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на тему

<u>ОПТИМІЗАЦІЯ РЕЖИМУ РУХУ СТРІЧКОВОГО КОНВЕЄРА ДЛЯ ТРАНСПОРТУВАННЯ КОРЕНЕПЛОДІВ</u>

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НАЦІОНАЛЬНИЙ УНІВЕРСТИТЕТ БІОРЕСУРСІВ
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Перелік питань, що підлягають дослідженню:

1. Провести аналіз існуючих конструкцій стрічкових конвеєрів
2. Розглянути перспективи створення нової конструкції стрічкового конвеєра
3. Виконати розрахунок стрічкового конвеєра
4. Розглянути питання охорони праці при роботі крокового маніпулятора
5. Виконати розрахунок економічної ефективності

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ABSTRACT

The master's thesis includes an abstract, introduction, six chapters, conclusion, references and appendices.

The master's qualification work describes the design of belt conveyors, their operating conditions and use in various industries. Their disadvantages, advantages and prospects for improvement are identified. The method of morphological analysis was used to develop design options for belt conveyors and their drive mechanisms.

In the master's qualification work, based on the method of morphological analysis, a new design of a belt conveyor and its drive mechanism was developed. The dynamic analysis of the belt conveyor motion was carried out, on the basis of which the loads in the structural elements and the drive were determined. To reduce the effect of dynamic loads and vibrations in the structural elements of the belt conveyor, the drive mechanism was optimized.

The master's work substantiates the measures for labor protection during the operation of the conveyor during the transportation of root and tuberous fruits, as well as economic calculations on the feasibility of developing a new design.

Key words: belt conveyor, drive, dynamic analysis, motion mode, optimization.

INTRODUCTION

Conveying machines, including belt conveyors, are widely used in technological and transportation operations in various industries. They are widely used to mechanize and automate production processes in order to increase productivity and improve working conditions.

Belt conveyors are designed to move massive loads of the same type in a continuous flow along a complex route, which may consist of vertical, horizontal, inclined and curved sections. Belt conveyors are widely used in technological processes, as well as in transportation and loading and unloading operations. They are used for loading and unloading bulk materials, piece goods, semi-finished products and materials from vehicles, warehouses and loading them into vehicles.

For transporting machines, including belt conveyors, the task is to provide comprehensive mechanization and automation of technological processes in the performance of basic and auxiliary operations in order to increase production efficiency.

An important area of development of modern production is the creation of high-performance, reliable automated machines and production lines that ensure high productivity and reliability of modern production, its intensification in all areas of the production process. In modern production conditions, the transition is being made from the use of individual types of conveying machines to the use of high-performance complexes, which are a promising direction for the development of conveying equipment.

In the master's qualification work, the task is to develop a highly efficient design of a belt conveyor for the transportation of small agricultural cargo (root and tuberous fruits). To accomplish this task, it is necessary to analyze the existing designs of belt conveyors and identify their disadvantages and advantages in performing these transportation operations. Based on this analysis, there is a need to develop an energy-efficient design of a belt conveyor for the transportation of root and tuberous crops.

To increase the productivity of the belt conveyor, there is a need to conduct a dynamic analysis of its movement in order to determine the dynamic loads acting on the structural elements and the drive. Therefore, there is a need to model the movement of the belt conveyor. To reduce dynamic loads, there is a need to optimize the drive mode.

In the master's qualification work, there is also a need to develop labor protection measures for the operation of belt conveyors during the transportation of root and tuberous crops. There is also a need for economic calculations to determine the feasibility of designing a new belt conveyor design.

CHAPTER 1. RELEVANCE OF THE DEVELOPMENT

1.1. General information about transporting mechanisms

Lifting and transport equipment is a set of machines and mechanisms required to perform labor-intensive work at enterprises: loading, unloading, moving and stacking of goods. The use of lifting and handling equipment makes it possible to facilitate heavy and time-consuming work, increase the productivity of agricultural workers, improve the level of technological processes and reduce the number of workers, rationally use the area and volume of warehouses and vehicles, and make wider use of self-service and advanced technology for moving goods in containers and equipment.

Lifting and handling equipment is classified according to the following criteria.

By the nature of cargo movement. Periodic and continuous operation. Equipment of periodic action (trolleys, elevators, etc.) operate on the principle of alternate movement: in one direction with cargo, in the opposite direction without cargo. Continuous equipment (conveyors) move goods in a continuous flow or at short intervals.

According to the type of energy that drives the equipment, they can be manually operated, electrically driven, or gravitational. Manual equipment (hand trucks, hand hoists, etc.) is used to move goods over short distances; electrically powered equipment is powered by the electrical grid or batteries. Gravity equipment (inclined slopes, roller conveyors) has an inclined surface from which goods roll under the action of their own gravity.

The main functional purpose is transportation, lifting and loading and unloading. The main function of transporting equipment (manual and electric trolleys, conveyors) is the horizontal and inclined movement of goods. Lifting equipment (elevators, hoists, electric hoists, etc.) is used to lift and lower cargo. Certain types of this equipment are used for horizontal handling, stacking, and loading and unloading operations. The main functions of loading and unloading equipment (electric forklifts, electric stackers) are to load goods onto vehicles (cars, wagons) and unload them.

