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Results of research and development of vibration machines for mining

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Results of research and development of vibration machines for mining

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Abstract. The paper presents results of the bulk material vibration displacement studies, the results being the basis for the creation of vibrotechnics for the mining industry. The analysis is given of the capabilities and technical characteristics of the machines being created in comparison with that of the existing technique similar in operation principle and purpose, advantages of the machines are shown.

1. Introduction

In mining and construction, it is required to handle large volumes of bulk multi-component materials having different physical and mechanical properties. As a rule, these mixtures include clayey components which considerably increase cohesiveness when wet. Process lines provide temporal storage of such materials in accumulation bins. The bins are unloaded by gravity or using feeders, for instance, vibro-feeders which reliably operate in mines, make it possible to improve capacity of discharge opening and prevent from bridging. However, handling of wet coherent rocks can face problems connected with adhering or freezing over of materials on load-carrying surface of feeders.

Many institutions engage in engineering of vibration machines for loose bulk materials [1–5] both in Russian and abroad, such as Vibrotekhmash Research and Production (Russia), Electrovibromachine Tskhvinvali Woks (South Osetia), AViTEQ Vibrationstechnik GmbH (Germany), Schenckprocess (Germany), leading European company and Shanghai Zenith Mining and Construction Machinery Co. (China). It should be mentioned that these companies offer standard design vibro-machines, with rigid active element fixated on heavy frame by elastic supports to ensure directional vibrations. Disadvantages of these machines are high metal and power consumptions, high dynamic loading on supports and small area of vibrational impact. These machines can only handle non-adhesive materials, which is specified in technical documents.

2. Vibro-feeder characteristics and schematic layout

For the same purposes, the Institute of Mining, SB RAS, has designed vibro-feeders Sibiryachka (VDPU-4TM) and Volna [6]. Vibro-feeder VDPU-4TM (Figure 1) is composed of a welded load-carrying element (platform) *1*, the unloading end of which is connected to two inertia vibration exciters V-4,5 with circular driving force, coupled by an elastic sleeve. The platform is affixed to the discharge excavation floor by supports *3* and *4*. The platform section between the supports oscillates laterally, and broken rocks flow under vibration and by gravity on the sloped load-carrying surface to a truck or a conveyor. This feeder has simple design, but slope of the active element to horizon to ensure the flow should not be less than 15–18°, and this requirement complicates the process control.

Shortages of this machine are large weight (more than 4 t), high power consumption and difficult assembly–disassembly.

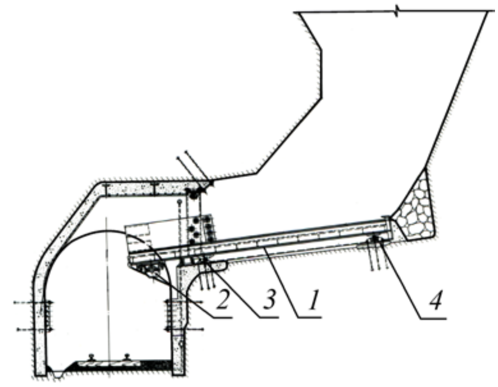

Figure 1. Schematic layout of Sibiryachka vibro-feeder in underground excavation: *1*—active element; *2*—vibration exciter; *3* and *4*—support.

Despite these disadvantages, Sibiryachka reliably operates in difficult conditions in Russian mines and is series-produced. This feeder is run in Evrazruda mines in Gornaya Shoria in ore drawing and ore chutes before loading rocks to haulage vehicles.

Vibration machines with elastic active element (vibro-belt) drastically differ from the other vibro-machines. This class feeders offer simple structure, small metal consumption and reliable operation under gobs under under subzero temperatures. Material is moved by an active element which is a thin metal oscillating sheet [7]. These machines are free from amortization, need no thick foundation and are driven by electric inertia or pneumatic vibro-exciters designed at the Institute of Mining, SB RAS.

Figure 2 depicts schematically Volna-4P feeder in ore drawing from extraction panel, and the Table 1 gives specifications of vibro-feeders Sibiryachka and Volna-4P.

