

RESEARCH OF EFFICIENCY OF CLEANING AND DEHYDRATION OF COAL SLIMS IN CENTRIFUGES

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Abstract - The efficiency of solid phase retention and dewatering of coal sludges from a coal preparation plant with a particle size of less than 3 mm was investigated using sedimentation centrifuges with a cylindrical-biconical rotor shape. It was established that the efficiency of solid phase removal from polydisperse sludge with a particle size of up to 3 mm reaches 85–93%, while the moisture content of the dewatered product (sediment) ranges from 17–25% due to the displacement of moisture from the sediment pores during compaction. The sediment moisture content increases with the growth of the centrifuge's volumetric capacity, the degree of solid phase retention, and the proportion of particles smaller than 63 μm. It was revealed that the efficiency of solid phase retention in the coal fraction depends on the particle size distribution and the centrifuge's capacity. As the capacity of the sedimentation centrifuge decreases, the degree of solid phase retention increases due to the longer exposure time on solid particles. When dewatering polydisperse sludges, compression of fine fractions within the sediment occurs between larger particles. An increase in the content of 0.4–1.5 mm size fractions above 30% contributes to a reduction in sediment moisture under otherwise equal conditions. It was established that when dewatering fine-dispersed sludges with particle sizes below 63 μm, the sediment moisture content increases with the rise in solid phase retention efficiency due to the high moisture content of fine fractions. An increase in the proportion of fine fractions leads to a rise in moisture content up to 33%.

Keywords: Polydisperse sludges, Solid phase retention efficiency, Dewatering degree, Sedimentation centrifuge, Sludge treatment.

1. Introduction

During the beneficiation of run-of-mine coal, a significant amount of liquid waste is generated, primarily consisting of swelling clay. The sludges and pulps from coal preparation plants are polydisperse systems containing solid phase particles ranging in size from fractions of a micron to several millimeters or more. Depending on the predominant particle size in the liquid waste, the following categories are distinguished: coarse-grained (0.5–0.3 mm), fine-grained (less than 0.3 mm), sludge-like (40–70 μm), and silt-like (less than 40 μm) pulps. The classification and separation of pulps into different categories present several challenges due to particle size variation and the presence of clay inclusions in

coal waste, which exist in the water-sludge system of coal preparation plants in the form of sludge suspensions [1].

Annually, in Ukraine alone, the discharge into sludge storage facilities (in terms of solid material) amounts to 3.0 – 4.0 million tons. Approximately 1 billion tons of coal beneficiation waste have already accumulated in ash and sludge repositories, and this volume continues to grow. The main reason for the accumulation of mineral raw materials in sludge storage facilities is the inefficiency of coal beneficiation technologies. No more than 10% of the generated sludge is reused, and increasing the beneficiation depth of coal leads to a higher proportion of waste being disposed of in sedimentation ponds [2]. The accumulation of

mining industry waste results not only in operational costs for maintaining sludge storage facilities but also in secondary environmental pollution [2].

The presence of a polydisperse phase in sludge is determined by the specific characteristics of the coal deposit and imposes additional requirements for the efficient dewatering of waste and beneficiation products using various apparatuses. The efficiency of dewatering depends on numerous factors, including the granulometric composition of granular media, structure, and physicochemical properties. It is also influenced by the specific characteristics of the raw material and the operational parameters of the equipment at a given plant.

Therefore, research aimed at improving the separation of polydisperse sludge suspensions, classifying them by particle size, and reducing the recirculating load on the water-sludge systems of coal preparation plants remains highly relevant.

2. Analysis of Literature Data and Problem Statement

The goal of dewatering is to achieve optimal separation of the liquid and solid phases while ensuring the highest possible purity of the liquid phase and the lowest possible moisture content in the solid phase. The problem of dewatering coal polydisperse suspensions is associated with the efficiency of solid matter and coal fraction extraction into sediment, the ash content and amount of solid phase in the separated liquid product (centrate, filtrate), and the potential for additional coal beneficiation.

The key performance indicators of dewatering equipment include: moisture content of the sediment, ash content of the sediment, efficiency of solid phase retention in sediment, solid content in the separated liquid product [3].

The accumulation of highly dispersed particles in sludge and the increase in their concentration make it difficult to achieve satisfactory values for these indicators.

Dewatering is understood as a technological process aimed at reducing the moisture content in processed materials.

