Justification of new construction diagrams of vibrating feeders for loose material discharging from hoppers

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Abstract. The paper present construction diagrams developed at the Chinakal Institute of Mining to expand capacities of vibrating feeders with low bending stiffness for discharging various difficult-to-transport materials, including cohesive, sticky and hot. The authors justify support elements for fixing the vibrating body on the frame and its equipment with auxiliary elements (chains, elastic seals and self-closing gate).

1. Introduction
Vibrating feeders designed at the Vibrotechnique Laboratory of the Chinakal Institute of Mining are intended for discharge of loose materials from hopper. The active part of these machines put on a support frame at an angle 10–15° relative to horizontal line and represents a thin metal sheet effecting bending vibrations under the action of exciting force. For creating the best conditions of loose material transfer, the vibrating sheet can be curved [1]. The vibration source can be an elastic or pneumatic exciter. Possible spills are eliminated using flexible rubber seals.

Unlike the machines with the stiff active part [2–4], the new vibro-feeders feature simple design, easy assemblage and maintenance as well as various modes of vibro-transport [5].

However, when a feeder operates under a hopper, vibrations greatly attenuate along the distance from the application point of exciting forces to the loading point of the feeder. The attenuation has no influence on transport efficiency in case of materials with low cohesion whereas during conveying of coherent and adhesive materials, high resistance forces arise in the material and at the feeder–material interaction zone. As a result, material adheres to the vibrating surface, and bridging is possible. Furthermore, rubber seals used to eliminate spills prevent from operation of the feeders with hot loose materials [6].

2. Vibrating feeders efficiency improvement
Currently, some engineering solutions are proposed, which enable using vibrating feeders with low bending stiffness for transporting loose, coherent, adhesive and hot materials.

Vibrations at the loading point of the feeder can be intensified by means of removal of friction between the carrying surface and the support. To this effect, it is proposed to the active part of the feeder is suspended on support elements with one end of which is connected with the active part and the other end is fixed on the support frame.

Such supports may be stiff elements (for instance, rods [7]) set in unstable equilibrium and elastically fixed. In this case, the exciting force of the vibration source generates bending vibrations of the active part; vibrations reach contact zones with the support elements and deflect them from the
initial position. The support elements each time reset equilibrium owing to elasticity. Such support elements ensure shuttle motion of the active part relative to the support frame, with variable forms and intensities of vibrations both at the loading and unloading points of the feeder. The values of vibrations at the loading points become commensurable with the value of bending vibrations at the unloading point in the zone of the vibration exciter attachment, which allows creating extra shearing force, overcoming resistance of material flow on the feeder surface and maintaining uniform flow of material along the transporting surface.

Figure 1 demonstrates two construction diagrams of a feeder with such support elements. In order to recover initial position, the elements can be hinged with spring-assistance on the frame (Figure 1a), or set in elastic holders fixed on the frame (Figure 1b).

![Figure 1](image_url)

**Figure 1.** Construction diagram of vibrating feeder with low-bending stiffness active part connected with the frame by support elements: (a) and (b) alternatives of loading point of the feeder; 1—active part; 2—frame support; 3—elastic support element at unloading points; 4—stiff support element in unstable equilibrium at the loading point; 5—vibration exciter; 6—elastic holder; 7—hopper.

The support can be elastic (e.g., flat springs) and bend. When suspended, the active part under the action of load can sag. The resultant tension force is transferred to the support elements and bends them. The support elements keep the active part strained owing to elasticity [8–10]. As there is no friction between the loaded active part and the frame, vibrations are intensified at the loading point, and coherent material is moved at the same rate along the length of the transporting surface.

The influence of stiffness of the support elements on the efficiency of vibro-discharge of coherent material from hopper was studied experimentally.

3. Numerical and experimental investigation results

The physical experimentation used a test bench composed of a vibro-feeder and a receiving container. The binder was sand clay composed of particles 0.005–0.1 mm in size, with clay content of 10%. Parameters of vibrations were determined a measurement and computation equipment. The time of discharge of measured volume of the coherent material was recorded.

The numerical modeling of the dynamics of feeder characterized with low bending stiffness was carried out using the finite element modeling in ANSYS environment.

