Increasing the Efficiency of Froth Flotation to Maximize Production of Coking Coal Concentrates in the Aspect of Sustainable Management of Natural Resources

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Abstract

Coking coal, due to its limited availability and the role and importance of steel as a raw material, essential in almost all industries, has been on the list of critical raw materials in the EU for many years. The article presents the results of laboratory tests of impact of the selected factors (feed parameters, process parameters, reagents) on the effectiveness of flotation, which is a commonly used method for beneficiation of fine coking coal grains. The large number of variables and significant differences in results clearly indicate the need for more detailed tests before each new application of flotation beneficiation technology. Selection of parameters that guarantee maximization of production from the point of view of rational and sustainable management of resources while minimizing the negative impact of the effects of this process on the environment should be the result of these tests.

Keywords: *mineral resources, coking coal, froth flotation, efficiency of the process*

1. Introduction

Coking coal, a critical raw material on the EU list [1], plays a key role in production of steel, one of the key materials used in construction and manufacture of machines, ships, cars and everyday items. Despite the technologies being developed to replace coke with green hydrogen, it is estimated that developing such a technology on a mass scale may still take several dozen years [2,3]. Difficulty in replacing the coking coal and its limited resources force the use of technological and design solutions that enable maximizing the production of high-quality concentrates while minimizing coal losses in waste.

In turn, steam coal, despite the ongoing decarbonization, resulting in a decline in its production and industrial use, will still continue to be a component of the energy mix in the coming years.

The production of hard coal with high quality parameters requires continuous improvement of the beneficiation technology and designs of the machines and devices used. The beneficiation process, depending on the grain size of the material (feed), is carried out in specialized machines and devices, including heavy media baths, dense medium cyclones, pulsating water jigs [4,5,6,7,8,9,10,11,12].

Very fine hard coal grains with a grain size below 0.5 mm are most often enriched by froth flotation [13,14,15,16,17].

Flotation can be used both for coking coal and steam coal, but in the case of the first one, much higher efficiency of the process is achieved.

Flotation is a physicochemical process based on the use of differences in the surface properties of useful mineral grains and waste rock, and above all, differences in hydrophobicity. In the case of hard coal, organic (coal) grains with hydrophobic surfaces are subject to flotation, while waste rock grains with hydrophilic surfaces, of high surface energy, do not float [18, 19,20,21].

The process of flotation of coal sludge generally is carried out in flotation machines, the so-called floaters.

A very important condition for an effective flotation separation process is the proper grain composition of the feed. The pioneer work on the relationship between particle size and flotation recovery was carried out by Gaudin et al. [22,23] Fig. 1 shows the dependence of flotation recovery on the grain size for a variety of raw mineral, including coal.

Although the coal flotation process is usually used for grains <0.5 mm, there are also reports in the literature of successful enrichment of grains coarser than <1 mm [24]. On the other hand, it was found in [25] that the maximum grain size that can be highly flotable is 0.589 mm.

A number of flotation kinetic models, which investigated the effect of particle size on the flotation process, can be found in the literature. Analysis of the available information showed that, despite significant differences in the grain size ranges, expected for maximum carbon recovery, the extreme grain sizes do not exceed 0.5 mm (maximum) and 0.074 mm (minimum) [22,26,27,28,29,30].

Increasing share of the finest grains <0.045 mm, with low floatability, in the flotation feed (grain class 0.5–0 mm) is an equally important problem that negatively affects the efficien-

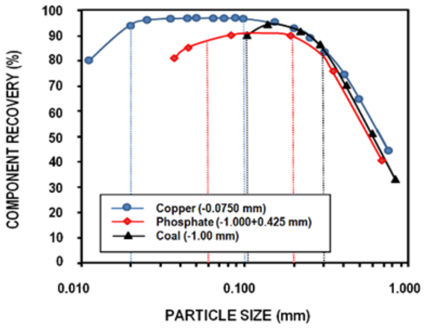

Fig. 1. Flotation recovery depending on the grain size for a variety of raw mineral [22,23]
Rys. 1. Odzysk flotacji w zależności od wielkości ziaren dla różnych surowców mineralnych [22,23]

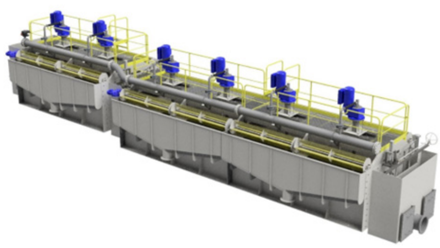

Fig. 2. IZ12K flotation machine [own elaboration]
Rys. 2. Maszyna flotacyjna IZ12K [opracowanie własne]

cy of the flotation process despite the possibility of flotation beneficiation of these grains. [31,32].

