Analyzing vibration effect on amber buoying up velocity

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Abstract. Industrial use of hydromechanical method and equipment made it possible to represent quantitative assessment of parameters for efficient amber extraction from amber-bearing deposits. Mined-out deposits with non-commercial reserves, being technogenic ones, may become potential source of amber mining; however, it should involve technological development. Due to imperfection of available methods, losses of the mineral in pillars and mine dumps excess 50%. Taking into consideration positive vibration effect in the process of amber extraction from sandy deposits, special structure of vibration classifier has been designed making it possible to extract maximally even fine-size amber with the least technological losses. The studies have helped determine that the use of the vibration classifier to extract amber makes it possible to mine up to 95% of the mineral; in this context, both medium density and vibration effect amber-bearing sand dilution. Maximum velocity of amber buoying up achieves depending upon changes in water and air consumption for certain amber-bearing rock masses. Laboratory tests and full-scale experiments have determined that velocity values of amber buying up to the surface are 0.1 m/s – 0.21 m/s. The research has proved possibility of efficient use of integrated effect on rock mass of enhancing density of amber-bearing medium, vibration, and air flows in the form of bubbles. In this context, closed cycle on the liquid phase of the effect is implemented making it possible to substantiate the developed method for amber extraction.

1 Introduction

World demand for mineral resources experiences almost 5% annual increase. Year over year, more than 100 bln tons of minerals and fuel are extracted from the entrails of the Earth. Ukrainian mineral raw material base is one of the fullest in the world since it includes totality of minerals and components which can be applied in many industries [1 – 3]. Among other things, Ukrainian mineral raw material base is represented by a number of various minerals and sources of their extraction [4 – 10]. They are ores of ferrous and non-

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ferrous metals, coal, oil, construction materials etc. [11, 12]. Moreover, significant amber reserves are concentrated in our state [13, 14].

Practices of hydromining method as for amber extraction are very limited taking into consideration huge differences in mining and geological characteristics of deposits, and enclosing rocks [15, 16]. Basing upon the analysis of available methods of amber extraction, a new technique of amber mining from sandy deposits has been proposed. The hydromechanical technique provides more efficient extraction while mitigating negative environmental impact [13].

Industrial approbation of the new hydromechanical method and facilities has helped assess parameters for efficient amber extraction from amber-bearing deposits. Relying upon the carried-out geological analysis it has been determined that amber occurs in sandy soil and in sandy-argillaceous soil. Depth is shell – 1 m to 10 – 15 m [14].

Key tendency to develop the mining method and to improve it is the advance in borehole mechanical-hydraulic technique with the use of water, air, and vibration as the basic influence factors [17]. Mined-out deposits with non-commercial reserves, being technogenic ones, may become potential source of mining [15, 19]; however, it should involve technological development [20, 21]. It is possible to substantiate regularities concerning distribution of minerals under the conditions of formation of such deposits which makes it possible to determine their location, and to identify parameters of the elevated concentration of minerals within technogenic deposits [22, 23].

Due to imperfection of available methods, losses of the mineral in pillars and mine dumps excess 50%. The obtained research results point out the necessity of mining from technogenic waste (among which precious minerals are available) while determining their maximum concentration area according to the determined dependences for extracting and further processing [24 – 26]. It is possible to model such zones of mineral concentration for their adequate classification [27, 28].

Available methods of amber extraction from sandy and sandy-argillaceous rocks are very energy-intensive as for rock breaking and segregation needs perfection of technology, and equipment to improve the efficiency of end product extraction, and reduced power, water, and air consumption. The proposed operation schedules [29 – 33] do not involve environmental component, and possibility to reclaim mining wastes when their technogenic nature needs additional studies taking into consideration different mining and geological characteristics and enclosing rocks as well as development of recommendations concerning both methods and equipment involving environmental component.

Objective of the research was to analyze medium density effect and vibratory excitation effect in the context of hydromechanical amber extraction with the determination of the operating procedure parameters and analysis of the operating medium characteristics.

2 Methodology

The prediction of the producing wells stability in the technology of underground coal gasification is supposed to be made in mines that develop thin and very thin coal seams. The enterprises are preferable that develop the seams with low thickness in difficult mining and geological conditions. In terms of location, the coal reserves are available in the Donetsk and Lviv-Volyn coal basins.

Taking into consideration positive effect of vibration in the process of amber extraction method implementation in the context of sandy deposits, special structure of vibration classifier has been designed making it possible to extract maximally even fine-size amber with the least technological losses [34, 35]. Further studies made it possible to upgrade spiral classifier up to the configuration when integrated action of vibration, and water and air supply is used intensifying a process of amber fractions buoying up [36, 37].

