Conditions of efficient vibrodischarge of rock materials in modern mining and processing technologies

SYa Levenson*, LI Gendлина and EG Kulikova

Chinakal Institute of Mining Siberian Branch Russian Academy of Sciences
Novosibirsk, Russia

*E-mail: shevchyk@ngs.ru

Abstract. The paper reviews vibration feeders used to discharge storage reservoirs in mineral mining. In spotlight are vibrofeeders equipped with an active member of low flexural rigidity developed at Chinakal Institute of Mining. The authors present the results of the physical and numerical studies on vibratory discharge of cohesive rocks from a bunker.

The development of mining industry indispensably relates to introduction of advanced mining technologies, new brand machinery to mine and handle different mineral materials.

One of present-day mining problems is the arrangement of favorable conditions for uninterrupted discharge of bulk material from storage bins, bunkers responsible for continuous operation of the mechanized mining plant. Efficiency of granular material haulage in most depends on physic-mechanical properties of the material. Thereto, cohesive dispersed media are characterized with essential cohesion forces acting between particles, which hamper the material motion along with internal friction. Discharge of such materials from bunkers encounters the pipe-formation and frequent hanging challenges and remains a burning problem so far.

Vibration feeders are capable to operate at high productivity under heavy-duty mining conditions, herewith hygiene, sanitary conditions and operation and labor safety as well as automated discharge of bulky material from bunkers are provided [1]. At present more than 50 types of vibrohaulage machines are available, most of them are designed and manufactured for specific industrial conditions.

The typical design of a vibrofeeder consists of a rigid active member, elastic element system, connecting it to a base, and vibroexciter in a single-mass scheme as a rule. Versions of such machines are electrovibration feeder of PE-type, Mekhanobrtekhnika, Russia, (Figure 1a) [2]. The active member of the feeder is fixed to bunker walls through the elastic element system and is actuated by a single electric vibroexciter. This and similar machines operate efficiently at mines and concentrators on dosed feeding of granular materials not prone to compaction, with low moisture content from storage bins. However they are not designed to operate with cohesive materials specified with appreciable cohesion.
Figure 1. Vibration feeders of a single-mass scheme: (a) PE electrovibration feeder; (b) GZD vibration feeder.

GZD feeder, Chinese Break-Day Co. (Figure 1b) [3], is designed as a heavy-duty vibration machine of a single-mass type to operate in an orepass. It is convenient in maintenance, efficient to haul bulk materials, but not usable for cohesive, sticky materials.

High-power feeder of double-mass scheme is proposed by US company, General Kinematics (USA) (Figure 2) [4].

Its design allows adjustment of eigen frequency of its active member, automated fitting to variations in pressure of a material to be discharged without reduction in delivery rate and a rise in power consumption.

This machine is capable to cope with heavy-duty loads on transporting surface and operates efficiently to discharge bulk rock materials of low moisture content from storage bunkers to haulage facilities.

Figure 2. Double-mass feeder, General Kinematics Co.

The general imperfections of vibrofeeders with a rigid active member are high labor intensity of preparation and mounting operations, need in heavy under structure, as the carrying members of these machines suffer appreciable loads under dynamic unbalance conditions. Their application scope is restricted as they are not applicable to handle cohesive and sticky materials.

At Chinakal Institute of Mining SB RAS the researchers developed a series of vibrofeeders with the elastic active member [5, 6].

The active member made of steel sheet of low bending rigidity is readily placed on the foundation and performs bending vibrations in the operation mode. The vibration source is an electric inertial or pneumatic vibroexciter. The operational principle of these machines enables to realize greater variety of haulage modes as compared to feeders of conventional scheme. They are distinguished for simple construction compact dimensions, small mass, and low mounting and demounting costs.
First vibration machines were VLR-1, BLR-2, and VLR-3 feeders designed to discharge ore from ore passes and to load ore into haulage facilities. Imperfection of these feeders is a small zone of vibro effect on a bulk material because of essential attenuation of vibration in its transmission from a vibration source along an active member. This drawback does not permit to discharge efficiently cohesive heavy-duty materials. Herewith, the additional preparation of foundation or a frame is required to mount the active member.

Alternatively to VLR-type feeders “Volna” vibrofacilities are manufactured with a case-type support frame, and this notably facilitates mounting operation. As an unloading facility the machine is fixed on bunker walls with elastic elements. Volna–1.5P, Volna–2P, Volna–3P, Volna–4P vibrofeeders have the same structure scheme, differ in overall dimensions and production capacity, and designed to handle different granular materials with low moisture content. Elastic active member of these machines is curved in a shape to improve material discharge at the expense of artificially created surface close in shape to natural slip surfaces which can be realized in a material under discharge with the aim to boost sliding of granular material. The pneumatic vibroexciters, designed at IM SB RAS, simple in design and high-reliable are employed as a vibration source. Figure 3 presents the scheme of Volna–4P vibrofeeder used to draw broken ore from a block.

Figure 3. Scheme of Volna–4P vibrofeeder to draw broken ore from a block: 1 – vibrofeeder; 2 – vibroexciter; 3 – air-supply hose; 4 – a hose pit; 5 – mine working.

The analysis of vibromachines revealed that the operating efficiency of available vibrofeeders sharply falls with increase in viscosity of granular media. These vibromachines are designed to handle bulk materials not prone to adhesion.

At IM SB RAS the research works are conducted on investigation into vibration handling of cohesive geomaterials and search for technical solutions to this problem.