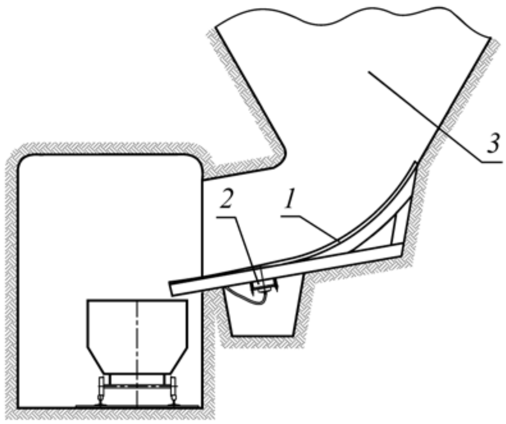

Figure 2. Schematic layout of Volna-4P vibro-feeder in underground excavation: *1*—active element; *2*—vibration exciter; *3*—accumulation bin.

Examination of loose rock discharge by vibro-belts show that curved active element of of the feeder creates more favorable conditions for rock flow. Application of such feeders in ore chutes, designed in conformity with the theory of loose material flow in narrowing and nonsymmetrical channels developed at the Institute of Mining, SB RAS, allows elimination of bridging of material at intersections of vertical and horizontal excavations.

Volna vibro-feeders ensure reliable discharge of loose materials from different reservoirs (ore chutes, bins) and loading to haulage machines in mining and construction.

Table 1. Specifications of vibro-feeders.

Description	Sibiryachka (VDPU-4TM)	Volna-4P
Dimension, mm:		
length	6015	3950
width	1200	1590
height	620	1040
Vibration exciter	electrical inertia	Napor-3M pneumatic
Number of vibration exciters	2	1
Driving force, kN	total 90	35.6
Vibration frequency, Hz	25	40
Slope, deg	15–20	15
Weight, kg	4000	1800
Capacity, t/h	Not less than 300	Up to 500

This class feeders ensure continuous and uniform flow of low-cohesive material. Difficulty arises in haulage of wet material with high content of clay, which entails bridging. It is possible to improve situation by enlarging the zone of vibration impact. This is especially important for machines with elastic active element as in this case, due to loss owing to external friction, vibrations damping greatly in both directions from vibro-source. As a consequence, amplitude of vibrations at the loading end of the active element can tens times less that at the vibration exciter, which decelerates flow rate of material and lengthens the period of material stay on the vibrating surface. As a result, loose material compacts at the loading end of the feeder. Since vibrations transferred to material at the loading end are much lower than at the vibro-exciter, a small portion of rocks directly above the unloading end of the feeder is only discharged, which results in chimney formation and in under-use of volume of accumulation bins.

In order to eliminate this disadvantage of vibration feeders with elastic active elements, their design was modified. In the new design, the active element of low bending stiffness is suspended on elastic supports installed normally to the end sections of the load-carrying surface. Each support has one its end rigidly connected with the active element and the other—with the frame, and takes bending moment. Thanks to such design, longitudinal oscillations of the active element are possible, which allows essentially higher vibrations of the loading section of the vibrating facility.

Bending stiffness of supports is selected in conformity with the admissible sag of the active element under maximum static load. On the assumption of maximum sag of the active element at the vibro-source arranged symmetrically relative to the supports, the relationship between the support bending stiffness W, design factors of the active element and its allowable sag f_{alwb} under maximum static load has been found and experimentally proved:

$$W = \frac{1}{3} N l_0^3 \left(R \sin \frac{l}{2R} - \frac{l^2}{8 f_{\text{alwb}}} \sin \frac{4 f_{\text{alwb}}}{l} \right)^{-1},$$

where l_0, l are the lengths of the support and active element; R is the curvature radius of the active element; N is the force applied on the support at the maximum static load on the active element.

The allowable sag value is set at design stage as per condition that the slope of the unloading section of the active element under maximum static load should not exceed 7–10°.

3. Experimental tests results

Figure 3 shows the experimental curves of the maximum dimensionless vibration velocity (V, V_s—vibration velocities at any point of the active element and at the vibro-source, respectively) of the active element without supports and with supports of different bending stiffness (curves *1* and *2*, *3*, respectively). The origin is matched with the loading end of the active element of the vibro-feeder, and the point of the maximum vibration velocity is the driving force application point. The measurements are taken at the beginning of discharge, when the load on the active element is maximal.

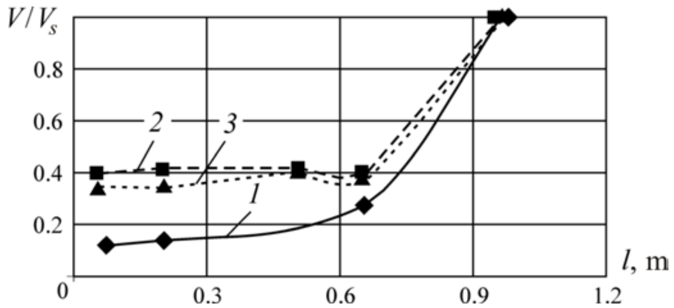

Figure 3. Distribution of dimensionless amplitude of vibration velocity along loaded active element without supports (*1*); and with supports with bending stiffness of 2.31 kN·m^2 (*2*) and 5.77 kN·m^2 (*3*).

