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NUMERICAL EXPERIMENTS ON THE DETERMINATION OF RATIONAL RANGE OF MODE PARAMETERS FOR THE EFFECTIVE DEWATERING OF VARIOUS SCREENING SURFACES

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Abstract. Dehydration of mineral raw materials on a vibrating screen occurs as a result of the passage of liquid through the cells of the screening surface. With fine and ultrafine screening, this process is hindered by the surface tension of the liquid. None of the screening theories makes it possible to determine which vibration excitation modes ensure dehydration.

With the help of numerical experiments on a mathematical model, the influence of vibration excitation modes on the intensity of the passage of liquid through the cells of various screening surfaces during dehydration on a vibrating screen was studied. In doing so, two tasks were solved: 1) determination of the amplitude and frequency of vibration excitation, when the required balance of water and the size of the cells of the screening surface are set; 2) determination of the remaining water on the screening surface depending on the cell size of the screening surface, the amplitude and frequency of vibration excitation. The developed mathematical model made it possible to solve both problems. On the basis of calculations and analysis, rational range of mode parameters of the vibrating screen for effective dehydration of various screening surfaces was established. The calculation algorithm is implemented on the basis of a mathematical model in the PC program «Sifting Surface» in C ++ with the connection of mathematical libraries and «Excel». The results of calculations, demonstration of the possibilities of various screening surfaces and modes are shown in the figures, which show the dependences of the residual water on the amplitude and frequency vibration excitation parameters. It is established that the vibro-impact effect, in comparison with the harmonic effect, provides better results in cleaning the cells from the liquid retained in them by surface tension forces, under less intensive modes.

The results obtained will be used in the development of a mathematical model of dehydration and a method for calculating technological parameters that ensure effective removal of liquid during fine and ultrafine screening of mineral raw materials, as well as to determine the rational design and dynamic parameters of the screen.

Keywords: dehydration, liquid surface tension, harmonic and vibroimpact vibration excitation, amplitude and frequency of vibration excitation, mathematical model.

1. Introduction

As a result of the activities of industrial enterprises on the territory of Ukraine, a huge amount of watered fine-grained waste has been accumulated, which, due to a significant amount of a useful component, are, in fact, man-made deposits [1, 2]. One of the ways to extract a useful component from technogenic raw materials is their separation by size on a screening surface [3-5]. However, in the presence of water and with a decrease in particle size, the processing of raw materials becomes more complicated. Dehydration requires efficient equipment [5–8].

One of the components of the process of dehydration of mineral raw materials on a vibrating screen is the passage of liquid through the cells of the screening surface. When screening in a class less than the capillary constant, this process is significantly hampered by surface tension forces [9–11], which are overcome due to dynamic action. None of the screening theories makes it possible to determine which modes of vibration excitation provide dehydration [11]. In this regard, it is important to know what mode parameters make it possible to overcome the surface tension forces acting in the cell of the screening surface and effectively remove water from them, and the problems associated with these solutions are undoubtedly relevant.

2. Methods and results of previous studies

In the IGTM of the NAS of Ukraine, in laboratory conditions, the influence of the design and vibration excitation modes on the intensity of the passage of liquid through the surface cells, which was characterized by the relative mass of water (%) remaining on the surface during the time of reaching the stationary value, was experimentally studied on a screen model with harmonic and vibro-impact excitation of the screening surface, [10]. The experiments were performed on various screening surfaces in the form of a sizing woven mesh (steel or polyamide) with different hole sizes, lying on rubber bands-strings or metal rods, a supporting polypropylene mesh, under which there were rubber bands-strings or metal rods (design options). We used steel and polyamide meshes with square cells l_0 = 0.63, 0.1 and 0.05 mm. The influence of mode parameters (amplitude A and frequency ν) on the change in the amount of remaining water W on various screening surfaces was studied under harmonic and vibroimpact excitation. The research results are given in [10].

Based on the analysis of experimental results by the least squares method, regression equations were obtained that describes this process [11]. The created mathematical model of dehydration of the screening surface of the screen allows you to calculate the amount of water remaining on various screening surfaces depending on amplitude and frequency of vibration excitation or determine the parameters of vibration excitation to achieve the required dehydration indicators. At the same time, rational range of mode parameters, under which effective dehydration of the screening surface is ensured, was not established.

The **purpose of this work** is to determine the rational range of the mode parameters of the vibrating screen for effective dehydration of various screening surfaces by numerical experiments.

