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Combined Delivery of Consolidating Pulps to the Remote Sites of Deposits

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Abstract. The problems of modern mining production include limitation of the scope of application of environmental and resource-saving technologies with application of consolidating pulps when developing the sites of the ore field remote from the stowing complexes which leads to the significant reduction of the performance indicators of underground mining of metallic ores. Experimental approach to the problem solution is characterized by the proof of technological capability and efficiency of the combined vibration-pneumatic-gravity-flowing method of pulps delivery at the distance exceeding the capacity of current delivery methods as it studies the vibration phenomenon in industrial special structure pipeline. The results of the full-scale experiment confirm the theoretical calculations of the capability of consolidating stowing delivery of common composition at the distance exceeding the capacity of usual pneumatic-gravity-flowing delivery method due to reduction of the friction-induced resistance of the consolidating stowing to the movement along the pipeline. The parameters of the interaction of the consolidating stowing components improve in the process of its delivery via the pipeline resulting in the stowing strength increase, completeness of subsurface use improves, the land is saved for agricultural application and the environmental stress is relieved.

1. Introduction

The industrial demand for the mineral raw materials is growing due to the population growth and the changes in geography of mining. It can be satisfied not only with the use of new technical facilities and modern technologies but also due to application of nonborrowed reserves of production. One of the trends of mining modernization is simplification of the methods of stowing pulps production and delivery to the place of its application [1-2].

During the underground extraction of the vast majority of metal ore deposits the scope of application of technologies using the consolidating stowing for controlling the state of the ore-hosting

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massifs is limited to developing parts of the ore field remote from the stowing complexes, that is why implementation of operating stowing complexes to satisfy the demand for the stowing materials is becoming a more and more relevant problem.

2. Materials and methods of research

The traditional methods of delivering the consolidating stowing from the stowing complex to the place of application through the pipes are as follows: gravity-flowing, mechanic, pneumatic and combined including the elements of two-three methods.

Transportation of the stowing materials through the pipes according to the gravity-flowing method depends upon the properties of the material and upon the horizontal and vertical components of the pipeline. The distance of consolidating stowing delivery often achieves 1500 meters under the favorable grade.

The delivery distance increases if gravity-flowing is completed with supply of compressed air into the pipeline. In the pipeline volumes of the consolidating stowing pulp are formed divided by air gaps and the speed of the material movement increases up to 25 m/s.

Both methods are reliable when the relation of the vertical and the horizontal parts does not exceed 1/5.

When developing the deposits remote from the main site it is necessary to deliver the materials at the distance over 1500 m under the small height of the vertical part of the pipeline [3].

Such problem turned up when developing the closely situated North Kazakhstan deposits Shokpak and Kamyshovoye. In the neighborhood of the deposits fertile land is situated making any methods of deposit management impossible beside application of consolidating stowing. At the same time building of the second stowing complex rose the price of ore extraction making it economically unacceptable [4].

To prove the technological capability and economic feasibility of the new technology includes modeling of the processes which confidentiality of results increases when applying the materials of on-the-farm research under the industrial conditions.

The practice of stowing materials delivery with increase of the gravity-flowing capability due to its combining with other methods is relatively small. For example, at the deposit “Vismut” (Germany) the consolidating stowing material was supplied by vibro-gravity-flowing method at the horizontal distance which three-fold exceeds the height of the vertical flight [5-6].

Vibration-pneumatic-gravity-flowing method differs fundamentally from the known methods due to the application of the phenomenon of the pipeline vibration on elastic support with the help of vibration generators ensuring its vibration.

3. Experiment

Installation of vibration-pneumatic-gravity-flowing transport which was first introduced in the USSR at the deposit Shokpak-Kamyshovoye (North Kazakhstan) united the horizontal and the vertical parts of the pipeline (Fig.) [7]. The horizontal part of the pipeline was set at rubber support. Each section of the pipeline 200 meters length was supplied with inertia single-shaft vibration generator with electric drive and pneumatic tie-in with electromagnetic valve. The sections of the horizontal pipeline were connected with elastic connecting parts to exclude influence of one section upon another.

