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ВІБРАЦІЙНІ КОНВЕЄРИ, ОСОБЛИВОСТІ БУДОВИ ТА ЕКСПЛУАТАЦІЇ

АНОТАЦІЯ*. У статті розглянуто конструктивні особливості, принципи роботи та переваги сучасних вібраційних транспортерів і конвеєрів, що застосовуються для транспортування сипких матеріалів у промисловості. Проаналізовано вплив різних конструктивних рішень на ефективність роботи обладнання, зокрема використання самобалансних вібраторів, напрямлених коливань та адаптивних систем регулювання потужності. Окрему увагу приділено питанням енергоефективності, довговічності та мінімізації експлуатаційних витрат. Розглянуто перспективи розвитку технологій транспортування матеріалів, зокрема впровадження інноваційних рішень у конструкції вібраційних конвеєрів для підвищення продуктивності та оптимізації витрат виробництва.*

Ключові слова: *вібраційний транспортер, інерційний транспортер, самобалансний вібропривід, енергоефективність, транспортування сипких матеріалів, промислові конвеєри, буровий шлам.*

VIBRATORY CONVEYORS: DESIGN FEATURES AND OPERATION

ABSTRACT. *The article examines the structural features, operating principles, and advantages of modern vibratory transporters and conveyors used for transporting bulk materials in industry. The impact of various design solutions on equipment efficiency is analyzed, particularly the use of self-balancing vibrators, directed oscillations, and adaptive power control systems. Special attention is given to energy efficiency, durability, and the minimization of operational costs. The prospects for the development of material transportation technologies are considered, including the implementation of innovative solutions in vibratory conveyor design to enhance productivity and optimize production costs.*

Keywords: *vibratory transporter, inertial transporter, self-balancing vibration drive, energy efficiency, bulk material transportation, industrial conveyors, drilling mud.*

1. Problem statement. Modern industrial enterprises are constantly faced with the need to increase the efficiency of transporting bulk materials, optimize production processes and reduce operating costs. Traditional mechanical conveyors, despite their reliability, have a number of disadvantages, including high energy consumption, significant wear of working elements and difficulty in maintenance.

Vibrating conveyors and conveyors offer a number of advantages, including uniform material movement, the ability to operate in difficult conditions, and reduced structural stress. However, there are also certain technical challenges, such as the dependence of the amplitude of oscillations on the load, the need for precise balancing of the system, and the impact of vibrations on supporting structures.

One of the key issues is the selection of the optimal design of a vibrating conveyor depending on the operating conditions and material characteristics. Factors such as the type of drive, frequency characteristics of vibrations, method of fastening and damping, as well as the possibility of integration into existing process lines must be taken into account.

Thus, the current task is to research and improve the designs of vibrating conveyors to ensure their high productivity, reduce energy consumption, and increase durability when transporting bulk materials in various industries.

2. Analysis of publications on the research topic. The transportation of bulk materials by mechanical means is a key stage in many production processes, which determines the efficiency and productivity of industrial systems. Studies of theoretical and applied aspects of this process [1–4, 7–8] allow us to generalize modern methods of designing equipment intended for the transportation of bulk cargoes. However, despite a significant number of scientific developments, there is still no single systematized theory that would comprehensively describe all the mechanisms and patterns of the movement of bulk materials [6–8].

One of the common approaches to the analysis of the transportation process is the probabilistic theory, which is based on modeling the motion of individual grains along the transporting surface [3–8]. Within the framework of this approach, it is assumed that a spherical grain interacts with the conveyor surface according to probabilistic laws, and its initial parameters determine the further trajectory of motion [7–8].

Current research in this area focuses on the influence of geometric parameters of conveying surfaces on the efficiency of material movement. The determining factors are the shape of the surface, the amplitude and frequency of vibrations, and the angle of inclination of the working plane. It has been established that the optimization of these parameters allows to increase the speed of conveying and ensure the uniformity of the material flow. Further development of scientific approaches in this area is aimed at improving existing technological solutions and creating new designs of conveying systems capable of ensuring high productivity and reliability of operation in modern production conditions.

