Ihnatiev Oleksandr, Postgraduate Student, https//orcid.org/0009-0003-6401-6765

Savielieva Oksana, Doctor of Technical Sciences, Professor, Department of machine dynamics and mechanical engineering, National University “Odesa Polytechnic”, Ukraine, https//orcid.org/0000-0002-0453-4777

STRUCTURAL ANALYSIS AND DEVELOPMENT TRENDS OF DRAG CHAIN CONVEYORS USED IN THE AGRO-INDUSTRIAL SECTOR

Abstract

The article investigates the current state, design features, and development trends of drag chain conveyors widely used in the agro-industrial sector of Ukraine for the transportation of grain, compound feed, oilseed processing products, and other bulk materials. The relevance of improving conveying and technological equipment is substantiated by the significant role of the agricultural sector in the national economy and the growing requirements for the efficiency of logistics processes. A review of scientific publications devoted to the energy efficiency, reliability, operating dynamics, and structural optimization of drag chain conveyors has been carried out.

An overview of the Ukrainian drag chain conveyor market is presented, including an assessment of the ratio between domestic and imported manufacturers and the identification of the main directions of industry development. The design of the main conveyor components, including conveyor casings, drive stations, tensioning stations, and various types of traction chains, is analyzed. Plate chains, welded steel chains, and fork chains are characterized with consideration of their operational advantages and disadvantages. The influence of design solutions and construction materials on the reliability, durability, energy efficiency, and manufacturability of the equipment is

examined. Particular attention is paid to the use of modern lining materials for extending conveyor service life under conditions of intensive abrasive wear.

The research findings may be applied in the design, modernization, and selection of drag chain conveyors for agro-industrial enterprises.

Keywords: drag chain conveyor, agro-industrial complex, grain processing, traction chain, drive station, tensioning station, energy efficiency, reliability, technological production, bulk material transportation.

Problem statement

Ukraine's agro-industrial complex is one of the fundamental sectors of the national economy, ensuring food security, generating a significant share of foreign exchange earnings, and contributing to the development of related industries such as mechanical engineering, logistics, and energy. The sector provides employment for a substantial proportion of the population (up to 14% of total employment), which is an important factor in maintaining social stability. Furthermore, due to its considerable natural resource potential, the sector remains highly attractive for investment.

According to data provided by the Ministry of Agrarian Policy and Food of Ukraine, the combined contribution of agriculture and agricultural processing to the country's gross domestic product accounts for approximately 17–20%, while agricultural and food products constitute 40–45% of total exports. Therefore, the development and improvement of technological equipment used for the processing, storage, and transportation of agricultural products represent an important scientific and practical challenge.

One of the key components of internal logistics systems at agro-industrial enterprises is the drag chain conveyor (DCC). These conveyors are widely used for horizontal and inclined transportation of grain, compound feed, oilseed cake, bran, fertilizers, and other bulk materials. Owing to their design, drag chain

conveyors ensure continuous material handling even under severe operating conditions characterized by high dust concentrations, temperature fluctuations, and increased humidity.

It is estimated that approximately 1,200–1,500 new drag chain conveyors are installed annually in Ukraine as part of elevator modernization projects and the construction of new agro-industrial facilities. The conveyor equipment market offers both domestically manufactured conveyor and chain systems as well as imported solutions developed by foreign manufacturers. These systems differ in design approaches, operational characteristics, and manufacturing technologies. Consequently, there is a growing need for obtaining reliable scientific and technical data regarding the structural features and market development trends of drag chain conveyors, as well as the influence of their design and material parameters on operational efficiency, reliability, and lifecycle costs.

Analysis of recent research and publications

The problem of efficient bulk material transportation, particularly in the agricultural sector, has been the subject of numerous studies in applied mechanics, materials science, and mechanical engineering. Considerable attention has been paid to the design analysis of drag chain conveyors, as well as to improving their energy efficiency, wear resistance, operational reliability, and adaptability to agro-industrial operating conditions.

Reference [1] provides a comprehensive review of the development, classification, design aspects, and application areas of mechanical conveyor systems. Various conveyor types, including belt, roller, chain, screw, and overhead conveyors, are examined with particular emphasis on their unique characteristics and advantages that contribute to improving industrial efficiency, productivity, and sustainability.

