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THE CONTROL OF THE PARAMETERS OF MAN-MADE PLACER BY THE IMPACT ON THE FRACTIONATION PROCESS

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Abstract. According to the research results, the work experience of the mining and beneficiation plants of Kryvbas was analyzed, which made it possible to determine that the existing beneficiation technologies are not able to completely separate valuable components during the processing of mineral raw materials. This leads to the accumulation of a valuable component in beneficiation waste repositories and requires the development of methods and technologies aimed at the extraction and processing of mineral raw materials in man-made placers. The authors proposed a solution to this problem by developing a mineral enrichment waste storage facility as a man-made deposit for extracting the remains of a valuable component, or using the storage facility as an empty rock dump to cover the produced space and free up capacity for new waste storage.

The purpose of the work is to determine the parameters of the man-made placer and alluvial massif in the process of controlling the parameters of the man-made placer, which is carried out by changing the parameters of the fractionation process during the flow along the dusting surface of the alluvium.

The parameters of man-made spill formed in the beneficiation waste repository include: the content of the valuable component; impoverishment and clogging of the placer, which is defined as the content of clay and dust particles; placement capacity; length of placer along the length of the dusting surface; extent of spreading along the alluvial front; near limit of man-made placer; far limit of man-made placer.

Based on the results of the research, it was established that when controlling the parameters of the fractionation process of enrichment waste in the form of a low-concentration pulp, the maximum volume of man-made spill can be accumulated due to the combined flow over the obstacle of the gap with the obstacle, and the minimum volume - when the flow through the threshold. In these conditions, the use of flow over the crack allows to accumulate an intermediate volume of man-made placer. An assessment of the parameters of the obtained placer and the alluvial massif was carried out, the scientific foundations of methods of managing the parameters of man-made deposits were developed and improved, which for the first time ensure the intensification of the process of the formation of man-made placers and their further extraction without stopping the waste storage process.

Keywords: waste storage facilities, man-made placer, parameters, fractionation process, dusting surface, washout front.

Introduction. The experience of the mining and beneficiation plantsof the Kryvorizkyi Iron Ore Basin (Kryvbas) indicates the inability of existing enrichment technologies to completely separate valuable components during the processing of mineral raw materials. This leads to the accumulation of a valuable component in enrichment wastestorage facilities, which requires the development of methods and technologies aimed at their extraction as man-made placers.The problem of extracting the remains of a valuable component from the waste processing of mineral raw materials should be considered in conjunction with other problems caused by the long-term man-made impact of mining on the environment: extending the life of existingstorage facilities, recycling of enrichment wastes and reducing their environmental hazard. The existing concept of waste storage, which did not imply their further processing and extraction of the remains of a valuable component, led to a dangerous environmental situation: the accumulation of significant amounts of environmentally harmful substances on the ground surface near densely populated residential areas. At the same time, the capacities of existing storage facilities are not sufficient to ensure the operation of mining and processing plants, and there are no areas for new storage facilities.

Thus, the existing waste storage facilities for mineral processing will have to be developed either as man-made deposits for the extraction of the remains of a valuable component, or as waste rock dumps for backfilling the mined-out space and freeing up a container for storing new waste, or in the process of recultivation and conservation to reduce environmental safety and return to the land fund. However, the existing waste storage facilities were built solely on the principle of ensuring the stability of their dams, embankment and accumulation of particles of clay, chalk and dusty fractions under a layer of water, and their further development was not expected.

In this context, today it is relevant not only to assess the parameters of already formed man-made placers, which will ensure their extraction after the decommissioning of waste storage sites, but also to develop methods for the formation of future man-made placers, which will ensure their compact storage and facilitate extraction both in future, as well as immediately after alluvium, without stopping the current storage process.

Methods. Initially, the issue of managing the parameters of man-made placers did not exist. At the time of the beginning of the storage of enrichment wastes in artificial storage facilities, the presence of man-made placers was not thought. The task of the concentration waste storage technologies was to remove the entire volume of liquid waste from the enrichment production and store them in storage facilities with a reliable cover of dusty, clay and chalk fractions under a layer of water in a settling pond [1–6].

In the process of operation, the size of the waste storage facilities increased, and there was a shortage of technical water, which began to be compensated with clarified water from overflowing settling ponds. The next stage in the development of the circulating water supply system was the use of technologies for thickening the enrichment waste even before entering the storage facility and returning the clarified water to the enrichment plant.

