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IMPROVING THE TECHNOLOGY OF EXTRACTING COAL CONCENTRATE FROM FLY ASH FROM THERMAL POWER PLANTS

Purpose. Study on the possibility of extracting coal underfire particles from the ash of the thermal power station by flotation. Intensification of the enrichment process of coal particles, development of a mathematical model for forecasting indicators of the ash function.

Methodology. The method of fractional flotation was used to study the kinetics of the process of extraction of the valuable component. The technique of the planned experiment was applied, including the central composite rotatable plan of the second order for four factors affecting the ash content of the coal concentrate.

Findings. According to fractional analysis, the concentration limit of coal particles was determined. During the flotation of fly ash, the best results were obtained on the EFM ejector type flotation machine, the yield of the foam product was 18.6 % with an ash content of 25.1 %, compared to the MFU mechanical type flotation machine, where the ash content of the foam product was 36.5 % with an average yield of 21.1 %. The optimal consumption of reagents at the level of no more than 3,500 g/t of the collector and foaming agent up to 250 g/t was determined experimentally, and the required flotation time was determined. Calculations were performed to determine regression coefficients and the degree of influence of factors on the flotation process. A mathematical model of the flotation process of TPP ash removal was determined, which characterizes the influence of the main factors. The graphs of the significance of the factors and the three-dimensional surface of the calculated response function were drawn up.

Originality. The degree of influence of factors such as pulp pressure in the feed pipeline, collector consumption, foaming agent consumption, and flotation time on the process of beneficiation of TPP ash on the EFM ejector type flotation machine was determined.

Practical value. The complex model makes it possible to predict the final indicators of the response function, namely the ash content of the secondary coal concentrate. The results will make it possible to improve the parameters of technological processes for the enrichment of TPP ashes.

Keywords: *ash removal, thermal power plants, ash slag waste, coal concentrate, flotation*

Introduction. Coal remains one of the main sources of energy in Ukraine, which means that ash and slag waste continues to accumulate. According to the European Business Association (EBA), coal used as an energy resource in Ukraine accounted for up to 30 % of the country's total energy resources in 2019. Operating thermal power plants (there are 15 in Ukraine) produce 6.2 million tonnes of combustion waste per year (data for 2019). The disposal of such waste is less than 10 % per year, which means that the remaining 5.58 million tonnes of waste continues to be stored and accumulate. As a result, we have a multi-tonnage volume of waste accumulated over many years. As of 2020, more than 360 million tons of stored ash and slag waste have been accumulated [1]. Government policy plans are to phase out coal-fired power generation by 2050. By this we mean that for at least another 25 years, waste from thermal power plants will be generated and accumulated. In thermal power plants, pulverised coal combustion is used, and some fuel particles are simply not ignited. This seems to be due to the fact that the combustion process is not perfect, the pulverisation does not fully uncover combustible particles, because every year more and more low-calorific and high-ash coal types are used, and therefore some fuel does not burn down or does not ignite at all. Unburned particles (or mechanical underburning) are dumped into ash and slag waste (ASW) [2]. Depending on the coal grade and its composition in a quantitative ratio the mechanical underburning can be from 3–5 to 10–20 % of the total waste mass [3, 4]. By recovering the mechanical underburning from the fly ash, we can reduce some of the fertile soil area occupied by the waste and also use the recovered coal concentrate as a secondary fuel for the power plants, which will significantly increase energy savings.

Literature review. At the moment there are some publications related to enrichment of fly ash by flotation method. For example, in [5] the task is to extract the carbon part of the ash by means of a column-type flotation machine. A significant disadvantage of this technology is that it produces a frothy product of up to 40 % with an average ash content of 50–75 %.

In [6] the enrichment method by applying a two-stage flotation scheme is described. Here the research was carried out on an impeller flotation machine (FM-1M). After the main flotation, the frothy product was crushed again and then sent for cleaner flotation. The yield of frothy products was between 15 and 37 %, while the average ash content was still high at 66–68 %.