Coal contains several types of moisture (Fig. 1), and its movement is influenced by various resistances determined by the properties of the solid phase and the forces binding moisture to it. Adsorbed and internal moisture are referred to as bound moisture.

Capillary forces, and consequently the mobility of moisture in pores and gaps between grains, depend on the particle size and moisture content of the coal. The finer the material and the smaller the pores, the stronger the capillary adhesion forces.

In dewatering practice, capillary moisture, which fills the gaps between the grains of a porous medium, is partially removed by vacuum filtration and almost completely by centrifugal filtration.

The efficiency of dewatering depends not only on the equipment used but also significantly on the properties of coal [4]. The granulometric composition and porosity of coal play a crucial role, as they determine its moisture absorption capacity.

The choice of dewatering equipment primarily depends on the dispersion (sieve or granulometric composition) of the solid phase in the sludge, as well as the feasibility of using the sediment as a commercial product.

In global practice, there is a growing trend toward increasing the use of mechanical dewatering methods for sludge and wastewater sediment from various sources. This trend is driven by the rising costs of energy resources, making thermal dewatering methods increasingly expensive in comparison to mechanical alternatives [5].

Among the most widely used methods for dewatering fine coal sludges and beneficiation slimes are thickening followed by filtration. Dewatering is performed using filter presses with flocculant application [6, 7], vacuum filtration [8, 9], or electro-osmosis for capillary moisture removal [10, 11].

The main drawback of filtration systems is the constant need for cleaning with fresh water, which is usually supplied from sludge settling tanks. When the solid phase load on the settling tanks increases, the load on the filters also rises, leading to a decrease in their efficiency. Therefore, an important task is reducing the recirculating solid phase load in the water-sludge system.

This can be achieved by introducing additional equipment that captures and dewateres part of the solid phase before the settling tanks and filters. The practical use of sedimentation centrifuges at various coal preparation plants confirms their high efficiency in dewatering granular products of different ash content [3, 12, 13].

The most important parameters of slurry affecting dewatering efficiency in a centrifuge are particle size, solid phase content in the suspension, and flow rate. Typically, the amount of ultrafine material is determined by the proportion of particles smaller than 0.04 mm in the total solid content of the feed. According to practical data [14], an increase in ultrafine fractions leads to higher sediment moisture, making it difficult to capture fine particles. It is known that the coal fraction is unevenly distributed by particle size, with the finest fractions (less than 0.05 mm) mainly composed of swelling clay [15].

Thus, literature sources indicate that dewatering processes in sedimentation centrifuges follow a common pattern: a constant moisture level

characteristic of the material's nature, a moisture level introduced by the fine fraction of the material.

There is an inverse negative relationship between solid retention efficiency and dewatering efficiency in the centrifuge: the higher the retention of fine solid particles, the higher the moisture content of the dewatered sediment.

In addition to the fine particle content, the sludge dewatering process is influenced to varying degrees by several other factors, which can be grouped as follows [16, 17]:

- Sludge properties: concentration and type of dispersed phase, particle size and density, ash content.

- Equipment design parameters: centrifuge rotor diameter and shape, operating mode (rotor and screw speed).

- Operational conditions: solid phase content in the feed, separation factor (for centrifuges), dewatering zone dimensions, dewatering duration, specific throughput capacity, sludge residence time, and other factors.

- Methods for process intensification: use of flocculants, regulation of solid phase concentration or dispersion in the dewatering equipment feed, optimization of aggregation conditions, etc.

A literature review shows that most factors influencing the efficiency of the dewatering process in centrifuges are technological and specific to a particular type of production. Suspension separation processes follow complex patterns, and the theoretical principles described in the literature are typically derived from idealized models, which do not account for all influencing factors. As a result, when solving practical industrial problems, applying generalized principles is often challenging.

3. Aim and Objectives of the Study

Aim of the Study: the study aims to identify the patterns of dewatering efficiency of granular coal-containing products with different granulometric compositions of the solid phase in sedimentation centrifuges.

Objectives: to achieve this goal, the following tasks need to be completed:

- Conduct laboratory studies on the composition and properties of actual sludges from a coal preparation plant at different stages of the technological process.

- Investigate the efficiency and identify the patterns of solid phase retention of granular classes, as well as the degree of dewatering of beneficiation products in centrifuges.

