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Impact by the operating and structural parameters of a screen on the technological parameters of vibratory basalt sieving

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Abstract

Purpose is to identify a dependence of basalt raw material fine screening upon the operating and structural parameters of sieving equipment.

Methods. The research results have been obtained relying upon comparative analysis of basalt raw material fine screening upon the operating and structural parameters of sieving equipment. In this regard, the analyzed grading efficiency characteristics were defined for three densities of basalt rock mass mined in open pits. They are $\gamma = 1.4$ g/cm^3 for tuff; $\gamma = 2.2$ g/cm^3 for lava-breccia; and $\gamma = 2.6$ g/cm^3 for basalt. The rock mass components are extracted selectively and processed separately.

Findings. Expediency of complex mining and processing of three basalt rock mass components (being tuff, lava-breccia, and basalt) as well as their selective treatment has been identified. Mathematical modelling has helped generate regression models of fine basalt raw material sieving upon the operating and structural parameters of a screen. The regression models as well as the represented calculation results are indicative of strong correlation between the efficiency of fine basalt raw material screening and the factors involved by the regression models (i.e. rock mass density; inclination angle of a disturbance force of a vibration exciter of a screen; inclination angle of a screen effector; mesh size; specific load on a screen; disturbance frequency of a screen drive; and a screen length).

Originality. For the first time, dependencies of fine basalt raw material sieving efficiency upon the operating and structural parameters of a screen have been modelled mathematically. Based upon the multifactor experiment, ideas have been developed concerning the fine grading process; selection of boundaries of each parameter control; and determination of the efficiency as well as a law of changes in technological parameters while controlling them.

Practical implications. Use of the findings will help make adequate solutions while selecting instrumental conditions of an operation schedule to prepare basalt raw material for its integrated processing.

Keywords: *basalt, tuff, lava-breccia, screen, sieving*

1. Introduction

Many countries mine basalt. Ukraine, Italy, the USA, China, Spain, India, Turkey, Japan, Korea, and Brazil are the main producers of the mineral. Basalt is a volcanic rock formed from high-temperature lava. It is applied to manufacture asphalt, construction materials, artificial stones etc. [1]-[3].

Ukraine is among global leaders as for the mineral reserves; among other things, it has the developed network of open pits where basalt raw material is extracted [4], [5]. Rivne-Volyn deposits of stone minerals are rather important from the viewpoint of their volumes [6], [7]. Nevertheless, taking into consideration the fact that basalts include other valuable materials, it is expedient to carry out studies for the integrated extraction of the last-mentioned [8]-[10].

Volyn basalts attract researchers owing to their unique mineralogical and chemical composition. According to potassium-argon dating, their isotopic age is 510-598 million years. The mineral is represented by two types: aphanitic basalt being black and dark-gray minerals. Mainly, it is plagionitic rock. Its mineral composition is as follows: 36% of plagioclase; 33% of pyroxene; 19% of glass; 6% of palagonite; and 6% of ore mineral [11]-[14]. The basalts are exposed in open pits of Berestivtsi, Yanova Dolyna, Ivanchi, and Polytsi villages (Rivne Region). Amygdaloidal basalt is greenish-gray fine-grained rock with numerous amygdalins which size is up to 15 mm. Its mineral composition is as follows: plagioclase; ore mineral (i.e. magnetite, ilmenite); apatite; and volcanic glass. The basic eruptions took place in the Styr River basin. The rock density is 2.65 g/cm^3.

The modern directions of resources mining and extraction growth is among the key tasks of mining sectors of the industrialized countries [15]-[18] as well as the developing countries inclusive of Ukraine [19]-[22]. Significant industrial use of nonferrous metals as well as increase in their cost needs global intensification of exploration and development of their deposits [23]-[25].

Despite extensive development of a mining branch, there are no enterprises extracting nonferrous metals in Ukraine.

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However, geological prospecting is intensive in the country; moreover, studies are carried out to prospect the deposits, identify their reserves, and perform their pre-mining activities. In this context, Volyn basalts are of great interest. They stretch from Moldova through Ukraine and Poland northward. In the capacity of raw materials base, they are of concern being a building material as well as ore manifestations of numerous valuable resources [26], [27].

Copper nuggets, discovered in Volyn basalts during the 1930s, initiated studies of the copper mineralization; mineralogical composition of enclosing rocks; identification of promising areas; and prospect of new mining site [28], [29]. Currently, two copper-ore objects are known in Volyn. One of them, being Rafalivka ore cluster in Rivne Region, has been identified by Rivne geological party as a result of a well drilling. Deposit analysis in several basalt open pits has shown that the native mineralization is of regional nature.

Ore mineralization refers to the process by which valuable minerals accumulate and become concentrated in rocks or deposits, often forming economically viable sources for extraction [30]. It belongs to several morphotypes with different localization conditions. Among other things, it concerns scattered-interspersed, layered-interspersed, veined-interspersed forms, and lava-clastic breccias [31], [32]. In this context, trappean basalt consists mainly of basalts, basaltic tuffs, and lava-clastic breccias. Owing to the fact that experts from Rivne geological party have prospected promising deposits of native copper within three components of the deposit, analysis of the formations, their composition, and characteristics becomes of practical significance [33], [34].

Even at the modern level of knowledge, the trappean structure of basalt deposits, variety of mineralization forms and mineral composition of the rock denote the necessity to apply the integrated approach developing the deposits. Moreover, it concerns both mining and processing procedures and use of termination products. For instance, multilayer structure of basalt formation, involving industrial quantities of basalt itself, tuffs varying in mineral compositions, lava-breccias with intensive native copper inclusions, and ore layers with inclusions of valuable metals, challenges the expediency of basalt mining only for the broken stone and finish tile production [35]-[37].