As a result of the most commonly used method of coal mining – longwall shearer technology – significant amount of very fine grains is formed, including grains <0.5 mm [33].

Such conditions justify research and development work aimed at increasing the efficiency of the flotation process in terms of both product quality parameters and process costs.

The article presents the test results on the efficiency of the flotation process for various ranges of grain size and different shares of each grain class in the feed.

2. Industrial flotation machines

The process of flotation of coal mud in a mass manner is carried out in flotation machines.

Flotation machines are most often classified according to the method of aerating the suspension [34,35]. Based on this criterion, three basic types of machines can be distinguished: mechanical flotation machines, in which the aeration and dispersion unit consisting of a rotor and a stator sucks in and agitates the flotation suspension and disperses the air sucked from the atmosphere, pneumo-mechanical flotation machines, in which the aeration and dispersion unit consisting of a rotor and a stator agitates the flotation suspension and disperses air supplied from the outside under pressure, pneumatic floating machines, in which there is no rotor, and special devices called aerators are used for air dispersion in the suspension. Compressed air is supplied from the outside or is sucked in from the atmosphere.

In addition, other types of flotation machines are known, not playing a significant role in industry, such as vacuum, cyclone, electro-flotation and combined machines.

Another division identifies five categories of flotation machines: mechanical agitation flotation machine, inflatable agitation flotation machine, flotation column, impeller flotation machine and rod flotation machine [36].

In the Polish processing plants, coal mud beneficiation by flotation almost exclusively uses pneumo-mechanical machines type IZ.

The KOMAG Institute of Mining Technology has developed a modernized version of the most popular pneumo-mechanical flotation machine – IZ12K (Fig. 2)

It is a trough-type machine and has a modular structure. It consists of three two-rotor units with two-sided intake of flotation foam.

Two-rotor units, each with a capacity of 13 m3, are connected in a complete flotation machine in cascade, with the first level being one unit (two working compartments), and the next two units, set lower with a difference in the bottom levels of the working compartments of 400 mm, are connected with the previous one by an intermediate box. After the last working compartment, this flotation machine is equipped with a tailings container. Each section is equipped with two rotors, a mechanical driving system, a compressed air collector and stator located around the rotor as well as a bottom channel. The flotation machine is equipped with an automatic adjustment of the level of dregs in the trough. The coal beneficiation process takes place during the movement of dregs in the machine bed [37].

3. Laboratory tests

Two series of tests were performed, in which the grain size range in the feed and share of each grain class in the above-mentioned materials were different.

Testing the impact of coking coal feed size distribution on the efficiency of the flotation process was carried out at the KOMAG Institute of Mining Technology on a specialized laboratory stand using a chamber (cell) with a capacity of 1400 cm^3 (Fig. 3).

Fig. 3. Stand for testing the flotation process [32]
Rys. 3. Stanowisko laboratoryjne procesu flotacji [32]

Rys. 6. Rozkład naprężeń równoważnych
Fig. 6. Equivalent stress distribution

Grain class, mm	Feed 0.5–0 mm		Feed 0.3–0 mm	
	Output, %	Ash, %	Output, %	Ash, %
0.5–0.3	22.35	18.34		
0.3–0.045	39.21	23.83	50.49	23.83
<0.045	38.46	34.58	49.52	34.58
Suma	100.00	26.74	100.00	29.16

3.1. Testing methodology

The chamber (cell) of the flotation machine was filled with water from the water supply system (processing water). Then, a weighed portion of the feed was poured into the flotation chamber, a flotation reagent was added in a given dose, appropriate for a given portion of the feed, and the resulting mixture was conditioned for 30 seconds at the rotor speed of 600 rpm. Then the process air valve (output equal to 2 dm3/min) supplied by the rotor was opened and the rotor speed was increased to 1040 rpm. The level of dregs in the flotation chamber was refill with water, so that it remained 1 cm below the overflow threshold. The flotation process was stopped after 180 s. The flotation products were filtered and dried at ambient temperature, and then weighed and the ash content was determined in accordance with PN-ISO 1171:2002.