According to the degree of mobility - stationary, installed indoors or outdoors; mobile with limited movement within the warehouse (stacker crane, electric pallet truck), and self-propelled with unlimited movement (electric trolleys, electric forklifts).

The lifting and handling equipment is assigned alphanumeric designations, with letters indicating the name of the equipment and its design feature, and numbers indicating the rated lifting capacity, model number, performance, etc.

Conveyor is a continuous machine designed to transport bulk and piece goods, such as minerals, rock, filling materials, etc. It is widely used in quarries, mines, and processing plants. Main types of conveyors:

- screw (auger),
- roller conveyors: non-driven (gravity) and driven,
- belt conveyors,
- belt and rope conveyors,
- belt-chain conveyors,
- scraper,
- vibratory,
- plate, etc.

Conveyors also include elevators and escalators.

The main elements of a conveyor are: traction, load or traction and load bodies; support and guide elements; conveyor post, mover.

According to the design features, conveyors with a flexible traction body and without a traction body are distinguished. In the first type of conveyors, the load moves along with the traction body on its working branch (belt, belt and rope, belt and chain, scraper, plate conveyors, elevators). In other conveyors, the translational movement of the load is carried out with the oscillatory or rotational movement of the working elements (inertial, vibratory, screw roller conveyors).

Conveyors are powered by electric, less often hydraulic and pneumatic energy. According to the angle of ascent, there are horizontal and slightly inclined (6-3o), inclined (up to 18-20o and up to 16o), and steeply inclined conveyors (over 18-20o and over 16o). The conveyor route can be either straight or curved, and the conveyor can be of constant or variable length. Conveyors can be stationary, semi-stationary and mobile, and can be used for underground or open-pit mining, general purpose or special purpose (e.g., feeders, reloaders, etc.). A special type of conveyor is a conveyor train. A conveyor section is a part of the conveyor structure.

A belt conveyor consists of supports with roller bearings for the load and idler branches attached to them. The main element of a scraper conveyor section is a rishtak. Other elements of the conveyor structure include a knife discharger, a scraper, and a conveyor belt. Advantages of conveyors: continuous movement of goods, non-stop loading and unloading, high productivity, long transportation distance, high degree of automation, ensuring safety conditions, high technical and economic indicators.

1.2. Analysis of belt conveyor designs

A belt conveyor is a continuously operating device with a single load-carrying and traction body in the form of a closed belt. The belt is driven by friction between the belt and the drive drum and is supported along its entire length by stationary roller bearings. In mines and quarries, a belt conveyor is used to transport minerals and rocks from sinking, stripping and mining workings through horizontal and inclined workings within mining enterprises, to raise them to the surface and further move them to a factory or a point of transfer to external transport, and rocks to a dump.

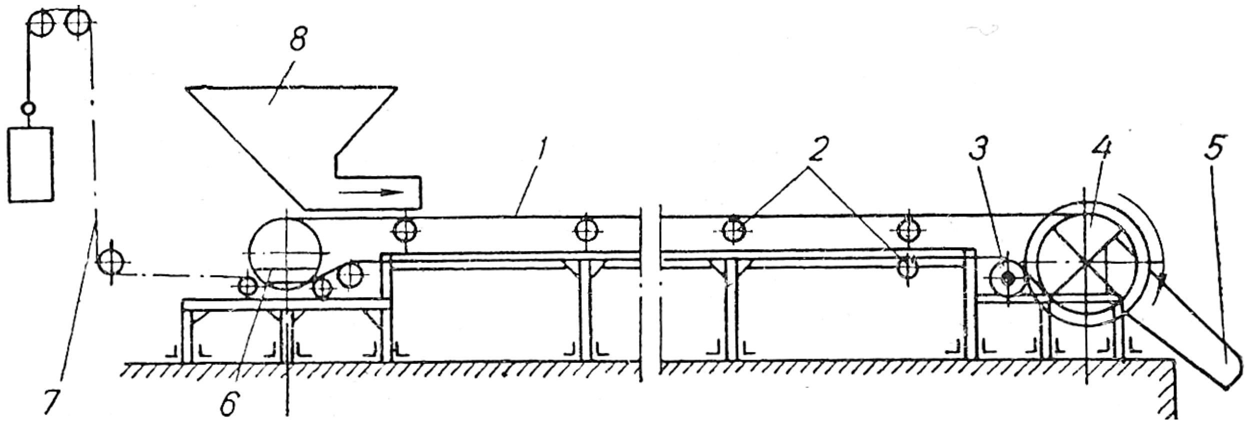

Figure 1.1 - General view of a belt conveyor: 1 - belt; 2 - rollers that support the belt; 3 - guide drums; 4 - drive drum; 5 - unloading device; 6 - tensioning drum; 7 - tensioning device; 8 - loading device.

The principle of operation of a belt conveyor is quite simple. An endless flexible belt, resting on the upper and lower roller bearings, bends around the drive and tension drums located at the ends of the equipment. It is located either perpendicular to the horizontal line or at an angle of 1-30 degrees.

The belt is the traction and bearing body of the belt conveyor. It perceives and transmits the driving (traction) force required to overcome all the resistances encountered when moving the load. Belts can be hemp, cotton, wool, rubberized and steel.

