	C_0 = 24.09
2.45	11.40	12.68	8.93	8.00	10.00
3.30	7.00	7.78	8.65	6.09	5.46
3.75	6.00	6.35	7.06	4.97	4.46
3.90	5.00	5.94	6.60	4.65	4.17
4.30	4.00	4.96	5.51	3.88	3.48
4.70	3.00	4.14	4.61	3.24	2.91
5.50	2.00	2.89	3.21	2.26	2.03
9.20	0.50	0.55	0.61	0.43	0.38

Figure 3 also shows the relationship between the amount of collector which is consumed during the separation of products having the csr content consistent with standards. The results can be fitted with the following empirical formula:

$$Z = 100\exp\left(-0.7t^{-1}\right). \quad (2)$$

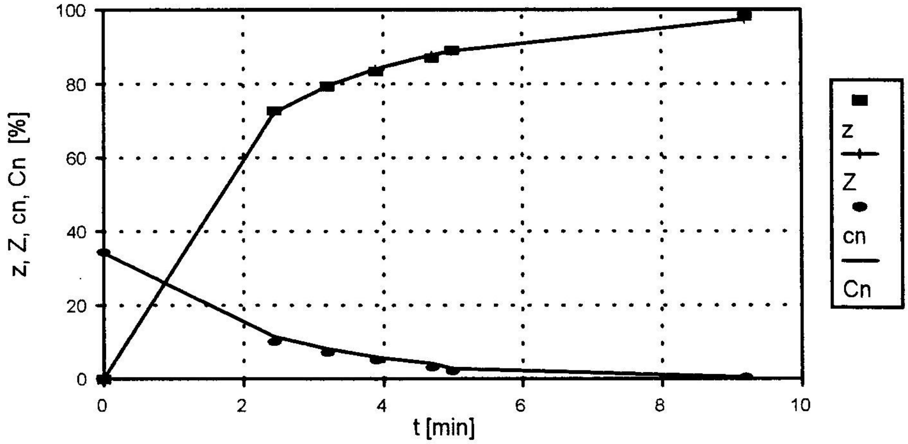


Fig. 3. Results of flotation of Slovak black coal fly ashes. The solid lines represent the content of combustibles in refuse as a function of the flotation time [$C = C_0\exp(-0.45t)$] and the collector consumption during flotation [$Z = 100\exp(0.7\,t^{-1})$]

Table 5. Optimum dose of Flotakol NX collector and its residual concentration after flotation of fly ash from sludge bed, fresh fly ash, and black coal

Sample	csr %	Consumption of Flotakol NX collector kg/Mg	Residual concetration of collector in main flotation as % of added amount of the collector
Fly ash from the sludge bed Layer:			
Upper	34.34	9	11.50
Middle	38.13	10	8.22
Lower	26.88	6	5.17
Fresh fly ash	24.09	6	6.75
Black coal	64.03	0.5	19.84

From the point of view of consumption of the collector, the technological aim is:

$$\lim_{t \to tcc} Z \to 100$$

where *tcc* is the required time for total consumption of the collector. It results from Fig. 3 that for 6–14 kg/Mg *tcc* is equal to 9–12 min. However, it seems to be not practical to prolong the time of flotation over 5 minutes.

The flotation results of black coal fly ashes and black coal with the FNX and its residual concentration are presented in Table 5.

CONCLUSIONS

The high content of csr in the fly ashes forces producers to treat them as wastes because the ashes cannot be used in civil engineering applications. It was shown in this paper that flotation is able to reduce substantially, down to 1%, the content of the csr in the ashes from black coals. After flotation, the tailings are of high quality and they can be used as substitutes of natural zeolites (Kolousek et al. 1993; Kovanda and Kolousek 1993) while the concentrates can be recycled and used in the power plants.

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Michalikova F., Florekova L., Benkova M. (1996), Flotacja slowackich popiołów lotnych, *Fizykochemiczne Problemy Mineralurgii*, 30, 49–55 (w jęz. angielskim)

Około 1Mt popiołów lotnych zgromadziło się przez ostatnie 26 lat w postaci osadów, w których zawartość części lotnych wynosi około 32%. Wykorzystanie tych popiołów przez budownictwo wymaga jednak redukcji części palnych. Do ich usunięcia zastosowano flotację. W pracy opisano wyniki badań optymalizacyjnych prowadzących do określenia warunków dla uzyskania produktów o określonej zawartości części palnych.