In study [2], conveyor designs intended for bulk material handling are investigated. The authors focus on selecting conveyor types according to material properties and operational requirements to achieve high productivity and energy efficiency. Particular attention is given to the advantages of belt and apron conveyors used in construction industries.

Paper [3] proposes essential safety measures for enclosed chain conveyor systems. Special attention is paid to loading and unloading zones, as well as drive components that may present operational hazards. Recommendations for implementing effective workplace safety practices are provided.

The modernization of chain conveyor designs is discussed in [4], where modifications to roller assemblies are proposed to increase service life and reduce energy consumption. The replacement of friction bushings with anti-friction bearings resulted in reduced failure rates, lower maintenance requirements, and improved operational efficiency.

Study [5] presents an analysis of the energy efficiency of Z-type chain conveyors and proposes optimization approaches. Based on an analytical model, several methods for reducing energy consumption without compromising productivity were developed.

Research [6] investigates the dynamic characteristics of drag chain conveyors, particularly the effects of chain speed fluctuations and terrain-induced disturbances on conveyor performance. The analysis of vibration signals enabled the development of recommendations aimed at reducing wear and improving operational efficiency.

The authors of [7] evaluated the influence of chain friction on conveyor dynamics and energy efficiency. Using spatio-temporal dynamic characteristics, relationships between vibration amplitudes and energy consumption were identified, providing opportunities for system optimization.

In [8], the Discrete Element Method (DEM) was applied to optimize the

geometry of conveyor flights. Numerical simulations were used to determine the influence of flight geometry on material transportation and to identify design parameters that improve productivity while reducing energy consumption.

Paper [9] examines the operating mechanism of trough chain conveyors and analyzes the resistance forces acting on transported materials. The study demonstrates the importance of proper chain design for ensuring energy-efficient operation and optimal performance of bulk material handling systems.

The reviewed studies provide a scientific basis for further investigations into drag chain conveyor design, performance evaluation under actual operating conditions, and the analysis of market trends and technological developments in agricultural logistics mechanization.

Purpose of the article

The purpose of this study is to analyze the design features, materials, and market development trends of drag chain conveyors used in the Ukrainian agro-industrial sector and to identify opportunities for improving their reliability, manufacturability, and energy efficiency.

To achieve this objective, a comparative analysis of domestic and imported traction chains and conveyor structural components was carried out, and their influence on operational performance indicators was evaluated.

Presentation of the main material of the study

The Ukrainian market demonstrates a stable annual demand for drag chain conveyors (DCC). According to industry estimates, approximately 1,200–1,500 new conveyors are installed annually as part of elevator modernization projects and the construction of new grain storage and agro-industrial facilities.

Grain elevators, storage facilities, and grain terminals use drag chain conveyors for handling a wide range of agricultural products, including wheat,

corn, barley, soybean, sunflower seeds, and other crops. These conveyors are employed for transporting grain from receiving points to cleaning and drying equipment, transferring material between bucket elevators, silos, and dryers, as well as loading grain into transportation systems and transfer stations.

Most conveying routes are designed as horizontal or inclined systems. Modern conveyor designs enable the creation of complex conveying lines incorporating multiple loading and unloading points controlled by automated gate systems.

In feed production facilities, drag chain conveyors play a critical role in transporting crushed grain, meal, premixes, protein supplements, and mineral additives. The conveyors are integrated into dosing systems, supplying components to mixers and transferring finished products to packaging or storage units. Their precise and continuous material flow contributes significantly to maintaining feed formulation consisten.

Oil-processing plants utilize drag chain conveyors for transporting by-products such as oil cake, meal, husks, and granulated residues generated during oil extraction and pressing processes. In addition, they may serve as components of raw material preparation systems, particularly in facilities processing sunflower seeds and soybeans.

Industry estimates indicate that during 2023–2025 Ukrainian manufacturers accounted for approximately 65–70% of the domestic drag chain conveyor market. This position is attributed to both economic factors, including lower logistics costs and local supply chains, and technical factors, such as the ability of domestic manufacturers to adapt equipment to the specific operating conditions of Ukrainian grain handling facilities.

