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ANALYSIS OF MATHEMATICAL MODELS OF MATERIAL SIZE SEPARATION CONSIDERING EQUIPMENT AND MATERIAL CHARACTERISTICS AND SCREENING CONDITIONS

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Abstract. The present research aims to analyze modern mathematical models that describe the process of product screening and to assess the possibility of their use in predicting technological parameters of iron ore concentrate production. To this end, the authors of the paper analyze theories of screening, search for and analyze in detail data on mathematical models built on the specifics of screening, assess the possibility of using existing models to describe iron ore raw material screening that consider features of processing technologies, and evaluate factors that are unprovisioned in existing mathematical models regarding their possible impact on the final characteristics of marketable products. The research establishes that each of the models is based on the theory of separation. The mathematical models under study are developed for a specific mineral, the medium in which separation takes place, and also analyze equipment characteristics and several factors impacting the process. The development of a mathematical model requires not only analysis, assessment and consideration of factors to achieve separation efficiency of 80 % and more size 0.056 (0.044) mm, but also provision of a high degree of adequacy and reliability of the model for a real object. The practical significance consists in the possibility of developing and further using the mathematical model for screening iron ore raw materials with a grain size of 0.056 (0.044) mm to enable predicting ore and product screening indicators in flowsheets. This will increase efficiency of the iron ore concentrate production technology by creating more optimal conditions for separating the material by size during its preparation for grinding and beneficiation. The research confirms possible development and adaptation of a mathematical model that would describe the process of screening iron ore raw materials of class 0.056 (0.044) mm. The research identifies the main factors that require further study to allow verification of the adequacy of future models based on experimental data. These factors include properties of the medium of separation, magnetic properties of components of iron ore raw materials, specific gravity and density of the components, efficiency of separation of fine classes, and are currently unprovisioned in existing models.

Keywords: screen capacity, screening efficiency, separation characteristic, mathematical model, screening probability, material segregation, motion theory, discrete element method.

1. Introduction

The process of separating material into different size classes is known under the general term of size classification. It is carried out in two ways:

a) screening, i.e. separation by size on screening surfaces with calibrated meshes;

b) separation of material into different size fractions in a liquid or gaseous medium [1].

Many modern production processes require mechanical separation (screening) of materials by size to prepare them for further processing and production of the final product.

Separation of materials by size plays an important role in various technological processes. For this purpose, various classifying devices, e.g. classifiers, hydrocyclones, screens, etc., are used.

Initially, screening was an auxiliary operation during material crushing in closed cycles with crushers. Later, screening began to perform a preparatory function, when it was necessary to prepare the material by class for further processing. The next step in the process was to make screening the main operation when it is necessary to separate the material by classes one of which becomes a finished product. Further development of screening has shown the possibility of its application to the liquid phase in

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two directions, namely separation by size and separation into liquid and solid phases [2].

In the world practice of mineral processing, the probabilistic theory of material screening is based on the study of the process of a single grain passing through screening surface meshes [3]. The idea behind this theory is that a spherical grain falls vertically onto a screening surface with square meshes. The current screening theory and practices enable obtaining general ideas about the process itself, conditions and factors that impact it.

This theoretical knowledge and practical experience allow calculating the screening equipment considering current conditions of the separation process.

The principle of screen operation is underlined by the probability of material passing through screen meshes of various geometric shapes and sizes.

Separation of this kind requires consideration of certain material characteristics, separation conditions and medium, equipment parameters and operating modes, etc. Determining optimal parameters ensures that the quality criteria for the separated material products are met. Operating parameters of screening equipment are calculated empirically. However, it should be noted that considering indicators is rather complicated because in practice these conditions sometimes contradict each other.

Today, the issue of saving resources and energy is very acute, so development of resource-saving technologies using energy-efficient equipment is relevant. The process of separating materials is also viewed from this perspective. Therefore, screening is increasingly being used as a resource-saving separation technology. Its involvement in the flowsheet requires modernization of available equipment and development of new equipment with lower energy consumption and increased productivity and separation efficiency.

Development of new types of screens is preceded by an analysis of specific conditions, characteristics of the material to be separated, etc., and development of theoretical models that describe the material's behavior during separation with maximum accuracy.

When developing mathematical models for separating material by size, a large number of indicators should be considered including the screen mesh size, the material feed rate, screen capacity and efficiency, density of the medium and material, screening probability, etc.