The width of the belt can be 100-3500 mm. The belt can be installed:

- PVC - 1-4 mm thick;

- Rubber fabric - 5-20 mm thick;

- Rubber cable - has high strength, which increases the productivity of the equipment. The length of the belt conveyor is selected according to customer requirements and can be from 1 to 100 meters. The speed of operation depends on the belt material and varies between 0.1-5 m/s.

The belt is driven by a drive drum and receives the required tension from a tensioning drum. Drums can be driven and guided. Drive drums transmit traction to the belt and change the direction of its movement, while guide drums serve only to change the direction of the belt and can be used to tension it.

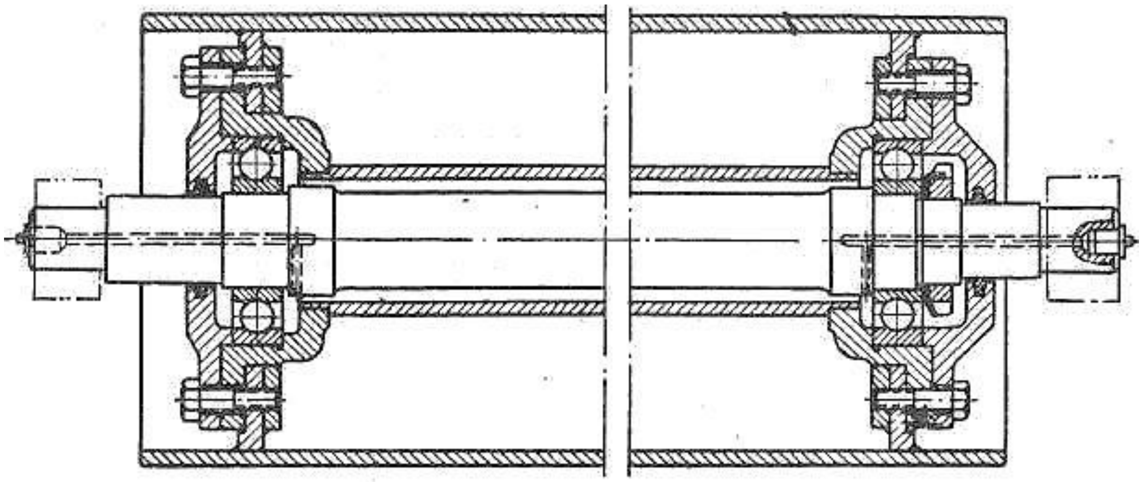

Figure 1.2 - General view of the drum

To load bulk materials onto the working surface, a loading hopper is used - usually mounted at the beginning of the equipment, above the end drum. Materials are unloaded at the end of the device from the drive drum.

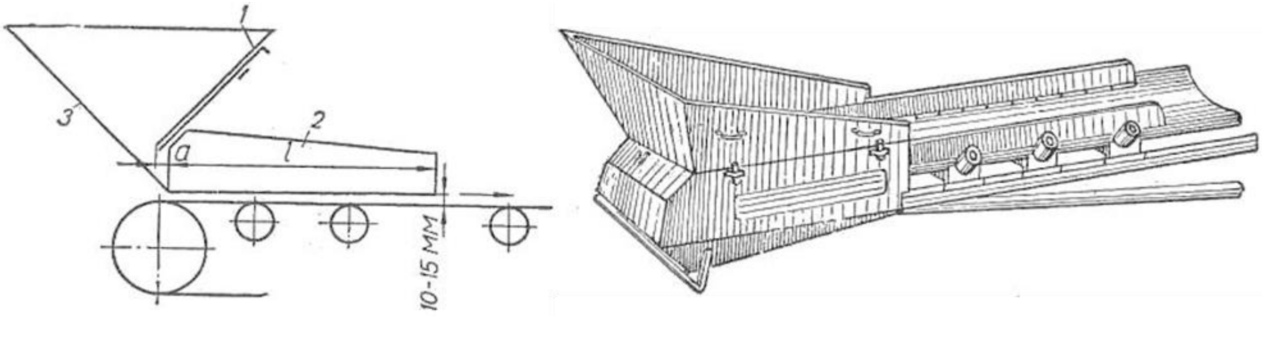

Figure 1.3 Loading a belt conveyor: 1 - latch; 2 - chute; 3 - guide boards

However, unloading can be intermediate: a mobile trolley or a stationary plow dump is used for this purpose. The flow of products discharged from the drum is directed by the discharge box.