The research has found that the amplitude of transverse vibrations at the loading point is independent of the stiffness of the support elements. The amplitude of longitudinal vibrations grows with the reduction in the stiffness. According to the calculation data, the maximum increase in the vibration amplitude is observed when the total stiffness of the support elements at the loading and unloading points, $E_{ls}$, is less than 40 kN·m². On the other hand, the physical tests show that given such stiffness, the active part of the feeder sags greatly, the slope of its unloading point is decreased and, as a consequence, the discharge capacity is reduced by 1.3–1.6 times [11]. Thus, parameters of support elements are limited by the allowable sag of the active part. The observations over the coherent...
material discharge reveal that the use of elastic support elements in the structure of vibro-feeder enables uniform decrease of the material level in the volume of the hopper.

Aimed to prevent adhesion of material to the surface of the active part, it is proposed to equip the latter with the flexible movable elements, e.g. chains or ropes freely placed on the active part of the feeder and fixed at the loading point (Figure 2) [12].

![Figure 2. Vibrating feeder: 1—active part; 2—vibration exciter; 3—support frame; 4, 5—elastic support elements at the unloading and loading points; 6—flexible movable elements.](image)

After the vibration exciter is actuated, coherent material is moved on the active part, tenses elements 6 in the line of unloading and presses them to the transporting surface. Under bending vibrations of the feeder, the contact between it and elements 6 is cyclically broken and recovered. At the same time, material on the vibrating surface is mixed, and the adhered material layer is decomposed, which improves efficiency of the vibro-feeder operation with adhesive materials.

With hit materials, it is possible to use heat-proof elastic (e.g., metal) plates (Figure 3) [13]. Each plate has a small length. The plates are arranged in two layers. In each layer, the plates are rigidly fixed in conjunction with each other and bent in the direction of active part 1. The bottom layer plates 5 freely lie on the feeder surface and the top layer plates 4 cover the conjunctions of the bottom player plates.

![Figure 3. Construction diagram of vibro-feeder with heat-proof seals: 1—active part; 2—walls of frame; 3—elastic support elements; 4, 5—elastic sealing plates to prevent spills.](image)
The seals have small lengths and are not connected rigidly; thus, even a mild force is sufficient for their elastic deformation. Bending vibrations generated in the active part under the actuation of the vibro-exciter make the plates bend too, but their contact with the transporting surface of the feeder is unbroken. Arrangement of the plates in two layers securely prevents spills, making the plates heat-proof allows using the feeder in transportation of hot materials. As the active part of the feeder is suspended on the frame, it is possible to supply cold air to the vibration exciter for cooling.

Spontaneous flow of material from the hopper in case of no vibrations can be prevented by a self-closing gate (Figure 4) [14]. The unloading section of the active part should be arch-wise bent downward. The gate composed of a flap and a back-balance is hinged on the frame at the level of the unloading end of the elastic active part.

When off-load (unactuated vibration exciter), back-balance 3.2 is directed vertically down (position a) so that the force moment created by the flap weight relative to the hinge exceeds the force moment created by the flap weight. Flex 3.1 closes completely the discharge hole of the hopper 4 and prevents unprompted flow of material on the active part 1 at the angle of repose. When the vibro-exciter 5 is actuated, loose material is moved along the active part 1 and creates pressure on the self-closing gate flap with increasing the force moment relative to the hinge. The gate turns toward the discharge side such that the flap goes from the position a to the position b and becomes an extension of the unloading point of the active part of the feeder. As the exciter is unactivated, the forced discharge of loose material is stopped. As the unloading section of the active part is arch-wise bent downward, its incline relative to horizontal line in the zone of the unloading end is higher than the angle of repose of loose material. Therefore, loose material moves by gravity and leaves totally this section of the active part. The force moment of the back-balance relative to the hinge becomes higher than the force moment of the flap and re-puts the self-closing gate into initial position. The discharge hole is shut.

The self-closing gate prevents spills of loose materials. The gate turns by itself without extra energy intake.

4. Conclusions
The use of support elements to connect the active part and the frame, as well as auxiliary movable flexible elements, elastic metal seals and self-closing gate allows handling of loose and difficult-to-transport materials, including, coherent, adhesive and hot. The proposed diagrams can be grouped in any combination, which will make it possible to expand capacities of vibrating feeders equipped with active part of low bending stiffness in discharge of geomaterials from hoppers.
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