Specificity of the analyzed deposit (being Rafalivka basalt open pit) is that tuff is stocked up in a waste dump not separately but together with lava-breccia. The matter is that the lava-breccia layer penetrates the basalt formation and tuff is underlying structure. When the open-pit bench is being blasted tuff mixes and lava-breccia mixes. Under explosive mass loading, they separate from basalt, and become rock mass in the form of tuff-breccia. Since tuff and lava-breccia can hardly be considered as marketable products, they are transported to a waste dump. Huge technogenic deposit is a result of long-term operation of the open pit. Nobody was engaged in the separation of the rocks at the stage of ore preparation; hence, development of the procedure should involve additional studies based upon consideration of physicomechanical characteristics of the two waste rocks as well as high content of useful metals in them [38], [39].

In such a way, the paper considers problems of the integrated processing of basalts and technogenic waste being tuff and lava-breccia as sources of valuable metals as well as residual silicate share which can be applied industrially. In this context, availability of native copper within the three components of the mined rock mass makes it possible to use simpler technique for its extraction to compare with sulphide copper [40]-[42]. Moreover, a reagentless extraction procedure can be applied [43], [44].

Experts from different organizations said repeatedly for the idea of comprehensive basalt raw material mining and processing [45]-[48]. Nevertheless, up to now such mining and processing practices have not been developed yet. There are some advertising ideas [49]-[52]; however, they are substantiated neither element by element nor technologically.

Thus, the conducted studies show that copper content in tuffs being 0.4-1.0% is of industrial interest. In addition, iron content is 17.0-30.0%; and titanium content is 1.0-4.0%. Each of enclosing rocks (i.e. basalt, tuff, and lava-breccia) demonstrates varying degrees of native copper content [53]-[57].

Spectral and chemical analyses of samples from basalt deposits have demonstrated the possibility to develop a lab-based technological line for ore preparation of all the raw material types to extract native copper, titanomagnetite, and silicate share useable for further utilization [58]-[61]. In this regard, all components of the deposit (i.e. basalt, tuff, and lava-breccia) may be processed in terms of the procedure separately without any waste generation. Hence, the fullest use of the deposit is implemented with higher level of expediency and environmental safety; currently, selective basalt mining takes place to manufacture constructional crushed stone; simultaneously, tuff and lava-breccia are transported to waste dumps [62], [63].

Positive laboratory practices of basalt raw material processing have helped formulate a proposal to establish research and production site right within an open pit. Mission of the site is testing of the integrated wasteless procedure of basalt raw material processing, and manufacture final products for marketing to recoup the costs of the site establishment. Based upon the procedure of local testing, it is possible to perform technical and economic assessment within the site to build a large-scale enterprise.

Rafalivka basalt open pit has been considered as the basic enterprise to develop the procedure of comprehensive basalt, tuff, and lava-breccia processing, and further analysis of their compositions. The open pit has been selected from the three considered open pits since it has large reserves of useful components with high content of copper, iron, and titanium as well as rather developed infrastructure for raw material mining and processing. Moreover, long-term period of basalt mining has resulted in huge tuff and lava-breccia waste dumps being of technogenic nature. They may become a part of operations.

Thus, the technical proposal is the stage-by-stage development of an enterprise in terms of the integrated wasteless procedure of basalt raw material processing to generate native copper, titanomagnetite, and product from residual silicate share (for instance, basalt wool for heat and sound insulation and tuff for agriculture, i.e. for animal breeding and water purification) [64]-[66].

Crushing, grinding, sizing, magnetic and electrical separation have their features both during ore preparation and during valuable component extraction [67], [68]. In this context, characteristics of magnetic separators (to obtain magneto-sensitive share of basalt raw material, i.e. titanomagnetite) and electrical separators (to generate native copper) are taken into consideration [69]. Earlier lab-based experiments have shown that the most efficient separation process results from a fine basalt classification (i.e. 0.5 and 0.1 mm) [70], [71].

Taking into consideration the expediency of the integrated mining and processing of tuff, lava-breccia, and basalt, being three components of basalt rock mass, their selective processing should help identify dependencies of the basalt fine sieving efficiency upon the operational and structural parameters of a screen. Namely, rock mass density; inclination angle of a disturbance force of a vibration exciter of a screen; inclination angle of a screen effector; mesh size; specific load on a screen; disturbance frequency of a screen drive; and a screen length are meant [72]-[74].

For the purpose, it is expedient to do mathematical modelling of the dependencies of basalt fine sieving efficiency upon the operational and structural parameters of a screen and verify adequacy of the assumed models.

2. Methods

It should be taken into consideration that processes of fine basalt rock grading with the help of vibration method is understudied, and available vibrators need adaptation of their characteristics to meet the process requirements. The studies were carried out in collaboration with experts from IGM of the NAS of Ukraine (Dnipro), and from the National University of Water and Environmental Engineering (Rivne) using laboratory test facilities of IGM of the NAS of Ukraine under the guidance of Naduty, V.P., Professor, Doctor of Engineering. A fine grading screen with dynamically active working area, specially designed by IGM of the NAS of Ukraine professionals, has been applied (Fig. 1).