To assess the flotation results, apart from the ash content in the products, recovery of combustible substance in the flotation concentrate (ε) was used, calculated according to the following relationship:

$$\varepsilon = \gamma \cdot \frac{100 - \lambda}{100 - \alpha} \qquad (1)$$

where:
α – ash content in the feed %,
γ – concentrate output %,
λ – ash content in the concentrate %.

3.2. Test results

3.2.1. Test series No. 1

Two materials with a grain size of 0.5–0 mm and 0.3–0 mm were the object of tests. Tested materials were obtained, through dimensional classification, from the feed for a pulsating fine coal jig in the grain class of 30–0 mm from the selected coking coal mine.

The results of the granulometric analysis of the above-mentioned materials are given in the Table 1.

The tested material had a significant amount of the finest grains >0.045 mm, which amounted to 38.46% in the case of the 0.5–0 mm grain class and as much as 49.52% in the 0.3–0 mm grain class. Due to the high content of such grains, the feed with so narrowed grain size range should be considered as of very low floatability.

Two complex flotation agents, marked as R1 and R2, were used in the tests. The tests were carried out at densities of 60, 80 and 100 g/l. Agent doses of 0.4; 0.8 and 1.2 kg/Mg of dry material were used.

The test results, using the R1 agent, i.e. ash content in products and recovery of combustible substance are given in the Table 2.

The analysis of the results showed a clear effect of the flotation agent dose on the parameters of the products and the efficiency of the flotation process, especially in the case of feed of grain size 0.5–0mm. Impact of the dose of the flotation agent on the results concerned all the analysed quantities, i.e. products yield, their ash content and recovery of the combustible substance in the concentrate. With increasing the dose of the agent, the ash content in tailings increased from 77.45% (0.4 kg/Mg of dry material) to 80.97% (0.8 kg/Mg). The recovery of the combustible substance also increased from 64.01% (0.4 kg/Mg) to 68.51% (1.2 kg/Mg). At the same time, the ash content in the concentrate increased from 8.36% (0.4 kg/Mg) to 10.31% (0.8 kg/Mg).

The tests did not show the impact of material density on the efficiency of the flotation process (both feeds).

Despite lower ash content in the concentrate in testing the feed of grain size 0.3–0 mm, it should be stated that more favourable results and higher efficiency of the flotation process were obtained in tests with feed in the 0.5–0 mm class.

In most cases, for the 0.5–0 mm class, higher ash content in tailings was obtained. In tests, in which the ash content in tailings of 0.3–0 mm class was higher, lower ash content in the concentrate was obtained for the 0.5–0 mm class.

In all tests, the yield of combustible substance in the concentrate was higher in the tests with the feed of 0.5–0 mm.

A very important issue in terms of the effectiveness of the flotation process are the costs related mainly to the cost of

Tab. 2. Parameters of flotation with use of R1 agent [38]

Tab. 2. Zestawienie parametrów procesu flotacji z wykorzystaniem odczynnika R1 [38]

Feed 0.5–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	77.23	9.15	23.77	77.45	64.01
	0.8	78.52	9.81	21.48	80.61	65.28
	1.2	80.36	10.12	19.64	77.56	68.51
80	0.4	75.39	8.36	24.61	75.97	61.71
	0.8	79.56	9.81	20.44	79.62	66.97
	1.2	79.38	10.01	20.62	79.78	66.69
100	0.4	77.86	9.16	22.14	76.77	65.02
	0.8	78.67	10.31	21.23	80.97	65.44
	1.2	79.95	10.01	20.05	80.52	67.39
Feed 0.3–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate. %		Tailings. %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	67.25	7.87	32.75	67.09	53.10
	0.8	65.87	8.18	34.13	62.68	52.52
	1.2	71.52	9.59	28.48	72.63	57.31
80	0.4	73.36	11.77	26.64	70.21	60.41
	0.8	70.10	8.49	29.90	68.70	56.30
	1.2	77.49	12.32	22.51	82.41	63.55
100	0.4	76.12	11.61	23.88	79.36	62.19
	0.8	70.90	9.60	29.10	72.03	62.79
	1.2	78.87	12.30	21.13	81.06	65.80