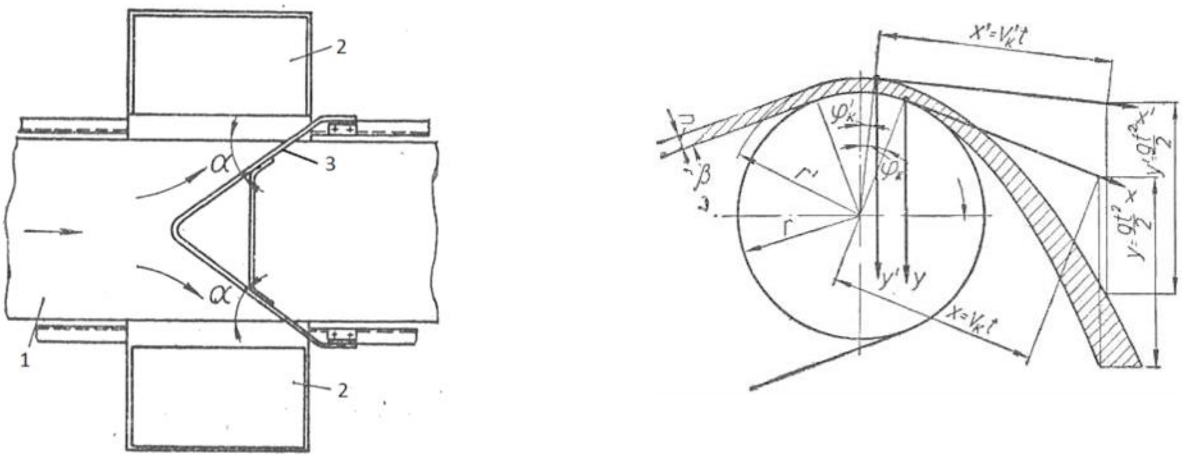

Figure 1.4 - Belt conveyor unloading: a - intermediate; b - final

To clean the belt from cargo residues, devices with rotating brushes (made of rubber, nylon) or fixed scrapers are mounted on the equipment. Their presence is mandatory, as sticking of the load on the rollers leads to their uneven rotation and accelerated belt wear. A rotating drum equipped with spiral scrapers is considered an effective solution for cleaning the belt.

One of the advantages of this equipment is its ease of assembly and disassembly in the warehouse. After all, the design of the belt conveyor is simple. All of its elements are installed on metal structures that are mounted on the bearing parts of the facility or on the foundation. The unloading box, the drive and the metal structure on which the drive drum is mounted are called the drive station. The tensioning station has a similar design, but with a tensioning device. The middle part of the equipment is made in the form of separate linear sections of the same size. In general, the installation of a belt conveyor is reduced to connecting linear sections, transition sections, tensioning and drive stations with bolts.

The main structural elements of a belt conveyor are a conveyor belt, a drive, a frame with roller bearings, a loading and tensioning device. In addition, belt conveyors are equipped with belt catchers, mechanisms for cleaning, loading, etc. The drive consists of an electric motor, gearbox, couplings, brake, and drive drum(s). There are several drive schemes based on the number and location of the drums. The conveyor belt is supplied with "rigid" and hinged-suspended roller bearings. The loading device of the belt conveyor has the form of a receiving funnel with sides that direct the cargo flow. Tensioning device electric drum winch with a system of rope blocks.

Belt conveyors are divided into five groups based on their application, design, and parameters:

- The first group includes belt conveyors for adjacent to the longwall workings with inclination angles of 3-6°.

- The second is for horizontal and slightly inclined workings.

- The third is for inclinations with an angle of up to 18°.

- The fourth is for bremsbergs with an angle of up to 16°.

- The fifth one is for inclined shafts and heading slopes with an angle of 3-18°.

The maximum angle of inclination of belt conveyors for raw coal is 20°, for crushed ores - up to 25°.

Mining belt conveyors are divided into face, dump, transfer and stationary main conveyors by design. In addition, they are an integral part of some mining units as part of rotary and chain excavators, dumpers, transport and dump bridges, and reloaders.

Belt conveyors are used to transport any kind of cargo: boxes, cartons, sacks, sand, grain, etc. Therefore, the equipment is selected taking into account the dimensions and weight of the product, as well as the task at hand. The most common conveyors are:

- horizontal (straight)
- inclined
- vertical
- grooved
- rotary
- mobile;
- mixed type.

Moreover, they can be used both independently and with other types of equipment, such as hoppers, dosing machines, and packaging machines.

Horizontal (straight) belt conveyors are based on a flexible endless belt, the working and idle branches of which are supported by roller bearings. The belt is driven by a drive drum and tensioned by a tensioning drum. The maximum productivity of straight conveyors can be 25 tons per hour, and their length can be 10 km. But this is in theory. In practice, such equipment is rarely used because the cost of a belt conveyor directly depends on its length. The longer it is, the more expensive it is. The horizontal belt conveyor is the most common type of equipment due to its versatility. It can be used to transport piece, lump, and bulk products. It is suitable for sorting lines, as well as for organizing work in warehouses and bases. And it is very easy to work with.

Another type of belt conveyor is an inclined one. Its main difference from horizontal (straight) models is the placement of the belt at an angle. In this case, it can have either a predetermined angle of inclination or an adjustable one. The principle of operation of this equipment is the same. The inclined belt conveyor is used for transportation of bulk and piece goods to upper/lower levels in warehouses and logistics complexes, as well as in various industries. The versatility of the device allows it to be used both indoors and outdoors.

Vertical belt conveyors are used to lift or lower boxes, crates, and other goods from one level to another. And at the same time, with high throughput and speed. Unlike inclined equipment, these models take up little space and allow for faster transportation of products to the desired location.

Grooved belt conveyors. The belt of such a conveyor is based on a grooved roller support made of aluminum or steel profile. The grooved belt conveyor is designed to move piece, lumpy and bulk cargo in a continuous mode. It is most often used to transport bulk cargo: grain, flour, sugar, etc. However, it is used not only in the food or agricultural sector, but also in the construction and chemical industries.

Rotary belt conveyors are widespread. Their main difference is the ability to change the direction of product supply. That is, the conveyor belt can bend around corners, turn to other rooms, make a 180-degree turn, and deliver goods to another platform. A rotary belt conveyor can be used in many industries, but it is most often used in the food and agricultural sectors.