Attempts to improve the quality of coal concentrate by using higher dosages of reagents are described in [7]. Dosage of collector was up to 8 kg/t, foaming agent up to 1 kg/t. As a result, with an initial ash carbon content of 13.9 %, a frothy product with an average coal content of 67.5–68.5, i. e. an ash content ranging from 30 to 32 %, is obtained. Mineralisation of the bubbles in the cyclone-static tube increased the coal recovery into concentrate to 89.69 %, which is 6.9 % higher than that of the impeller machine [8].

The authors of [9] made a study aimed at the extraction of carbon from TPP ashes on an impeller-type flotation machine. Using mathematical statistics, the two main factors affecting carbon recovery – collector and foaming agent dosage – could be determined. The resulting coal concentrates contain up to 28.8 % combustibles, and the authors do not justify the consumption of reagents such as kerosene at up to 500 g/t. Determining reagent dosages is an important task and, in our opinion, the flotation process can be investigated once the optimum reagent consumption has been determined.

We used statistical research methods to study the influence of some factors on the qualitative and quantitative indicators of coal enrichment from ash wastes. The results showed the possibility of producing low ash coal concentrates with an average carbon content of up to 28.8 %.

Purpose. The purpose of this study is to investigate the flotation process in detail, making it possible to determine a rational reagent consumption using an ejector-type flotation machine. Using a multi-factor experiment, to obtain data on which factors have the greatest influence on the flotation process.

Main part. To achieve this goal, a sample of material was taken from the ash dump of the Chernihiv thermal power plant (TPP), which is located in Chernihiv, Ukraine. This TPP is designed for A-anthracite and T-lean coal.

Storage ash waste Chernihiv TPP are alluvial dumps. Therefore, we applied the following testing method: the entire area of the dump was divided into sections depending on the order in which the waste was stored. Then, lines and sampling points were marked for each site, assigning distances between them in accordance with the debit of waste release during laying. The sampling points were located 500 mm apart from each other. The depth of the pits was up to 1.5 m. The weight of the average sample was determined by the formula

$$Q = Kd^{a},$$

where Q is initial sample weight, kg; d is the largest diameter of particles, mm; K and a are constant values, depending on the fineness and how evenly the valuable components are interspersed.

The average sample weight was 80 kg. The granulometric composition of the sample was determined and the results are presented in Table 1.

To determine the amount of mechanical underburning, each size class was calcined in a muffle furnace for one hour. The greatest amount of unburned fuel is observed in the – 0.2 + 0.05 and – 0.05 + 0 mm classes. Under laboratory conditions the fractional composition of the ash was also studied, the results are presented in Table 2. Zinc chloride ($ZnCl_2$) was used as the heavy liquid.

The flotation properties of coals depend on the mineralogical composition, the degree of oxidation of the grain surface and the nature (composition and dispersion) of the waste rock inclusions. In nature, two main processes occur in coals over time, affecting the flotation properties of coals in opposite directions. Firstly, the organic matter is carbonised, and its crystal structure is streamlined. These processes increase the natural hydrophobicity of coals. Secondly, organic matter is oxidised to form carbonyl and carboxylic groups which actively interact with water and hydrophobize the surface of the coals. Therefore, coals of a certain medium degree of metamorphism (coking, fat coal) are characterised by maximum hydrophobicity.

Subsequent microscopic analysis showed that the charcoal particles are sharp-angled, porous and have a metallic sheen. Waste rock minerals are represented by quartz particles, glassy material (mullite) and aluminosilicate spheres. The aluminosilicates are represented by spheres smaller than 100 µm with an average density of up to 760 kg/m^3, which makes it possible to classify these particles as light. When they are submerged in water, some of them float to the surface of the water. Therefore, to achieve the best enrichment performance, these particles should be removed first. This thesis was confirmed by the results of laboratory studies, which were obtained using ejector-type and impeller-type flotation machines.

The study on fly ash flotation kinetics was carried out using an ejector flotation machine (EFM) and a mechanical coal flotation machine (MFC).