The volume of separate portions of the consolidating stowing was changing within the limits of 200…400 m^3.

After filling of the stage site and the first section of the horizontal site with the stowing material the vibration generator was turned on beginning with the first one which reduced the resistance of the material to the transportation.

The measured difference in pressure through the length of the section made: under gravity-flowing 0.6-1.0 MPa, grad P =3.0-5.0 kPa/M, and under the vibration mode – 0.12-0.20 MPa, grad P = 0.8-1.0 kPa/M.

When the stowing material was moving at a speed of 1.0-1.5 m/s in the pipeline the components of the pulp were redistributed with decomposition of the granules and prevention of lamination which improved its strength by 20-25%.

Energy consumption of the stowing material when transporting it at the distance of up to 2.5 km, vibration frequency of 10-30 Hz, amplitude 0.5-1.5 mm made 0.15-0.22 kW/h for 1 m^3.

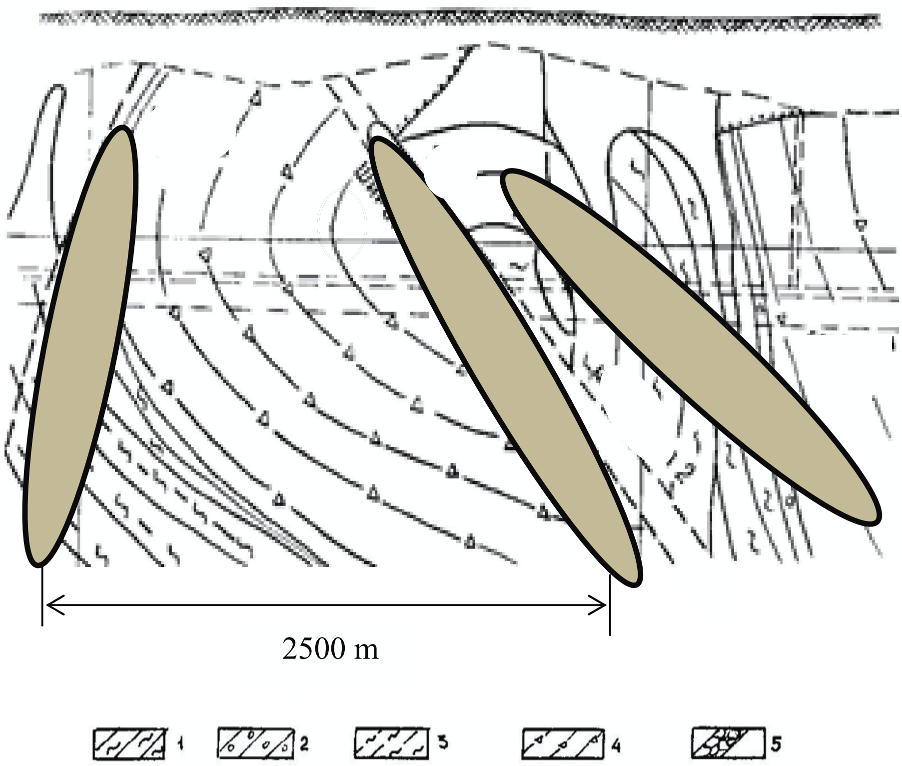

Fig.1. Deposit Shokpak-Kamyshovoye: 1-jasper-quartz rock; 2-conglomerates; 3-siltstone; 4-gravelstone, breccia; 5-zone of rock crush

The properties of materials for producing consolidating stowing: sand from the local open-cut: density 2.64 t/m^3; content of dust-like, clayey and silty 10 30 %; 5.0 mm sieve residue is 1%; specific surface – 6.9 m^3/kg without taking the levigated particles into consideration.

For gravity-flowing to increase the transportability water is added into the pulp until cone slump 11 which increases the consumption of binding materials and the cost of the pulps. And with the help of the vibration generator the stowing was transported even under the cone slump 9.

The differential pressure in the stowing line 1200 m long:

- productivity 80 m^3/h:12.03 – 4.55 = 7.48 atm.;
- productivity 100 m^3/h:15.0 – 5.38 = 9.62 atm.