Any mathematical model should be the best alternative and optimal solution to a given problem, especially when the objective functions are contradictory and reach extreme values at different points of the set of possible solutions.

A large number of requirements, factors and criteria impacting the process of material separation by size is a disadvantage of a mathematical model.

Therefore, it is virtually impossible to develop a single mathematical model that considers all the requirements for material separation by size, as each indicator characterizes the solution only partially, and only the combination of all parameters is functionally complete.

Purpose and objectives of the study. The article aims to analyze existing mathematical models of the screening process and to establish factors that can be used for development of a new mathematical model and its further application to predict technological parameters of separation in iron ore raw material processing.

2. Methods

The main technological indicators of screening are the screen capacity Q and screening efficiency E [4].

Values of these indicators depend on many factors that can be divided into two groups:

- factors that depend on physical and mechanical properties of the input material (particle size distribution, density and moisture content, red mud content);
- structural and mechanical factors of the screen (screening method, feed uniformity, shape and size of screening surface meshes, screen inclination angle, vibration amplitude and frequency).

Each of the mentioned factors significantly impacts the material separation process and should be considered in mathematical modeling.

Below are considered currently existing mathematical models that describe the screening process and their advantages and disadvantages.

In the second half of the 20th century, a mathematical model based on separation characteristics of the screen and kinetics of screening [5] was developed and it looked like:

$$\varepsilon(d,t) = 1 - exp\left[u_{max} \cdot (1 - (\frac{d}{a}))^{\psi} \cdot t\right] \text{ or } \varepsilon(d,\frac{M}{Q}) = 1 - exp\left[\frac{u_{max} \cdot (1 - (\frac{d}{a}))^{\psi}}{h \cdot Q} \cdot M\right], \qquad (1)$$

where ε is the narrow range of classes extracted from d into the undersize product, unit fr.; d is the particle size, mm; a is the screen mesh size, mm; ψ is the coefficient, $\psi = 1$ for slotted screen meshes, $\psi = 2$ for square screen meshes; u_{max} is the maximum particle screening rate, m/s; h is the average thickness of the material layer above the screen, $h = const$ (taken to simplify the model), m; t is the screening time, s; M is the material reserve on the screen, t; Q is the input capacity, t/h.

The great advantage is that the separation characteristic of the screen can be treated as a function of the probability of screening depending on the particle size d. In this case, the screening time or screen capacity is introduced into model (2). In the separation characteristic, the coefficient of the useful screen area is probably considered in the experimentally obtained value. The model is quite effectively adapted for separating large size classes.

However, the model describes shapes of screen meshes to a lesser extent, and does not consider characteristics of the raw material, such as magnetic properties, specific gravity, etc.

The screen volumetric capacity model [6] looks like

$$Q = \frac{(S \cdot \varphi \cdot \omega \cdot d_b \cdot (1 - \frac{d_b}{a})^2 \cdot 6 \cdot 10^{-5} \cdot (1 - C_v)^{-1})}{(C_l \cdot \frac{d_b (1 - \frac{d_b}{a})^2}{(d_l (1 - \frac{d_l}{a})^2}) + C_{lg} \frac{d_b}{d_{lg}} + C_{lg})}, \quad (2)$$

where Q is the volumetric capacity of the screen, m^3/h; a is the screen mesh size, mm; φ is the screen useful area, unit fr.; S is the screen area, m^2; ω is the circular vibration frequency, rad/s; $d_b, d_l, d_{\lg}$ are the size of boundary, “light” and large grains, respectively, mm; $C_b, C_l, C_{\lg}$ are the volumetric part of boundary, “light” and large grains in the feed, respectively, unit fr.; C_v is the void coefficient of the ground material, unit fr.

In another model, three different size fractions are involved: 1 – boundary grains, corresponding to “heavy” grains of size a>d>0.75a; 2 – “light” grains of size d<0.75a; 3 – large grains with d>a. The probability of screening “heavy” and “light” grains is estimated by Gaudin’s formula.

The specificity of this model is that it considers the impact of the fractional composition of the input product on the screen capacity. However, this model is not applicable to fine classes.