A mobile belt conveyor (also known as a portable or mobile conveyor) is another popular type of this equipment today. It is equipped with special wheels, which makes it an effective device for transporting goods. After all, it can be installed anywhere, moving around the perimeter of the warehouse. The mobile belt conveyor can be used for loading and unloading products directly from the transport - all you need to do is install the equipment near the machine. The scope of application of this model is not limited: it is capable of transporting any type of cargo (lumpy, bulk, piece).

And the last type of belt conveyor is a mixed one. In fact, it is a combination of all the above types of warehouse equipment. For example, for warehouses with limited space, where it is not possible to install straight or inclined models, Z-shaped or L-shaped conveyors are installed. They combine 2 types at once: horizontal and vertical. At the request of the customer, conveyors of various designs are manufactured: horizontal mobile, inclined trough type (for grain transportation). In addition, if necessary, they can be equipped with a loading hopper, protective bumpers along the edges of the belt (to prevent cargo from falling), a meadow discharger, etc.

The unloading box, the drive and the metal structure on which the drive drum is mounted is called the drive station. The tensioning station has a similar design, but with a tensioning device. The middle part of the equipment is made in the form of separate linear sections of the same size. In general, the installation of a belt conveyor is reduced to connecting linear sections, transition sections, tensioning and drive stations with bolts. For intermediate unloading of bulk goods away from the belt, dumping trolleys can be used, and for bulk and piece goods, plow dumpers can be used.

Conveyor equipment can also be equipped with locking devices, two-pad closed brakes, belt catchers (in case of belt breakage) and other safety devices.

Belt conveyors can be installed outdoors, in buildings, galleries, and tunnels. They can be operated at temperatures ranging from -50 to +45°C, and some models can operate at temperatures up to +200°C.

The main requirements for conveyor belts are high longitudinal strength, sufficient longitudinal and transverse flexibility, resistance to abrasive wear and impacts from pieces of cargo falling on it during loading, and the lowest possible longitudinal elastic and residual deformation. According to the type of longitudinal force absorbing frame, they are divided into rubber-fabric and rubber-tube frames.

Depending on the operating conditions and purpose, the following types of conveyor belts are manufactured: general purpose, food, frost-resistant, heat-resistant, flame-retardant, flame-retardant, and refractory. Conveyor belts are manufactured in widths from 500 to 1200 mm on the basis of synthetic polyester fabrics of the EP, PP, RA types with a tensile strength in the longitudinal direction of 100, 125, 160, 200, 250, 315, 400, 500 N/mm with the number of gaskets in the frame from 2 to 6, with a rubber double-sided lining of 2-12 mm and rubber sides.

All products are regulated by the interstate standard GOST 20-85, state standards of Ukraine DSTU ISO 251:2009, DSTU 7306:2013, DSTU ISO 21183-1:2010, DSTU ISO 21183-2:2010 and industry standard GOST 12.00185790.001-99 and must be confirmed by appropriate certificates.

The conveyor belt has clear markings every 10-20 m along the length of the belt.

The marking contains:

- The trademark of the conveyor belt manufacturer;

- Type and type of conveyor belt;

- Type of fabric of the conveyor belt;

- The width and number of pads of the conveyor belt;

- Thickness of rubber covers and rubber class of the conveyor belt;

- Belt number;

- Year of manufacture of the conveyor belt.

Rubber cable conveyor belts are available in widths. 800-2400 mm (3200 mm) wide, with a longitudinal strength of 1500-6000 N/mm belt width. They are characterized by increased breakdown resistance and minor longitudinal deformations (up to 0.5% of the belt length). The ultimate longitudinal strength of rubber-tether belts is approx. 10000 N/mm of belt width. The creation of particularly strong belts is associated with the use of synthetic fibers.

The belt of a rope conveyor belt has one or two fabric pads, between which transverse steel springs are located at 60-80 mm intervals. The belt is covered with upper and lower covers. It has rubber sides with wedge-shaped grooves, which are attached to the belt to support the traction ropes. Under the influence of the transported cargo, the springs bend, and the belt acquires a grooved shape in cross section.

The belt of the belt and chain conveyor serves only as a load-carrying body, and one or two round link or plate sleeve-roller chains serve as a traction body. The chains are connected to the belt either rigidly or with the help of friction pads, which determines the design features of the belt.

General-purpose conveyor belts are used for transportation of various lumpy, bulk and piece cargoes: from ferrous and non-ferrous metal ores, hard rocks, coal, soft rocks, low-abrasive and non-abrasive materials at temperatures from -45°C to +65°C. The traction frame of conveyor (conveyor) belts of types 2.1 and 2.2 consists of 3-6 EP-200 fabric pads (the warp is made of polyester fiber, the weft is made of polyamide fiber). Between the fabric pads are rubber interlayers to increase the elasticity of the conveyor belt. Rubber covers and sides protect the conveyor belt frame from atmospheric, mechanical and other influences. Depending on the operating conditions and purpose of the conveyor belt, rubber covers are made of rubber classes A, B, I.