4. Research Methodology

4.1 Materials and Methods of Research

According to the operational scheme of the coal preparation plant, after heavy-media beneficiation, granular coal-containing products are directed to pressure hydrocyclones GC-150, where the

thickened sludge is further processed in spiral separators. The overflow from the hydrocyclones and the rejects from the spiral separators are sent to a radial thickener.

The concentrate from the spiral separators undergoes preliminary dewatering on arc sieves and final dewatering in sedimentation-filtering centrifuges, reducing moisture content to 24%. The fugate and filtrate from the filtering centrifuges ultimately flow into the radial thickener. The rejects from the spiral separators are dewatered on high-frequency screens to a moisture content of **26%**, with the undersize product also being directed to the radial thickener.

The study was conducted using granular products from an operational coal preparation plant, which were processed in a centrifugal unit during industrial trials:

- Concentrate from spiral separators;
- Rejects from spiral separators;
- Undersize product from high-frequency screens.

To determine the qualitative and quantitative indicators of dewatering efficiency for granular coal-containing products under the conditions of a coal preparation plant, tests were conducted on the purification and dewatering of sludge formed at different stages of the process.

For the dewatering of coal beneficiation sludge, a sedimentation horizontal screw centrifuge Ecomash SHS 511A-113 (manufactured by NTC "Ecomash", Kharkiv, Ukraine) was used, with its characteristics presented in Table 1.

The Ecomash SHS 511A-113 centrifugal unit belongs to the category of horizontal sedimentation centrifuges with screw discharge of sediment. This centrifuge is designed for the extraction and dewatering of fine-grained beneficiation products of coal, anthracite, and similar materials at coal preparation facilities.

Table 1. Technical characteristics of the centrifuge Ecomash SHS 511A-113

No	Parameters	Indicators
1	Volumetric water capacity, Q_n , m ³ /hour, not less than	45
2	Rotor profile	cylinder-biconical
3	Rotor length to internal diameter ratio, L/d, mm	2,4
4	Rotor internal diameter, maximum, mm	510
5	Rotor rotation speed, max., r/pm	2600
6	Operating rotor speed range, r/pm	1640...2500
7	Operating range of separation factor, Fr	760...1770
8	Weight of centrifugal unit (excluding control panel), no more, kg	3500
9	Installed power, kW	45 (37,5+7,5)

A distinctive feature of the Ecomash SHS 511A-113 sedimentation centrifuge, with its cylindro-biconical rotor shape (Fig. 1), compared to a classical centrifuge with a cylindro-conical rotor of the same size, is the increased efficiency in retaining fine-grained solid phase fractions (less than 40 mcm) by approximately 15–20%.

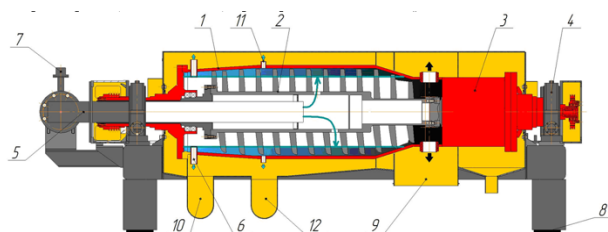


Figure 1: Schematic diagram of a centrifuge with a cylindrical-biconical rotor: 1 – rotor; 2 – screw; 3 – planetary gear; 4 – rotor support; 5 – feed pipe; 6 – concentrate tubes; 7 – electric drive crane; 8 – retractable support with shock absorber; 9 – sediment shaft; 10 – concentrate shaft; 11 – thickened product tubes (or plug in dual-product mode); 12 – thickened product or wash liquid shaft

The suspension enters the screw housing (position 2) through the feed pipe (position 5) and passes through the discharge windows into the inner cavity of the rotating rotor (position 1). Under the influence of centrifugal force, solid phase particles settle on the inner surface of the rotor (position 1) and are removed by the screw (position 2) through the dewatered sediment discharge shaft (position 9). The clarified liquid phase (fugate) moves towards the larger diameter of the rotor and exits through the fugate drainage tubes (position 6), which are integrated into the rotor shell (position 1). The fugate is then directed into the fugate discharge shaft (position 10) of the centrifuge. The separation of the solid phase from the liquid phase, discharge of the dewatered sediment, and fugate removal occur continuously. Inside the cylindrical rotor shell, tubes (position 11) are installed for the removal of fine solid particles or for flushing liquid during centrifuge shutdown. The screw drive is powered by a two-stage planetary gearbox (position 3), which is connected to the rotor shell. The gear ratio of the gearbox can be adjusted by changing the rotation of the sun gear shaft, which is linked to an additional screw electric drive. Depending on the centrifuge modifications, the gearbox may be located either on the side of the dewatered sediment discharge or on the fugate discharge side. The horizontal position of the rotor axis is adjusted by extending the dampers (position 8).