The screen capacity model for screens with square meshes looks like [7]:

$$Q = k \cdot \frac{u \cdot \varphi \cdot S \cdot d_b}{C_{mfc} \cdot \varepsilon_c} \cdot (1 - \frac{S_c}{a} \cdot \varepsilon_c), \quad (3)$$

where Q is the screen capacity, t/h; k is the correction factor for dimensions of quantities; u is the particle screening rate, m/s; S is the screen area, m^2; φ is the screen useful area, unit fr.; a is the screen mesh size, mm; d_b is the bulk density of the material, t/m^3; C_{mfc} is the mass fraction of the calculated class in the feed, unit fr.; ε_c is the calculated class extracted into the undersize product, unit fr.; S_c is the size of the calculated class, mm.

The model can be applied to various types of screens and considers both the volumetric capacity of the screen and the impact of the input material’s fractional composition. The model can be used for both dry and wet separation. However, it should be noted that the disadvantage of this model is that it does not consider magnetic properties of materials and the impact of specific gravity.

The model of hydraulic screening is based on fixed curved and horizontal screens [8]. Its separation characteristic (by the undersize product) is equal to:

$$\varepsilon(d) = 1 - (1 - \gamma_\upsilon - \sigma)^{(\frac{d_l - d}{d_l - d_f})}, \quad (4)$$

where ε is the narrow range of classes extracted from d into the undersize product, unit fr.; γ_υ is the volumetric yield of the undersize product pulp, unit fr.; σ is the correction factor that considers the difference between the yield of water and pulp, unit fr.; d_l is the maximum size of large particles passing through the screen – an analogue of the screen mesh size of Gaudin's formula for a "dry" screen, mm; d is the average size of the calculated class, mm; d_f is the maximum size of fine particles, extraction of which under the screen coincides with dewatering, taken at the level of – 0.074 mm.

The advantages of this model include its adaptability to the fixed "wet" curved and horizontal screens, separation conditions (dry, wet screening) and the fact that it considers the volumetric capacity of the screen. However, like some of the models discussed above, this model does not consider material properties, specific gravity, etc.

The fundamental difference of the next model from the above-mentioned ones is that it considers the motion of a particle on the screen surface as a random process – "diffusion". In this case, the random motion of the particle stops when it reaches the screen (absorbing screen panel). The center of each mesh is surrounded by an absorbing hemisphere of the diameter proportional to the difference $(a - d)$.

However, when deriving the formula for particle extraction into the undersize product, the author of this model then divides $(a - d)$ by d (as a previous assumption). Moreover, the value $(a - d)$ characterizes the screening process (the hemisphere diameter), and the value d (denominator) characterizes the "diffusion" of the particle (segregation motion of the material to the screen) [9]. The formula for particle extraction into the undersize product is as follows:

$$\varepsilon(d,t) = 1 - exp \cdot \left[- k \cdot (\frac{a - d}{d}) \cdot \gamma \cdot t \right], \quad (5)$$

where k is the screening coefficient (volumetric screening rate), determined experimentally, cm/s; γ is the concentration of particles with d (the number of particles per unit of volume), 1/cm.

Models (4) and (5) contain the parameters of the screening rate and the probability of particle screening. However, in (5), the difference $(a - d)$ is normalized with respect to d (in Gaudin's case, with respect to a) and, in addition, there is no power index ψ. The coefficient of the useful area of the screen and the power index ψ are apparently incorporated in the experimentally obtained coefficient k.

Thus, this model considers randomness of the particle motion and volumetric capacity, but at the same time, the disadvantage of this model is that it does not consider such criteria as material properties and specific gravity.

3. Theoretical part

Researchers of the Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NASU) conducted many experiments on fine screening and created a mathematical model that describes the process of screening with dewatering and considers the initial distribution of particles, height of the liquid, segregation, mixing, screening, features of vibration transportation (speed, multiplicity and number of drops during vibration transportation) and layer height changes.

The novelty of the model consists in considering the mutual impact of size classification and dewatering [10]. The model describes the process of screening particles of a given size and removing the liquid in the capillary bridges between particles. This is achieved by modeling the transition of particles and the liquid along the layer height by a discrete Markov process with discrete states. The model enables determining probabilities of transitions of a particle and the liquid from one elementary layer to another, disintegrating elements – to elementary layers, from elementary layers – to disintegrating elements [10].

One of the latest developments of the IGTM of the NASU proposes a model that considers "double" impacts, where the first percussion helps to detach the material from the screening surface and loosen it, and the second percussion is created during the flight phase and transmits additional acceleration to the screening surface. This ensures that particles stuck in meshes are removed and break the liquid meniscus. It is important that when the second percussion is applied, the material to be screened does not interfere with the removal of particles and the liquid [11].