The issue of extraction of valuable components remaining in the enrichment waste became relevant at a time when most of the artificial waste storage facilities were nearing the end of their operation phase. At this point, the research on this issue shifted from theoretical considerations to the practical plane, and moved on to substantiating possible technologies for the extraction of man-made placers. This required an assessment of the parameters of man-made placers formed in existing storages. For storage facilities where enrichment waste is no longer stored, this issue determines the prospects for their further development and reclamation. For thosestorage facilities where enrichment waste is still stored, this issue determines the possibility of extending the service life and only then the prospects for their further development and recultivation. The prospect of extending the life of the storage facility is due to the fact that the extraction of man-made placer from a freshly washed layer, before the construction of the next dike dam, will increase the storage capacity. In this situation, the task of storage technology becomes more complicated and cannot be reduced only to ensuring the storage of dusty, clayey and chalk fractions under a layer of water in a settling pond. Now it includes the need to manage placer parameters in order to facilitate the process of its extraction.

The parameters of the man-made placer formed in the beneficiation waste storage facilities include [7 – 12]: the content of a valuable component; placer contamination, defined as the content of clay and silt particles; placer power; the length of the placer along the length of the dusting surface; the extent of the placer along the alluvium front; near boundary of man-made placer; far boundary of man-made placer. Of all the listed parameters, the most stable are power of the man-made placer and its extent along the alluvium front. The power of the man-made placer is equal to the thickness of the alluvium layer, and the extent of the placer along the alluvium front is equal to the perimeter of the inner side of the dike dam. Both of these parameters do not require any regulation, since they are completely determined by the parameters of mining operations performed during the build-up of dike dams.

The content of a valuable component is determined not only by the efficiency of the enrichment production, but also depends on the technology of storage of beneficiation waste. As some studies show [12], the dilution of man-made placer can be minimized by choosing the total number of outlets. The remaining parameters of the man-made placer - the length along the dusting surface and the alluvium front, as well as the near and far boundaries of the man-made placers are determined by the parameters of the fractionation process, the density and fineness of the particles of the valuable component, particles of sand, clay, chalk and dusty fractions. So, along with particles of a valuable component, which are characterized by high density and small geometric size, particles of waste rock, which have a lower density, but a larger geometric size, will be deposited in the body of the man-made placer.

Thus, the parameters of man-made placers are controlled by changing the parameters of the processes of outflow of enrichment waste from the pipeline and their fractionation during the flow along the dusting surface alluvium.

The combined overflow method assumes that the barrier is located immediately behind the far edge of the gap, so that the surfaces of the far slope of the gap and the front slope of the barrier are aligned. This arrangement enhances the effect of separation factors due to the frictional properties of particles, which contributes to the separation of valuable components of man-made placers from particles with similar hydraulic size.

It should be noted that the control methods based on changing the parameters of the process of fractionation of beneficiation waste during the flow along the dusting surface alluvium are cyclic. Since after filling the gap or space in front of the barrier with particles of man-made placer, it is necessary to stop the alluvium in this area and, after drying, to carry out mining operations to extract the valuable component, as well as restore the shape of the slot or barrier. Therefore, in order to use them, it is necessary to assess the change in the parameters of the man-made placer and alluvial mass during the entire cycle.

The purpose of the work is to determine the parameters of man-made placer and alluvial mass in the process of controlling the parameters of man-made placer by changing the parameters of the fractionation process during the flow along the dusting surface alluvium.

In case of non-pressure storage of beneficiation waste in the form of low-concentration pulps, the power of the alluvium tier, as well as the total volume of beneficiation waste and the volume of solid particles that form man-made placer, which will be stored during the reclamation of one tier, can be determined by the formulas:

$$H = C\frac{Q \cdot T}{B \cdot L}, \qquad W = C \cdot Q \cdot T, \qquad W_R = \varepsilon \cdot W, \tag{1}$$

where H – the power of the alluvium stage; B – the length of the alluvium front; L – the length of the dusting surface; W – the volume of beneficiation waste forming the alluvium layer; C – volumetric concentration of stored waste; Q–the volumetric flow rate of the pulp supplied to the alluvial layer; T– time of alluvium; W_R – the volume of the formed man-made placer; ε – volume fraction of enrichment wastes with a hydraulic size equal to the hydraulic size of man-made placer particles.

When using methods for managing the parameters of man-made placer, the power of the alluvium layer along the length of the dusting surface will not be the same. In this case, it is advisable to divide the length of the alluvial dusting surface into three unequal sections (Fig. 1): the section preceding the man-made placer, where particles with a hydraulic size greater than those of the man-made placer are stored; man-made placer, an area where particles of man-made placer and particles with the same hydraulic fineness are concentrated; the area separating the man-made placer from the pond, formed by particles with a hydraulic size smaller than that of the particles of the man-made placer.