In the centrifuge connection scheme (fig. 2) used during testing, a loading device was included to ensure smooth feeding of coal sludge into the centrifuge and to regulate the load during the centrifugation process.

The loading device is equipped with a sieving wedge-wire surface with 3 mm and 1.5 mm gaps to prevent large particles from entering the centrifuge, thereby protecting it from mechanical damage.

The efficiency of solid phase retention and dewatering of coal-containing products was studied by sequential classification based on particle size (3 mm and 1.5 mm). This was achieved by replacing the sieving surface and feeding products with different ash content.

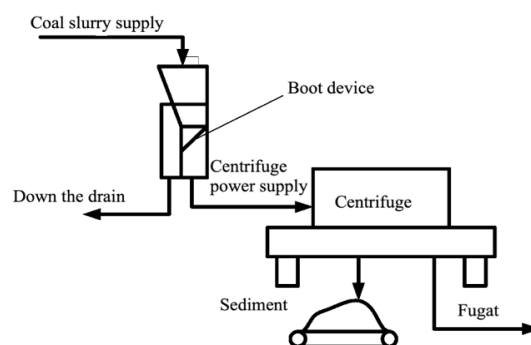


Figure 2: Connection diagram of the centrifugal unit Ecomash SHS 511A-113

The operating modes of the sedimentation centrifuge were adjusted by varying the rotor speed and the slurry feed rate. The rotor speed was measured by determining the frequency of the drive inverter current. The slurry feed rate to the centrifuge was measured using an ultrasonic flow meter.

In each experiment, the following parameters were determined according to industry standards: Sieve composition of solids in the centrifuge feed, solids content in both the feed and the fugate, ash content of the solids, moisture content of the dewatered product from the centrifuge.

The efficiency of solid phase capture in the sediment was evaluated using the following formula:

$$\eta = \frac{\tilde{N}_{\text{сн}} - \tilde{N}_{\text{ис}}}{\tilde{N}_{\text{сн}}} \cdot 100\% \quad (1)$$

C_{in} – solid phase content in the initial suspension, kg/m^3 ;

C_{out} – solid phase content in the liquid separation product (centrifuge fugate or classifier tank filtrate), kg/m^3 .

The efficiency of sludge dewatering was calculated using the following formula:

$$\eta_w = \frac{W_{\text{с}} - W_{\text{ф}}}{W_{\text{с}}} \cdot 100\% \quad (2)$$

W – moisture content of the sediment, %;

$W_{\text{ф}}$ – moisture content of the feed, %

5. Research Results on the Efficiency of Dewatering Granular Coal-Containing Products

5.1 Results of the Study on the Composition and Properties of Actual Sludges

Due to the continuous changes in the operating conditions of the water-sludge system at the coal

preparation plant, multiple sample collections were conducted on different days during the experiments to ensure reliable testing.

The results of the analysis of granular sludges with varying ash content, fed into the Ecomash SHS 511A-113 centrifuge during industrial trials, are presented in Tables 2-5.

Table 2. Coal-containing granular middlings of spiral separators with ash content of A^d 50% in centrifuge feed Ecomash SHS 511A-113

Sludge sample selection number	1	2	3	4
Class size, mcm	Class Contents, %			
+3000	8,8	0,62	0,84	1,58
1000...3000	17,64	30,88	25,16	25,63
500...1000	9,63	12,27	9,01	9,18
100...500	6,92	7,86	7,76	6,33
-100	56,99	48,38	57,23	57,28
Total, %	100	100	100	100
Content of solid phase in sample, g/l	278	200	198	140
Ash content of the solid phase of the sample, %	53,9	55	50,6	42,9

Table 3. Coal-containing granular waste from spiral separators with an ash content of A^d of approximately 80% in the feed of the Ecomash SHS 511A-113 centrifuge after classification on a slat with a gap of 3 mm