These results show that the new design offers essentially higher (3.5–4.0 time) oscillation amplitude of the loading end of the active element, and, as a consequence, coherent material flow accelerates at this end, which creates conditions for sufficiently steady-state and uniform flow along the whole transporting surface of the vibration facility.

The research results on vibration discharge of coherent materials were used in design of a new vibro-feeder (Figure 4). The active element *1* made of steel sheet 5 mm thick is suspended on the frame *2* using elastic elements fixated at the ends of the active element, which enables longitudinal vibrations of the feeder and higher oscillations of the loading end. The active element and the frame, which is a box, form a reservoir with the bottom represented by the active element. The vibration source is inertia electric vibration exciter.

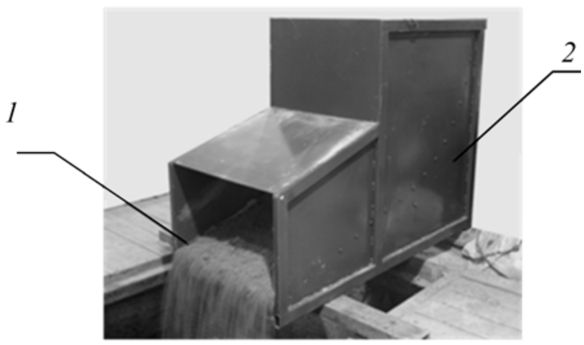

Figure 4. Development model of virbo-feeder for loose and coherent materials: *1*—active element; *2*—frame.

Specifications of the feeder:

Dimension, mm:	
length	1500
width	664
height	1050
Discharge opening area, m^2	0.27
Weight, kg	160
Vibration frequency, kHz	35
Driving force, N	2400
Vibro-exciter capacity, W	950

Under the specified driving force, discharge capacity of loam with clay content of 10% and moisture content of 13.5% makes 550–560 t/h.

For application in open pit mining, the feeder should be not shorter than 6 m, but the length is limited as vibrations damping. This shortage is eliminated by distributing driving force along the active element by means of installation of two vibration exciters at certain spacing as well as by ensuring their synchronous rotation.

The experimental research and analysis of dynamics of vibro-system [8] including elastic active element and inertia vibration exciters using physical models show that such system develops steady-state stable synchronous regime of vibration sources based on the phenomenon of synchronization [9]. The results of this research have become the framework for engineering feeder for vibrational dumping.

For dumping using dump trucks with capacity up to 300 t, the Institute of Mining, SB RAS, has designed a self-propelling vibrational stacker with the load-carrying element composed of three vibrating transportation facilities [10].

In the dumping technology with vibrational facilities, the stacker is arranged so that the unloading end of the load-carrying element is beyond the boundary of the dump level. The stacker length ensures unloading of dump truck beyond a possible sliding triangle. The distance from the dump level edge to the unloading point is set according to the operational safety standards. Broken rocks are unloaded from a dump truck onto receiving table of the load-carrying element and moved by vibration down the slope of the dump level.

Economic efficiency of the proposed technology was evaluated in comparison with the dozer stacker in the conditions of Lomonosov Mining and Processing Plant of Severalmaz Co. It is found that in operation with dump trucks with capacity of 90 t, the vibro-stackers with annual productivity of 3.8 Mm make it possible to reduce the number of dozers by 67%, to diminish the number of dumps and levels as well as to enhance operating safety. The dumping capacity can be increase 2.5 times, while operating and capital costs are cut down by 43 and 54%, respectively. The use of one self-propelling vibrating stacker allows the annual economic efficiency round 8 million rubles.

Currently, the pilot vibrating stacker has been manufactured for operation with dump trucks MAZ-5551. Efficiency of the stacker has been proved in the condition of a testing ground.

4. Conclusions

Design features of the vibration machines engineered at the Institute of Mining, SB RAS, are suitable for rock discharge from extraction panels and ore chutes in difficult conditions of mines.

Based on results of vibro-discharge tests, the designed structural layout of the feeder reduces damping of oscillations at the loading end of the active element of the feeder. The vibro-feeder designed by this layout implements uniform discharge of loose and coherent materials.

Application of stackers equipped with vibrating facilities with elastic active element improves safety and economic efficiency of mining.

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