Screens of this type are of simple design, but realization of the vibro-percussion mode is only possible with certain combinations of structural and dynamic parameters. Experimental determination of the parameters is extremely laborious, so [11] considers a mathematical model of the screen and obtain a model describing the motion of the screen surface during excitation by two percussion mechanisms. The model provides for no energy loss in the deformed bonds.

Experimental studies demonstrate that implementation of the screening surface vibration mode, with additional percussions, compared to single ones, increases efficiency of material screening by 5–15% depending on its physical and mechanical properties [11].

In [2], it is noted that most often, there is no sufficient time for the material to be sorted and it has to be directed to re-screening or it is necessary to increase the length of the screen or the screening time, thus reducing the rate. These measures lead to additional costs.

When particles are large enough (with a low specific surface area), the material layer on the screen can be one or several medium-size particles thick. All the particles are in close proximity to the screen, and efficiency of the particles passing through the screen depends only on the relationship of their size and the size of the screen meshes.

Full yield of all particles that can potentially pass through the screening surface determines kinetics of screening [12]. In other words, screening is divided into two phases: the passage of lower-class material grains to the screening surface through the entire layer and the direct passage of material grains through the screening surface.

In [2], the author proposes to introduce an additional vibration exciter, that enables the increase in screening efficiency of existing vibroscreens. The additional vibration exciter increases the difference of motion speeds of bulk material particles relative to each other. This activates the process of lower fraction particle passing to the screen surface through the entire bulk material layer.

This, in turn, increases efficiency of screening and, as a consequence, enables the increase in screening capacity while maintaining the quality of sorting.

When developing a mathematical model that would describe the motion of particles with additional introduction of a vibration exciter, the author considers the theory of random particle motion [2] and the matrix of transient probabilities, which, under the accepted restrictions, has the following final form:

$$P = \begin{vmatrix} P_{s1} & d & 0 & 0 & 0 & 0 \\ \upsilon + d & P_{s2} & d & 0 & 0 & 0 \\ 0 & \upsilon + d & P_{s3} & d & 0 & 0 \\ 0 & 0 & \upsilon + d & P_{s4} & d & 0 \\ 0 & 0 & 0 & \upsilon + d & P_{s5} & 0 \\ 0 & 0 & 0 & 0 & \upsilon_f & 1 \end{vmatrix}, \qquad (6)$$

An additional vibration exciter enables an acceleration of the speed of the bulk material due to a decrease in the material's resistance to motion resulted from a decrease in the amount of material per unit of area. Accordingly, the remaining material interferes less with itself. Besides, when applying an additional vibration exciter, the amount of energy that was initially supplied for the entire volume of the material and depended on the amplitude and frequency of the screen vibrations, is now spent on just part of the material due to a decrease of its specific gravity.

This mathematical model describes the impact of the volumetric capacity of the screen and randomness of the particle motion. However, it does not consider the factor of the separation medium, namely separation in the liquid phase, properties of the input material, such as magnetic ones, and specific gravity.

Separation processes and development of a mathematical model for separation of recyclable materials are investigated in [13].

The study focuses on the following:

- properties of complex cable and wire production wastes;
- the speed of motion of complex cable and wire production waste particles in free and restricted conditions;

- experimental determination of aerodynamic characteristics of complex cable and wire production waste components;
- development of a model of the vibration-pneumatic separation process and study of the impact of material layer looseness on particle motion parameters;
- the study of air separation parameters in laboratory and pilot conditions and development of technological modes of separation.

The developed model of a pneumatic vibration separator considers the analysis of forces acting on light and heavy particles and allows determining values of angular velocities at which heavy particles are thrown up on the lower screen of the separator and light particles slide on the upper screen. The separation mode is determined mainly by the angular velocity at which heavy particles are thrown up on the lower screen.

The parameters of the plant's operating mode are determined to achieve effective separation of multi-component non-ferrous scrap with 96–99% aluminum recovery into one product and 90–99% rubber recovery into another. In [13], it is concluded that the method of vibropneumatic separation enables effective separation of the material under the impact of an upward air flow and vibrations. This results in stratification of the material by particle size and density. Separation into products is carried out by moving created material layers in opposite directions on the working surface.

Pilot tests on a testing bench confirm effectiveness of the developed component separation mode, which will allow obtaining an economic effect from its implementation [13].