3. Purpose and objectives of the study. The purpose of the article is to analyze and optimize the designs of vibrating conveyors to increase the efficiency of transporting bulk materials, reduce energy consumption and increase the durability of the equipment. The study considered existing designs of conveyors, identified the main factors affecting their efficiency and energy consumption, developed a method for calculating dynamic characteristics, and analyzed the influence of design parameters on the performance and reliability of the system. The task of the study is to analyze the design features of vibrating conveyors, assess their efficiency and reliability, and develop recommendations for optimization to increase productivity and reduce energy consumption.

4. Analysis of modern approaches to the transportation of bulk materials by vibrating conveyors

Vibrating flat conveying devices are characterized by a wide range of design solutions and methods of excitation of vibrations (Fig. 1).

In modern production, the most common are gyration (eccentric) and inertial vibrating conveyors. The latter, depending on the nature of the oscillations, are divided into devices with non-directional (in particular circular) oscillations and models with directional oscillations, known as self-balancing conveyors.

The main function of vibrating conveyors is to move and sort materials by size during the transportation process. The trajectory of movement, amplitude and nature of vibrations are determined by the dynamic characteristics of the system, which depend on the coercive force generated by the drive, the mass of the moving elements, the number and properties of the elastic elements, as well as their location in the structure.

Fig. 1. Vibrating conveyor

The movement of material in vibrating conveyors is provided by the oscillatory movement of the moving part of the frame. Such devices are used for transporting and sorting lumpy and loose materials, separating the solid phase pulp into fractions of different sizes through calibrated holes in the transporting surface, removing moisture from the material, as well as for combined operations, such as washing the material with subsequent separation of small particles and their dehydration. Structurally, vibrating conveyors have much in common with vibrating screens, which is explained by the similarity of the principle of their operation.

Due to their wide functionality, vibrating conveyors are actively used in various industries. In the mining sector, they are used for transporting and segmenting materials before crushing, washing before enrichment in difficult environments, cleaning suspensions and dewatering enriched products. In the mining, chemical and coal industries, these devices provide sorting of products such as coal, crushed stone or sand-gravel mixtures before their shipment to end consumers. In metallurgy, vibrating conveyors are used to separate small particles unsuitable in size from the composition of raw pellets, as well as for re-sorting after their firing. The productivity of such installations is selected in accordance with the requirements of a specific production, and the transportation efficiency reaches 95%.

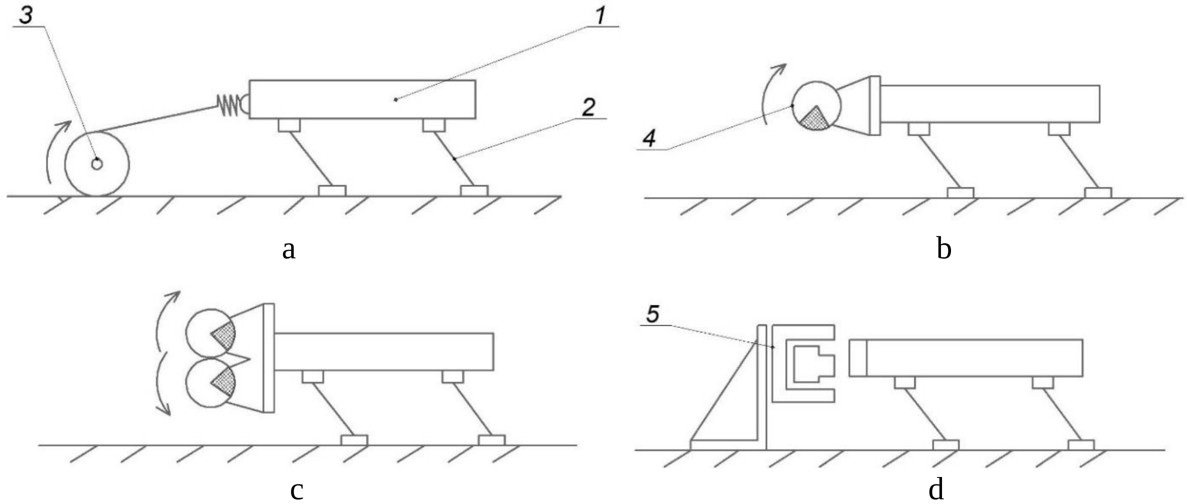
Various design schemes and excitation mechanisms of vibrating conveyors are shown in Fig.2.