Among the leading domestic manufacturers are: KMZ Industries, Eskeeper, Grain Capital, Lubnymash. These companies supply conveyors with capacities ranging from 20 to 1,000 t/h and offer galvanized or painted conveyor casings

designed for operation in grain-processing environments.

Imported equipment accounts for approximately 30–35% of the market and is primarily represented in specialized applications, including:

– stainless-steel conveyors for food and chemical industries;

– highly automated conveying systems with complex routing configurations.

The major foreign suppliers originate from Türkiye (Mysilo, Obial), Sweden (Skandia elevator), Latvia (Preco), Denmark (Monsun, Cimbria), Italy (AGI PTM), USA (GSI), China (Muyang) and Switzerland (Buhler).

The performance, durability, and reliability of drag chain conveyors are determined by several key structural units. A typical conveyor consists of: conveyor casing (trough); traction chain with flights; drive station; tensioning station; loading and unloading devices; monitoring and safety systems.

The conveyor casing represents the primary load-bearing component of the conveyor system. It performs two essential functions: forming an enclosed channel for material transportation; providing structural support for the chain and flights while withstanding static and dynamic loads.

The quality of the casing directly affects energy efficiency, wear resistance, conveying speed, service life, and noise levels.

The operational performance of the casing depends on several factors, including material selection, wall thickness, and geometric dimensions (Table 1).

The drive station provides conveyor motion through a geared motor that transmits torque to the drive sprocket. Drive selection depends on conveyor capacity, conveying distance, operating conditions, installation constraints, and maintenance requirements.

Several drive configurations are commonly employed in drag chain conveyors (Figure 1).

The bevel-helical gear motor is one of the most widely used drive solutions

due to its high reliability and compact design. Its mechanical efficiency may reach 96%. The hollow output shaft allows direct mounting onto the drive shaft using a keyway or shrink disc connection, simplifying installation and maintenance procedures.

Parallel-shaft helical gear motors also provide high efficiency, reaching approximately 96%. Their installation characteristics make them suitable for applications with limited mounting space, such as under-silo and over-silo galleries.

An important advantage is their lower manufacturing cost, typically 5–15% lower than that of bevel-helical gear units. As a result, they are frequently selected when installation space limitations are not critical.

Table 1. Comparative Characteristics of Conveyor Casings Manufactured by Different Companies.

Parameter	KMZ Industries	Eskeeper	Grain Capital	Lubnymash	Cimbria	Preco
1	2	3	4	5	6	7
Capacity: 50 t/h						
Casing cross-section (W × H), mm	200 × 360	200 × 340	190 × 330	200 × 340	190 × 380	200 × 280
Chain speed, m/s	0.55	0.70–0.75	0.70	0.65–0.75	0.55	0.70
Steel thickness, mm:						
– Bottom plate	4	3	3	3	3	2 + 10*
– Side walls	3	3	2	3	2	2
– Cover	1.5	2	1.5	1.5	2	1.5
Capacity: 100 t/h						
Casing cross-section (W × H), mm	320 × 470	320 × 470	300 × 350	300 × 410	280 × 470	330 × 360

Continuation of table 1

1	2	3	4	5	6	7
Chain speed, m/s	0.55–0.65	0.65–0.75	0.70	0.65–0.75	0.55–0.60	0.60–0.70
Steel thickness, mm:						
– Bottom plate	4	4	3	3	3	2 + 10*
– Side walls	3	3	3	3	3	2
– Cover	1.5	2	1.5	1.5	2	1.5
Capacity: 200 t/h						
Casing cross-section (W × H), mm	450 × 470	400 × 470	400 × 470	450 × 470	440 × 470	200 × 280**
Chain speed, m/s	0.55	0.70–0.75	0.70–0.75	0.65–0.75	0.55–0.60	0.70
Steel thickness, mm:						
– Bottom plate	4	4	4	4	4	2 + 10*
– Side walls	3	3	3	3	3	3
– Cover	1.5	2	1.5	2	2	1.5

* Additional wear-resistant liner (typically UHMW-PE or wear-resistant steel) with a thickness of 10 mm.