3. Theoretical and experimental parts

To designate a screening surface (design options), a record is adopted that includes four positions separated by a hyphen. They respectively indicate the initial letter of the material from which the mesh is made, the size l_0 of the side of the square hole in millimeters; the letter Sup is indicated in the presence of a supporting mesh, the letter S is written when the string ribbons are installed. In the case when the equation describes the residual water on the screening surfaces St-0.05, St-0.05-S and St-0.05-Sup-S, the designation S-0.05-G is used, where the last letters are an abbreviation for the word «generalized».

An example of the designation St-0.63-Sup-S – the screening surface consists of a steel mesh, in which the side of the square hole is 0.63 mm, a supporting mesh and string ribbons.

In the accepted notation for vibro-impact excitation, R and H (abbreviations for the words rods and hammer) are accepted for screening surfaces in the position after the cell size. For example, the record P-0.05-R-H means a polyamide mesh with 0.05 mm square holes, under which the rods and the hammer are installed.

When calculating the parameters of the process of dehydration of the screening surface, the following tasks are given:

1) the required water balance W and the cell size l_0 of the screening surface are set – it is necessary to calculate the amplitude A and the vibration excitation frequency v;

2) to determine the remaining water W on the screening surface depending on the cell size l_0 of the screening surface, the amplitude A and the vibration excitation frequency v.

The developed mathematical model allows solving both problems.

The calculation algorithm is implemented on the basis of mathematical model in the PC program «Screening Surface» in C ++ with the connection of mathematical libraries and «Excel».

4. Results and discussion

We will study the possibilities of dehydration of various screening surfaces and the influence of mode parameters with the help of numerical experiments on the mathematical model.

During the studies, the operating parameters were varied: amplitude from 1 mm to 5 mm, frequency from 10 Hz to 60 Hz.

Task 1.

The required water balance W is set.

Initial data:

screening surface S-0.1-R-H – steel mesh, rods, hammer,

required water balance $W = 5\%$,

the mesh size of the screening surface $l_0 = 0.1$ mm.

It is necessary to calculate the amplitude A and the frequency of vibration excitation v, which will provide the required balance of water.

To do this, we use the regression equation for the screening surface S-0.1- R-H [4].

To automate the solution of this problem, we use the built-in function «Search for a solution» of the MS Excel spreadsheet processor.

As a result of the calculation, we obtain: to reduce the residual water to $W = 5\%$, vibration excitation modes with the following parameters are required: amplitude A = 2 mm, frequency v = 31 Hz.

Task 2.

The cell size l_0 of the screening surface, the amplitude A and the vibration excitation frequency v are given. Let us determine the remaining water W. To automate the solution of these tasks, we use the spreadsheet MS Excel.

The results of calculations, a demonstration of the possibilities of various screening surfaces and modes are shown in fig. 1–7, which shows the dependence of the remaining water W on the parameters of vibration excitation of amplitude A and frequency v on various screening surfaces during dehydration on vibrating screen.

As can be seen from fig. 1, complete removal of water from the screening surface St-0.63-G is realized at amplitudes A above 1 mm and frequencies v over 40 Hz.

For dehydration of the St-0.05-G screening surface (Fig. 2), more intense vibration excitation modes with amplitude A of at least 5 mm and a frequency v above 55 Hz are required.

Effective removal of water from the screening surface St-0.63 (Fig. 3) is realized at amplitudes *A* of more than 3 mm and a frequency *ν* above 45 Hz.

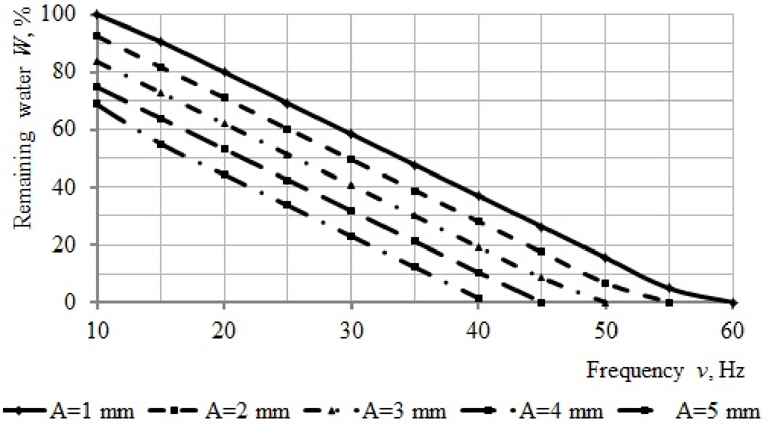

Figure 1 – The dependence of the remaining water *W* from the amplitude *A* and frequency *ν* of vibration excitation for the screening surface St-0.63-G