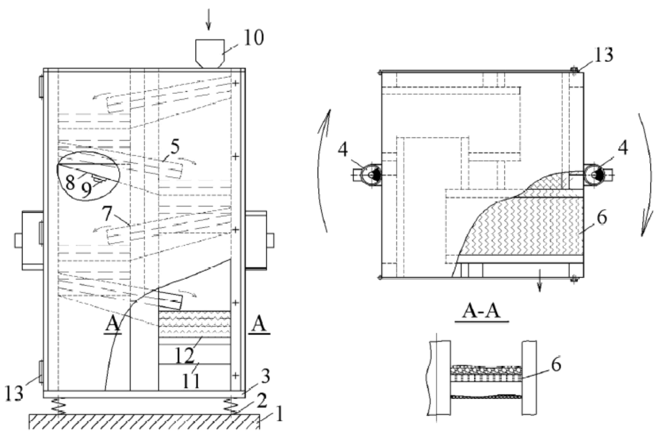

Figure 1.** **Structural scheme of a vertical vibrating screen: 1 – frame; 2 – damping devices; 3 – supporting column; 4 – vibration exciter; 5 – effector; 6 – resonance belt vibrating screens; 7 – mechanism varying inclination angle of the screens; 8 – chute; 9 – sliding shutter; 10 – loading hopper; 11, 12 – unloading tray for undersize and superficial products; 13 – body

Its specificity is as follows. The screen operates in a vibratory percussion mode at the expense of impacts by a supporting dynamically active resonance rubber belt vibrating screen on the upper sizer made of metal or polyamide mesh.

As with experiments, concerning fine grading, the following has been assumed in the capacity of the controlled parameters: γ being rock mass density, g/cm^3; β being inclination angle of a disturbance force of a vibration exciter of a screen, degrees; α being inclination angle of a screen effector, degrees; Δ_n being mesh size of a supporting dynamically active screen, mm; q being specific load on the screen, t/h·m^2; ω being disturbance frequency of the screen drive, rpm; and L being screen length, m.

In this context, the analyzed grading characteristics were defined for three density degrees of open-pit basalt rock mass: γ = 1.4 g/cm^3 for tuff; γ = 2.2 g/cm^3 for lava-breccia; and γ = 2.6 g/cm^3 for basalt. The rock mass components are extracted selectively and processed separately.

The screen efficiency depending upon changes in its parameters were analyzed from the viewpoint of previous analysis of the studies. In this regard, lower number of the parameters varied. Constant parameters were those ones having extremum of function under the influence on sieving efficiency (for instance, ω = 1500 rpm) or on the function (for instance, L = 4.5 m or α = 10°).

Consistency of amplitudes of screen body vibration ($A_к$ = 2.0 mm) as well as an elastic resonance belt vibrating screen, supporting a metal grading mesh (A_c = 6.0 mm) depends upon the stress state invariance of metal structure of high-frequency screen within the tolerable limits.

3. Results and discussion

To identify rational parameters of the screen, multifactor experiment has been carried out concerning fine grading of basalt raw material (i.e. tuff, lava-breccia, and basalt).

The multifactor experiment is required to develop ideas of a fine grading process; selection of control boundaries for each parameter; and regularities of changes in technological parameters while controlling. If the process is optimized then it is required for selection of changes in a target function.

Hence, the obtained data help do modelling as well as define swiftly rational or optimal grading mode. Under such an analysis of all the basic apparatuses of manufacturing chain, the abovementioned helps solve a synthesis problem of its parameters.

Table 1 demonstrates results of the research efforts concerning efficiency dependence upon the controlled parameters.

Table 1 shows experimental findings of fine basalt raw material grading (i.e. tuff with 1.4 g/cm^3 density; lava-breccia with 2.2 g/cm^3 density; and basalt with 2.6 g/cm^3) for 0.5 and 0.1 mm sizes in terms of variable parameters of a screen which design is represented in Figure 1.

The findings of the efficiency dependence upon varying factors, shown in Table 2, support the idea that inclination angle β = 45° is perfect for fine screening to achieve simultaneously adequate sieving and performance.

Graphical analysis of the obtained dependencies of screening efficiency and sieve performance has shown significant impact by the disturbance force of a vibration exciter direction for the two analyzed sizes. Figure 2 represents graphs of screen performance dependence (in terms of undersize product) upon the inclination angle of a disturbance force of a vibration exciter for 0.5 and 0.1 mm sizes, respectively.

It is important fact that β = 45°, being extremum of function, is the rational inclination angle to achieve high screening efficiency as well as reasonable performance. From the viewpoint, influence by other screen characteristics on the technological parameters was analyzed in its kinematically assumed angle.

Figure 3 represents fine screening dependence upon drive disturbance frequencies in terms of different sizes. The dependencies in Figure 3 explain that the function has its stable extremum within ω = 1450-1500 rpm.

Availability of the function extremum denotes the possibility to set the fixed frequency within the mentioned boundaries while adding fine sieving parameters.