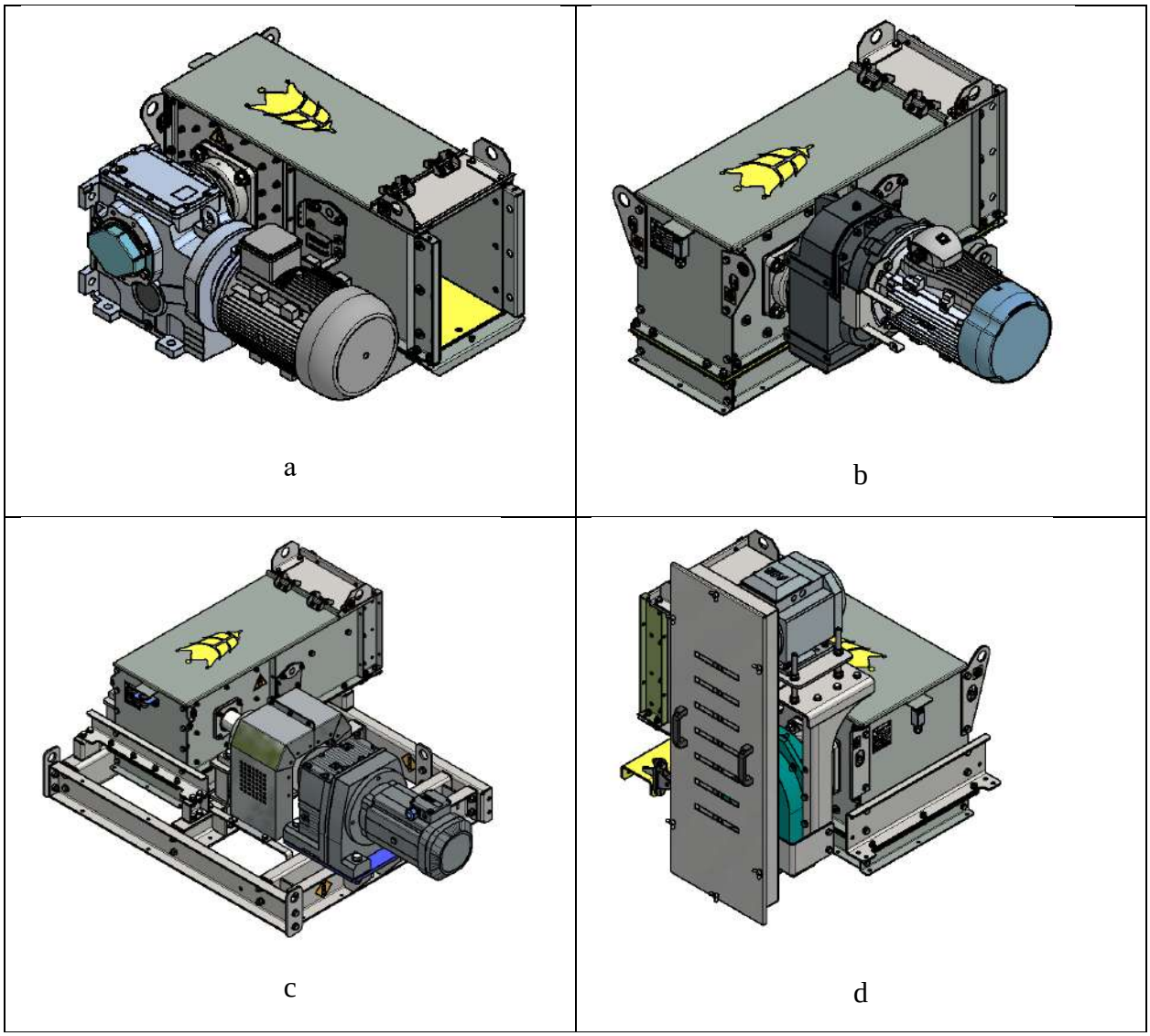
** The value should be verified with the manufacturer's catalogue, as the indicated cross-section appears inconsistent with the stated conveyor capacity of 200 t/h

Inline drive systems equipped with flexible couplings compensate for shaft misalignment, dampen vibrations, and protect drivetrain components from shock loads.