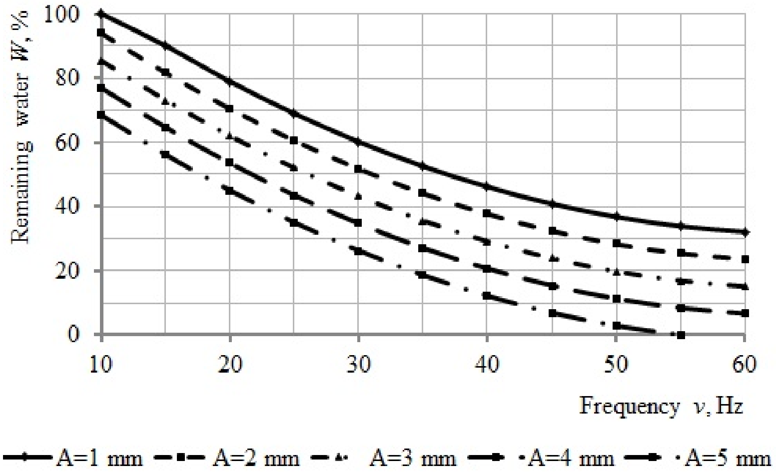

Figure 2 – Dependence of the remaining water *W* from the amplitude *A* and frequency *ν* of vibration excitation for the screening surface St-0.05-G

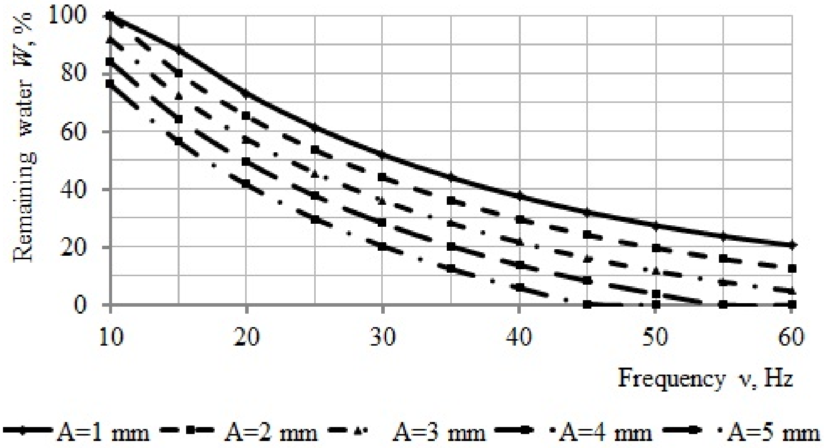

Figure 3 – Dependence of the residual water *W* from the amplitude *A* and frequency *ν* of vibration excitation for the screening surface St-0.63

When belt-strings are installed (screening surface St-0.63-S), less intensive modes are required, and complete dehydration is achieved at amplitudes *A* from 1 mm and frequencies *v* from 40 Hz (Fig. 4).

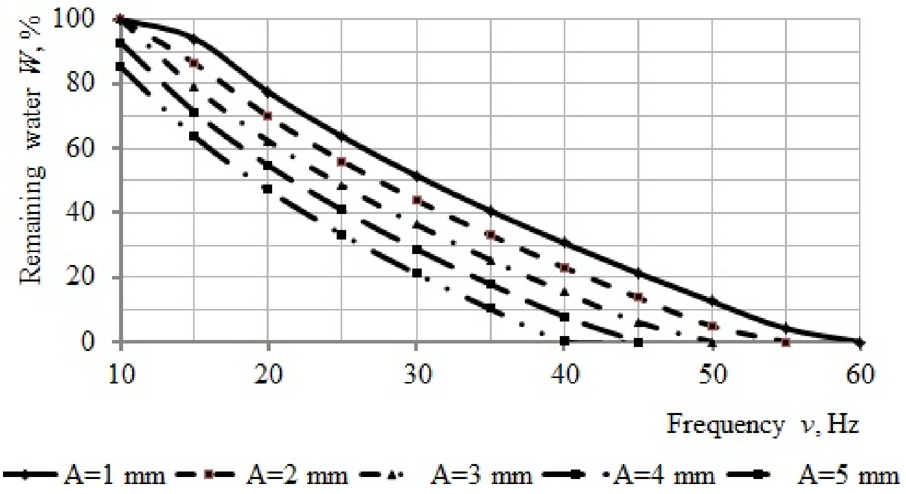

Figure 4 – Dependence of the remaining water *W* from the amplitude *A* and frequency *v* of vibration excitation for the screening surface St-0.63-S

For the screening surface P-0.05-Sup-S, effective water removal (Fig. 5) requires sufficiently intensive modes: amplitude *A* over 3 mm and frequency *v* over 40 Hz.