The mechanical coal flotation machine (MFC) consists of a device for mixing and aeration of the pulp (impeller, stator) and a flotation tank. The impeller rotating on the shaft captures the slurry with its blades and throws it into the stator, the blades of the latter straighten the slurry-air flow, ensuring its shockless entry into the flotation tank. Air is sucked into the flotation machine by the ejecting action of the pulp flows, which passes under the holes of the stator, these holes are in communication with the air sampling tube. Particles of a useful mineral, treated with special reagents, are selectively fixed on air bubbles, the bubble-particle complex floats into the foam layer, where it is removed with foam.

The ejector flotation machine (EFM) differs from the MFC flotation machine in its simple design. The EFM consists of a device for aeration of the pulp (aerator), a flotation tank and a pump for pumping the pulp. The aerator is a fixed part of the flotation machine and consists of a pipe, inside of which there is a nozzle, through which the slurry passes under high pressure created by the pump. The aerator itself is installed vertically, part of the aerator pipe is immersed in the pulp to create a hydraulic seal. The pulp jet exits the nozzle at high speed and hits the pulp mirror inside the pipe, which causes the pulp to be forced out of the pipe. Due to this, a rarefaction is created inside the pipe, air is sucked in through the air collector installed immediately after the nozzle, which is crushed by the pulp jet into tiny bubbles. After

Table 1

Granulometric composition of the TPP fly ash sample

Size classes, mm	Yield, %	Ash content, %
+ 0.2	1.05	90.3
– 0.2 + 0.05	17.97	67.0
– 0.05 + 0	80.98	80.9
Total	100.0	78.5

Table 2

Fractional composition of fly ash

Fractional density limits, kg/m^3	Fractional yield, %	Ash content of the fractions, %
1800	11.51	49.2
1800–2000	19.39	53.1
2000	69.1	90.85
Total	100.0	78.7

fixing particles of a useful mineral on the surface of the bubble, this complex floats to the surface of the pulp, forming a foam layer, which is removed by the blades of the foam machine.

Since our tests were on a laboratory scale and the flotation machine could process 0.4 kg of material at a time, we therefore performed sample reduction. After each stage, the obtained sample was mixed by the ringing method.

The average carbon content of the feed material was 19.7 %. Reagent consumption was – collector (kerosene) 4,500 g/t, foaming agent (T-66) 350 g/t. The results of these laboratory tests, carried out by multistage flotation, are shown in Table 3 and Figs. 1, 2.

As can be seen from Fig. 1, with the same flotation time on the ejector-type machine we get a frothy product with considerably lower ash content.

The ejector-type flotation machine EFM produced a froth product with a yield of 19.9 % and ash content of 27.6 %, which is the best result compared to the froth product of the mechanical flotation machine MFC, where the ash content of the froth product was 36.5 % with an average yield of 21.1 %. The ejector flotation machine also has a higher flotation speed, as the flotation time was 180 s compared to the MFC flotation machine, which had a flotation time of 210 s.

Thus, the ejector-type flotation machine is more efficient for the enrichment of fly ash and all further studies will be carried out on this type of flotation machine.

Under the influence of high temperatures in the furnaces of TPP boilers, coal fuel particles have retained their hydrophobic properties, so they are extracted by flotation [10]. Coal particles have a certain degree of oxidation in air during waste storage [11]; it is also worth considering that the surface of coal particles has a porous structure and this can cause an increased consumption of flotation reagents, it is necessary to determine their optimal consumption.

For this purpose, a series of laboratory tests with different reagent dosages were carried out. The results are presented in Table 4.

The minimum ash content of the foamed product of 24.8 % and yield of 17.6 % can be achieved at the consumption of 3,000 g/t of the foaming agent and 250 g/t of the collector. The ash content of the mineral part was 90.0 %. If we increase the reagent consumption of the collector to 3,500 g/t and the foaming agent to 250 g/t, we obtain a frothy product with a yield of 18.6 % with an ash content of 25.1 %, the ash content of the mineral part – 90.2 % at a yield of 81.4 %. We believe that these indicators can be considered optimal.