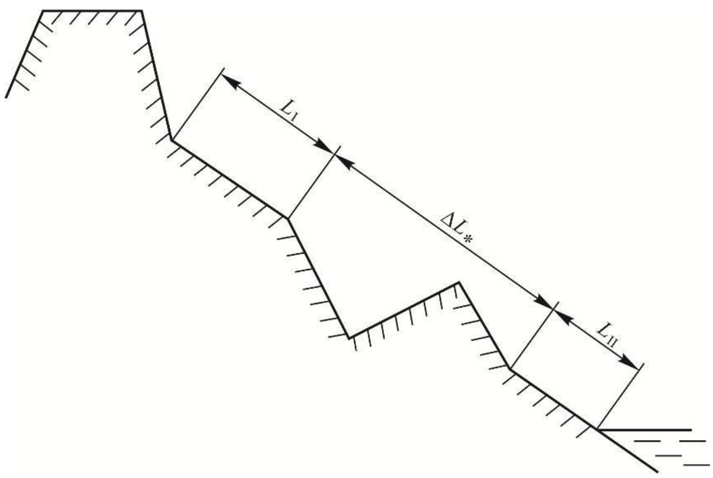


Figure 1 - Division of the alluvial dusting surface into sections

To determine the values of σ and L_Δ, we consider three types of obstacles (Fig. 2): a gap, *a* barrier, and a gap with barrier.

When using methods for managing the parameters of man-made placer, its volume will be determined by the type of obstacle used

$$W_R = \sigma \cdot L_{\Delta}^2 \cdot B, \tag{2}$$

where σ – coefficient taking into account the shape of the obstacle; L_{Δ}– the length of the section with an obstacle.

Thus, using formulas (1) and (2), it is possible to determine the formation time of man-made placer

$$T = \frac{\sigma \cdot L_{\Delta}^2 \cdot B}{\varepsilon \cdot C \cdot Q}, \tag{3}$$

which makes it possible to coordinate the parameters of the waste storage system, taking into account the regulations requiring the formation of a placer, its drying and extraction within one cycle.

In the remaining two sections, uniform tiers will be formed with power

$$H_I = \delta \frac{L}{L_I} H, \; H_{II} = \frac{1-\varepsilon-\delta}{1-\wp} H, \; L_{II} = (1-\wp)L, \; \wp = \frac{L_I}{L} + \sqrt{\frac{\varepsilon}{\sigma}\frac{H}{L}}, \tag{4}$$

where H_I –the power of the alluvial tier in the area preceding the man-made placer; L_I– the length of the area preceding the man-made placer; δ– volume fraction of enrichment waste with a hydraulic size greater than that of man-made placer particles; H_{II} – the power of the alluvial tier in the area separating the man-made placer from the pond; $\wp$ – rate of the controlledlength of the dusting surface; L_{II} –the length of the section separating the man-made placer from the pond.