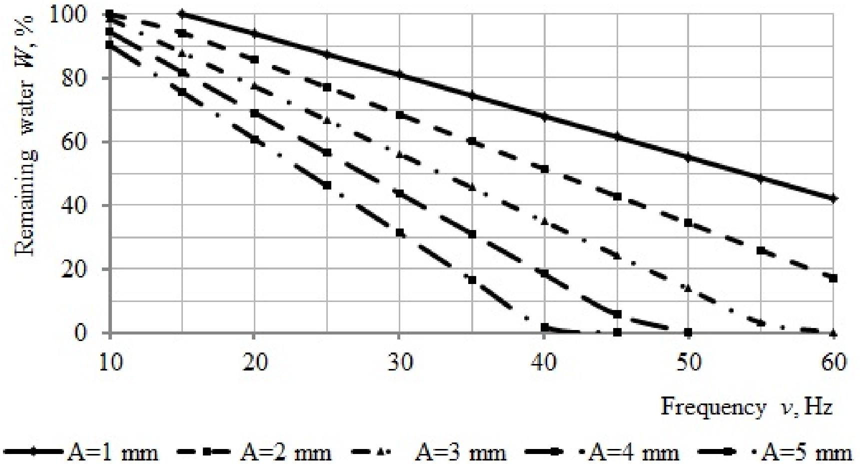

Figure 5 – Dependence of the remaining water *W* from the amplitude *A* and frequency *v* of vibration excitation for screening surface P-0.05-Sup-S

Due to the use of vibro-impact in the range of amplitudes *A* from 3 mm to 5 mm and frequencies *v* from 35 Hz to 60 Hz, almost complete dehydration of the screening surface St-0.05-R-H is achieved (Fig. 6).

Effective dehydration for the screening surface G-0.1-R-H is realized with vibro-impact in the range of amplitudes *A* from 3 mm to 5 mm and frequencies *v* from 45 Hz to 60 Hz (Fig. 7).

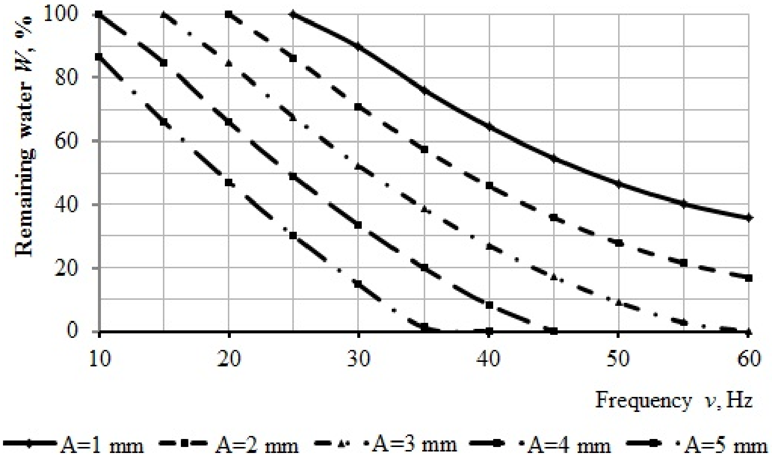

Figure 6 – Dependence of the remaining water *W* from the amplitude *A* and frequency *ν* of vibration excitation for the screening surface St-0.05-R-H

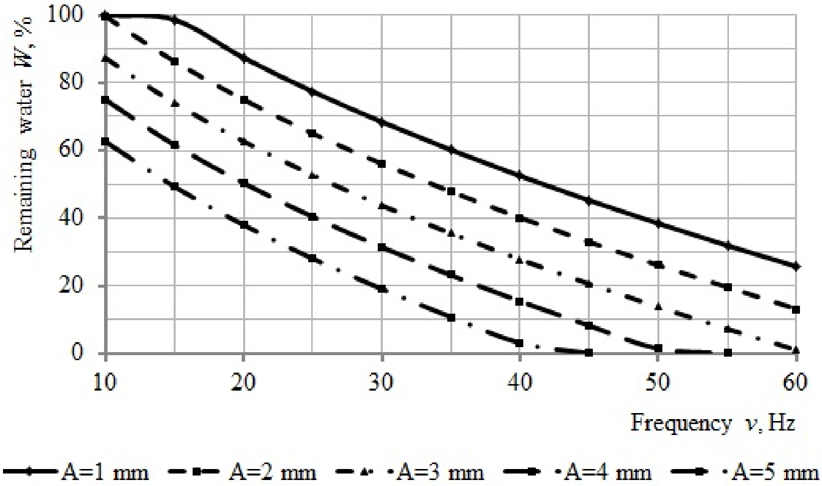

Figure 7 – Dependence of the residual water *W* from the amplitude *A* and frequency *ν* of vibration excitation for the screening surface G-0.1-R-H

In fig. 1–7, it can be seen that with a decrease in the cell size of the screening surface, more intense impact modes are required in order to overcome the forces of surface tension.