Sludge sample selection number	5	6	7	8
Class size, mcm	Class Contents, %			
+1000	28,95	9,71	10,96	11,22
500...1000	10,72	27,89	26,62	27,96
100...500	20,11	17,15	15,45	16,47
-100	40,21	45,25	46,97	44,35
Total, %	100	100	100	100
Content of solid phase in sample, g/l	30	54	58	116
Ash content of solid phase of sample, %	81,1	80,6	77,5	80,2

Table 4. Coal-containing granular waste from spiral separators with an ash content of A^d of approximately 80% in the feed of the Ecomash SHS 511A-113 centrifuge after classification on a slat with a gap of 3 mm (continued from Table 3)

Sludge sample selection number	9	10	11
Class size, mcm	Class Contents, %		
+1000	24,89	33,82	37,73
500...1000	27,2	14,44	14,93
100...500	15,14	10,94	13,75
-100	32,77	40,80	33,58
Total, %	100	100	100
Content of solid phase in sample, g/l	126	156	216
Ash content of solid phase of sample, %	73,4	67,6	77,2

Table 5. Coal-containing granular waste from spiral separators with 80% ash content in the feed of the Ecomash SHS 511A-113 centrifuge after classification on a slat with a gap of 1.5 mm

Sludge sample selection number	12	13	14	15	16
Class size, mcm:	Class content, %				
+1000	2,86	0,04	0	0	0
500...1000	16,64	6,37	3,06	4,38	4,79
250...500	28,32	28,54	10,11	21,92	21,48
63...250	18,24	22,51	39,28	19,51	18,98
-63	33,95	42,55	47,33	54,19	54,75
Total, %	100	100	100	100	100
Content of solid phase in sample, g/l	206	402	280	292	296
Ash content of solid phase of sample, %	78,7	79,8	77,6	78,4	81,9

The analysis of data from Tables 2–5 indicates that granular coal-containing beneficiation products contain approximately 40% of fractions larger than 250 μm and up to 30% of fractions larger than 1.0 mm. Separating part of the solid phase in the centrifuge will help reduce the load on radial thickeners and decrease the retention time of liquid clay waste in the water-sludge system of the coal preparation plant. The analysis of Table 5 shows that the undersize product from high-frequency screens primarily consists of particles smaller than 500 mcm (up to 97%), with up to 70% of the material being finer than 250 μm. This confirms that preliminary classification of granular sludge by particle size occurs before the material enters the centrifuge.

5.2 Study of Granular Sludge Purification and Dewatering Processes

Research was conducted on the dewatering process using a centrifugal unit for the following granular coal-containing products:

- Rejects from spiral separators (Table 2);
- Products after spiral separators (Tables 3,4);
- Undersize product from high-frequency screens (Table 5).

The results of the dewatering process trials using the centrifugal unit are presented in Table 6 and 7.

Table 6. Results of industrial dehydration tests

№	Rotor speed	Auger speed	Volumetric performance in nutrition	Solids performance in nutrition	Content of solids in nutrition
	N, r/pm	Δn, r/pm	Q _n , m ³ \hour	T, t\hour	C _{ng} /l
Spiral Separator Products					
1	1600	28	10,80	3	278
2	1600	28	17,3	3,46	200
3	1750	29,5	18	3,56	198
4	1900	37	20,6	2,88	140
Spiral separator waste					
5	1600	28	9,00	0,27	30
6	1600	28	3,60	0,17	54
7	1750	30,1	5,00	0,29	58
8	1850	31	4,00	0,46	116
9	1600	33,7	8,5	1,07	126
10	1600	33,7	16	2,5	156
11	1400	30	16	3,46	216
Undersize product of high-frequency screens					
12	1600	28	1,5	0,31	206
13	1600	28	8	3,22	402
14	1750	29	8	2,24	280
15	1900	32	13	3,8	292
16	2100	35	13	3,85	296