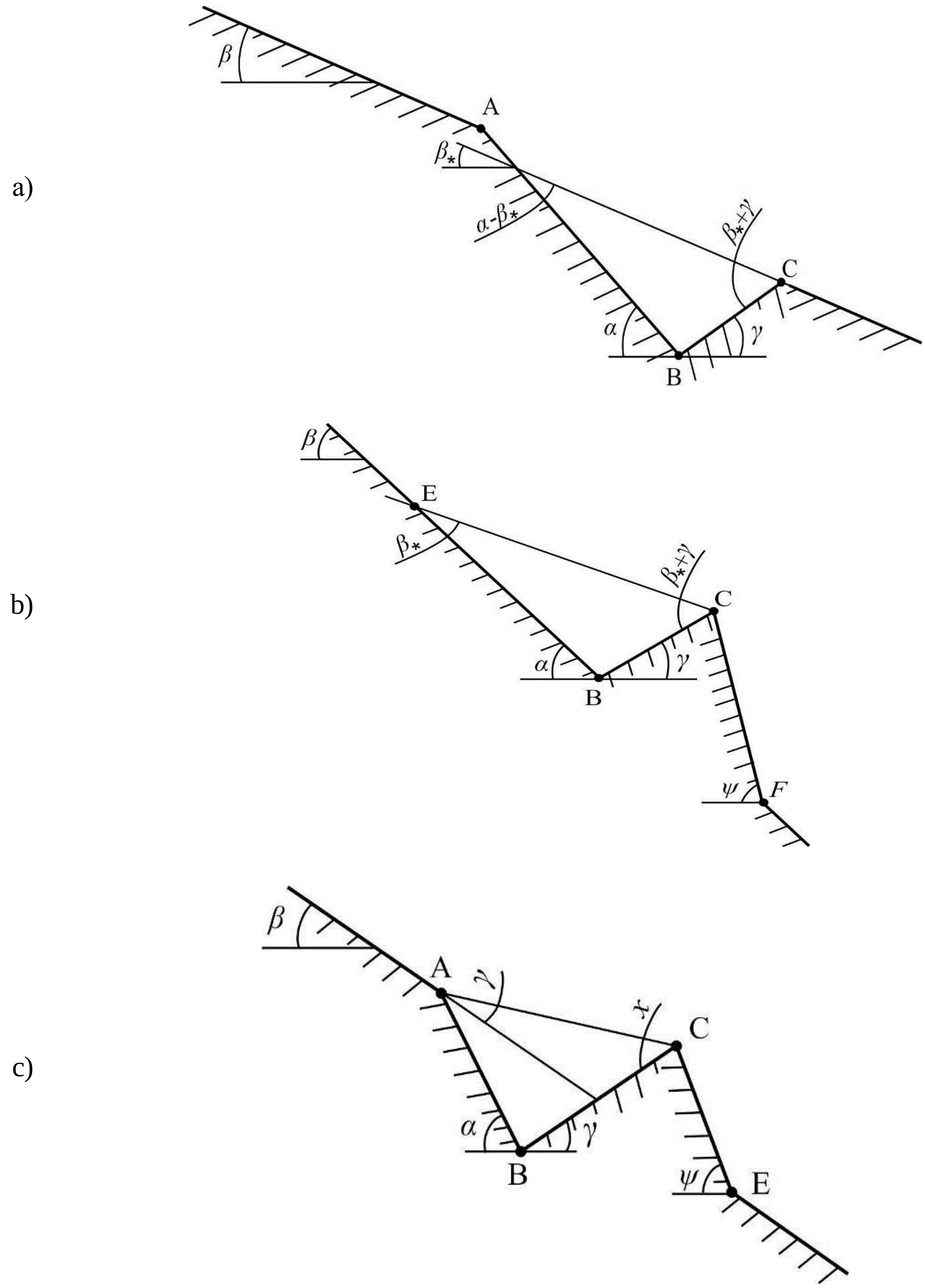
The simplest type of obstacle is a gap, which is obtained by removing part of the volume of an already reclaimed dusting surface (Fig. 2a). A solid particle of the man-made placer, falling into a niche, is decelerated during the ascent along its ascending face, stops and stays in the gap space. Gradually, as the volume of the gap is filled, the upper face will be inclined to the horizon at an angle determined by the properties of the particles of the man-made placer. The filling of the gap will continue until this face reaches the lower edge of the gap.

The second type of obstacle is a barrier, which is obtained by filling an additional small-sized dam on the dusting surface (Fig. 2.b). The third type of obstacle is a gap with a barrier, which is a combination of the first and second obstacles (Fig. 2.c), and is a sequentially located excavation of a part of the volume of an already reclaimed beach and a small-sized dam on the surface of the reclaimed dusting surface. The mechanism of trapping particles of man-made placer in a gap with a barrier is similar to the previous types of obstacles, and the placer formation ends at the moment when its upper face reaches the crest of the barrier.

It can be shown that, as a result of geometric constructions, it is recommended to use the following dependence to calculate the coefficient σ in formula (2) (Table 1, Fig. 4)

$$\sigma = \frac{F}{4}\sqrt{2\left(a^2 + b^2\right) - \left(a^2 - b^2\right)^2 - 1}, \tag{5}$$

where F– function of placer occurrence angles and geometric angles of obstacle (Fig. 3, Table 1); b – a parameter that takes into account the angle of inclination of the ascending edge (Fig. 4, Table 1); a – a parameter that takes into account the angle of inclination of the descending edge (Fig. 5, Table 1).