Comparing flat vibrating conveyors with other types of similar equipment, we can note their lower weight and more compact dimensions with the same productivity. Higher efficiency is achieved due to the constant involvement of the entire conveyor plane in the transportation process and the active phase of throwing the material, which improves its uniform distribution and movement.

The design of the working surface of vibrating conveyors is presented in various options, which are shown in Figure 3.

Vibrating conveyors are widely used in various branches of mechanical engineering due to the high requirements for quality and reliability, which are mandatory for equipment of this type. The specifics of the design of these conveyors, based on the principle of dynamic excitation of vibrations, imposes special requirements on their operational characteristics. The main indicators that determine the quality and reliability of vibrating conveyors are the stability of the system, the coefficient of the coercive force and the balance of the structure.

Among the various types of vibrating conveyors, inertial conveyors have gained the greatest popularity in the modern non-metallic materials industry. Due to their simple design, high reliability and cost-effectiveness, these devices are gradually replacing alternative options. Inertial conveyors demonstrate high performance and stability even under difficult operating conditions, which makes them an ideal choice for intensive production processes.



1 – movable frame; 2 – springs; 3 – eccentric drive; 4 – vibration damper unbalanced ; 5 – electromagnetic vibration exciter

a) eccentric mechanical drive; b) vibration unbalanced drive; c) vibration unbalanced directional action; d) electromagnetic

Fig. 2. Structural diagrams and excitation elements of vibrating conveyors

The design features of inertial conveyors also ensure minimal maintenance requirements, which, in turn, reduces equipment operating costs. Due to their versatility, inertial conveyors are able to move materials of various fractions, which makes them indispensable in the mining, construction and metallurgical industries.

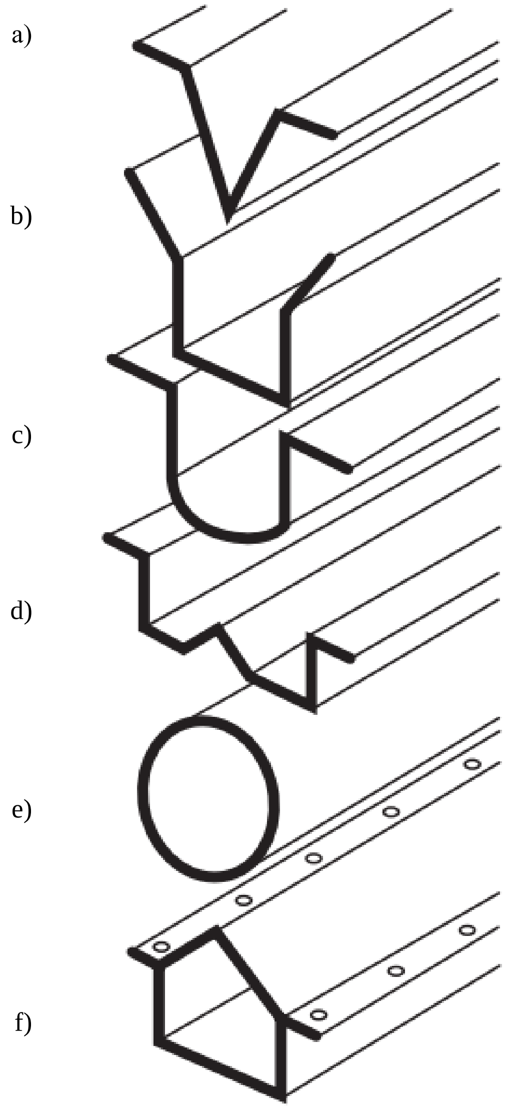
The use of inertial vibrating conveyors at enterprises allows not only to optimize production processes, but also to significantly reduce equipment maintenance costs, thus increasing overall work efficiency.

In the conditions of constantly increasing standards of environmental friendliness and productivity of production processes, conveyors remain important components in material transportation systems. In particular, in the operation of inertial conveyors with simple unbalanced vibrators, the geometric axis of the shaft together with the housing describes a cylindrical trajectory in space, which negatively affects the transportation process. This leads to uneven distribution of materials, increased wear of structural elements and a decrease in the efficiency of power transmission systems, in particular V-belt drives.