the agent. With comparable product parameters, the higher the reagent consumption, the lower the process effectiveness.

Therefore, special attention should be paid to the results of testing the use of lowest amounts of the agent (0.4 kg/Mg), especially in the case of the 0.5–0 mm grain size class. Regardless of the feed density, in each case the ash content in the concentrate was <10%, the ash content in tailings was higher than 75%, and the recovery of the combustible substance was not less than 64%.

Fig. 4 and 5 graphically show the comparison of parameters of flotation products for the tested grain classes, obtained at the extreme process parameters used during tests.

During the tests, a significant dispersion of results was observed regarding the ash content in the separation products and the recovery of combustible substance in the concentrate.

Use of the R2 reagent, despite the lower ash content in the concentrate, resulted in a significantly lower efficiency of the process due to the significantly lower ash content in tailings and lower recovery of combustible substance in the concentrate.

In most cases, there was a relationship between the dose of the flotation reagent and the parameters of products, especially of tailings, and the efficiency of the flotation process. With the increase in the dose of the agent, the yield of tailings decreased and, at the same time, the ash content in the above-mentioned product increased. In the case of the 0.3–0 mm grain class, a positive effect of the increase in flotation pulp density was also observed.

Fig. 6 and 7 show a graphical comparison of the parameters of flotation products for the tested grain classes, obtained at the extreme process parameters used in testing.

3.2.2. Test series No. 1

Three materials with a grain size of 0.5–0 mm, 0.25–0 mm and 0.125–0 mm, from the selected coking coal mine were tested. The granulometric-ash composition of the raw material is presented in Table 4.

The finest grains (<0.045 mm) had the largest share in the analyzed grain sizes – 65.84%.

Ash content increased inversely proportional to the grain size from 12.57% (0.5-0.25 mm) to 41.93% (<0.045 mm). Subsequent tested feeds with grain size of 0.5–0 mm, 0.25–0 mm and 0.125–0 mm had increasingly higher ash content.

Flotation agent R1 was used in the tests. The tests were carried out at densities of 60 and 100 g/l. Agent doses of 0.4, 0.8 and 1.2 kg/Mg of dry material were used.

Parameters of the flotation process such as yield and ash content in the products as well as the recovery of combustible substance are presented in Table 5.

Analysis of the results showed a clear effect of the dose of flotation agent and the density of flotation pulp on products parameters and the efficiency of the flotation process for all tested feeds.

With increase of the agent dose, the yield of the concentrate increased, but ash content in this product also increased. At the same time, the ash content in tailings increased. A similar dependence was observed during the recovery of a combustible substance. Increasing the density, for the same agent doses, resulted in an increase in the yield of the concentrate with a simultaneous increase in the ash content in tailings.

The tests clearly show the negative impact of narrowing the grain size class and reducing the upper range of grains on product parameters and process efficiency. As the size of grains in the feed decreased, the quality parameters of the separation products deteriorated. The ash content in concentrate of the tested classes of 0.5–0 mm, 0.25–0 mm and 0.125–0 mm increased and was in the range of 11.83–14.36%,; 12.44–16.43% and 15.01–18.48%, respectively, with a simultaneous increase in yields. The ash content in tailings decreased in the analyzed size classes, in the ranges 60.54–79.79%; 60.86–74.86% and 60.63–72.99% respectively.

Figures 8–10 show the impact of the extreme process parameters during tests on the products quality parameters.