Table 1. Findings of fine screening dependence upon variables

Variables		Efficiency (*E*), %					
		Δ = 5 mm, *a* = 0.5 mm			*Δ* = 5 mm, *a* = 0.1 mm		
		γ, g/cm³					
		1.4	2.2	2.6	1.4	2.2	2.6
β, degrees	25	25	33	40	18	22	30
	30	37	46	55	24	29	38
	40	50	65	73	40	49	59
	45	58	68	75	45	56	65
	50	54	66	74	45	55	64
	60	45	64	70	44	48	55
α, degrees	2.5	59	70	78	50	61	69
	5	55	65	75	46	58	65
	10	47	58	65	40	51	58
	15	40	47	52	34	43	48
	20	30	37	45	25	34	40
ω, rpm	700	40	45	49	33	38	40
	900	44	50	54	38	46	49
	1200	48	60	66	44	53	60
	1500	49	60	70	46	55	60
	1600	45	57	65	45	54	57
q, t/h·m²	1	66	76	82	50	62	70
	2	63	70	75	50	58	67
	3	56	67	75	42	55	60
	4	50	62	66	40	50	60
	5	50	57	65	36	44	55
	6	45	55	60	30	42	47
L, m	1	27	32	35	23	27	29
	1.5	31	37	40	27	30	32
	2.5	43	47	55	32	40	43
	3.5	60	70	78	35	48	53
	5	63	70	75	42	54	58
	6	56	67	75	42	55	60

Table 2. Findings concerning the screen efficiency dependence upon variables

Variables		Performance (*Q*), t/h					
		Δ = 5 mm, *a* = 0.5 mm			*Δ* = 5 mm, *a* = 0.1 mm		
		γ, g/cm³					
		1.4	2.2	2.6	1.4	2.2	2.6
β, degrees	20	0.6	0.8	0.9	0.3	0.4	0.6
	30	1.4	1.7	2.0	0.7	0.9	1.1
	40	2.2	2.5	2.6	1.1	1.5	1.8
	45	2.2	2.8	3.0	1.3	1.6	1.8
	50	2.2	2.3	2.5	1.2	1.5	1.7
	60	1.5	1.6	1.7	0.5	0.8	1.0

Since fine grading needs high efficiency and performance, the obtained results may be applied to adjust a vibrating screen.

In such a way, the findings make it possible to select adequate facilities for the specific conditions of basalt raw material treatment and identify its parameters satisfying the demands of ore preparation procedure and extraction of minerals using wasteless method taking into consideration comprehensive processing.

The results are suitable for rock mass where moisture is up to 5%. In the time of fine grading (i.e. up to 50 um) of each component of basalt rock mass in the form of slurry in terms of 1:3 solid-liquid ratio, efficiency of basalt grinding was 60%; lava-breccia grinding efficiency was 62%; and tuff grinding efficiency was 60%. The obtained experimental dependencies of sieving efficiency upon variable factors were identified by means of multifactor regression dependencies.

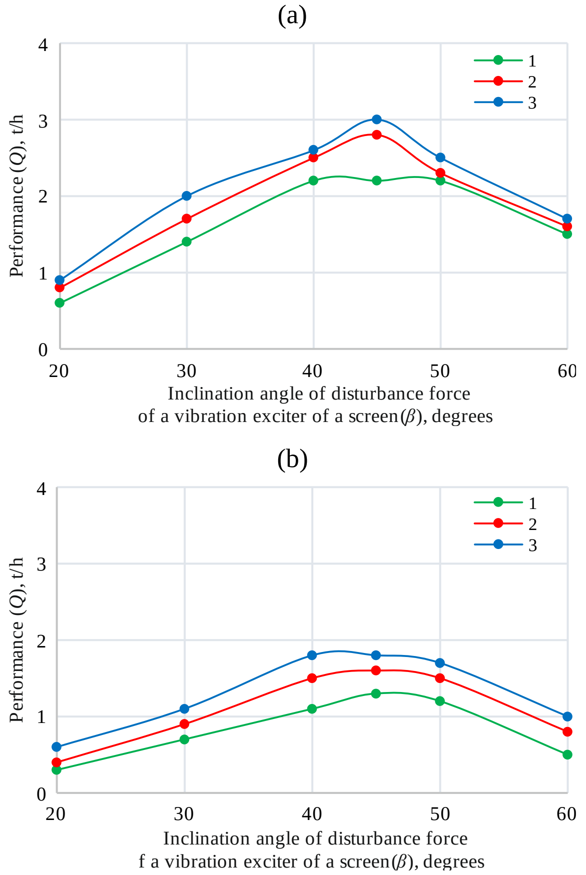

Figure 2. Dependence of screen performance (in terms of superficial product) upon the inclination angle of disturbance force of a vibration exciter: (a) for 0.5 mm size; (b) for 0.1 mm size; 1 – basalt; 2 – lava-breccia; 3 – tuff

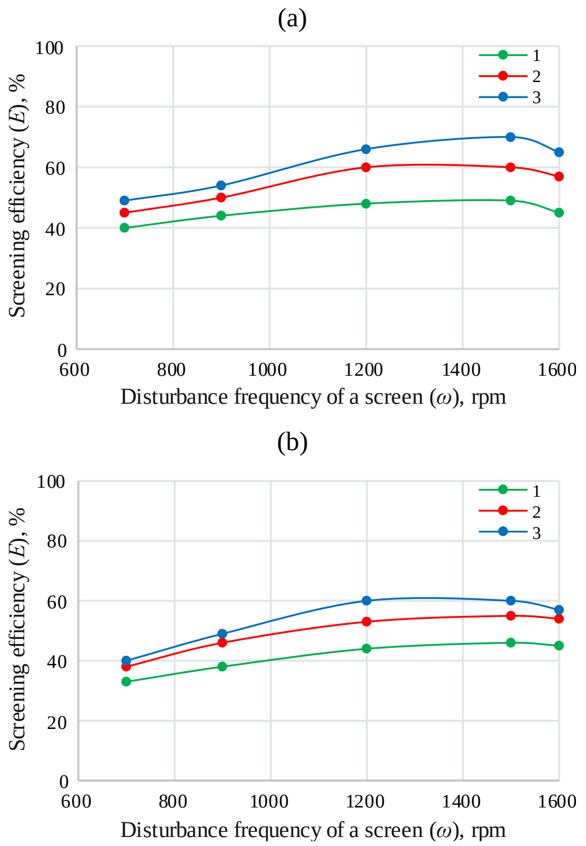

Figure 3. Dependence of screening efficiency upon the disturbance frequency of a screen: (a) for 0.5 mm size; (b) for 0.1 mm size; 1 – basalt; 2 – lava-breccia; 3 – tuff