Table 7. Results of industrial dehydration tests

№	Ash content of solids in nutrition	Solids content in the filtrate	Ash content of the filtrate	Moisture content of beneficiation	Ash content of beneficiation	Efficiency of solid phase capture
	A ^d , %	C ₆ , g/l	A ^d , %	W, %	A ^d , g/l	%
Spiral Separator Products						
1	53,9	40	72,4	26,5	36,8	85,6
2	55	20	76	26,8	36	90,0
3	50,6	28	82	24,6	43,6	85,8
4	42,9	20	80	26,2	45,1	85,7
Spiral separator waste						
5	81,1	4	-	20,4	77,2	86,6
6	80,6	4	82	22,2	77,5	92,6
7	77,5	6	82	21,6	75,8	89,7
8	80,2	8	82	20,9	81,8	93
9	73,4	18	87	19,4	81,2	85,7
10	67,6	22	83	17,6	80,9	85,8
11	77,2	28	83	18,2	81,5	87
Undersize product of high-frequency screens						
12	78,7	5	78,1	27,1	77,1	97,5
13	79,8	56	80,9	20,7	77,7	86,1
14	77,6	40	76,9	20,8	80	85,7
15	78,4	32	78,9	22,6	78,3	89,1
16	81,9	48	80,5	20,1	81,8	83,8

During the centrifuge trials on granular sludges, the following results were obtained: Moisture content of the dewatered sediment ranged from 17.6% to 27.1%. Efficiency of solid phase retention varied from 83.8% to 97.5%. However, it should be noted that no direct correlation was observed between these parameters and any single influencing factor. This suggests that the sedimentation and dewatering processes in sedimentation centrifuges are highly multifactorial, requiring a detailed analysis of the contribution of individual factors to the overall efficiency of the process.

6. Discussion of the Research Results on the Dewatering of Coal-Containing Products

The analysis of data from Tables 6 and 7 reveals fluctuations in solid phase retention efficiency and moisture content of the dewatered sediment, which result from variations in the initial solid phase concentration and its sieve composition (Tables 2–5).

Changes in the properties of the feed entering the centrifuge influence the sedimentation processes, and consequently, the efficiency of sludge dewatering. The moisture content of the centrifuge sediment depends on multiple factors, each contributing to varying degrees and interacting with one another.

A distinctive feature of sludge dewatering in solid-bowl centrifuge rotors is the mechanism of moisture removal from the sediment, which compacts under the influence of the centrifugal field. Moisture is squeezed from the sediment pores toward the rotor axis, meaning it moves in a direction opposite to the centrifugal force.

For this reason, the process is considered as liquid movement through a sediment layer with time- and space-dependent porosity. The driving force of the process is the compaction of the sediment, where moisture is displaced due to the denser packing of solid phase grains in the sediment.

The analysis of dewatering results for polydisperse sludges up to 3 mm (samples 1–11)

demonstrates the possibility of reducing moisture content to 17%. This is due to the fact that polydisperse fractions form a specific sediment structure, where pores between larger particles are filled with smaller ones.

In the case of spiral separator rejects (samples 5–11), this leads to the displacement of some water from the pores and a reduction in moisture content to 17.6–22.2% due to the denser packing of solid grains.

The obtained data generally align with classical concepts of aggregation and structure formation processes in sediments undergoing dewatering [18, 19]. Under the given process conditions, the sediment can only be dewatered to a certain limit (residual moisture content).

For compressible sediments, consisting of irregularly shaped particles smaller than 3 mm, the specific surface area decreases during compaction, which reduces porosity and moisture content, following established patterns. As the size of the original particles decreases, both specific surface area and sediment porosity increase, resulting in higher moisture content.

Therefore, an increase in the fraction of fine particles (smaller than 100 μm exceeding 45%) leads to a decrease in solid phase retention efficiency and an increase in sediment moisture content (Fig. 3). The lowest moisture content is observed when the fraction of particles smaller than 100 μm is around 45%.

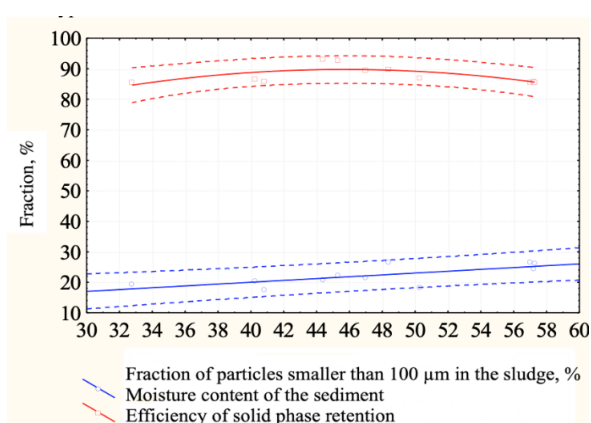


Figure 3: Dependence of the efficiency of solid phase retention and sediment moisture content of samples 1–11 on the content of class less than 100 μm

At the same time, the analysis of dewatering data for the fine-dispersed phase (samples 12–16) of the fraction smaller than 0.63 mm (Table 5) shows a maximum sediment moisture content of up to 27%,

with a maximum purification efficiency of 98% at a minimum processing capacity of 1.5 m³/h.