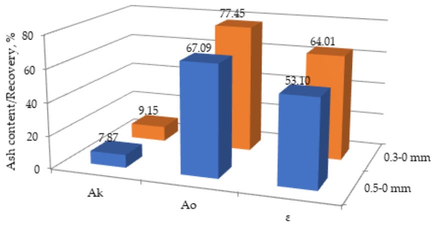

Fig. 4. Comparison of qualitative parameters of the flotation products – pulp density 60 g/l, agent dose 0.4 kg/Mg (Ak – ash content in the concentrate, Ao – ash content in tailings, ε – recovery of combustible substances in the concentrate) [38]
Rys. 4. Porównanie parametrów jakościowych produktów flotacji – zagęszczenie 60 g/l, dawka 0,4 kg/T (Ak – zawartość popiołu w koncentracie, Ao – zawartość popiołu w odpadach ε – uzysk substancji palnej w koncentracie) [38]

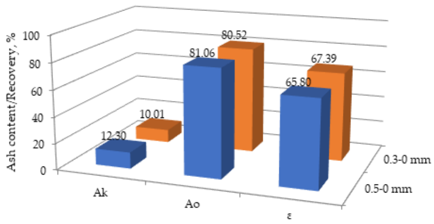

Fig. 5. Comparison of qualitative parameters of the flotation products (pulp density 100 g/l, agent dose 1.2 kg/Mg) [38]
Rys. 5. Porównanie parametrów jakościowych produktów flotacji (zagęszczenie pulpy 100 g/l, dawka odczynnika 1,2 kg/T) [38]

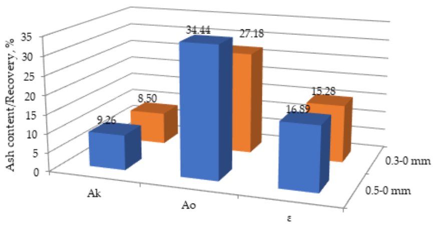

Fig. 6. Comparison of qualitative parameters of the flotation products (pulp density 60 g/l, agent dose 0.4 kg/Mg) [38]
Rys. 6. Porównanie parametrów jakościowych produktów flotacji (zagęszczenie 60 g/l, dawka 0,4 kg/T) [38]

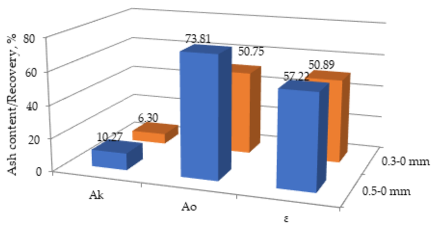

Fig. 7. Comparison of qualitative parameters of the flotation products (pulp density 100 g/l, agent dose 1.2 kg/Mg) [38]
Rys. 7. Porównanie parametrów jakościowych produktów flotacji (zagęszczenie pulpy 100 g/l, dawka odczynnika 1,2 kg/T) [38]

4. Conclusions

Reduced coal extraction associated with gradual decarbonization should not limit further development of technologies and design solutions for equipment used in the mining industry, including the coal processing. Due to the key role of coking coal in steel production, further R&D work allowing for a constant increase in the efficiency of both coal mining and processing is justified.

Froth flotation is one of the important methods for beneficiation of hard coal, including the stem coal.

Due to the increasing share of fine grains (<0.5 mm) in run-of-mine and material sent to flotation, selection of parameters, including the optimal grain range of the feed in terms of quality parameters of flotation products is an extremely important problem.

Testing the impact of the feed grain size distribution on the flotation efficiency showed that narrowing the grain size

Tab. 3. Parameters of flotation with use of R2 agent [38]
Tab. 3 Zestawienie parametrów procesu flotacji z wykorzystaniem odczynnika R2 [38]