In [14], it is noted that screening efficiency is an important estimation indicator of screening capacity, and it is difficult to predict it on the basis of existing parameters while designing vibroscreens due to the complex impact of the complicated process of particle screening as many factors affect selection or determination of these parameters. Therefore, understanding prediction of screening efficiency is of great practical importance.

Many researchers study the screening process using the Discrete Element Method (DEM), considering the qualitative relationship between efficiency of screening and its parameters in a vibroscreen, such as amplitude, vibration frequency, screening surface mesh size, particle size and vibration direction angle, etc. However, the results of DEM modeling require further studies and improvement, as dispersed materials and modeling boundary conditions are difficult to match with actual conditions [14].

Screening efficiency was studied in the real-time mode through gathering vibration parameters of the screen. However, results of these studies have little impact on the screening equipment [14].

When studying the process of vibration screening, a relationship between screening efficiency and screening parameters (amplitude, vibration frequency, vibration direction angle, particle size, and screen mesh size) is established based on probabilistic and discrete element models. The disadvantage of the approach is that this relationship with screening efficiency is seen when only one parameter changes but not all parameters together [14].

Based on the statistical analysis of experimental data, [14] establishes a mathematical dependency between screening efficiency and the screen inclination angle and screen mesh size, which provides a theoretical basis for the design of a vibroscreen but ignores the impact of the screen length.

Despite development and studies of models that consider relevant screening efficiency functions, there is still no widely accepted formula for predicting screening efficiency based on separation parameters.

According to experimental results of [14], screening efficiency first increases due to an increase in the vibration amplitude and screen length, and then decreases due to an increase in the vibration frequency, screening surface mesh size, and inclination angle. This study focuses on a detailed analysis of the impact of the screening surface mesh size, surface length, and inclination angle.

In the [14], the impact of the mesh size on screening efficiency is also described. The mesh size can also be characterized by the relationship between the screening surface mesh size and the separation size. The small surface mesh size causes low screening efficiency due to similar sizes of meshes and separation, as well as a lower probability of fine particles penetration and a higher proportion of fine particles remaining with larger particles. A larger surface mesh size results in higher screening efficiency due to a greater probability of small particles going through the surface mesh. When the mesh size is too large, the screening efficiency becomes lower due to the greater probability of penetration of particles larger than the separation size and smaller particles mixed with a greater proportion of larger particles.

The impact of the surface length on screening efficiency is described in detail in the [14]. Screening efficiency increases significantly depending on the increase in the screening surface length. However, the screening efficiency decreases with the further increase in the surface length, provided that the relationship of the screening surface mesh with the separation size is greater, due to the high probability of penetration of particles larger than the separation size and smaller particles mixed with an increasing amount of impurities. If this relationship is greater, the optimum surface length is shorter due to the high probability of penetration of particles smaller than the separation size at the start of screening.

As noted in the [14], screening efficiency depends on the angle of inclination that mainly impacts the size of the horizontal projection of meshes and the speed of the particle motion on the surface. With an increase in the inclination angle, the size of the horizontal projection of the surface meshes decreases and the probability of particle vertical penetration decreases, thus leading to a smaller number of penetrations of particles larger than the separation size. Meanwhile, the ability of particles smaller than the separation size to penetrate and group increases with the increase in the particle motion speed on the screen surface. The increase in the angle of inclination has its limits and, at certain values, results in a decrease in screening efficiency due to a sharp decrease in the size of the horizontal projection of the surface meshes, and a sharp increase in the speed of particle motion on the screen surface and a reduction in time of particle remaining on the surface.

The impact of vibration amplitude on screening efficiency is also considered in the [14]. When vibration amplitude and frequency increase, the probability of penetration of particles smaller than the separation size becomes greater, so screening efficiency increases. However, when vibration frequency increases significantly, screening efficiency decreases because a higher vibration frequency can lead to a higher probability of penetration of particles larger than the separation size.

4. Results and discussion

Fine screening can be used in beneficiation of ores, including iron ores, only in flowsheets involving grinding and beneficiation.

However, application of fine screening is not primarily conditioned by the separation size, but by the technical ability of screen manufacturers to produce screening surfaces with the smallest possible mesh. Over the past 20 years, the size of screening surface meshes has decreased from 100 µm to 45 µm and smaller. At present, screening surfaces with the smallest meshes are produced by the American company Derrick Corp., and their size is 325 mesh (0.045 mm) [15]. Although it should be noted that ores are mined at pit depths of more than 200–400 m, which causes a decrease in useful component dispersed inclusions to 0.03–0.05 mm and less in size, at that grinding such ores already reaches almost 100% of less than 0.045 mm class.