Alternatively, horizontal inertial conveyors with directional oscillations are used, which provide significant advantages due to the use of mounted vibrators. These mechanisms ensure directional movement of the conveyor body, which, in turn, contributes to the uniform movement of materials along the conveying surface.

Self-balancing conveyors have found wide application in production environments where space is limited, for example, in mobile crushing and screening plants or specialized technological schemes that require high accuracy and efficiency of operations. Their productivity can reach 160 tons per hour with a transportation efficiency coefficient of 90%. Fig. 4-5 show technological processes in which vibrating conveyors are used[5].

The main disadvantage of self-balancing conveyors is the complexity of their design, which leads to an increase in production costs and complicates maintenance. However, these disadvantages are compensated by a number of significant advantages. Among them, it is worth noting the reduced level of vibrations, high accuracy of material sorting and stable operation even in extreme operating conditions. Thanks to these characteristics, self-balancing conveyors become indispensable in production processes, where there are high requirements for reliability and minimization of operating costs. They are actively used in the construction, mining and chemical industries for transporting materials in difficult conditions.



a) v-shaped, b) flanged, c) rectangular with rounded bottom, d) rectangular with stiffening rib, e) tubular, f) rectangular with covered top

Fig. 3. Types of working surface of vibrating conveyors

However, inertial conveyors have a common drawback: the dependence of the amplitude of oscillations on the load level. When starting or stopping such devices, a sudden increase in the amplitude of oscillations of the box is observed. This creates additional dynamic loads, which, in turn, requires the installation of special foundations to protect building structures and elements of the transport system from these loads.

Despite these limitations, the numerous advantages of inertial conveyors make them popular among users. Simple design, low repair costs, high reliability in operation and efficiency of technical indicators have allowed these devices to occupy a stable position in the market. They have become an integral part of production processes in the mining, construction, metallurgical and agro-industrial sectors.

Today, the market offers a wide range of inertial conveyors with various design features, which allows you to choose the optimal solution for any operating conditions. Models with an average screening area are especially popular, such as conveyors of the Derrick and Smico series with vertical or circular oscillations, as well as Midwestern devices (USA).

Fig. 4. Technological process of transporting parts using a vibrating conveyor

Fig. 5. Technological process of transporting and dosing blanks

Midwestern models have a number of unique advantages, including low vibration levels on supporting structures, environmental friendliness, ease of maintenance, and the ability to be equipped with additional systems such as water spray or screen heating. The productivity of these conveyors is within 100 m^3/h, which makes them universal for transporting and sorting various materials. The Midwestern model , equipped with a multivibrator and a parallel-arc arrangement of sieve tiers, deserves special attention. This technical solution significantly increases the efficiency of transport operations and sorting materials, while reducing energy consumption. Thanks to these characteristics, conveyors of this design are gaining popularity in industry, in particular in conditions of high requirements for productivity and energy efficiency.

Modern inertial conveyors perform much more than just moving materials. They actively contribute to increasing the overall efficiency of production processes, which allows to reduce operating costs and strengthen the competitiveness of enterprises. This is achieved by integrating several different conveyors into a single system that optimizes all stages of material transportation and sorting.

One of the most common types of conveyors is the horizontal self-balancing model with a large screening area. Their capacity ranges from 80 to 400 m³/h, which provides an efficiency of up to 96%. These conveyors are particularly effective in sorting materials, as they require less height for installation in industrial premises. They are widely used for transporting and dewatering commodity materials, which makes them indispensable in various industries. A vivid example of such equipment is the products of the Chinese company WUXI CHANGRONG (Fig. 6), which has established itself on the market due to the high reliability and efficiency of its transport solutions.

Fig. 6. GZG200 vibrating conveyor

In modern industry, there is a growing demand for high-speed sorting machines operating on NSS (Non-Segregated Sorting) technology. Screening). One example is the solution of the company *Derrick* , which implements the principle of uneven load distribution on the screen: the initial part has a greater angle of inclination than the final one. This design provides high sorting efficiency and a significant reduction in energy consumption, which makes these systems optimal for production with increased requirements for productivity and energy efficiency.