Graphs *4-8* demonstrate experimental results (dashed lines) and mathematical modelling results (solid lines). In this context, curves *1* are for basalt; curves *2* are for lava-breccia; and curves *3* are for tuff.

Gradually, a model with the varied inclination angle of a disturbance force of a vibration exciter was considered in the form of following regression models: $E = f(\gamma, \beta)$ if $a = 0.5$ mm; $E = f(\gamma, \beta)$ if $a = 0.1$ mm; and $E = f(\alpha, \gamma, \beta)$.

Table 3 demonstrates calculation results for $E = f(\gamma, \beta)$ model; and Table 4 shows them for $E = a_0 + a_1\alpha + a_2\gamma + a_3\gamma^2 + a_4\beta + a_5\beta^2$ model.

Table 3. Parameter calculation for E = f (γ, β) dependence

a, mm	a_0	a_1	a_2	a_3	a_4	R^2	F
0.5	-98.4	4.58	2.95	5.85	-0.06	0.982	173.9
0.1	-69.4	-26.7	9.89	5.38	-0.054	0.968	98.5

Table 4. Parameter calculation for E =a₀ + a₁α + a₂γ + a₃γ² + a₄β + + a₅β² dependence

$E = a_0 + a_1a + a_2\gamma + + a_3\gamma_2 + a_4\beta + a_5\beta^2$ a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
-92.8	29.72	-11.04	5.61	5.61	-0.057	0.973	213.8

The obtained multiply coefficients of determination R^2, and Fisher's criterion F have demonstrated sufficient convergence of experimental and analytical characteristics shown in Figure 4.

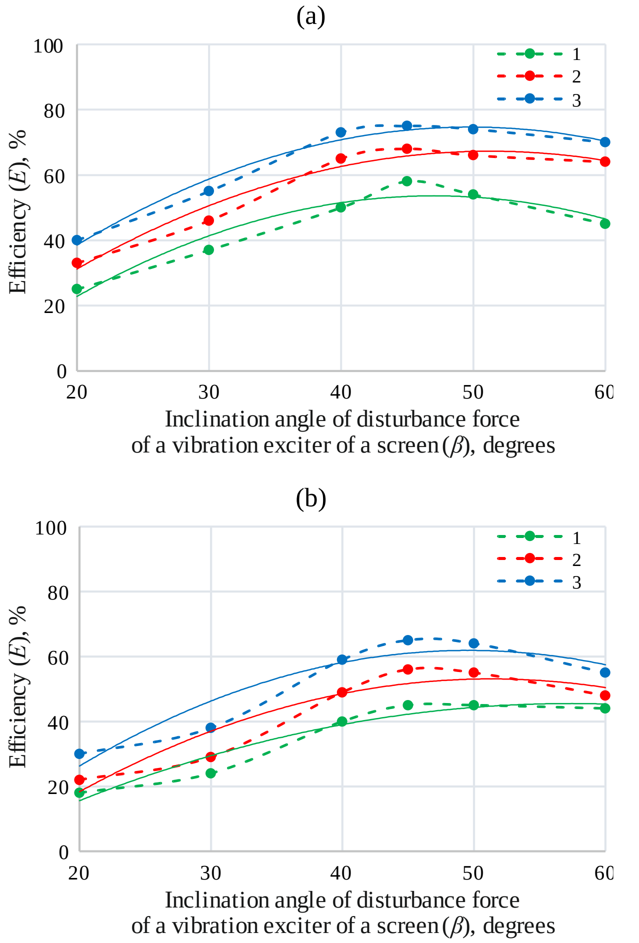

Figure 4. Dependence of screening efficiency upon the inclination angle of a disturbance force of a vibration exciter E = f (γ, β, α): (a) 0.5 mm mesh; (b) 0.1 mm mesh; 1 – basalt; 2 – lava-breccia; 3 – tuff

A model, describing a dependence of fine screening upon inclination angle of a sieve, is calculated as follows: $E = f(\gamma, \alpha)$ if $a = 0.5$ mm; $E = f(\gamma, \alpha)$ if $a = 0.1$ mm; and $E = f(\alpha, \gamma, \alpha)$. Table 5 demonstrates calculation results for $E = f(\gamma, \alpha)$ dependence. Table 6 demonstrates calculation results for $E = a_0 + a_1\alpha + a_2\gamma + a_3\gamma^2 + a_4\alpha + a_5\alpha^2$ dependence.

Table 5. Calculation of E = f (γ, α) dependence parameters

a, mm	a_0	a_1	a_2	a_3	a_4	R^2	F
0.5	67.67	-11.0	6.25	-1.59	-0.0104	0.99	264.1
0.1	44.54	2.5	2.92	-1.18	-0.0158	0.995	460.8

Table 6. Calculation of E =a₀ + a₁α + a₂γ + a₃γ² + a₄α + a₅α² dependence parameters

a_0, mm	a_1	a_2	a_3	a_4	a_5	R^2	F
51.06	16.8	-4.25	4.58	-1.39	-0.0131	0.987	373.7

Figure 5 shows sufficient convergence of the experimental and analytical data from the dependence.