Such systems provide enhanced durability and maintainability, particularly in high-capacity and long-distance conveyors. Although their overall dimensions are larger than those of alternative drive arrangements, they remain attractive because of their simplicity, reliability, and economic efficiency.

Gear motors combined with V-belt transmissions are less frequently used in modern conveyor systems. Their advantages include smooth operation, vibration

reduction, simple speed ratio adjustment, and protection against motor overloads.



a – bevel-helical geared motor; b – parallel-shaft helical geared motor; c – inline geared motor; d – geared motor with V-belt transmission

Figure 1. Conveyor Drive Types.

However, the need for continuous monitoring and periodic adjustment of belt tension significantly limits their practical application.

The purpose of the tensioning station is to maintain the required chain tension and compensate for chain elongation during operation. The most common tensioning systems include: screw tensioners; counterweight tensioners;

spring tensioners; hydraulic tensioners.

The screw tensioning mechanism is the most widely used solution. Chain tension is adjusted through a threaded mechanism that gradually moves the driven sprocket. The system is characterized by reliability, simplicity, low cost, and accurate adjustment. However, it requires periodic manual adjustment, especially under intensive operating condition.

Counterweight tensioners automatically maintain chain tension through gravitational force acting via pulleys and cables connected to the sprocket shaft. Their main advantage is the ability to provide a constant tension force regardless of chain elongation. This reduces shock loads, improves operational smoothness, and extends chain service life. The main disadvantages are increased structural weight and the requirement for additional installation space.

Spring tensioners employ elastic components to compensate for chain elongation and absorb short-term fluctuations in chain tension. Such systems are commonly used in compact or mobile conveyors where counterweight installations are impractical. Their advantages include ease of installation and compact dimensions; however, they provide only a limited compensation range and require regular inspection of elastic elements

Hydraulic tensioners represent the most advanced tensioning solution currently available. Hydraulic cylinders automatically compensate for chain elongation and maintain optimal tension regardless of load variations. These systems provide superior adjustment accuracy and smooth operation. Their disadvantages include higher manufacturing costs and increased maintenance requirements.

The traction chain is the principal working element of a drag chain conveyor, responsible for transmitting pulling forces and moving flights through the conveying channel. The operational reliability, durability, energy efficiency,

and maintenance requirements of the conveyor largely depend on the type and quality of the chain employed.

Three major types of traction chains are commonly used in the Ukrainian market and industrial practice: plate chains manufactured according to national and international standards (DSTU, DIN), welded steel chains, and fork chains. Each type possesses distinct structural characteristics, advantages, limitations, and application areas.

Plate chains are the most widely used traction elements in drag chain conveyors. Structurally, they consist of two parallel side plates connected by pins, bushings, and, in some designs, rollers. Chain pitch and plate dimensions are standardized according to international or national standards, ensuring interchangeability and manufacturing consistency.

The main advantages of plate chains include high tensile strength, accurate pitch geometry, reliable attachment of flights, and ease of maintenance. They demonstrate satisfactory performance under dusty and moderately aggressive operating conditions while maintaining good resistance to abrasive wear.

Another important advantage is their compatibility with various attachment configurations used for mounting conveyor flights. Plate chains can be employed in both single-strand and double-strand conveyor systems, providing flexibility in conveyor design.

In most applications, plate chains are manufactured from alloy steels subjected to heat treatment processes to increase the hardness of pins and bushings. This significantly improves wear resistance and ensures stable operation under abrasive conditions. Consequently, plate chains represent the standard solution for medium- and high-capacity grain-handling conveyors.

Welded steel chains are primarily used in heavy-duty conveyor systems operating under high loads and severe service conditions. Typical applications include the transportation of compound feed, meal, moist grain mixtures, and

other bulk materials characterized by increased weight and abrasive properties.

These chains are composed of welded steel elements forming a rigid structure capable of withstanding substantial tensile and impact loads. Owing to their robust design, welded chains exhibit excellent resistance to deformation and are particularly suitable for environments involving abrasive dust, moisture, and fluctuating loading conditions.

The increased thickness of structural components and the larger contact area between pins and bushings contribute to an extended service life and reduced maintenance requirements. However, these advantages are accompanied by greater chain weight, which increases power consumption and dynamic loads on conveyor components.

