Modeling of vibro screening at fine classification of metallic basalt

Naduty V.P.

D.Sc. in engineering, professor
Institute of Geotechnical Mechanics named after N.S. Polyakov of the NAS of Ukraine, Dnipro, Ukraine

Malanchuk Z.R.

D.Sc. in engineering, professor
National University of Water Management and Nature Resources Use, Rivne, Ukraine

Malanchuk E.Z.

D.Sc. in engineering, associate professor
National University of Water Management and Nature Resources Use, Rivne, Ukraine

Korniyenko V.Ya.

PhD in Technical Sciences, associate professor
National University of Water Management and Nature Resources Use, Rivne, Ukraine

Abstract
Currently, intensive research on comprehensive development of basalt deposits in Volhyn with the use of non-waste technology is being conducted. This is due to the rich mineral composition of basalt raw material, which besides basalt contains a significant portion of zeolite-selective tuff and lava cluster breccia. All the three components of the fields contain high percentage of iron, titanium and native copper. These components are of industrial interest, but their extraction requires special technology of pretreatment. In the Institute of Geotechnical Mechanics named after N.S. Polyakov of the NAS of Ukraine and the National University of Water Management and Natural Resources Use the research on the development of comprehensive technology for the processing of basalt raw material is being conducted. In addition, the dependence of technological parameters of each unit of the necessary equipment on the key forces of their impact were investigated.
Keywords: CLASSIFICATION, ORE PREPARATION, METAL, VIBROSCREENING, BASALT

Introduction

The purpose of these studies is to determine the dependence of efficiency of basalt rock mass fine vibrating screening on the main dominant adjustable parameters.

Considering that the processes of fine classification vibration method are not fully studied, and existing vibroscreens require adaptability of their characteristics to the requirements of technology for performing these purposes, the research has been conducted on fine classification screening with dynamically active working surface specially designed by Institute of Geotechnical Mechanics named after N.S. Polyakov of the NAS of Ukraine (IGTM NAS of Ukraine). Its peculiarity consists in the fact that the screening in the separation process is carried out in vibro-impact mode due to the impulses (strokes) of the supporting dynamically active rubber resonant band-string sieve at the top classifier of rigid metal or nylon mesh.

The process of vibro screening

Due to the fact that physical-mechanical characteristics of the rock mass make a significant impact in the classification performance and the terms previously established according to a specific classification require clarification and correction, the present research has experimentally determined the efficiency of basalt raw material fine screening in their dependence on a number of variable parameters, in particular: γ - density of the rock mass (γ_1 = 2,6 - basalt, γ_2 = =2,2 - lavabreccia, γ_3 = 1,4 - tuff), β - angle of the perturbing force inclination, α - angle of inclination of the vibroscreen working mechanism, Δ - screen opening size, q - screen unit loading, ω - perturbation frequency of screen drive and its length L. Change of these parameters has a significant impact on the efficiency of screening. To analyze the effect of these factors on the system it is necessary to work out multivariate regression dependence [1-3].

Calculation of the linear regression dependencies has been carried out by the method of the least squares. This nonlinear dependence on the factor attributes were given to the change of variables by linear method. In the studied case, it is the dependence of the efficiency on the size of the sieve opening $E=f(\Delta)$, and for the others listed above, parabolic dependence appeared to be more adequate. On the basis of correlation coefficient R for each pair of attributes the correlation matrix has been designed, and the multiple coefficient of determination has been calculated, showing what portion of variation of the resultant attribute is explained by the factor attributes variation of the model. In its turn, the adequacy of the model has been evaluated using Fisher statistics F, which was compared with its critical value F_{cr} according to the adequacy level of α = 0,05 or α = 0,01.