Planned experimental methods were used to investigate the flotation process of TPP ashes. To obtain a regression

Table 3

Investigation of fly ash flotation kinetics on flotation machines EFM and MFC

No.	EFM (ejector machine)			MFC (impeller type)		
	Frothy product		Flotation time	Frothy product		Flotation time
	Yield, %	Ash content, %	*t*, s	Yield, %	Ash content, %	*t*, s
1	0.7	34.8	5	1.4	42.6	5
2	1.3	28.6	10	1.6	39.2	10
3	2.0	26.4	10	2.1	37.1	15
4	2.4	24.5	15	2.6	35.7	15
5	2.6	24.4	15	2.9	34.7	15
6	2.8	25.4	20	3.1	33.5	20
7	3.0	27.3	20	3.2	35.6	25
8	2.9	31.7	25	2.4	37.2	30
9	1.3	30.6	25	1.5	38.2	35
10	0.9	31.1	35	0.3	40.1	40
Total	19.9	27.6	180	21.1	36.5	210

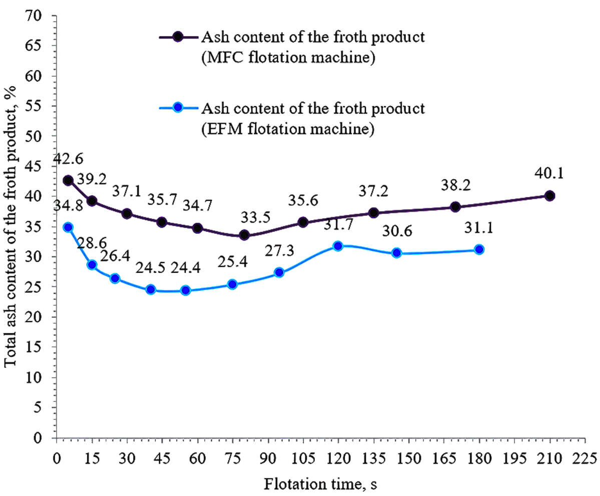

Fig. 1. Summary of ash characteristics for multistage flotation froth product on EFM and MFC machines

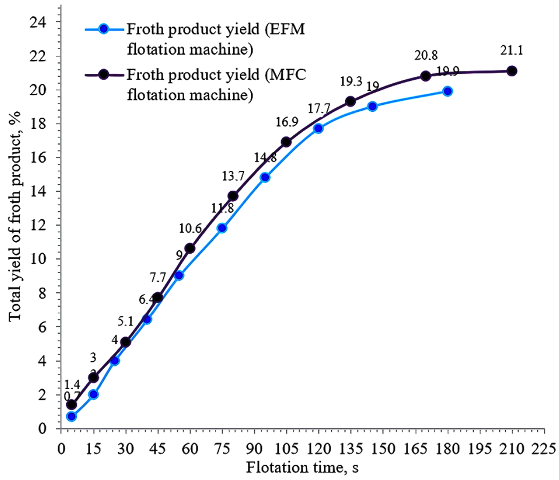

Fig 2. Summary of yields for multistage flotation froth product on EFM and MFC machines

Table 4

Data on the selection of optimum reagent consumption for ash flotation in EFM

No. of the series of experiments	Kerosene consumption, g/t	T-66 consumption, g/t	Flotation feed		Froth product		Chamber product	
			Yield, %	Ash content, %	Yield, %	Ash content, %	Yield, %	Ash content, %
I	1000	100	100.0	78.3	8.9	34.1	91.1	82.6
	2000	100	100.0	78.8	11.7	34.9	88.3	84.6
	3000	100	100.0	78.6	13.7	35.9	86.3	85.4
	4000	100	100.0	78.3	15.7	36.3	84.3	86.1
II	1000	200	100.0	78.4	12.8	25.1	87.2	86.2
	2000	200	100.0	78.5	14.6	27.5	85.4	87.2
	3000	200	100.0	78.6	17.3	29.2	82.7	88.90
	4000	200	100.0	78.5	18.4	29.7	81.6	89.5
III	1000	300	100.0	78.0	15.4	27.5	84.6	87.2
	2000	300	100.0	78.5	16.2	29.3	83.8	88.0
	3000	300	100.0	78.6	21.0	34.2	79.0	90.4
	4000	300	100.0	78.2	24.5	38.4	75.5	91.1

model of the flotation process, a second-order central rotatable plan for four factors was applied. To obtain a regression model of the flotation process, a second-order central rotatable plan was applied for four factors (Sdvyzhkova O., 2015).