Vibration classifier (Fig. 1) consists of a base 1 on which casing 3 with vibration exciter 4 is mounted with the help of spring elements 2; screw 5; drive 7; support 6; mechanism to lift lower parts of the screw 8; slurry; loading device 10; unloading device 11; blade extractors for mineral; vibration exciters 13; and intake drainage trench 14.

The vibration classifier operates as follows. With the help of loading device 10, material in the form of slurry is supplied to a cavity shaped by a casing 3 where it is blended under the action of screw 5 and vibration exciter 4. During the blending, the heaviest and largest material classes are deposited and leave the classifier through unloading device 11 in the form of sand owing to screw 5, being rotated by means of a drive 6. In this context, the material is both unloaded and dried; operation by vibration exciter 4 favours the process. There is also possibility to vary inclination angle of the screw since it is mounted on support 7 and regulated by a lifting mechanism 8. The material parts, which density is less than density of slurry, buoy up to the surface under the action of screw 5, and vibration exciter 4. There, being acted by both vertical component and horizontal component of vibration exciters 4, they are taken off by means of blade catchers, and supplied to intake drainage trench 14. To intensify the process of fraction buoying up, air is supplied to slurry using air piping 15. Unloading device 11 is required to control slurry density providing medium providing medium to classify material.

Fig. 1. Vibration classifier with blade extractors for the mineral.

The following was observed while analyzing effect of vibration parameters on the medium density:

- amber buoying up velocity has its maximum, and depends upon vibration frequency, amplitude, and medium density;
- there are certain medium densities in terms of which maximum amber buoying up velocity is maximum depending on vibration frequency, and water and air supply;
- medium density varies significantly amber buoying up velocity also effecting the efficiency of amber mining facilities; and
- there are such values of vibration parameters, and air and water supply parameters, in terms of which suspense medium is not generated; thus, amber buoying is not available.

It is possible to intensify the process while combining vibration, and water, or water and air supply to the rock mass [38 – 40] as well as was shown during filtration modelling [41 – 44], application ignition, optical and concrete composition [45 – 48].

3 Results and discussion

Basing upon experimental data, concerning amber fractions with $m = 15 - 20$ g weight, graphic dependences of medium density (ρ_c) (Fig. 2, Table 1), amber buoying up velocities (V) (Fig. 3, Table 2) and amplitudes of intensification means (A) (Fig. 4, Table 3) on vibration frequency (ω) have been obtained during experiments involving vibration classifier.

Table 1. Dependence of medium density on vibration frequency.

ω , rpm	1100	1300	1500	1700	1900	2100
ρ_c^1 , kg/m ³	1995	1855	1735	1688	1682	1705
ρ_c^2 , kg/m ³	2000	1990	1870	1700	1550	1660
ρ_c^3 , kg/m ³	2100	2000	1770	1750	1700	1660

In Table 1 ρ_c^1 is variation of medium density by means of water and air supply to the rock mass; ρ_c^2 is variation of medium density with no water and air supply to the rock mass; and ρ_c^3 is variation of medium density with no water and air supply to the rock mass.

According to the experiment results, dependences of medium density (ρ_c) upon vibration frequency (ω) are approximated using following expressions:

– for $\rho_c^1 = 22.696 \omega^2 - 216.47 \omega + 2190.1$ medium density with $R^2 = 0.9973$ value of approximation reliability;

– for $\rho_c^2 = 8.5714 \omega^2 - 151.14 \omega + 2194$ medium density with $R^2 = 0.8564$ value of approximation reliability;

– for $\rho_c^3 = 18.14 \omega^2 - 216.64 \omega + 2312$ medium density with $R^2 = 0.961$ value of approximation reliability.

Fig. 2. Dependence of the density of the medium on the vibration frequency: 1 – no water and air; 2 – water and air supply; 3 – air and no water.

Table 2. Dependence of amber buoying up velocity (V) on vibration frequency (ω).

ω , rpm	1100	1350	1450	1550	1700	2100
V_1 , m/s	0.045	0.145	0.148	0.132	0.13	0.117
V_2 , m/s	0.041	0.199	0.185	0.109	0.086	0.055
V_3 , m/s	0.037	0.183	0.092	0.086	0.062	0.033
V_4 , m/s	0.033	0.167	0.169	0.063	0.038	0.011
V_5 , m/s	0.029	0.051	0.146	0.04	0.014	0.005
V_6 , m/s	0.025	0.035	0.023	0.017	0.01	0.0005

In Table 2 V_1 is air consumption $q_a = 0.0055$ m³/hour; V_2 is air consumption $q_a = 0.0025$ m³/hour; V_3 is air consumption $q_a = 0.0035$ m³/hour; V_4 is air consumption $q_a = 0.0045$ m³/hour; V_5 is air consumption $q_a = 0.0065$ m³/hour; V_6 is air consumption $q_a = 0.0070$ m³/hour.