Mine rubber fabric conveyor belts are designed for conveyors of concentrating plants and surface complexes, transporting coal in pieces up to 500 mm and rock in pieces up to 300 mm. The frame of the conveyor belt consists of 3-6 fabric pads with rubber interlayers between them, with rubber covers for working and non-working surfaces and rubber sides. The width of the conveyor belt is from 600 to 1200 mm inclusive. The polyester-polyamide fabrics of the conveyor belt frame are impregnated with a special compound, the rubber covers contain special ingredients - flame retardants, which effectively reduces combustion and gives the conveyor belt the ability not to continue burning when removed from the flame source.

Heat-resistant conveyor belts of the 2T1, 2T2, 2TZ types are designed for transportation of hot materials with temperatures of 100 °C, 150 °C and 200 °C, respectively, at ferrous and non-ferrous metallurgy, chemical industry and other enterprises.

1.3. Conveyor belt joining

The most common methods of joining conveyor and conveyor belts are: hot vulcanization of belts, conveyor belt bonding (cold vulcanization) and mechanical joints. Our company specializes in performing any repair, joining and restoration. Hot vulcanization. This method is the most reliable and high-quality way of joining conveyor belts, and in the case of using heat-resistant and rubber-cable belts, it is the only possible one. This method guarantees very high quality and durability of the connection. Cold vulcanization (gluing belts). This method is quite common due to its simplicity and versatility, a vulcanization press is not used for the work, which greatly simplifies the work. The cold vulcanization method allows you to glue conveyor belts of any length and width, and it is also widely used to repair damage (cuts and tears). The use of conveyor belt bonding technology will allow you to restore the operation of the conveyor system in the shortest possible time, the work time does not exceed 1 day. The cold vulcanization method can be used in most industries, since the connection is designed for a very wide temperature range of operation.

- Mechanical connectors for conveyor and conveyor belts provide:
- Maximum speed of installation;
- Easy docking (in most cases, the Customer can perform the connection himself);
- Possibility of docking in any conditions (hard-to-reach places, bad weather conditions, contamination of the conveyor);
- Possibility of starting the conveyor immediately after docking.

CHAPTER 2. DESIGN AND CALCULATION OF THE CONVEYOR BELT STRUCTURE

2.1. Technological calculation of the conveyor belt Input data for the calculation of the conveyor belt:

Belt conveyor performance $Q = 20\frac{\text{т}}{\text{год}} = 5.5\frac{\text{кг}}{\text{с}}$;

Length of transportation route $L = 20\text{м};$

The cargo being moved is potatoes;

Loading of potatoes through a hopper, unloading – free, through the end drum of the belt conveyor. Let us determine the angle of inclination of the belt conveyor to the horizon according to the following dependence

$$sin\beta = \frac{H}{L} = \frac{0}{20} = 0, \quad \beta = 0°, \tag{2.1}$$

Where $\beta -$ the angle of inclination of the conveyor to the horizon.

2.2. Morphological analysis and synthesis of a stitch conveyor

The method of morphological analysis and synthesis, developed by the Swiss astronomer F. Zwicky. This method is built on the principles of combinatorics. Its essence lies in the fact that a group of basic constructive or other features is distinguished in a technical system. For each feature, alternative options are selected, that is, possible options for its implementation. By combining these options with each other, it is possible to obtain a set of different technical solutions for a particular system, including those solutions that have practical significance.

The application of the above method for constructing new technical solutions for a particular mechanism or machine consists in constructing a morphological table, filling it with possible alternative options and selecting the most acceptable technical solutions from the entire set.

The main features that characterize its design are selected for the belt conveyor. These features include:

1) type of conveyor;

2) actuator;

3) place of work;

4) safety devices;

5) auxiliary devices;

6) power supply;

7) method of loading cargo;

8) method of unloading cargo;

9) type of drum;

10) type of cargo;

11) movement of the conveyor.

A variant of the developed morphological table of possible technical solutions for the belt conveyor is given in Table. 2.1.

A morphological table of possible technical solutions for drive mechanisms of belt conveyors has also been constructed. Here, the following are selected as the main characteristics of the drive mechanism:

1) engine;

2) transmission mechanism;

3) coupling device;

4) brake mechanism;

5) belt type;

6) transmission.

A variant of the morphological table of possible technical solutions for drive mechanisms is given in Table 2.2.

A morphological table of possible technical solutions for belt conveyor devices has also been constructed. The following features have been selected for the devices:

1) tensioning device;

2) rollers;

3) drive drum;

4) tensioning drum;

5) unloading.

A variant of the morphological table of auxiliary devices of the belt conveyor is given in Table 2.3.

Table 2.1

Morphological table of possible solutions for belt conveyors

	Elements					
	Conveyor	**Executive Mechanism**	**Place of work**	**Safety devices**	**Auxiliary devices**	**energy source**
1	Stationary	Tape	Composition	Clutch	Rollers	electric motor
2	Movable	Scraper	Atmosphere	Backstop	Tension devices	Oil engine
3	portable	Rod	Production workshop	Brake	Limiting boards	Hydraulic motor
	Elements					
	Loading	**Unloading**	**Drums**	**cargo**	**Movement of goods**	
1	bunker	final	Actuated cylindrical	Loose	High-speed	
2	Conveyor	Intermediate	Drive barrel-shaped	Tarni	Peaceful	
3	self loading	Final tray	Driven with rods	Root crops and tubers	gravitational	
4	Lotkovo			others		