The factors were selected based on our observations. Flotation factors can be divided into two categories:

- those typical for the ore and not controlled by the concentrator;

- those amenable to management and regulation.

Naturally, we consider factors that we can adjust in the flotation process. The number of these factors is large; for example, they include pulp density, temperature, pH value, circulation load, residence time of the pulp in the flotation cell, etc. When solving a statistical problem, it is difficult to take into account all factors at the same time, the calculations will be too cumbersome and difficult to implement in real conditions. Therefore, we relied on the outcomes that we received as a result of the study on flotation kinetics, and chose factors based on our observations. The first two factors that were chosen are the consumption of flotation reagents of kerosene q_c and frother T-66 q_f in the EFM flotation machine, which turned out to be lower than in the MFC. The following factor should also be taken into account – this is the flotation time t_f; in the EFM flotation machine it is 30 seconds less than in the MFC. An important role in the flotation process is played by the degree of pulp aeration, the size of air bubbles in the volume of the pulp. By direct measurements of many studies, it has been established that in mechanical flotation machines, the size of the main amount of air bubbles ranges from 0.5 to 1.2 mm. It is obvious that for coal particles of a certain size there are air bubbles of the most optimal size. It has not yet been possible to establish this under real conditions of the flotation process.

It is generally accepted that the efficiency of the flotation process increases with an increase in the dispersion of air bubbles. In the EFM cell, we can influence the degree of aeration and the size of the air bubbles by increasing the pressure of the pulp on the nozzle, so we have chosen the pressure of the pulp on the aerator nozzle p as the fourth factor.

The factors and their variation limits are shown in Table 5. The target function is the ash content of the froth product – A^d. Statgraphics software was used to statistically process the data from the matrix [12].

The study matrix with the flotation results is presented in Table 6.

A regression model is derived from the results of the study, which has the form

$$A^d = 24.83 + 0.45X_1 + 1.31X_2 + 4.05X_3 + 2.33X_4 + \\ + 1.76X_1^2 + 2.68X_1X_3 + 0.67X_1X_4 + 2.96X_2^2 + \\ + 0.41X_2X_3 + 0.97X_4 + 4.52X_3^2 - 0.16X_3X_4 + 1.5X_4^2,$$

where A^d is ash content of the foam product, %; X_1, X_2, X_3, X_4 are factor codes given in Table 5.

The coefficient of determination was $R^2 = 98.3$ %, which is a rather high value, and the standard error of the estimate took a minimum value of $S_E = 0.2459$. These figures indicate the adequacy of the resulting ash flotation model to the industrial process. Fig. 3 shows a graph, according to which statistically significant coefficients (values whose values are located on the right side of the vertical bold line) can be selected.

This graph shows how significantly the factors and their combinations influence the ash content of the A^d froth product. The drawn vertical line corresponds to 95 % of the significance of the factors.

Fig. 4 shows three-dimensional cross-sections of the hypersurface of the A^d response function.

The coordinates of the minimum points correspond to the optimum values of the relevant factors.

It is known that in three-dimensional graphs, one variable depends on the other two variables and the other two variables are independent.

So, in our case, the dependent variable is the ash content of the coal concentrate, and the independent variables are the following 4 variables: pulp pressure P, collector dosage q_c and foaming agent q_f, flotation time t_f.