The use of such technological solutions allows to significantly increase productivity and reduce operating costs during the transportation of materials. This contributes to the increase in the overall cost-effectiveness of production and its competitiveness. In particular, resonant conveyors have found wide application abroad in the movement of coal, ores, crushed stone , anthracite, sand-gravel mixtures and other bulk materials. They demonstrate productivity up to 300–350 t/h with a transportation efficiency coefficient of 90–96%. In the EU countries, such systems are used less often, mainly in the coal industry. Their main advantage is the increased efficiency of engine power compared to other types of vibration devices. The production of resonant conveyors is carried out under licenses of American, Japanese and Italian companies.

Special attention is paid to conveyors of the Austrian company *L. Binder* , which are distinguished by high reliability and long service life. Analysis of the main types of conveyors for working with non-metallic materials allows us to determine the prospects for the development of the industry and ways to improve transportation methods. The main criteria for evaluating such systems remain productivity, efficiency of material movement and the degree of contamination of the upper layers of the bulk mass. Only some models of conveyors are equipped with mechanisms for regulating the speed of material movement using controlled oscillations.

Among the innovative developments, it is worth noting the modular vibrating conveyors *BRUKS SIWERTELL GROUP* , which are characterized by high efficiency and versatility in transporting and processing bulk materials of various fractions, including large-sized and long elements of processed wood. In particular, the *CV330 conveyor (Figure 7)* is widely used for transporting wood, which is confirmed by its practical use in relevant production processes.

Fig. 7. CV330 Vibrating Conveyor

The design of vibrating conveyors ensures a consistently high transport speed even under significant dynamic loads. Such devices can be integrated into complex production lines and adapt to changing operating conditions. One of the effective solutions is their combination with *Bruks sorting screens* , which ensures high-quality separation of large and small particles of material directly during the transport process. In some cases, this eliminates the need for separate sorting units, which increases the versatility of the system.

Vibrating conveyors are widely used in conjunction with horizontal chippers and are compatible with gravity- fed systems. In addition, they can be equipped with built-in metal detectors or heating elements, which significantly expands their functionality. This is especially important for operation in low temperature conditions or increased requirements for raw material purity control.

The main applications of such conveyors include the sawmill and pulp and paper industries, as well as bioenergy facilities. They are available in light, medium and heavy duty designs, allowing them to transport a wide range of materials: from logs and boards to wood scraps, shavings, sawdust and bark.

One of the key advantages of these systems is the ability to transport different materials in parallel without mixing them, which makes them indispensable in modern production processes with high demands on selective movement of raw materials.

Each vibratory conveyor can be adapted to specific operating conditions to achieve maximum efficiency and optimal technical characteristics. For example, the use of guide fins in the bottom of the chute promotes correct orientation of the material, which is especially important when shredding short wood waste (Figure 8-9).

Vibrating conveyors are characterized by low operating costs due to the design in which the tray is supported by springs driven by a crankshaft and one or more connecting rods. The use of steel or fiberglass springs ensures high durability of the system and minimizes the need for maintenance. Reinforced mountings contribute to smooth starting and stopping of the equipment, which increases overall reliability of operation.

By distributing the material evenly over the conveying surface, the vibratory motions minimize shock loads, preventing damage to the raw material. The design of the conveyors can be balanced or unbalanced depending on the budget requirements and the type of foundation. Concrete bases or built-in counterweights are used to compensate for dynamic loads.

Fig. 8. Transportation of waste from wood processing enterprises [3]

Fig. 9. Transportation and sorting of waste from wood processing enterprises [3]

Due to their high versatility, durability and energy efficiency, vibratory conveyors are the optimal solution for transporting materials in various industries. Their use ensures maximum efficiency of transport operations with minimal maintenance costs.

6. Conclusions. As a result of the study, it was found that vibrating conveyors, due to their structural simplicity and versatility, are effective and reliable solutions for transporting materials in various industries. The use of inertial conveyors with self-balancing vibrators significantly increases the stability and productivity of work, reducing the level of vibrations and improving the sorting of materials. However, their complexity and cost of production can be significant limitations for use in some conditions. The choice of the optimal type of conveyor depends on the specific requirements of the production process, in particular, on the required productivity, sorting efficiency and energy consumption. Further improvement of the designs of vibrating conveyors and the introduction of innovative technologies will reduce maintenance costs and increase the competitiveness of enterprises.

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