This work has established the dependence of the efficiency of fine screening on the most influential factor characteristics in the form of

$$E = f(\beta,\alpha,\omega,q,\Delta,L,\gamma). \quad (1)$$

Stage by stage, there has been studied the model of effectiveness dependence of screening on individual factors at fixed sieve opening size Δ and variations of the type of rock characterized by the density γ. Then, there has been obtained a generalized model with density factor γ taking into account the influence of the angle of the perturbing force inclination. The calculation was performed with Δ = 2 mm, 3 mm, 5 mm, the results of the calculations are given in table 1.

Table 1. Calculation results of the regression parameters

Δ	a_0	a_1	a_2	a_3	a_4	R^2	F
2	-25.12	-11.67	5.9	3.94	-0.038	0.979	153.2

3	-47.08	29.58	-4.17	3.35	-0.032	0.979	154.4
5	-35.82	3.33	2.43	4.07	-0.039	0.099	341.6

Results of calculations

The regression model has been specified as:

$$\acute{E}(\gamma,\beta) = a_0 + a_1\gamma + a_2\gamma + a_3\beta + a_4\beta^2. \quad (2)$$

The generalized model with the inclusion of the sieve opening size Δ in the number of variable factors, other factors (α,ω,q,L) have been recorded

$$\acute{E}(\Delta,\gamma,\beta) = a_0 + a_1\Delta + a_2\gamma + a_3\beta + a_4\beta^2. \quad (3)$$

The results of calculations of the parameters of this regression are given in Table 2.

Table 2. Calculation results of the regression parameters

a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
-45.45	2.83	7.07	1.39	3.78	-0.036	0.972	331.3

For each of the sieve opening size Δ the regression model was specified as variable parameters γ and α

$$\acute{E}(\gamma,\beta) = a_0 + a_1\Delta + a_2\gamma + a_3\alpha + a_4\alpha^2. \quad (4)$$

The generalized model with the inclusion of the inclination angle of screening and the number of variable factors has been determined as:

$$\acute{E}(\Delta,\gamma,\alpha) = a_0 + a_1\Delta + a_2\gamma + a_3\gamma^2 + a_4\alpha^2 + a_5\alpha^2. \quad (5)$$

The factors not included in the model, are fixed at a constant level. The calculation results are shown in Table 3, 4.

Table 3. Calculation results of the regression parameters

Δ	a_0	a_1	a_2	a_3	a_4	R^2	F
2	61.93	-8.0	5.21	-0.337	-0.036	0.991	271.7
3	68.12	-6.5	4.58	-0.6	-0.031	0.986	176.7
5	36.79	34.5	-5.83	0.439	-0.081	0.963	64.9

Table 4. Calculation results of the regression parameters

a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
39.4	4.71	6.67	1.32	-0.166	-0.49	0.973	282.5

The dependence of the screening efficiency on the perturbation frequency of the vibrator ω, the specific load on the screen q and the length of the sieve on the screen, similarly to the previous case, has been determined in stages.

The model with the influence factor ω has the following form:

$$E(\gamma,\omega) = a0 + a1\,\gamma + a2\gamma2 + a3\omega + a4\omega2. \quad (6)$$

The calculation results are shown in Table 5.

Table 5. Calculation results of the regression parameters

Δ	a_0	a_1	a_2	a_3	a_4	R^2	F
2	-50.88	10.42	0.0	0.156	-0.000058	0.866	93.2
3	-62.65	38.33	-6.42	0.146	-0.000057	0.949	60.2
5	-43.07	15.83	-0.694	0.159	-0.000065	0.934	46.1

Generalized model in this case is obtained in the form:

$$E = -62,84 + 3,19\Delta + 21,53\gamma - 2,37\gamma 2 + 0,154\omega - 0,00006\omega 2 \quad (7)$$

The model including the specific load on the screen q has the form:

$$E = (\gamma,q) = a0 + a1\gamma + a2\gamma 2 + a3q + a4q2. \quad (8)$$

The results of the calculation of the coefficients in the model are given in Table 6.