Table 5

Factors that affect the qualitative parameters of the coal concentrate and their boundaries

Factor	Factor code	Unit of measure	Factor levels		
			–1	0	+1
Pulp pressure in the feed pipe, P	X_1	MPa	0.2	0.3	0.5
Collector consumption (kerosene), q_c	X_2	g/t	2000	3000	4000
Foaming agent consumption (T-66), q_f	X_3	g/t	200	250	300
Flotation time, t_f	X_4	s	150	180	210

Table 6

Study matrix and flotation results for fly ash

No.	Factor value in dimensionless scale				Value of factors on an in-kind scale				Ash content A^d, %
	X_1	X_2	X_3	X_4	p, MPa	q_c, g/t	q_f, g/t	t_f, s	
1	–1	–1	–1	–1	0.15	2000	200	150	31.6
2	–1	–1	–1	1	0.15	2000	200	210	33.4
3	–1	–1	1	–1	0.15	2000	300	150	34.2
4	–1	–1	1	1	0.15	2000	300	210	37.7
5	–1	1	–1	–1	0.15	4000	200	150	32.5
6	–1	1	–1	1	0.15	4000	200	210	35.3
7	–1	1	1	–1	0.15	4000	300	150	38.9
8	–1	1	1	1	0.15	4000	300	210	40.4
9	1	–1	–1	–1	0.45	2000	200	150	29.5
10	1	–1	–1	1	0.45	2000	200	210	31.7
11	1	–1	1	–1	0.45	2000	300	150	41.1
12	1	–1	1	1	0.45	2000	300	210	49.8
13	1	1	–1	–1	0.45	4000	200	150	31.6
14	1	1	–1	1	0.45	4000	200	210	33.8
15	1	1	1	–1	0.45	4000	300	150	44.9
16	1	1	1	1	0.45	4000	300	210	52.1
17	–2	0	0	0	0.10	3000	250	180	33.1
18	2	0	0	0	0.50	3000	250	180	23.2
19	0	–2	0	0	0.30	1000	250	180	30.2
20	0	2	0	0	0.30	5000	250	180	35.7
21	0	0	–2	0	0.30	3000	150	180	34.8
22	0	0	2	0	0.30	3000	350	180	43.6
23	0	0	0	–2	0.30	3000	250	120	20.6
24	0	0	0	2	0.30	3000	250	240	33.6
25	0	0	0	0	0.30	3000	250	180	24.7

In Fig. 4, *a*, $A^d(q_c, t_f)$, at a combined variation of the factor level +/– 0.5 of collector dosage q_c and flotation time t_f, the ash content of the coal concentrate varies within 25–28 %. If you increase the variation step for these factors to +/–1.0, the maximum ash content of the froth product is 35 %, which is quite high. By increasing the level variation step to 2.5 for the two factors, ash content takes on maximum values of up to 65.0 %.

In Fig. 4, *b*, $A^d(p, q_c)$ we see that a combined variation of +/– 0.5 factors of pulp pressure p and foaming agent dosage q_f has a significant effect on concentrate ash content up to 35 %. Even a small change in these factors causes a significant increase in ash content. The adjustment of these parameters should be changed at the smallest interval possible.

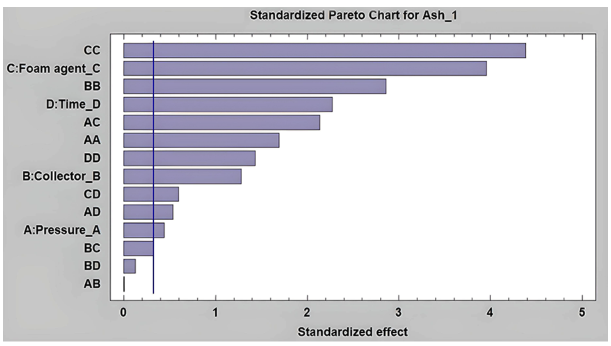

Fig. 3. Pareto plot of significance of regression coefficients

In Fig. 4, *c*, $A^d(q_c, q_f)$ with a combined change in the dosage factor levels of collector q_c and foaming agent q_f, even at a large range of –1.0 to +1.0, we observe a slight variation in ash content of the coal concentrate, ranging from 25.0 to 31.0 %.