Table 3. Dependence of amplitude (A) on vibration frequency (ω).

ω , rpm	1100	1300	1500	1700	1900	2100
A , mm	1.51	2.75	2.45	2.32	1.91	2.05

Fig. 3. Dependence of amber buoying up velocity on vibration frequency if: 1 – $q_a = 0.0055 \text{ m}^3/\text{hour}$; 2 – $q_a = 0.0025 \text{ m}^3/\text{hour}$; 3 – $q_a = 0.0035 \text{ m}^3/\text{hour}$; 4 – $q_a = 0.0045 \text{ m}^3/\text{hour}$; 5 – $q_a = 0.0065 \text{ m}^3/\text{hour}$; 6 – $q_a = 0.0070 \text{ m}^3/\text{hour}$.

In accordance with the experiment results, dependences of amber buoying up velocity (V) on vibration frequency (ω) are approximated as follows:

– $V_1 = 7 \cdot 10^{-10} \omega^3 - 4 \cdot 10^{-6} \omega^2 + 0.0063 \omega - 3.2883$ for amber buoying up velocity where approximation reliability is $R^2 = 0.9777$;

– $V_2 = 2 \cdot 10^{-9} \omega^3 - 1 \cdot 10^{-5} \omega^2 + 0.0153 \omega - 7.781$ for amber buoying up velocity where approximation reliability is $R^2 = 0.9336$;

– $V_3 = 1 \cdot 10^{-9} \omega^3 - 7 \cdot 10^{-6} \omega^2 + 0.0116 \omega - 5.8309$ for amber buoying up velocity where approximation reliability is $R^2 = 0.7602$;

– $V_4 = 2 \cdot 10^{-9} \omega^3 - 1 \cdot 10^{-5} \omega^2 + 0.0161 \omega - 8.0969$ for amber buoying up velocity where approximation reliability is $R^2 = 0.9036$;

$V_6 = 2 \cdot 10^{-10} \omega^3 - 1 \cdot 10^{-6} \omega^2 + 0.0016 \omega - 0.7472$ for amber buoying up velocity where approximation reliability is $R^2 = 0.9501$.

Fig. 4. Dependence of amplitude (A) on vibration frequency (ω).

According to the experiment results, dependence of amplitude of intensification facilities (A) upon vibration frequency (ω) is approximated in such a way:

– for amplitude of intensifier (A): $A = 1 \cdot 10^{-8} \omega^3 - 5 \cdot 10^{-5} \omega^2 + 0.0873 \omega - 44.062$ where approximation reliability is $R^2 = 0.9218$.

The carried-out studies have determined ($\rho_c = 1650 - 1850 \text{ kg/m}^3$) medium density which is achieved if oscillation frequency is 22.5 – 28 Hz, amplitude $A = 1.51 - 2.75 \text{ mm}$, air supply $q_a = 0.0025 - 0.0055 \text{ m}^3/\text{hour}$ when amber buoying up velocity is $V = 0.11 - 0.199 \text{ m/s}$.

Moreover, the experiments have helped identify dependences, and supported regularities of the effect of vibration parameters of hydromechanical method for amber extraction from amber-bearing deposits; medium density, amplitude, and vibration frequency are the basic parameters effecting the intensity of amber buoying up velocity.

Vibration classifier (Fig. 1) was applied to study effect of vibration as well as air and water supply on the amber buoying up velocity to determine basic factors of the process

To determine buoying up velocity of different amber fractions, amber-bearing rock mass experienced action of vibration; water and air were supplied. Experimental values have been obtained for different operation modes of the device: with vibration action and without it; with water supply and without air supply; and with air supply and without water supply. Table 4 demonstrates the data.

Table 4. Experimental data of buoying up velocity of different amber fractions in the context of different operation modes.