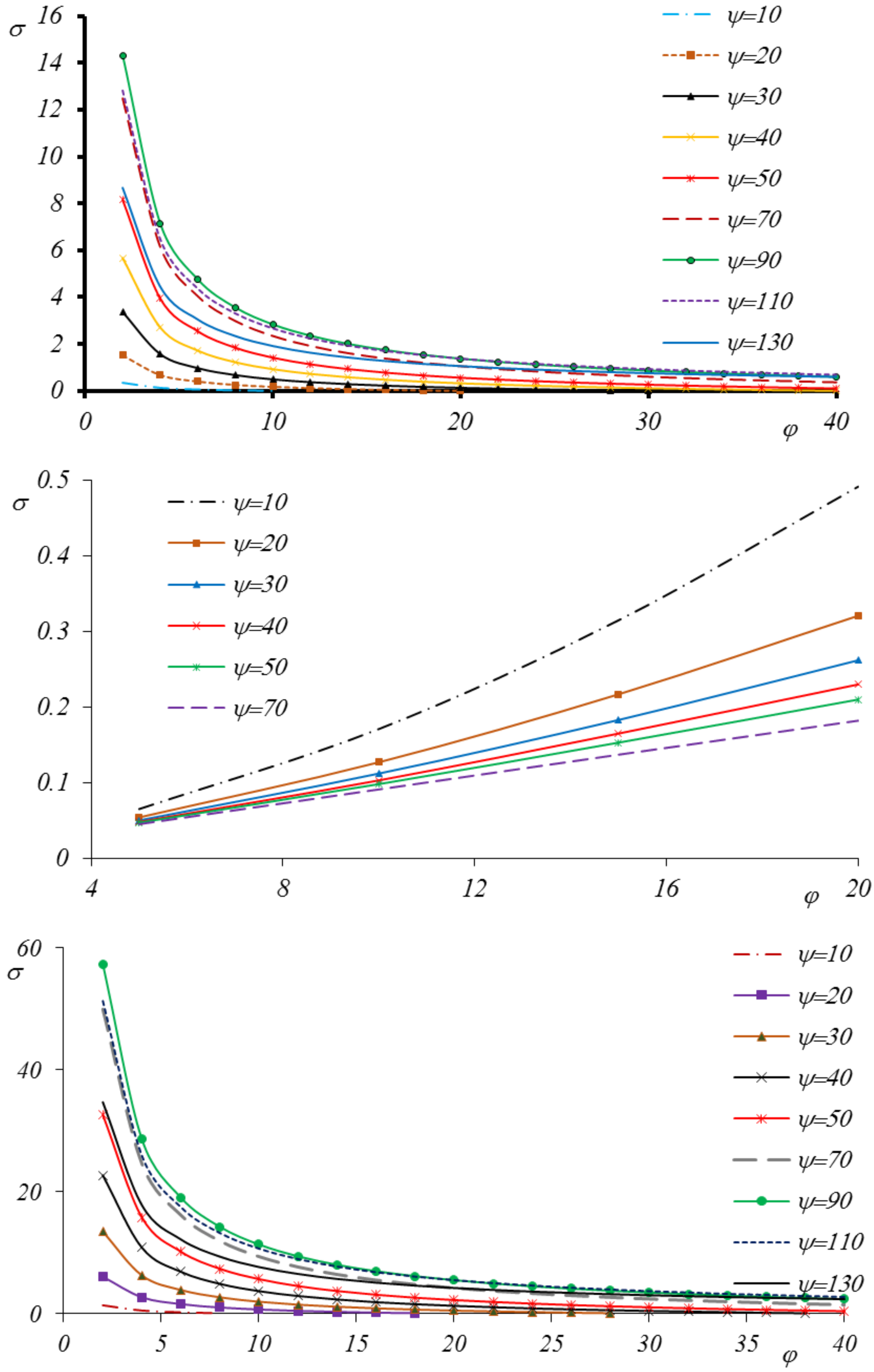
a)triangular gap; b) triangular barrier; c) gap with barrier

Figure 2 - Geometric characteristics of obstacles:

a)

b)

c)