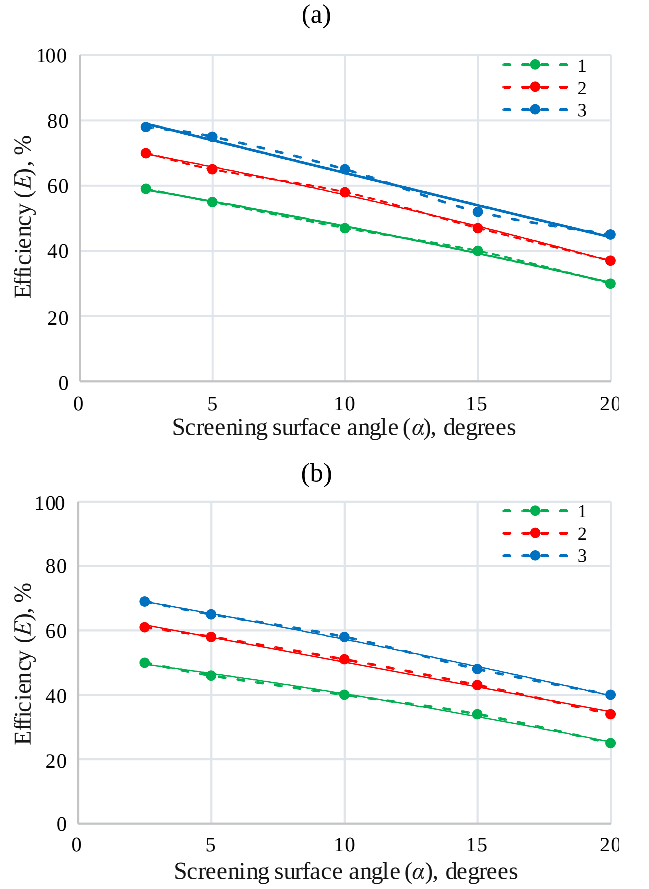

Figure 5. Dependence of sieving efficiency upon the screening surface angle E = f (γ, α, α): (a) 0.5 mm mesh; (b) 0.1 mm mesh; 1 – basalt; 2 – lava-breccia; 3 – tuff

Influence by the frequency of a vibration exciter of a screen was determined experimentally; in addition, it was calculated through the regression models as follows: $E = f(\gamma, \omega)$ if $a = 0.5$ mm; $E = f(\gamma, \omega)$ if $a = 0.1$ mm; and $E = f(\alpha, \gamma, \omega)$. Tables 7 and 8 demonstrate the calculation results; graphs in Figure 6 illustrate them.

Table 7. Calculation of E = f (γ, ω) dependence parameters

a, mm	a_0	a_1	a_2	a_3	a_4	R^2	F
0.5	-14.62	-2.0	3.75	0.087	-0.000031	0.919	28.3
0.1	-33.63	10.0	0.0	0.094	-0.000034	0.973	91.1

Table 8. Calculation of $E = a_0 + a_1\alpha + a_2\gamma + a_3\gamma^2 + a_4\omega + a_5\omega^2$ dependence parameters

a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
-28.3	14.0	4.0	1.88	0.091	-0.0000325	0.94	75.3

Figure 6 shows convergence of the experimental and analytical results.

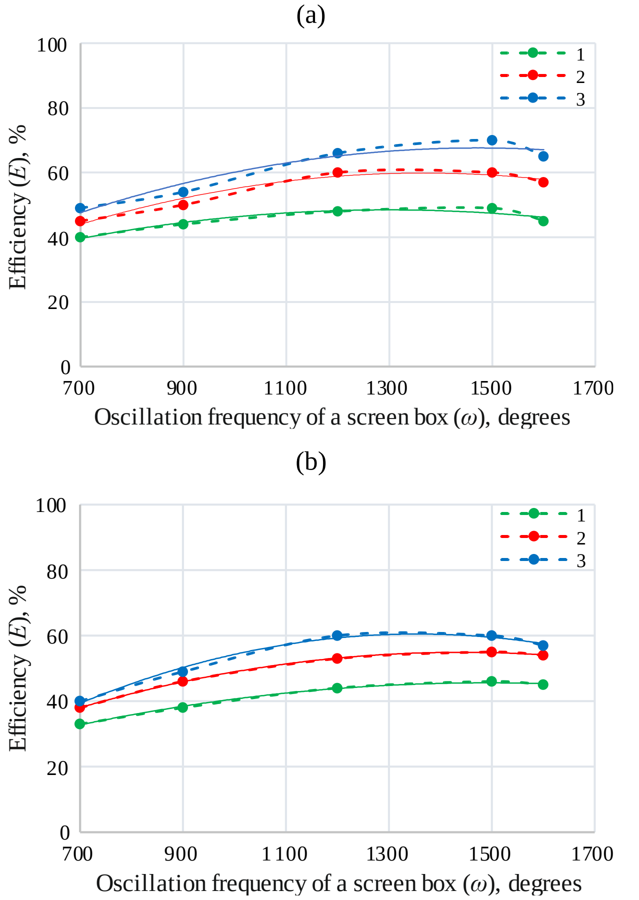

Figure 6. Dependence of sieving efficiency upon the oscillation frequency of a screen box $E = f(\gamma, \alpha, \omega)$: (a) 0.5 mm mesh; (b) 0.1 mm mesh; 1 – basalt; 2 – lava-breccia; 3 – tuff

Variations in the specific load on a sieve influence its efficiency; hence, the dependence nature was identified experimentally and calculated with the help of a regression model as follows: $E = f(\gamma, q)$ if $a = 0.5$ mm; $E = f(\gamma, q)$ if $a = 0.1$ mm; and $E = f(\alpha, \gamma, q)$.