Amber mass m , g	Amber buoying up velocity, m/s				
	Vibration with water and air	Vibration with water and without air	Vibration without water and air	Without vibration, with water and air	Without vibration, with water, and without air
~ 15	0.10	0.05	0.001	0.05	0.0011
~ 20	0.12	0.08	0.0012	0.08	0.0014
~ 25	0.13	0.09	0.0014	0.085	0.0018
~ 30	0.13	0.11	0.0022	0.09	0.0029
~ 35	0.14	0.15	0.008	0.10	0.01
~ 40	0.15	0.18	0.009	0.11	0.011
~ 45	0.20	0.19	0.01	0.12	0.012
~ 50	0.21	0.2	0.015	0.14	0.017
~ 55	0.24	0.21	0.021	0.14	0.023
~ 60	0.28	0.22	0.022	0.15	0.024
~ 65	0.30	0.24	0.023	0.16	0.025
~ 70	0.33	0.25	0.022	0.17	0.027

Basing upon the experimental data, graphic dependences of amber buoying up velocity (V) on the weight amber fraction (m) were obtained in the context of different operation modes of the device (Fig. 5).

According to the results of the experiment, the dependence of the rising rate of amber (V) on the mass fraction of amber (m) under different operation modes of the installation, are approximated by the following expressions:

- for buoying up velocity if vibration action with water and air is available $V = -7 \cdot 10^{-05} m^3 + 0.0028 m^2 - 0.0053 m + 0.1114$ with $R^2 = 0.9877$ value of approximation reliability;
- for buoying up velocity if vibration action with water and air is available $V = -2 \cdot 10^{-05} m^3 + 0.0006 m^2 - 0.0286 m + 0.0198$ with $R^2 = 0.9863$ value of approximation reliability;
- for buoying up velocity if vibration action with water and air is available $V = -4 \cdot 10^{-05} m^3 + 0.0008 m^2 - 0.0157 m + 0.0416$ with $R^2 = 0.9822$ value of approximation reliability;
- for buoying up velocity if vibration action with water and air is available $V = -4 \cdot 10^{-05} m^3 + 0.0009 m^2 - 0.0124 m + 0.0027$ with $R^2 = 0.9816$ value of approximation reliability;
- for buoying up velocity if vibration action with water and air is available $V = -4 \cdot 10^{-05} m^3 + 0.0009 m^2 - 0.0024 m + 0.0027$ with $R^2 = 0.9816$ value of approximation reliability.

Graphic dependences (Fig. 5) help conclude that it is possible to intensify amber extraction process while combining vibration, water supply to the rock mass, of water and air consumption.

The experiments determined maximum velocity (i.e. $V = 0.33$ m/s) achieved for $m = 70$ g amber fractions under the action of vibration with water and air supply.

Fig. 5. Graphic dependences of various amber fraction buoying up velocity in the context of different operation modes of the device: 1 – vibration with water and air; 2 – vibration with water and without air; 3 – water-and airless vibration; 4 – water-and airless vibration; 5 – without vibration, with water and without air.

As for the smallest (i.e. $m = 15$ g) fractions, maximum velocity, being $V = 0.1$ m/s is achieved if vibration is combined with water and air.

The studies also determined dependences of vibration action, and water and air supply on amber buoying up velocity in the context of hydromechanical method of amber extraction from amber-bearing deposits making it possible to mine the smallest amber fractions and vibration action, and water and air supply are the basic parameters, effecting the intensity of amber buoying up to the surface.

The studies, concerning amber extraction from sandy amber-bearing rock masses, identified the following:

- amber extraction velocity depends upon vibration frequency, amplitude, and medium density; moreover, it has its optimum;
- optimum values of water and air supply, under which maximum amber buoying velocity is achieved, are available in terms of different vibration frequency values; and
- medium density effects significantly the development of fast amber buoying up to the slurry surface of vibration classifier.

The experiments have determined medium density, being $\rho_c = 1790 - 1875$ kg / m³, with 20 – 30 Hz oscillation frequency, $A = 1.5 - 2.55$ mm amplitude, and $q_n = 0.0025 - 0.0055$ m³/h air supply when amber buoying up velocity is 0.1 m/s – 0.21 m/s.

4 Conclusions

The experiments, concerning vibration effect on the amber buoying up velocity, have determined that:

- the use of vibration classifier makes it possible to extract up to 95% of amber from deposit; in this context, medium density as well as vibration effects amber-bearing sand dilution;
- maximum velocity of amber buoying up velocity is achieved depending upon changes in water and air consumption depending upon certain amber-bearing rock masses; in this context, 0.1 m/s to 0.21 m/s amber buoying up velocity values have been identified; and
- operation schedule of hydromechanical method for amber extraction has been improved; possibility to use efficiently the integrated effect on higher density amber-bearing rock mass,

vibration, and air flows in the form of bubbles. In this context, closed cycle of amber extraction from amber-bearing sands is implemented making it possible to develop both process procedure and specifications concerning industrial extraction of amber.

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