Table 2.2

Morphological table of possible technical solutions of belt conveyor drive mechanisms

	elements					
1	Engine	Transmission mechanism (reducer)	Connecting device	Brake mechanism	Tape	transfer
2	Direct current electric motor	Cylindrical	Toothed clutch	Block type with an electromagnetic pusher	Penkova	Pasova
3	Alternating current electric	Planetary	Chain coupling	Block type with a hydraulic	Rubberized	Lantsiugova

	motor			pusher		
4	Hydraulic motor	Conical	Cam-disc clutch	Disk	Cotton	Diskova
5	Internal combustion engine	wormy	Hydraulic coupling	ratchet	Woolen	Serrated
6		Wavy	Cam shaft	Powder electromagn etic	Steel	
7		Gear motor	Flexible coupling		hinged	
8		Combined				

Table 2.3

Morphological table of possible variants of technical solutions of belt conveyor devices

	Elements				
	Tightener	Rollers	Drive drum	Tension drum	Unloading
1	Helical	Steel	Steel	Steel	Plow
2	gravimetric	Wooden	Wooden	Wooden	Shield
3	Electromagnetic	Lined	Lined	Lined	Hinged tape with a groove
4	Automatic	Sliding surface	polymeric	polymeric	Hinged belt with a conveyor

Development of the own design of the belt conveyor

Taking one element from each column of the morphological tables given in table 2.1 - table 2.3, we will get one of the variants of the belt conveyor. In the master's qualification work, a belt conveyor with the following characteristics was chosen: a mobile belt conveyor, in which the executive body is a belt. As a traction body, we accept a rubberized conveyor belt. The friction coefficient f_0 of the load at rest on the rubberized belt is selected from the table (Appendix U1-U6): the friction coefficient is f_0 = 0.58. The conveyor is placed in a warehouse, in which a stop is used as a safety device, and supporting rollers are used as auxiliary devices. An AC asynchronous electric motor was used as the power source. The conveyor uses hopper loading and final tray unloading. In the conveyor, the drive and tension drums are cylindrical with a lined surface on the drive drum. The conveyor will transport root crops, in particular potatoes, at a normal speed so as not to destroy the fruits. The transmission mechanism of the drive is a cylindrical reducer, which is connected to the electric motor by an elastic coupling, and to the drive drum by a safety coupling. The selected version of the conveyor is presented in the table. 2.4.

Table 2.4

Elements							
Conveyor	Executive mechanism	Place of work	Auxiliary devices	Power source	Loading	Cargo	Tape motion
Tape movable	tape	composition	Rollers, tension device	Gear motor	From the bunker	potato	slow-moving

2.3. Calculation of the belt conveyor

Let's find the coefficient of friction of the potato against the rubberized belt during the movement of the belt conveyor from the following condition:

$$f = (0{,}7 \dots 0.9) f_x \tag{2.2}$$

$$f = 0.8 \cdot 0.58 = 0.46$$

But $f = tg\rho = 0.46$, then кут тертя становить $\rho = 27°30'$.

We choose a belt conveyor with a flat belt. We determine the width of the tape according to the following dependence:

$$B = \sqrt{\frac{Q}{0.16 v \cdot c \cdot y \cdot tg\varphi}} \quad (2.3)$$

where

$Q = 5.5\frac{кг}{с}$ – продуктивність стрічкового конвеєра, $v = 0.7 \dots 1.5$м/сthe

recommended limits for the speed of movement of potatoes on a rubberized belt. We assume the speed of transporting potatoes v= 1 m/s;

c is a coefficient that takes into account the angle of inclination of the conveyor to the horizon, which is $\beta = 0°$,therefore$c = 1$;

$\rho = 670 - 700$ кг/м^3- cargo density; we take it for potatoes$\rho = 700$кг/м^3;

$\varphi_0 = 35°$- the angle of the natural slope of the potato at rest;

$\varphi = (0.4 \dots 0.6)\varphi_0 = (0.4 \dots 0.6)350 = 14° \dots 21°$;we take $\varphi = 15°$- the angle of the natural slope of the potato when moving.

Then the width of the tape is determined by the formula, which takes the following value:

$$B = \sqrt{\frac{5.5}{0.16 \cdot 1 \cdot 1 \cdot 700 \cdot tg15°}} = 0.424\text{м}.$$

According to GOST 20-76 (Appendix A1), we accept ширину стрічки $B = 450$mm, the type of tape with the nominal strength of tensile spacers of 100 N/mm, the number of spacers $z = 4$.

We determine the length of the sides of the loading device as follows

$$l_б = \frac{v^2 - v_0^2}{2g(f\cos\beta - \sin\beta)} \quad (2.4)$$

We take the initial speed of the potato $v_0 = 0$. Then the length of the sides is:

$$l_б = \frac{1}{2 \cdot 9.81(0.46 \cdot 1 - 0)} = 0{,}11\text{м}.$$

We calculate the forces of resistance to the movement of the traction bodyW_1, W_2, W_3, W_4;

A) The force of resistance caused by the acceleration of the load upon hitting the belt is determined by the dependence:

$$W_1 = \frac{Qf(v^2 - v_0^2)cos\beta}{2v(fcos\beta - sin\beta)} \qquad (2.5)$$

And takes such a numerical value

$$W_1 = \frac{5.5 \cdot 0.46 \cdot 1 \cdot cos0°}{2 \cdot 1 \cdot (0.46 \cdot cos0° - sin0°)} = \frac{2.53}{0.92} = 2.75H.$$