Tables 9 and 10 demonstrate the calculation results; graphs in Figure 7 illustrate them.

Table 9. Calculation of $E = f(\gamma, q)$ dependence parameters

a, mm	a_0	a_1	a_2	a_3	a_4	R^2	F
0.5	61.54	4.58	2.08	-5.93	0.244	0.981	172.2
0.1	53.5	-4.5	5.73	-2.83	-0.196	0.985	210.5

Table 10. Calculation of $E = a_0 + a_1\alpha + a_2\gamma + a_3\gamma^2 + a_4q + a_5q^2$ dependence parameters

a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
48.23	30.97	-1.46	3.91	-4.38	0.023	0.995	1187.9

Dependence of fine grading efficiency upon the screening surface has been obtained experimentally through the repeated return of undersize product from unloading section to a loading one.

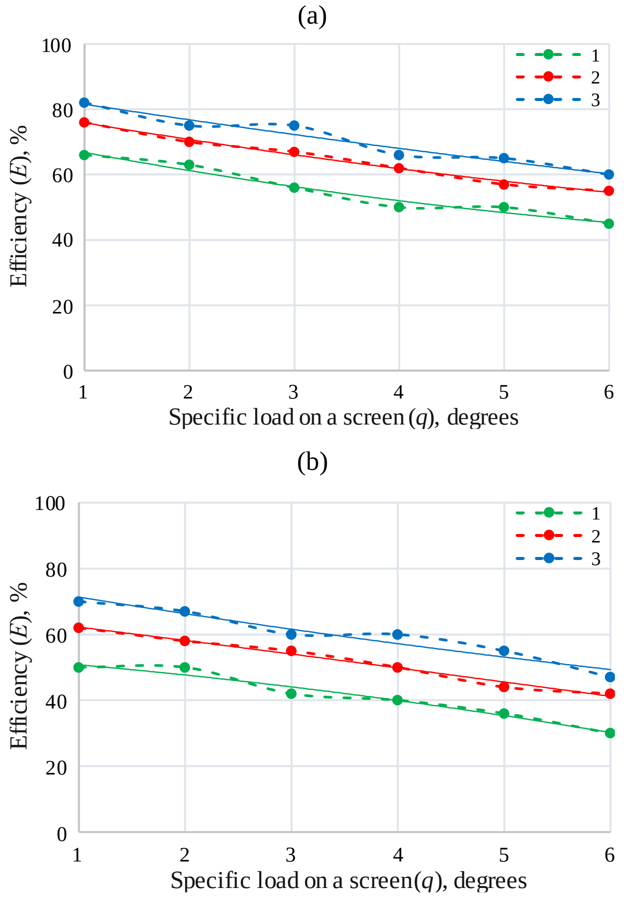

Figure 7. Dependence of screening efficiency upon the specific load on a sieve $E = f(\gamma, q, \alpha)$; (a) 0.5 mm mesh; (b) 0.1 mm mesh; 1 – basalt; 2 – lava-breccia; 3 – tuff

Graphs in Figure 8 illustrate the experimental results; regression models in the form of $E = f(\gamma, L)$ if $a = 0.5$ mm; $E = f(\gamma, L)$ if $a = 0.1$ mm; and $E = f(\alpha, \gamma, L)$ visualized them. Tables 11 and 12 represent the calculation results.

Table 11. Calculation of $E = f(\gamma, L)$ dependence parameters

a, mm	a_0	a_1	a_2	a_3	a_4	R^2	F
0.5	12.8	-7.5	4.17	15.91	-1.32	0.991	365.6
0.1	-5.82	13.75	-1.56	11.34	-0.96	0.984	194.1

Table 12. Calculation of $E = a_0 + a_1\alpha + a_2\gamma + a_3\gamma^2 + a_4L + a_5L^2$ dependence parameters

a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
-4.38	26.25	3.125	1.30	13.63	-1.14	0.966	171.9

The research, carried out within Rafalivka ore cluster in Rivne Region (Ukraine) and specifically Rafalivka basalt open pit with a waste dump, has supported the expediency of fine grading of basalt raw material (i.e. tuff, lava-breccia, and basalt). The results of multifactor experiment and mathematical modelling have made it possible to identify the unique rational parameters of a screen for fine grading of basalt raw material.

It is possible that future studies, based upon the designed screen for fine grading of basalt raw material, differing in rational parameters, will help propose modern production line of scientific and research site at an enterprise Rafalivsky Karier PJSC.

The research, described in this context, is very important for industrial sector, i.e. for basalt raw material production.