Furthermore, manufacturing costs are relatively high due to the complexity of welding operations and the necessity of quality control procedures for welded joints.

Fork chains represent a high-strength cast-chain solution designed for demanding industrial applications. Each chain link consists of a fork-shaped casting that encloses the pin of the adjacent link, creating a large contact area and ensuring uniform load distribution.

This design provides exceptionally high tensile strength while maintaining a lower mass compared with conventional plate chains. As a result, fork chains are particularly suitable for long conveyors, high-capacity systems, and applications involving substantial shock loads.

Fork chains offer several important advantages: high tensile strength; superior wear resistance; reduced inertial mass; smooth conveyor operation; extended service life; excellent pitch accuracy throughout the operating period.

Maintaining pitch accuracy is particularly important for ensuring synchronized operation of conveyor flights and sprockets in long conveying systems.

Despite their technical advantages, fork chains remain relatively expensive due to the complexity of casting and machining processes. Additionally, maintenance and replacement of individual links may be more complicated compared with conventional plate-chain systems.

A comparison of the three major chain types indicates that plate chains remain the most versatile and economically attractive solution for grain-handling and feed-processing facilities. Welded steel chains are preferable for heavy-duty operating conditions where maximum durability is required, while fork chains represent a premium solution for high-capacity conveyor systems demanding exceptional strength and long service life.

Therefore, the selection of a traction chain should be based on a comprehensive assessment of conveyor capacity, operating conditions, expected service life, maintenance strategy, and economic considerations.

One of the most important factors affecting conveyor durability is the protection of surfaces exposed to intensive abrasive wear. During operation, conveyor casings, flights, loading zones, and discharge sections are continuously subjected to friction generated by transported bulk materials.

To reduce wear and extend service life, manufacturers increasingly employ wear-resistant lining materials applied to critical surfaces.

The most commonly used lining materials include: ultra-high-molecular-weight polyethylene (UHMW-PE); polyurethane; wear-resistant steels (Hardox, Raex, Creusabro); polymer composite materials; ceramic wear-resistant inserts (Table 2).

The analysis indicates that polymer-based lining materials are increasingly replacing conventional steel solutions in grain-handling applications due to their low weight, reduced friction coefficient, corrosion resistance, and ease of installation. Among polymer materials, UHMW-PE exhibits the most favorable combination of wear resistance and operational performance. However, in areas

exposed to intensive impact-abrasive wear, Hardox 450 and Hadfield manganese steel remain the preferred solutions owing to their superior durability and load-bearing capacity. Hybrid lining systems combining polymer and metallic materials represent a promising approach for extending conveyor service life while reducing energy consumption and maintenance costs.

Table 2. Comparative Characteristics of Wear-Resistant Lining Materials Used in Drag Chain Conveyors

Material	Wear Resistance	Application Area	Main Advantages	Limitations
PE-500 (HMW-PE)	Medium	Conveyor trough bottom, chain flights	Lightweight, food-grade approved	Not suitable for high temperatures or severe impact loads
PE-1000 (UHMW-PE)	High	Conveyor trough bottom, chain flights, loading and discharge chutes	Lightweight, food-grade approved, very low coefficient of friction	Not suitable for high temperatures or severe impact loads
Cast Nylon (PA-6, Polyamide)	Medium	Conveyor trough bottom, chain flights	Lightweight, high mechanical strength, good impact resistance	Not suitable for high temperatures or severe impact loads
TIVAR H.O.T. (High-Temperature UHMW-PE)	High	Conveyor trough bottom, chain flights, guide rails	Resistant to elevated temperatures, food-grade approved, low friction coefficient	High cost; not suitable for severe impact loads
PTFE (Polytetrafluoroethylene, PTFE)	Medium	Conveyor trough bottom, chain flights, guide rails	Excellent temperature resistance, chemically inert	High cost; relatively low abrasion resistance under abrasive conditions
Low-Hardness Polyurethane (Elastic PU)	High	Loading zones and grain impact areas	Elastic, absorbs impacts, low noise level	Not suitable for high temperatures or areas in direct contact with the chain

Current technological trends indicate increasing adoption of advanced polymer materials, composite structures, and hybrid lining systems combining several wear-resistant materials within a single conveyor.

