Vibratory feeders with elongated conveying surface in rehandling of mined rock in open pit mines

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Abstract. Deep-level mining in open pits involves increased volumes of overburden. It is difficult to operate heavy-duty dump trucks at bottom levels of deep open pit mines due to limited size of working areas and high angles of roads. In this case, it is expedient to use more maneuverable crawler dumps or articulated dump trucks of comparatively low capacity and to rehandle mined rocks to larger capacity dump truck at bin trestles with forced discharge constructed on accumulation horizons. This article discusses mined rock discharge from an accumulating bin of the rehandling point by a set of vibratory feeders representing the bottom of the bin. These vibratory feeders are to provide reliable operation under high static and dynamic loads.

1. Introduction
Modern mining sciences are highly concerned with creation of innovative energy- and resource-saving technologies and equipment meant to increase efficiency and safety of in open cutting [1]. To date majority of open pit mines operated in complicated geotechnical conditions: increased depth of mining, longer haul distances and, consequently, decreased economic performance. Overgrowth of volumes of overburden makes its handling by dump trucks, which transport up to 90% of mined rock in open pits, a neck stage.

In deep open pit mining, the share of intermodal transport grows, thus, engineering of rehandling facilities is one of the most topical problems.

The review of different rock rehandling techniques and equipment [2, 3] shows that efficiency of all chains in the load–haul–dump system with intermodal transport is best achieved with bin trestles constructed as separate units and ensuring rehandling points of high accumulation and throughput capacity.

Design and operational reliability of bin trestles are in many ways governed by the type of a feeder. The operation experience of different type feeders in discharging of coarse rocks from bins, as well as design studies of bin stations and vibratory haulage machines for open pit mining [4–9] shows that it is advisable to equip bin rehandling points with elastic vibratory feeders designed at the Institute of Mining, SB RAS and taking a special place in the line of vibrating machines used in discharging and handling of various materials. In this type feeders, the conveying surface makes wave-like vibrations. Therefore, vibratory feeders with elastic conveying surface feature much less metal- and energy-consumption, as well as higher capacities to implement various modes of transportation. They are efficiently applicable to discharging moist and adhesive materials, which has been experimentally proved. On the other hand, vibrations greatly damp at the discharging end, and the travelling speed of
material reduces, which limits the length of the conveying surface. This disadvantage can be eliminated through distribution of the driving force along the conveying surface using two or more vibration exciters. In this case, it is required to ensure synchronous rotation of all exciters.

2. Experimental results

Figure 1 shows an alternative chart of a rehandling point with a bin loaded from dump trucks from the shunting site adjoining the back wall of the trestle. The front wall of the bin trestle has openings to discharge rocks. The bin bottom is constructed from vibratory feeders with self-synchronizing vibration exciters.

![Figure 1. Layout of rehandling point: 1—bin trestle; 2—articulated dump truck CAT-470; 3—dump truck CAT-785; 4—elastic conveying surface; 5—vibration exciters; 6—bin filled with mined rock.](image1)

For assessment of applicability of vibratory feeders with elastic conveying surface and distributed driving force in rehandling with intermodal transport, the experimental studies were carried out with intent to:

—find conditions of steady-state synchronous rotation of vibration exciters and to examine effect exerted on steady-state synchronous mode by the change in the static and dynamic loads on the conveying surface;
—determine time of settling of the steady-state synchronous mode in rotation of eccentric masses of the vibration exciters.

![Figure 2. Test bench for granular material discharge, with elastic conveying surface and self-synchronizing exciters: 1—reservoir with transparent walls; 2—elastic conveying surface; 3—immobile frame of the feeder; 4—inertia vibration exciters.](image2)
For the experiments, the test bench was developed (Figure 2). The test bench has reservoir 1 with transparent walls for observing flow of granular material. The bottom of the reservoir accommodates straight-line elastic conveying surface 2 mounted on immobile frame 3. The conveying surface is put into vibration by two inertia vibration exciters 4 actuated through a frequency converter with a working range from 0 to 90 Hz. The converter allows adjustment of vibration frequency of the vibratory feeder.

The test bench design provides adjustment of the feeder incline and the discharge opening height.

In the vibratory feeders with elastic conveying surface, vibrations of the conveying surface essentially decay in both sideways of a vibration exciter. This vibration attenuation is the main reason for limiting the length of the conveying surface.

Figure 3 demonstrates the distribution of the vibration velocity amplitude along the conveying surface in discharging of granular material with or two vibration exciters: curve 1—operating exciter in the unloading section; curve 2—operating exciter in the loading section; curve 3—operation of two exciters; curve 4—vibrations of empty conveying surface in simultaneous operation of two exciters. The coordinate $L$ is counted from the end of the loading section. The presented results are valid for the start of the discharge at the maximum loading of the vibratory feeder.

It follows from the plot that during operation of one exciter, the intensities of vibration of the loading and unloading sections of the conveying surface differ by an order of magnitude.

Under operation of two vibration exciters, vibrations in the loading and unloading sections have the same order (Figure 3, curve 3). The pattern of discharging is also changed: granular material flows along the whole length of the conveying surface at the sufficiently uniform velocity which considerably lowers only by the end of the discharge when pressure from the above-lying layers of the materials decreases. It is found that productivity of the feeder with two vibration exciters can be increased by 1.7–2.0 times.

The experiments show that the exciters arranged at the elastic conveying surface operate in the steady-state synchronous mode. The setting time of the steady-state synchronous mode is 3.5–5.0 s of the exciters are actuated simultaneously, or one of them is connected to the already operating second exciter. This time period includes speedup of the exciters.

In case of derangement under dynamic impact on the conveying surface, the steady-state mode recovers in 1.3–1.5 s.

During granular material flow, the load on the conveying surface was varied from a maximum value to zero, and the stead-state synchronous mode was preserved within the whole process. This means that the static load has no essential influence on the self-synchronization. The dynamic loads
derange the operation of the exciters, though the synchronous mode recovers rather quickly as compared with the discharging time.

3. Conclusion
In deep open pit mines using intermodal transport, it is advisable to arrange bin rehandling points with vibration discharge of mined rocks.

The promising solution for rock discharge from the bin at the rehandling points is the use of vibratory feeders with elongated conveying surface and two vibration exciters arranged at the loading and unloading sections.

The new proposed equipment is the backbone of novel safe and efficient technologies and transport systems for deep open pit mines.

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