Feed 0.5–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	18.26	8.50	81.74	27.18	15.21
	0.8	43.92	9.94	56.08	35.29	36.98
	1.2	73.31	6.82	26.69	68.82	60.29
80	0.4	23.77	9.75	76.23	29.16	19.87
	0.8	56.06	6.50	43.94	47.19	45.34
	1.2	67.47	6.21	32.53	60.33	54.80
100	0.4	22.41	7.40	77.59	28.58	18.44
	0.8	64.39	7.51	35.61	55.14	52.59
	1.2	62.06	6.30	37.94	50.75	50.89
Feed 0.3–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	21.58	9.26	78.42	34.44	16.89
	0.8	54.67	9.27	45.33	48.66	43.91
	1.2	65.58	8.30	34.42	64.57	51.73
80	0.4	27.02	8.19	72.98	35.80	21.09
	0.8	57.40	7.32	42.60	54.97	44.83
	1.2	65.76	9.33	34.24	63.97	52.19
100	0.4	28.93	7.75	71.07	33.95	23.09
	0.8	63.10	8.08	36.90	65.05	48.67
	1.2	71.67	10.27	28.39	73.81	57.22

Tab. 4. Granulometric-ash compositions of tested feeds for the flotation [38]
Tab. 4. Składy granulometryczno-popiołowe nadaw doświadczalnych do procesu flotacji [38]

Grain size mm	Feed 0.5–0 mm		Feed 0.25–0 mm		Feed 0.125–0 mm	
	Yield, %	Ash, %	Yield, %	Ash, %	Yield, %	Ash, %
0.5-0.25	11.32	12.57				
0.25-0.125	9.47	15.8	10.67	15.80		
0.125-0.045	13.37	18.24	15.08	18.24	16.88	18.24
<0.045	65.84	41.93	74.25	41.93	83.12	41.93
Suma	100.00	32.97	100.00	35.57	100.00	37.93

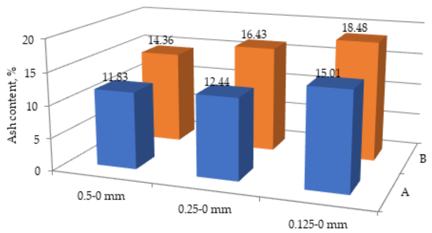

Fig. 8. Ash content in the concentrate depending on pulp density and agent dose (A – density 60 g/l, dose 0.4 kg/Mg; B – density 100 g/l, dose 1.2 kg/Mg) [38].
Rys. 8. Zależność zawartości popiołu w produkcie koncentratowym od zagęszczenia pulpy i dawki odczynnika (A – zagęszczenie 60 g/l. dawka 0,4 kg/T; B – zagęszczenie 100 g/l, dawka 1,2 kg/T) [38]

class and reducing the upper range of grain sizes in majority of tests resulted in deterioration of quantitative and qualitative parameters of the separation products and the decrease in the efficiency of flotation i.e. the recovery of combustible substance in the concentrate.

The test results clearly indicate that a high share of the smallest, very difficult to float grains <0.045 mm has a definitely negative impact on all product parameters. With the increase in the percentage of fine grains in the feed, the quality parameters of the products deteriorates. Therefore, it seems that the separation of the above-mentioned grains from the feed for flotation should significantly increase the process effectiveness.

The tests also confirmed the significant impact of the flotation agent type on the efficiency of recovery of combustible substance. The flotation agent, due to its high cost, is a significant component of cost effectiveness of the process, therefore it is extremely important to select the right type and dose of the agent in terms of the expected and acceptable parameters of the enrichment products.

Significant differences in the results require detailed tests before each new application of flotation enrichment technology. The tests, preceded by a grain size and ash analysis, should include the selection of the type of flotation agent, its dose, as well as other process parameters, including flotation pulp density.

Proper selection of the process parameters can significantly increase the efficiency of the flotation process, allowing both to reduce the production costs of coal concentrates and to maximize the production of high-quality assortments. The

Tab. 5. List of selected parameters of the flotation process [38]
Tab. 5. Zestawienie wybranych parametrów procesu flotacji [38]

Feed 0.5–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	58.75	11.83	41.25	60.54	45.36
	0.8	70.41	14.33	29.59	75.77	55.46
100	0.4	66.67	13.07	33.33	68.80	52.14
	0.8	71.55	13.79	28.45	75.84	56.42
	1.2	73.67	14.36	26.33	79.79	58.85
Feed 0.25–0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	56.86	12.44	43.14	60.86	43.29
	0.8	66.99	14.35	33.01	76.33	50.98
100	0.4	63.25	14.19	36.75	67.04	48.93
	0.8	67.10	15.93	32.90	73.25	52.05
	1.2	69.83	16.43	30.17	74.86	55.10
Feed 0.125-0 mm						
Concentration, g/l	Amount of agent, kg/Mg	Concentrate, %		Tailings, %		Recovery, %
		Yield, %	Ash, %	Yield, %	Ash, %	
60	0.4	53.35	15.01	46.65	60.63	39.99
	0.8	61.21	16.43	38.79	67.93	46.57
100	0.4	59.50	16.13	40.50	64.08	45.72
	0.8	64.01	18.32	35.99	69.71	49.51
	1.2	66.04	18.48	33.96	72.99	51.04