In Fig. 4, *d*, $A^d(p, q_f)$ the combined change in the levels of the foaming agent dosage factor q_f and the pulp pressure p from –1.0 to +1.0 has no significant effect on the ash content of the concentrate, which is in the 27 % limit.

In Fig. 4, *e*, $A^d(p, t_f)$ we see that pulp pressure p and flotation time t_f have some combined effect on the value of the response function. At values of these factors from –0.5 to +0.5 the ash content of the concentrate varies from 25 to 29 %.

In Fig. 4, *f*, $A^d(q_f, t_f)$ we observe that a combined change in the levels of the foaming agent dosage factors q_f and the flotation time t_f from –0.5 to +0.5 causes a change in the response function of 25 to 30 %. Separately, it is worth highlighting the fact that the ash content of the coal concentrate rises with increasing flotation time, i.e. with increasing levels of variation. This indicates the content of fine particles (aluminosilicates) in the pulp, which are carried away into the froth product with increasing flotation time. Therefore, it is necessary to extract particles smaller than 30 μm before flotation and reduce the flotation time, which will eventually bring us closer to the minimum value of the response function (ash content of the coal concentrate).

By analysing the above graphs, we can conclude that each of the factors, as well as various combinations of factors individually, play a certain role in the variability of the response

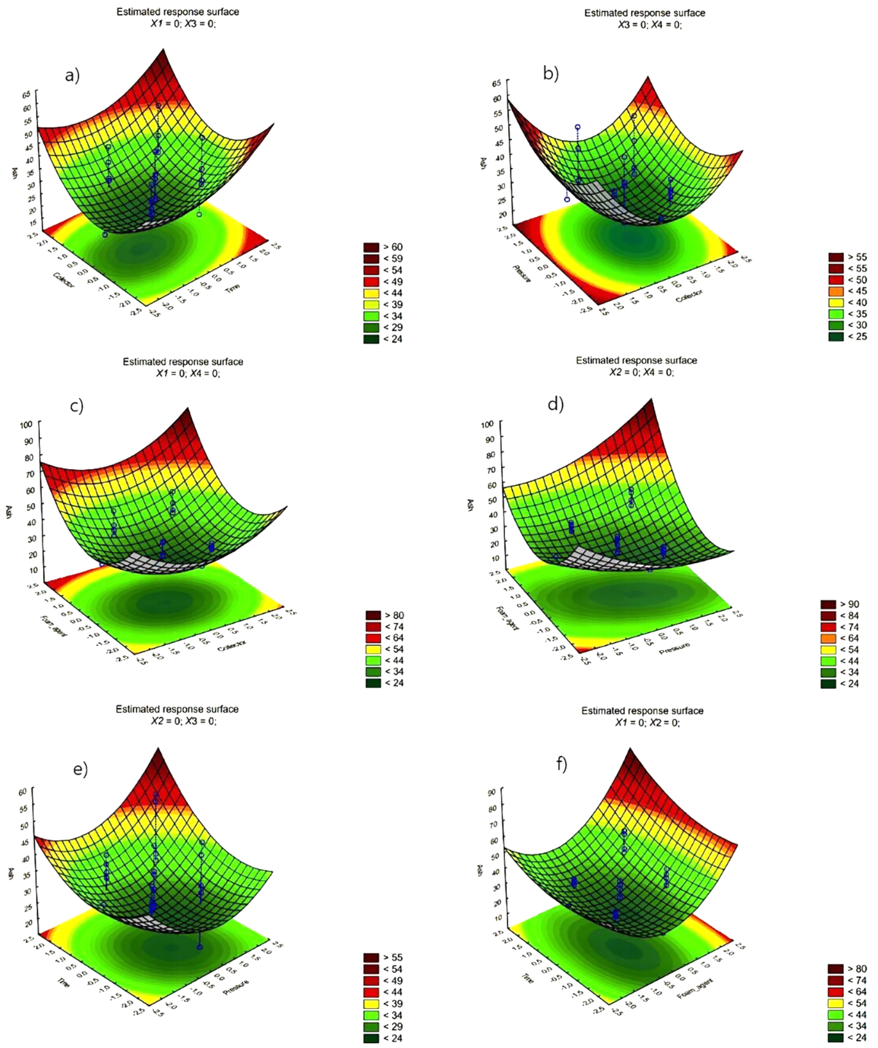

Fig. 4. Three-dimensional change in the response function depending on the level of factors:
a – $A^d(q_c,t_f)$; *b* – $A^d(P,q_c)$; *c* – $A^d(q_c, q_f)$; *d* – $A^d(P, q_f)$; *e* – $A^d(P, t_f)$; *f* – $A^d(q_f, t_f)$