The polyamide screening surface, compared to steel, is less efficient in ensuring the passage of water and requires more intensification of the impact, although it has such an advantage as low cost. Vibro-impact action intensifies the passage of water up to 60 % compared to harmonic.

Determination of the appropriate direction. Based on the results of calculations and analysis, rational range of mode parameters of the vibrating screen for effective dehydration of various screening surfaces were determined. It is established that the vibro-impact effect, in comparison with the harmonic effect, provides better results in cleaning the cells from the liquid retained in them by surface tension forces. To increase the efficiency of dehydration, it is necessary to clean the cells when the raw material is not in contact with the surface, that is, at the stage of its flight as a result of impact. Therefore, the vibro-impact effect with the use of additional shocks during the excitation period seems promising.

These results are one of the components in the mechanism of dehydration of technogenic raw materials, taking into account of which the «Method for calculating technological parameters that ensure the cleaning of the screening surface during fine screening of technogenic raw materials» was created.

5. Conclusions

Thus, with the help of numerical experiments, rational range of the mode parameters of the vibrating screen for effective dehydration of various screening surfaces was determined. The results obtained show the possibility of calculating the amount of water remaining on the screening surface, depending on the amplitude and frequency of vibration excitation, which makes it possible to calculate the parameters of vibration excitation for various screening surfaces. These data will be used in the development of a mathematical model of dehydration and a methodology for calculating technological parameters that ensure effective removal of liquid during fine and ultrafine screening of mineral raw materials, as well as to determine the rational design and dynamic parameters of the screen.

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ЧИСЕЛЬНІ ЕКСПЕРИМЕНТИ З ВИЗНАЧЕННЯ РАЦІОНАЛЬНИХ ОБЛАСТЕЙ РЕЖИМНИХ ПАРАМЕТРІВ ДЛЯ ЕФЕКТИВНОГО ЗНЕВОДНЕННЯ РІЗНИХ ПОВЕРХОНЬ, ЩО ПРОСІВАЮТЬ

Лапшин Є.С., Шевченко О.І.

Анотація. Зневоднення мінеральної сировини на вібраційному грохоті відбувається в результаті проходження рідини через чарунки поверхні, що просіває. При тонкому та надтонкому грохоченні цьому процесу перешкоджає поверхневий натяг рідини. Жодна з теорій грохочення не дозволяє визначити за яких режимів віброзбудження забезпечується зневоднення.

За допомогою чисельних експериментів на математичній моделі вивчено вплив режимів віброзбудження на інтенсивність проходження рідини через чарунки різних поверхонь, що просівають, при зневодненні на вібраційному грохоті. При цьому вирішувалися два завдання: 1) визначення амплітуди і частоти віброзбудження, коли заданий необхідний залишок води і розмір чарунок поверхні, що просіває; 2) визначення залишку води на поверхні, що просіває, в залежності від розміру чарунки поверхні, що просіває, амплітуди і частоти віброзбудження. Розроблена математична модель дозволяла вирішувати обидві задачі. На основі обчислень та аналізу встановлені раціональні області режимних параметрів вібраційного грохоту для ефективного зневоднення різних поверхонь, що просівають. Алгоритм розрахунку реалізований на основі математичної моделі в програмі для ПК «Поверхня, що просіває» мовою С++ з підключенням математичних бібліотек та «Excel». Результати обчислень, демонстрація можливостей різних поверхонь, що просівають, і режимів показані на рисунках, де наведені залежності залишку води від параметрів віброзбудження амплітуди і частоти. Встановлено, що віброударна дія в порівнянні з гармонійною забезпечує більш високі результати очищення чарунок від рідини, що утримується в них силами поверхневого натягу, при менш інтенсивних режимах.

Отримані результати будуть використані при розробці математичної моделі зневоднення та методики розрахунку технологічних параметрів, які забезпечують ефективне видалення рідини при тонкому та надтонкому грохоченні мінеральної сировини, а також для визначення раціональних конструктивних та динамічних параметрів грохоту.

Ключові слова: зневоднення, поверхневий натяг рідини, гармонійне та віброударне віброзбудження, амплітуда та частота віброзбудження, математична модель.