Specific resistance (ΔP_C):

- productivity 80 m3/h: $\Delta P_C = \frac{7.48}{1200} = 0.00623$ atm. or 62kg/m2/1 m; (1)
- productivity 100 м3/ч: $\Delta P_C = \frac{9.62}{1200} = 0.008$ atm. or 80 kg/m2/1 m. (2)

- for productivity 80 m3/h and 100 m3/h, accordingly:

$$\tau 0 = \frac{62.3 \cdot 0.17}{4} = 2.6\ \text{kg/m}^2 \text{ and } \tau 0 = \frac{80 \cdot 0.17}{4} = 3.4\ \text{kg/m}^2 \quad (3)$$

To monitor the pressure in the stowing pipeline manometers were installed along the pipeline route in the pickets from RM1 to RM9 (Fig. 2). Air cut-ins were installed near the vibration generators. Under the reverse slope of the pipeline 0.003 the stowing pulps are transported by gravity-flowing until picket 7 (1580 m) and then – with application of vibration generators.

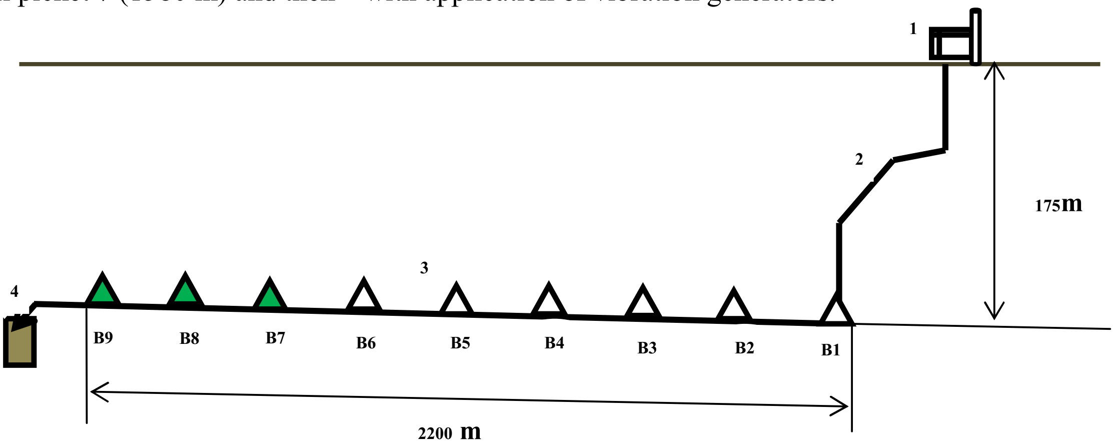

Fig.2. The diagram of vibration-pneumatic-gravity-flowing transportation of consolidating pulps from the stowing complex of Shokpak deposit to the shrink stoping of the deposit Kamyshovoye: 1 – stowing complex; 2 – vertical part of the pipeline; 3 – vibration generators; 4 – the stowing chamber of the block; B1-B9 – single-shaft vibration generators with electric motor drive

The limit length of the gravity-flowing transport is 1600 m; the experimentally found length of vibration-pneumatic transport is 600 m; the delivery distance of the pulps is 2200m.

During the experiment set up the pressure in the stowing pipeline was measured in points 1, 7, 8 and 9 simultaneously at three minute interval separately under the productivity of the stowing plant of 80 and 100 m^3/h.

At first the pulps were transported with application of air without the vibration generators. Up to picket 7 at the distance of 1500 m the stowing materials were successfully transported by gravity-flowing. From picket 7 to the place of the deposit the stowing pulps were transported with application of vibration generators to the distance of 600 m in horizontal direction.

Air pressure in the air and stowing lines:

- under the productivity of 80 m^3/h:

$P_М$= 60800 kg/m^2 (6.08 atm.); $P_Т$= 45500 kg/m^2 (4.55 atm.);

- under the productivity of 100 m^3/h:

$P_М$ = 67400 kg/m^2 (6.74 atm.); $P_Т$ = 53800 kg/m^2 (5.38 atm.).