function (ash content of coal concentrate). When each factor or combination of factors occupies an optimal level of variation, we are approaching the minimum value of the response function. And to find out these optimal values of factor levels, we turned to the basic principles of experiment planning, namely using a central second-order compositional rotatable plan for the four factors.

Conclusions. The best ash enrichment results were obtained with the ejector-type flotation machine EFM, a concentrate with a yield of up to 18.6 % at an ash content of up to 25.1 %. This is primarily due to the formation of smaller air bubbles, which are more selectively attached to the surface of the carbon particles. The lower consumption of reagents in the EFM flotation machine compared to the MFC (mechanical type) is due to a better redistribution of the collector reagent on the surface of the particles. The kerosene consumption was 3,500 g/t, that of the collector made 250 g/t. The next step of our research could be a theoretical justification of the minimum amount of collector, which will cover a particle of a valuable component, for example, with a molecular layer. The main factors affecting the flotation process are the dosage of the foaming agent and the flotation time. The optimum foaming agent dosage can be determined experimentally, thereby reducing the probability of extracting waste rock minerals into the concentrate.

As the flotation time increases, the probability of extracting aluminosilicate microspheres into the froth product increases, which increases the ash content. The flotation time needs to be reduced and a fine classification of ash prior to flotation should be applied.

The data obtained will be used for an in-depth study on the influence of the selected factors on the flotation process of the ash and to be able to predict the values of the separation products.

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Удосконалення технології вилучення вугільного концентрату із золи винесення теплоелектростанцій

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Мета. Вивчення можливості вилучення частинок вугільного недопалу із золи винесення ТЕС методом флотації. Інтенсифікація процесу збагачення вугільних частинок, розробка математичної моделі прогнозування показників функції зольності.

Методика. Використано метод дробної флотації для вивчення кінетики процесу вилучення цінного компоненту. Застосована методика планованого експерименту, що включає центральний композиційний ротатабельний план другого порядку для чотирьох факторів, які впливають на зольність вугільного концентрату.

Результати. За даними фракційного аналізу визначена межа концентрації вугільних частинок. При флотації золи винесення кращі результати отримані на флотаційній машині ежекторного типу ЕФМ, вихід пінного продукту становив 18,6 % із зольністю 25,1 %, порівняно із флотаційною машиною механічного типу МФУ, де зольність пінного продукту склала 36,5 % із середнім виходом 21,1 %. Попередньо експериментально визначені оптимальні витрати реагентів на рівні не більше 3500 г/т. збирача та спінювача до 250 г/т., встановлено необхідний час флотації. Виконані обчислення щодо визначення коефіцієнтів регресії та ступеня впливу факторів на процес флотації. Визначена математична модель процесу флотації золи винесення ТЕС, що характеризує вплив основних факторів. Складені графіки значущості факторів і тривимірної поверхні розрахункової функції відгуку.

Наукова новизна. Визначена ступінь впливу факторів, таких як тиск пульпи у трубопроводі живлення, витрата збирача, витрата піноутворювача, час флотації, на процес збагачення золи винесення ТЕС на флотаційній машині ежекторного типу ЕФМ.

Практична значимість. Складена модель дозволяє прогнозувати кінцеві показники функції відгуку, а саме зольність вторинного вугільного концентрату. Результати дозволять покращити параметри технологічних процесів збагачення зол винесення ТЕС.

Ключові слова: *зола винесення, теплові електростанції, золошлакові відходи, вугільний концентрат, флотація*

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