Moreover, a clear correlation is observed between sediment moisture content and solid phase retention efficiency for the undersize product from high-frequency screens (Fig. 4).

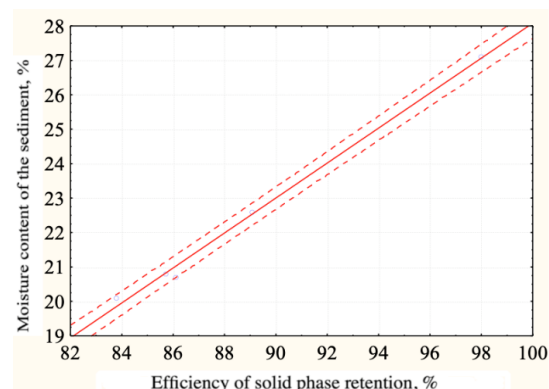


Figure 4: Dependence of sludge moisture on the degree of retention of solid phase of class up to 0.5 mm (samples 12 – 16).

In Fig. 4, it is evident that a decrease in solid phase retention efficiency for particles smaller than 0.63 mm leads to a reduction in the moisture content of the formed sediment. This can be explained by the carryover of the finest clay particles with the fugate (Fig. 4), which would otherwise form high-moisture sediment with moisture content reaching up to 33%. As a result, fine-dispersed fractions contribute to increased sediment moisture, with their influence becoming noticeable starting from solid phase sizes below 250 μm (Fig. 3) and clearly observed with an increasing fraction of particles smaller than 63 μm (Table 5, samples 14–16).

The analysis of Tables 6 and 7 also reveals a decrease in the ash content of the sediment, along with an increase in the ash content of the solid phase in the fugate compared to the feed ash content. This indicates that particles smaller than 0.1 mm are primarily composed of clay, which retains moisture poorly [20].

This assertion is further supported by the reduction in sediment moisture when solid phase retention efficiency decreases, as observed when comparing polydisperse sludge samples (samples 1–11) with fine-dispersed phase samples containing a high proportion of particles smaller than 0.63 mm (samples 12–16) (Fig. 4).

In the case of slurries with a concentration of up to 100 g/l, fine fractions make the greatest contribution to sediment moisture content. At high

retention efficiency, a significant portion of these fine particles transition into the sediment, carrying film moisture on their surface and within pores.

Additionally, the grain packing in the sediment prevents moisture from being effectively removed under the centrifugal field of the centrifuge. However, if the fraction of particles larger than 500 μm exceeds 25%, the moisture content remains stable at around 21% as efficiency increases.

In the case of slurries with a concentration ranging from 100 to 400 g/l, an increase in solid phase retention efficiency leads to a decrease in sediment moisture content.

The most likely reason for this is a more favorable granulometric composition of the sediment, which, when compacted, forms fewer pores. Fine fractions, in the presence of coarser particles, fill the pores and displace moisture, resulting in a grain packing structure that allows sufficient moisture removal under the centrifugal field.

Thus, as solid phase retention efficiency increases, the sediment structure becomes denser, enabling more effective moisture extraction under centrifugation.

7. Conclusions

Laboratory studies on the composition and properties of actual sludges from a coal preparation plant revealed significant fluctuations in concentration and particle size distribution. It was found that approximately 40% of the solid phase fractions larger than 100 μm can be removed through filtration or centrifugation. Changes in the particle size distribution may affect the efficiency of dewatering equipment.

The dewatering patterns of granular coal-containing products smaller than 3 mm in a centrifuge were investigated. It was established that the operating modes of the centrifuge have varying effects on the efficiency of sludge dewatering, depending on the particle size distribution of the solid phase. The removal efficiency of the solid phase for polydisperse sludge fractions up to 3 mm reaches 85–93%, with the moisture content of the dewatered product (sediment) ranging from 17% to 25%, due to moisture displacement from sediment pores during compaction

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