The speed of the stowing material movement:

- for the productivity of 80 m^3/h: 6.7 m/s;
- for the productivity of 100 m^3/h: 5.7 m/s

The length of the portions of the stowing pulp:

- for the productivity of 80 m^3/h:88 m
- for the productivity of 100 m^3/h:128 m

Specific resistance of the stowing to the movement:

- for the productivity of 80 m^3/h:517 kg/m^2 for 1 m;

- for the productivity of 100 m^3/h:420 kg/m^2 for 1 m.

Correction factors for the speed:
- for the productivity of 80 m^3/h:0.027 s^2/m^2;
- for the productivity of 100 m^3/h:0.24 s^2/m^2.

The increasing of the strength of the stowing after pneumatic-gravity-flowing to the distance of 1500 m is about 11% at 28 days and 13-14 % at 90 days [8].

4. Results and their discussion

The stable operation of the transportation is ensured by the compliance of velocities at the gravity-flowing and pneumatic sites or the equality of the time of the total portion transportation and its filling into the pipeline. The transportation conditions can be regulated either by the plasticity of the pulps or by changing the productivity of the stowing plant. Turning the vibration generators up to the possibility frontiers of the gravity-flowing transport increases resistance to the pulp motion, that is why when transporting along the pipeline with reverse slope the vibration generators do not always improve the indicators of consolidating stowing transportation.

For the objective comparison of the opportunities of transport diagrams we compare the results of the mathematical modeling of pneumatic-gravity –flowing and pneumatic-vibration-gravity-flowing transportation under similar productivity of the complex (80 m^3 /h) and delivery distance of 1500 m which is critical for the first scheme and starting for the second one. Under the pneumatic-gravity-flowing transportation to the distance of up to 1500 m strength increasing of the stowing pulp reaches 3% at 28 days and 6% at 90 days and under pneumatic-gravity-flowing transportation to the same distance it reaches 11% at 28days and 14% at 90 days.

All transportation conditions being equal the new technology reduces the resistance to the motion, increases the length of the delivered portion of the pulp and improves the strength of the consolidating stowing due to the vibration of the pipeline walls. The efficiency of the consolidating stowing activation under the alternative layouts is characterized by the values:
- for the pneumatic-gravity-flowing delivery – 1.03-1.05;
- for the vibration-pneumatic-gravity-flowing delivery – 1.05-1.20.

In the case of pulps transportation to Kamyshovoye deposit from the operating stowing complex at Shokpak deposit there is no necessity to build a new stowing complex with corresponding capital costs which are replaced by much smaller costs associated with the pipeline construction. As a result of the pulp activation the cement consumption can be reduced leading to reduction of the pulp cost price by 15%.

When transporting the consolidating stowing according to the new technology the completeness of the use of subsurface resources increases and the ecological stress is reduced.

The efficiency of the consolidating stowing transportation technology is estimated through comparison of the reduced costs [9-12]:

$$E = [(C_1 + E_h K_1) - (C_2 + E_h K_2)] \cdot A_y \quad (4)$$

where E – annual cost advantages, rub; E_h – ratio of discounting expenditures and profit in the course of time, unit fractions; K_1 and K_2 – capital investments into production funds under building a new stowing complex and combined delivery accordingly, rub; C_1 and C_2 – producing cost of 1 t of concentrate under the compared variants accordingly, rub; A_y – annual production after involving new deposit resources into operation. Combining of the methods of pulps delivery is an element of the mining enterprises economy management system under the intensification of competition at the market and surviving without the governmental support [13-15].

5. Conclusions

1. The scope of application of the development systems implementing stowing increases if the consolidating stowing is supplied to remote sites of the deposit according to the combined diagram with application of vibratory technology.

2. Application of vibration generators improves the opportunities of pulp transportation to the distances exceeding the capabilities of traditional pneumatic-gravity-flowing delivery due to reduction of friction on the walls of the pipeline.
3. The consolidating stowing activated in the process of delivery via the pipeline is characterized by a more uniform distribution of the filler which results in its better strength.

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