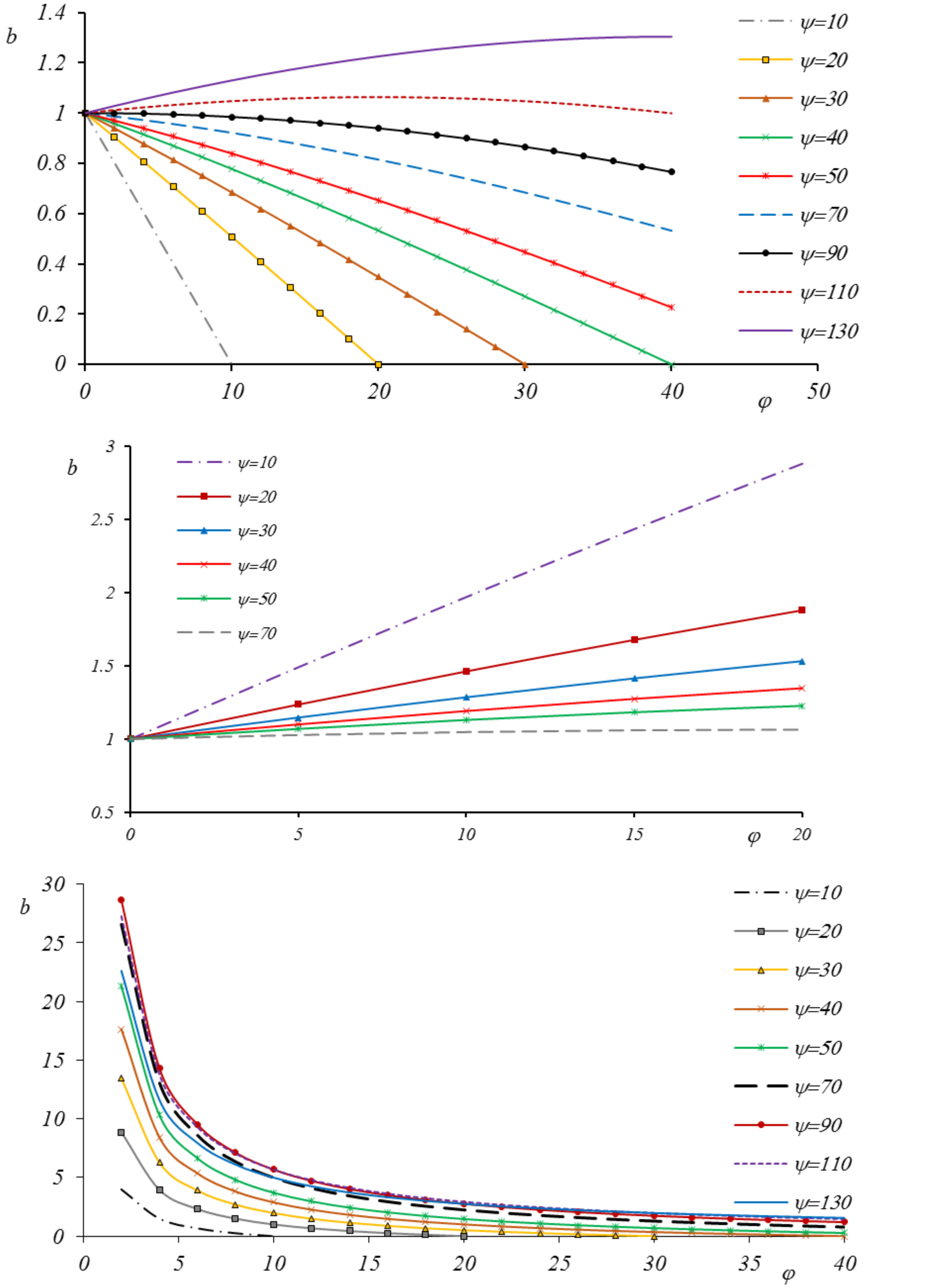
a) a gap; b) barrier; c) a gap with a barrier

Figure 3 - The dependence of the valueσ on the angle of filling the gap at different values of the opening angle of the gap for various obstacles

a)

b)

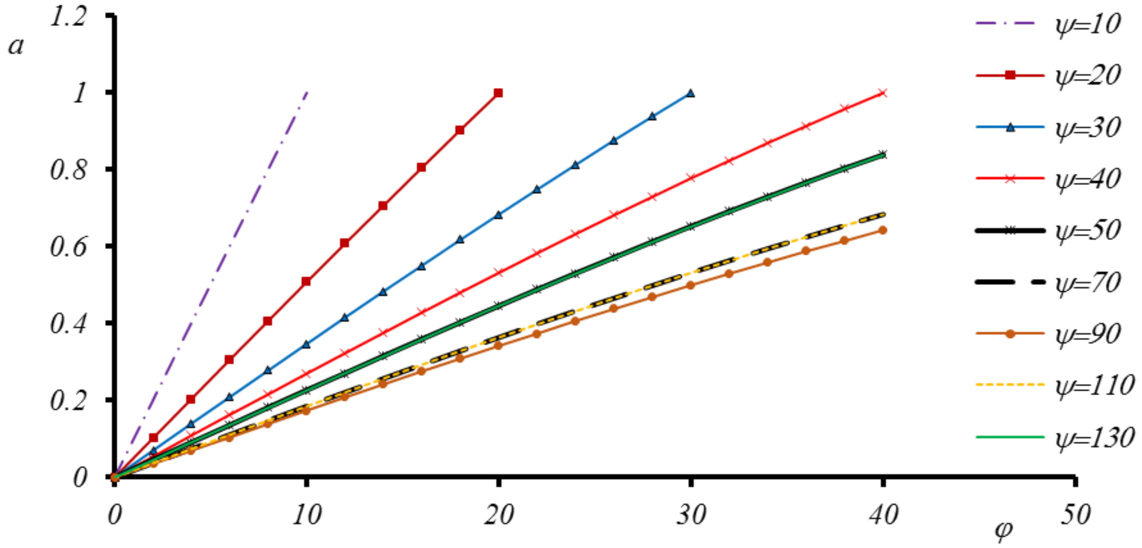
c)