Table 6. Calculation results of the regression parameters

Δ	a_0	a_1	a_2	a_3	a_4	R^2	F
2	66.09	2.86	2.53	-6.06	0.302	0.986	279.4
3	86.25	-15	6.84	-3.34	-0.079	0.985	269.4
5	71.64	7.5	1.19	-3.46	0.012	0.977	170.9

In its final form the generalized regression model has taken the form:

$$E = 59,82 + 4,45\Delta - 1,55\gamma + 3,52\gamma^2 - 4,29q + 0,078q^2. \quad (9)$$

The model including the length of the sieve L is given in the form:

$$E = a_0 + a_1x + a_2\gamma^2 + a_3L + a_4L. \quad (10)$$

The calculation results are shown in Table 7.

Table 7. Calculation results of the regression parameters

Δ	a0	a1	a2	a3	a4	R2	F
2	0.896	-3.214	2.98	24.59	-2.13	0.991	458.0
3	13.92	-11.43	5.36	24.49	-2.17	0.983	235.0
5	3.54	5.0	1.34	23.49	-1.97	0.993	541.0

The calculations found that the generalized model has the form:

$$E = -5,23 + 3,4\Delta - 3,21\gamma + 3,22\gamma^2 + 24,19L - 2,09L^2. \quad (11)$$

Presented models allow us to solve individual problems of the screen parameters choice and determination of efficiency. The ultimate goal of our research was the modeling of the dependence of the efficiency of screening on the complex of factor attributes in the form of

$$E = f(\Delta,\gamma,\beta,\alpha,\omega,q,L). \quad (12)$$

Estimates of the model coefficients have been carried out according to methods described above, in this case for factor Δ there was adopted linear dependence (based on experimental data), and for other factors - parabolic. The total sample size was $n = 279$, the number of overlay links $m = 14$ and the number of freedom degrees $v = n - m = 265$.

Resulting from calculation there has been obtained the generalized model of screening efficiency dependence of vibrating screen based on the key factor attributes:

$$E = -161,42 + 3,7\Delta + 5,54\gamma + 1,54\gamma^2 + 1,67\beta - 0,012\beta^2 + 2,12\alpha - 0,153\alpha^2 + 0,162\omega - 0,00065\omega^2 + 4,18q - 0,863q + 17,28L - 1,25L^2. \quad (12)$$

With the coefficient of determination $R^2 = 0,88$, and Fisher's statistics $F = 150,3$, the adequacy of the resulting model has been proved.

Conclusions

The results of the research allow to analyze the process of fine vibratory screening of basalt raw material when in separate complex processing, to predict rational or optimal settings of screen for the required efficiency of screening. This stage of ore pretreatment is important because fine size classes contain a significant amount of native copper, titanomagnetite and their clusters. Therefore, the efficient separation of fine fractions allows the use of extensive scheme of extraction of useful components [4].

References

1. Bulat A. F., Naduty V.P. (2010). Perspektivi kom-

pleksnoi pererobki bazaltovoi sirovini Volini [Prospects of complex processing of basalt raw materials of Volhynia]. Collection of Institute of Geotechnical Mechanics named after N.S. Polyakov of the NAS of Ukraine "Geotechnical mechanics", Dnipro, 2010, No 85, p.p. 3-8

2. Naduty V.P. Obgruntuvannya neobhidnosti kompleksnoi pererobki ceolito-smektitovih tufiv Volini [Justification of need of complex processing of zeolites- smectite tufa of Volhynia]. National Mining University. Materials of International conference, section "Geology". 21-23 October 2010, Dnipro, p.p. 50-55.
3. Franchuk V.P., Naduty V.P., Egurnov A.I Mathematical modeling of vibrating screening with regard to sensitive, constructive and technological parameters of thunder. Scientific-technical collection of National mining University. Dnipro, 2011.Vol. 45(86), pp. 48-52.
4. Malanchuk Z.R., Malanchuk E.Z. (2014). Experience in the use of products processing of basalt raw material in Ukraine. American Journal of Scientific and Educational Research. July-December. «Columbia Press», New York. No 2(5), p.p. 642-648.