To be particular, the use of extra vibroactuator appreciably intensifies vibration of a loading section of the elastic active member and reduces the effect of fading of bending vibrations on discharge of granular materials including cohesive ones. However, in this case the requirement to provide synchronous operation of vibroexciters is difficult to realize.

The principally new structure scheme is proposed as an alternative solution, where an active member of small bending rigidity is fixed in a suspended state on elastic support elements connecting
it to a support frame [7]. The researchers propose a vibromachine where there is no contact between the active member and the foundation, unlike a vibromachine with elastic active member where the longitudinal component of vibrations is negligibly small because of friction between the active member and the foundation, and the output is realized due to bending vibrations. In the new version attenuation of vibrations is reduced along transporting surface and amplitude of vibrations on the loading section of the feeder is intensified.

The physical and numerical modeling techniques were applied to study dynamics of vibrofeeders. Physical experiments were carried out at the stand consisting of a vibrofeeder and a storage bin. The test cohesive material was clayey sand of 0.005…0.1 mm in particle size and 10% clay content. Cohesion was varied by altering moisture within 10–18%. Vibration parameters were measured by means of measurement–computing complex. The time of output of the measured volume of cohesive material was recorded.

The numerical modeling was performed by the finite element method in ANSYS software. Solution of the complete system of dynamics equations (Full Transient Analysis) was carried out with the use of implicit scheme of direct integration in time based on Newmark method [8].

It was experimentally demonstrated that the unattenuating longitudinal component appreciably intensifies vibrations of the loading section of the active member (Figure 4); in the outlet their amplitude remains practically the same.

![Figure 4. Oscillograms of longitudinal (a) and lateral (b) components of vibrovelocity, \(\nu\).](image)

1 – a spot of driving force application, 2 – loading end.

It is established that to realize efficient cohesive material discharge and to meet admissible sinking-down of the active member under a load implies that ratio \(\frac{l_{\text{in}}}{E_I}\) should not exceed 0.025–0.030 (\(l_{\text{in}}, \text{m,} E_I, \text{Nm}^2\) – length and rigidity of a support, respectively).

A vibrofeeder prototype to discharge granular and cohesive materials from a bunker was developed on the base of experimental results (Figure 5). A curved active member 1 of small bending rigidity is inside a case-type frame 8. Its loading and discharging end are rigidly connected to elastic support elements fixed on the frame. One of design support version is shown in Figure 5b. It consists of elastic
metallic plates 2 and 3, rubber–fabric plates 4 and 5, and mounting blocks 6 and 7 to fix plates to the active member and the frame, respectively.

Figure 5. Pilot vibrofeeder to discharge granular and cohesive materials: (a) general view; (b) arrangement of support component in the loading end: 1–active member; 2, 3–elastic metallic plates; 4, 5–elastic rubber-fabric plates; 6, 7–mounting blocks; 8–frame.

Figure 6. Vibrovelocity of lateral (a) and longitudinal (b) vibrations of the active member: 1–in a spot of the driving force application; 2–in the middle of the active member; 3–in the loading end.

The laboratory feeder tests showed its high performance. The discharge of clayey sand of 10% clay content and 13% moisture proceeded uniformly with none of sticking. Sticking or compaction of the feed in loading end of the active member was not observed, vibration in this section was confirmed by oscillograms of the active member vibrations recorded in the course of output (Figure 6).

The output capacity amounted to 55–60 t/h at driving force parameters cited in the Table 1.
Table 1. Feeder specifications

| Dimension                          | Value    |
|------------------------------------|----------|
| Overall dimensions, mm:            |          |
| –length                            | 1500     |
| –width                             | 664      |
| –height                            | 1050     |
| Area of output window, m²          | 0.27     |
| Mass, kg                           | 160      |
| Vibration frequency, Hz            | 35       |
| Driving force, N                   | 2400     |
| Capacity of vibroexciter, W        | 950      |

Conclusion

The elastic supporting elements in the feeder design enable to increase intensity of vibrations in the loading end of the active member of a small bending rigidity, thus providing conditions for efficient discharge of not only bulk materials, but cohesive materials as well.

References

[1] Molotilov SG, Vasil’yev YeI, Kortyelyev OB, et al 2000 *Intensification of Loading and Haulage Operations at a Quarry* Novosibirsk: SB RAS (in Russian)

[2] Electric vibrating feeders (vibrating feeders)—Site access mode: http://www.mtspb.com/production_current.php?id=4&id_group=22

[3] Vibrating feeder—Site access mode: http://www.break-day.com/ru/vibrating_feeder.htm

[4] Vibratory Rock Screens / Feeders – Site access mode: http://www.generalkinematics.com/mining/proddesc.cfm/productid/94

[5] Tishkov AYa, Gendlina LI and Levenson SYa 1992 Vibratory equipment with flexible active member to mining operations *News of the Higher Institutions Mining Journal* No 10 (in Russian)

[6] Levenson SYa, Gendlina LI, Eremenko YuI, Kulikova EG and Morozov AV 2008 Vibratory equipment for underground and open cast mining *Proceedings of the VI International Scientific and Technical Conference “Technical Equipment for the Mining and Oil and Gas Industry”* Ekaterinburg (in Russian)

[7] Gendlina LI, Levenson SYa, Alesik MYu and Kulikova EG 2013 About vibratory equipment parameter effects on the process of coherent rock material discharge from the bunker *Mining Equipment and Electromechanics* No 1 (in Russian)

[8] Lukashevich AA 2003 *Modern Numerical Methods of Structural Mechanics* Khabarovsk: KhGTU (in Russian)