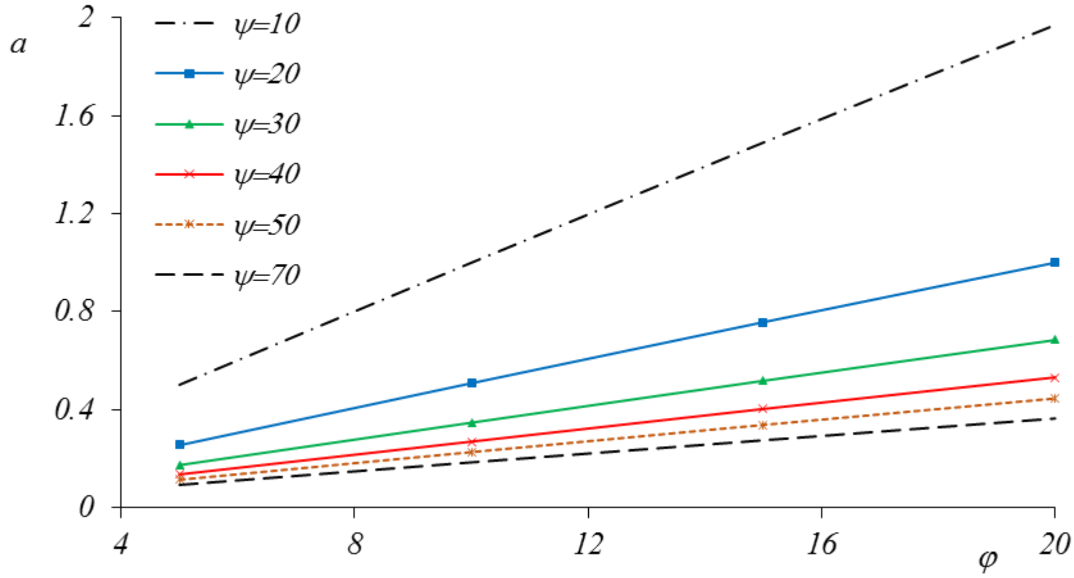
a) a gap; b) barrier; c) a gap with a barrier

Figure 4 – The dependence of the parameter *b* on the gap filling angle at different values of the gap opening angle for various obstacles

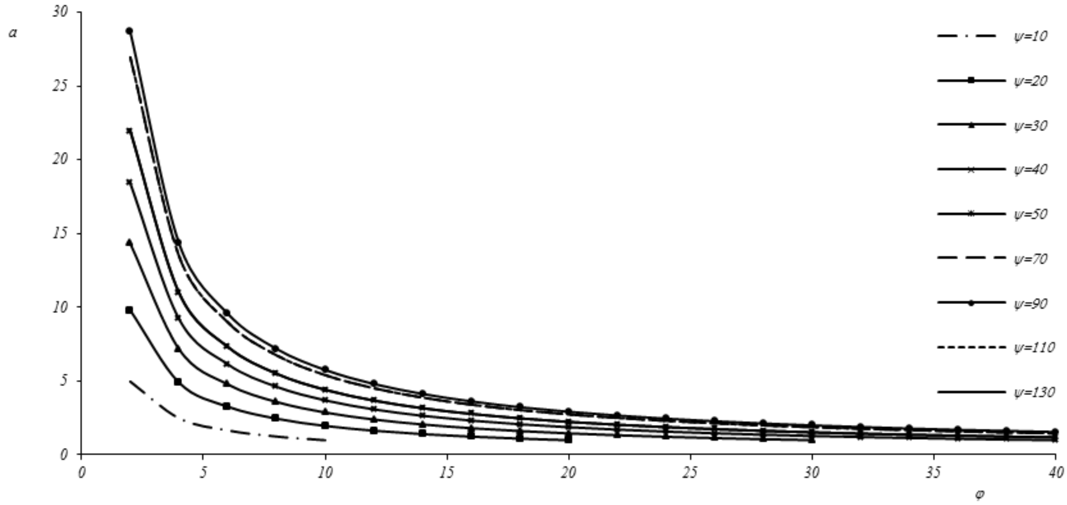
a)



b)



c)



a)a gap; b) barrier; c) a gap with a barrier

Figure 5 - The dependence of the parameter a on the angle of filling the gap at different values of the opening angle of the gap for various obstacles

Table 1 - Calculated dependencies for determining the coefficient using different types of obstacles