Such solutions allow manufacturers to optimize the balance between durability, weight, energy consumption, and overall operating costs. Consequently, wear-resistant lining technologies are becoming one of the key directions for improving the performance and competitiveness of modern drag chain conveyors used in agro-industrial applications

Conclusions

The conducted study confirms that the development of drag chain conveyors is currently focused on improving operational efficiency, reliability, durability, and energy performance. The increasing use of advanced materials, modern drive technologies, automated control systems, and wear-resistant lining solutions contributes to the enhancement of conveyor performance and reduction of maintenance costs.

The analysis shows that the operational characteristics of drag chain conveyors are strongly influenced by the design and configuration of their main components, including the conveyor casing, drive station, tensioning system, and traction chain. The selection of appropriate structural solutions should be based on the required capacity, conveying distance, operating environment, and maintenance conditions.

A comparative assessment of the most common traction chain types used in Ukraine demonstrates that plate chains remain the most versatile solution for grain-processing facilities, while welded steel chains and fork chains provide advantages under heavy-duty operating conditions and increased abrasive wear. Furthermore, the application of modern wear-resistant lining materials significantly increases the service life of conveyor components and improves overall system reliability.

Future research should focus on the quantitative evaluation of the influence of chain design parameters, lining materials, and operating modes on the

durability, energy consumption, and economic performance of drag chain conveyors. The integration of digital monitoring technologies, predictive maintenance approaches, and advanced engineering materials is expected to become a key direction in the further development of high-performance conveyor systems for agro-industrial applications.

References

1. Deka, R., Borthakur, P. P., Baruah, E., Sarmah, P., & Saikia, M. (2024). A comprehensive review on mechanical conveyor systems: Evolution, types, and applications. *International Journal of Natural and Engineering Sciences*, *18*(3), 164–183.

2. Diachenko, O., Delembovskyi, M., Levchuk, K., & Protyven, O. (2024). An overview of the constructions of conveyors for moving bulk materials, comparison and study of their parameters. *Mining, Construction, Road and Reclamation Machines*, (103), 33–44. https://doi.org/10.32347/gbdmm.2024.103.0301

3. Živanić, D., Ilanković, N. Basic safety measures for chain conveyors (2023). *International Scientific and Professional Conference POLITEHNIKA–2023*. Belgrade, 15 December 2023. Belgrade. Mechanical Engineering / Occupational Safety. 302–307.

4. Radha Krishnan, B., Ramesh, M., Giridharan, R., Sanjeevi, R., & Srinivasan, D. (2018). Design and analysis of modified idler in drag chain conveyor. *International Journal of Mechanical Engineering and Technology, 9*(1), 378–387.

5. Shaikh, A., Bobere, F., Khatawate, V. H., & Patole, A. (2012). Design and energy optimization of Z-type chain conveyor. *International Journal of Engineering Research and Applications, 2*(4), 1421–1424.

6. Jiang, S., Huang, S., Mao, Q., Zeng, Q., Gao, K., & Lv, J. (2022). Dynamic properties of chain drive in a scraper conveyor under various working con-

ditions. *Machines*. Vol. 10, № 7. Article 579. DOI: https://doi.org/10.3390/machines10070579.

7. Osychev, O., & Tkachenko, A. (2021). Enerhozberezhennia ta enerho-audyt na osnovi analizu enerhetychnykh system [Energy saving and energy audit based on the analysis of energy systems]. *Enerhetyka, Elektronika ta Elektromekhanika*, (5–6), 159–160. https://doi.org/10.20998/2313-8890.2021.05.02.

8. Zidek, M., Zegzulka, J., Jezerska, L., Hlosta, J., & Necas, J. (2015). Optimisation of geometry of the chain conveyor carriers by DEM method. *Inżynieria Mineralna – Journal of the Polish Mineral Engineering Society*, 16(2), 143–148.

9. Katterfeld, A. (2021). Conveying and construction machinery. In K.-H. Grote (Ed.), *Springer handbook of mechanical engineering* (pp. 829–991). Springer. https://doi.org/10.1007/978-3-030-47035-7.