For magnetite ores, fine screening should be used not only as a method of size separation, but also as a method of beneficiation that increases the mass fraction of iron in the undersize product. At the same time, further actions should be considered for the oversize product with low iron content, that is, however, sufficiently higher than the "cut-off" iron content (at the level of 40–50%), which makes it impossible to dispose it at dumps.

5. Conclusions

The analysis of the current state of screening fine size classes shows that this process depends on many factors that cannot be studied simultaneously in practice, so mathematical modeling is used for a multifactorial study.

Based on the analysis performed, it can be concluded that currently there is no widely accepted formula for predicting screening efficiency based on separation parameters. Many developed models describe the screening process, and they all have their advantages and disadvantages, so introduction of additional parameters and coefficients can help improve them.

The further research directions will include:

- development of mathematical models considering factors identified during the analysis, namely: properties of the medium in which separation takes place, magnetic properties of the components of iron ore raw materials, specific gravity and density of the components of iron ore raw materials, and efficiency of separation of fine size classes;
- tests to gather experimental data;
- statistical processing of the obtained experimental data;
- verification of the developed models adequacy;

- formulation of conclusions and recommendations for industrial conditions, considering the data obtained in the course of testing and mathematical analysis.

Conflict of interest

Authors state no conflict of interest.

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АНАЛІЗ МАТЕМАТИЧНИХ МОДЕЛЕЙ РОЗДІЛЕННЯ МАТЕРІАЛУ ЗА КРУПНІСТЮ, З УРАХУВАННЯМ ВЛАСТИВОСТЕЙ ОБЛАДНАННЯ, ХАРАКТЕРИСТИК МАТЕРІАЛУ ТА УМОВ ПРОЦЕСУ ГРОХОЧЕННЯ

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Анотація. Метою даних досліджень є аналіз сучасних математичних моделей, які описують процес грохочення продуктів та оцінка можливості їх використання при прогнозуванні технологічних параметрів виробництва залізорудних концентратів. Для досягнення поставленої мети в роботі проаналізовано теорії грохочення, виконано пошук та детальний розбір інформації щодо математичних моделей, які враховують особливості процесу грохочення, надано оцінку можливості застосування існуючих моделей для опису грохочення залізорудної сировини з урахуванням особливостей технологій їх переробки, оцінено фактори, що невраховані в існуючих математичних моделях щодо можливого їх впливу на кінцеві показники товарної продукції. В рамках дослідження встановлено, що-кожна із моделей базується на теорії розділення. Розглянуті математичні моделі розроблено для конкретної корисної копалини, середовища, в якому відбувається розділення і враховують особливості обладнання та декілька факторів що вливають на процес. Розробка математичної моделі потребує не тільки аналізу, оцінки та врахування факторів для досягнення ефективності розділення за крупністю 0,056 (0,044) мм залізорудної сировини на рівні 80 % та вище, але й забезпечення високого ступеню адекватності та надійності моделі для реального об'єкту. Практичне значення полягає в можливості розробки та подальшому використанні математичної моделі грохочення залізорудної сировини за зерном 0,056 (0,044) мм для прогнозу показників розділення руди та продуктів в технологічних схемах переробки. Це дозволить підвищити ефективність технології виробництва залізорудних концентратів за рахунок створення більш оптимальних умов для розділення матеріалу за крупністю при його підготовки до подрібнення та збагачення. В рамках цього дослідження підтверджено можливість розробки та адаптації математичної моделі, яка б описувала процес грохочення залізорудної сировини за класом 0,056 (0,044) мм. Визначені основні фактори, такі як :властивості середовища в якому протікає розділення, магнітні властивості компонентів залізорудної сировини, питома вага та щільність компонентів залізорудної сировини, ефективність розділення тонких класів крупності, які на даний час не враховані в існуючих моделях. Зазначені фактори та потребують додаткового вивчення, що дозволить при отриманні експериментальних даних перевірити адекватність розроблених в подальшому моделей.

Ключові слова: продуктивність грохоту, ефективність грохочення, сепараційна характеристика, математична модель, ймовірність просіювання, сегрегація матеріалу, теорія руху, метод дискретних елементів.