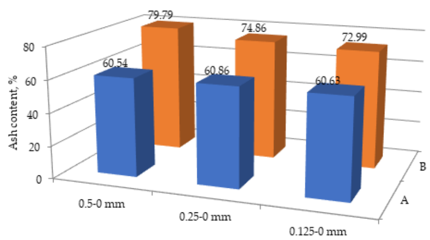

Fig. 9. Dependence of ash content in tailings on pulp density and the agent dose (A – density 60 g/l, dose 0.4 kg/Mg; B – density 100 g/l, dose 1.2 kg/Mg) [38].
Rys. 9. Zależność zawartości popiołu w produkcie odpadowym od zagęszczenia pulpy i dawki odczynnika (A – zagęszczenie 60 g/l. dawka 0,4 kg/T; B – zagęszczenie 100 g/l, dawka 1,2 kg/T) [38]

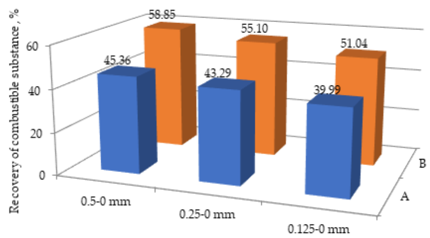

Fig. 10. Dependence of ash content in tailings on pulp density and the agent dose (A – density 60 g/l, dose 0.4 kg/Mg; B – density 100 g/l, dose 1.2 kg/Mg) [38]
Rys. 10. Zależność uzysku substancji palnej w produkcie koncentratowym od zagęszczenia pulpy i dawki odczynnika (A – zagęszczenie 60 g/l. dawka 0,4 kg/T; B – zagęszczenie 100 g/l, dawka 1,2 kg/T) [38]

end result will be a reduction in consumption of resources and, above all, in the case of combustion of steam coal concentrates, thus reduced emissions of pollutants.

The control system, which enables a wide selection of process parameters and its increased control is an important element that impacts the efficiency of the process and, as a result, the quality parameters of the products.

Higher efficiency of the process will also allow for the reduction of coal losses in tailings, which will have an additional positive impact on the natural environment by reducing the risk of spontaneous combustion of the material stored in post-mining landfills (heaps).

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Zwiększenie efektywności procesu flotacji pianowej dla maksymalizacji produkcji koncentratów węgla koksowego w aspekcie zrównoważonej gospodarki surowcami naturalnymi

Węgiel koksowy z uwagi na jego ograniczoną dostępność oraz rolę i znaczenie stali jako surowca, który jest niezbędnym materiałem wykorzystywanym praktycznie we wszystkich gałęziach przemysłu, znajduje się od wielu lat na liście surowców krytycznych w UE. W artykule przedstawiono wyniki badań laboratoryjnych wpływu wybranych czynników (parametry nadawy, parametry procesowe, odczynnik) na skuteczność procesu flotacji, powszechnie stosowanej metody wzbogacania drobnych ziaren węgla koksowego. Duża liczba zmiennych i znaczące różnice w wynikach wyraźnie wskazują na konieczność prowadzenia szczegółowych badań przed każdym nowym zastosowaniem technologii wzbogacania flotacyjnego. Efektem tych badań powinien być dobór parametrów gwarantujących maksymalizację produkcji z punktu widzenia racjonalnej i zrównoważonej gospodarki zasobami przy zminimalizowaniu negatywnego oddziaływania efektów tego procesu na środowisko.

Słowa kluczowe: *zasoby mineralne, węgiel koksujący, flotacja pianowa, efektywność procesu*