Parameter	Calculation formula		
	Gap	Barrier	Gap with barrier
F	$\left(1-\frac{1{,}117}{(\beta-\beta_*)^{1{,}04}}\varphi\right)^2\frac{1}{a}$	1	$(1+k)^2\frac{sin^2(\varphi-\beta+\beta_*)}{sin^2\psi}$
a	$\frac{sin\,\varphi}{sin\,\psi}$	$\frac{\sin\psi}{\sin\varphi}$	$\frac{sin\,\psi}{sin\,\varphi}$
b	$\frac{sin(\varphi-\psi)}{sin\,\psi}$	$\frac{sin(\psi+\varphi)}{sin\,\varphi}$	$\frac{sin(\psi-\varphi)}{sin\,\varphi}$
φ	$\alpha-\beta_*$	$\beta-\beta_*$	$\alpha-\beta$
ψ	$\gamma+\alpha$	$\gamma+\beta_*$	$\gamma+\alpha$

The following designations are accepted in the table:

γ – the angle of inclination to the horizon of the ascending edge of the gap or barrier;

α – the angle of inclination to the horizon of the descending edge of the gap or barrier;

β – the angle of inclination to the horizon of the dusting surface;

β_* – the angle of slope formed by settled particles of man-made placer;

φ – the gap filling angle or angle between the placer and the dusting surface;

ψ – the opening angle of the gap or the angle between the placer and the barrier;

k – barrier coefficient, calculated as the ratio of the length of the barrier edge to the length of the gap edge.

Conclusion and direction for further research. For perspective methods for controlling the parameters of man-made deposits formed in enrichment waste storage facilities, based on the regulation of the parameters of such placers during non-pressure storage of low-concentration pulps, the parameters of the resulting placer and washed mass were made.

On the basis of this, the scientific foundations of methods for controlling the parameters of man-made deposits formed in the storage of enrichment wastes have been developed and improved, which for the first time ensure the intensification of the process of formation of man-made placers and their subsequent production without stopping the process of storing waste.

It has been established that by controlling the parameters of the process of fractionation of enrichment waste in the form of a low-concentration pulp, the maximum volume of man-made placer can be accumulated due to the combined overflow at the obstacle of the gap with the barrier, and the minimum volume - when overflowing through the threshold. The use of flow over the gap under these conditions makes it possible to accumulate an intermediate volume of man-made placer. It should be noted that the question of the effectiveness of choosing one or another type of obstacle must be investigated taking into account the degree of filling of the alluvial stage, as well as the analysis of the movement of solid particles, which is beyond the scope of ongoing research.

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КЕРУВАННЯ ПАРАМЕТРАМИ ТЕХНОГЕННОГО РОЗСИПУ ВПЛИВОМ НА ПРОЦЕС ФРАКЦІОНУВАННЯ

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Анотація. За результатами досліджень у роботі проаналізовано досвід роботи гірничо-збагачувальних комбінатів Кривбасу, який дозволив визначити, що існуючі технології збагачення не здатні повністю сепарувати цінні компоненти під час переробки мінеральної сировини. Це призводить до акумулювання цінного компонента у сховищах відходів збагачення та вимагає розробки методів, технологій, що спрямовані на видобуток та переробку мінеральної сировини у техногенних розсипах. Авторами запропоновано вирішення вказаної проблеми шляхом розробки сховища відходів збагачення мінеральної сировини як техногенного родовища для видобутку залишків цінного компонента, або використання сховища як відвалу порожньої породи для закладки виробленого простору та звільнення ємності для складування нових відходів.

Мета роботи полягає у визначенні параметрів техногенного розсипу та намивного масиву в процесі керування параметрами техногенного розсипу, що здійснюється через зміну параметрів процесу фракціонування при течії по пляжу намиву.

До параметрів техногенного розсипу, що сформувався в сховищі відходів збагачення відносять: зміст цінного компонента; збіднення та засмічення розсипу, що визначається як вміст глинистих і пилуватих частинок; потужність розсипу; протяжність розсипу по довжині пляжу; протяжність розсипу фронтом намиву; ближня межа техногенного розсипу; дальня межа техногенного розсипу.

За результатами проведених досліджень встановлено, що при керуванні параметрами процесу фракціонування відходів збагачення у вигляді пульпи низької концентрації максимальний обсяг техногенного розсипу вдається акумулювати за рахунок комбінованого перетікання на перешкоді щілини з перешкодою, а мінімальний об'єм – при перетіканні через поріг. Використання в цих умовах протікання над щілиною дозволяє акумулювати проміжний обсяг техногенного розсипу. Проведено оцінку параметрів одержуваного розсипу та масиву, що намивається, розвинені та вдосконалені наукові основи методів управління параметрами техногенних родовищ, які вперше забезпечують інтенсифікацію процесу формування техногенних розсипів та їх подальший видобуток без припинення процесу складування відходів.

Ключові слова: сховища відходів, техногенний розсип, параметри, процес фракціонування, пляж, фронт намиву.

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