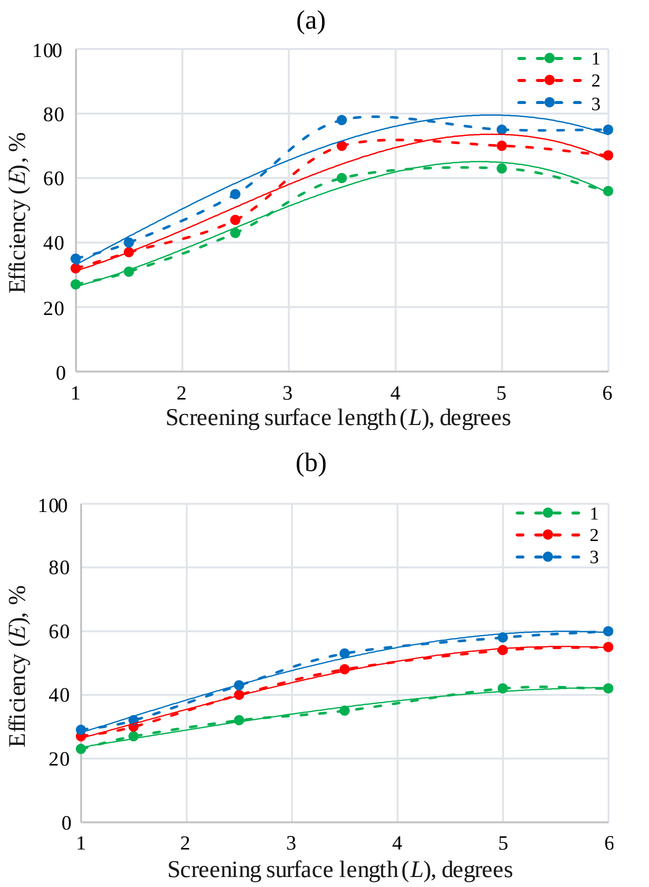

Figure 8. Dependence of screening efficiency upon the length of a screening surface $E = f(\gamma, L, \omega)$; (a) 0.5 mm mesh; (b) 0.1 mm mesh; 1 – basalt; 2 – lava-breccia; 3 – tuff

Development of a screen with rational parameters for fine grading of basalt raw material is a step towards the product quality improvement as well as decrease in production costs.

The study makes it possible to identify the optimum screen parameters to grade basalt raw material into finer fractions (i.e. tuff, lava-breccia, and basalt). In turn, the process influences positively the final product quality. Moreover, the abovementioned helps an enterprise save expenses for operations with irrelevant materials and improve product quality which influences market competitiveness. In addition, the study may be used for further activities while developing innovative engineering solutions and products.

In such a way, continuation of the studies is an important move towards product quality improvement and increase in market competitiveness while being the potential source for future scientific research and development.

4. Conclusions

Thus, the experiments, concerning fine screening of three components of basalt rock mass and their identification have made it possible to define:

1. Analysis of the derived regression models and the calculation results shows that in the context of all considered cases, determination coefficient is more than 0.9; in some cases, it is close to unity. In such a way, a multiply correlation coefficient is more than 0.95 for each model. Thus, strong correlation is between the screening efficiency and the factors incorporated into the regression models.

2. In all the cases, Fisher's criterion F is more than a critical value which supports adequacy of the models. The statement is also illustrated by graphic dependencies where the research data agree well with the analytical ones. Hence, the derived dependencies may substantiate parameters of fine vibrating screening in the course of basalt raw material preparation for its integrated processing.

3. In terms of each factor, values and signs of regression coefficients denote both degree of influence and efficiency of fine screening which makes it possible to make the right decision while selecting parameters of facilities for the procedure of the integrated processing of basalt raw material.

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Вплив режимних та конструктивних параметрів грохота на технологічні показники вібраційного грохотання базальту

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Мета. Встановити залежності продуктивності та ефективності тонкого грохотання базальтової сировини від режимних та конструктивних параметрів грохота.

Методика. Результати досліджень отримані на основі порівняльного аналізу залежностей продуктивності та ефективності тонкого грохотання базальтової сировини від режимних та конструктивних параметрів грохота. При цьому досліджувані характеристики ефективності та продуктивності класифікації визначалися для трьох густин базальтової гірничої маси кар'єрного видобутку: для туфу – $\gamma = 1.4$ г/см^3; для лавобрекчії – $\gamma = 2.2$ г/см^3; для базальту – $\gamma = 2.6$ г/см^3. Ці складові гірничої маси витягуються селективно та переробляються окремо.

Результати. Встановлено доцільність комплексного видобутку та переробки трьох складових базальтової гірничої маси (туфу, лавобрекчії та базальту) разом з їх селективною переробкою. На основі математичного моделювання представлені регресійні моделі залежності продуктивності та ефективності тонкого грохотання базальтової сировини від режимних і конструктивних параметрів грохота. Регресійні моделі та наведені результатів розрахунків свідчать про наявність сильного кореляційного зв'язку між ефективністю тонкого грохочення базальтової сировини та факторами, що включені до регресійних моделей (щільність гірничої маси, кут нахилу збурюючої сили віброзбудника грохота, кут нахилу робочого органу грохота, розмір комірки, питоме навантаження на грохот, частота збурень приводу грохота, довжина грохота).

Наукова новизна. Вперше проведене математичне моделювання залежностей продуктивності та ефективності тонкого грохотання базальтової сировини від режимних та конструктивних параметрів грохота. На основі багатофакторного експерименту розвинуті уявлення про процес тонкої класифікації, вибір меж регулювання кожним параметром, визначення ступеня впливу та закону зміни технологічних параметрів при їх регулюванні.

Практична значимість. Використання результатів досліджень дадуть змогу ухвалити правильні рішення при виборі параметрів обладнання технологічної схеми рудопідготовки базальтової сировини до комплексної переробки.

Ключові слова: *базальт, туф, лавобрекчія, грохот, грохотання*