B) The force of resistance to the movement of the belt on the rectilinear working area of the conveyor is determined as follows:

$$W_2 = (q_в + q_m)Lg(w_s cos\beta + sin\beta), \qquad (2.6)$$

where $q_в = \frac{Q}{V} = \frac{5.5}{1} = 5.5\text{кг/м}$ is the mass of potatoes per 1 m of conveyor belt length (running mass);

$q_м$- the mass of a tape 1 m long, determined by the dependence:

$$q_m = \delta B y_л \qquad (2.7)$$

In this formula:δ – товщина стрічки;

B – її ширина стрічки і її щільність вантажу $\rho_c = 1100\text{кг/м}^3$

$\delta_1 = 1.9$мм – thickness of one strip of tape;

$z = 4$ – the number of tape inserts;

$\delta_р = 4$мм – the thickness of the rubber lining of the working surface of the tape;

$\delta_{нр} = 2$мм – the thickness of the rubber lining of the non-working surface of the tape.

Then the total thickness of the tape takes the following value: $\delta = 1.9 \cdot 4 + 4 + 2 = 13.6$мм

Therefore, the linear weight of the tape is $q_m = 0.136 \cdot 0.4 \cdot 1100 = 59.84 \frac{кг}{м}$.

We believe that the belt rests on straight roller supports on the working and non-working branches. We take the coefficient of resistance to the movement of the tape $w_s = 0{,}08$. Then the amount of resistance to the movement of the tape takes the following value

$$W_2 = (5.5 + 59.84)20 \cdot 9.81(0.08cos0° + sin0°) = 944.74H.$$

The distance between the rollers on the rectilinear working area is taken as 0.8 m, on the non-working branch - 1.5 m, in the potato loading area - 0.35 m, the diameter of the roller is taken as $d_р = 108$. In accordance with the table (Appendix B1), we accept a smooth roller

Roller G – $108 \times 500 - 16 \times 14$GOST 22646-77, where G is a smooth roller,

108 is the outer diameter of the roller in mm,

16 – the length of the coot in mm,

500 is the length of the roller in mm,

14 – the width of the coot in mm.

A sketch of the video is shown in Fig. 2.1.

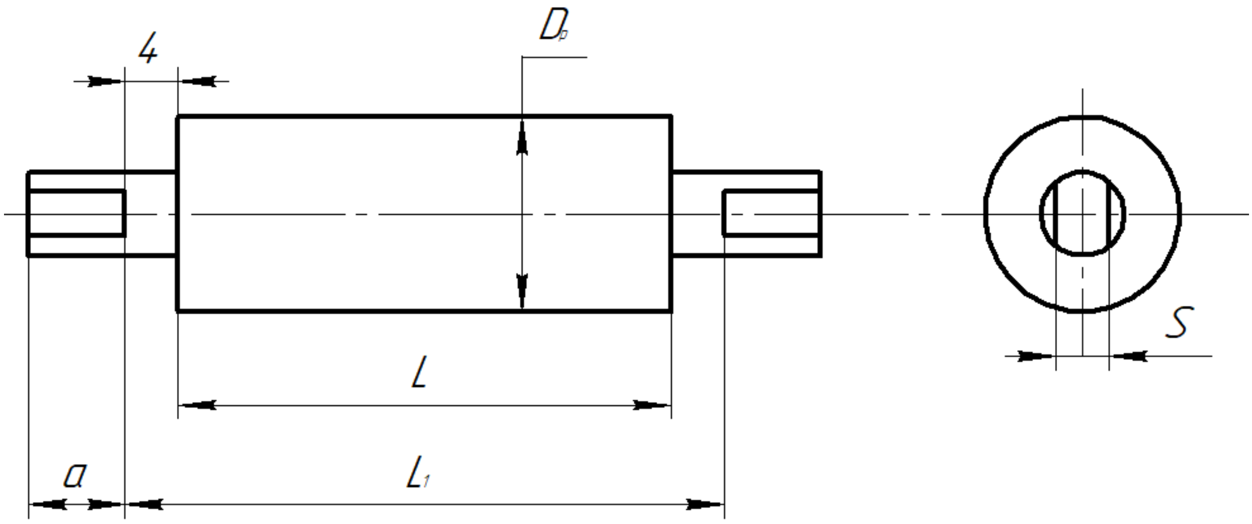

Figure 2.1 - Sketch of the video

C) The resistance force on the non-working branch of the conveyor is determined by the following dependence:

$$W_3 = q_m L g (w_s cos\beta - sin\beta) \qquad (2.8)$$

And takes the following value

$$W_3 = 59.84 \cdot 20 \cdot 9.81(0.08cos0° - sin0°) == 939.24H.$$

D) Since the unloading of potatoes is free, there is no resistance, i.e

$W_4 = 0$

The circular force on the leading drum is determined by the formula:

$$F_t = C_1(W_1 + W_2 + W_3) \qquad (2.9)$$

And it has this value

$F_t = C_1(W_1 + W_2 + W_3) = 1.1(2.75 + 944.74 + 939.24) = 2075.4H;$

$C_1 = 1.1 -$ коефіцієнт, що враховує втрати на зминання стрічки.

We determine the tension of the tape in the loops of the conveyor belt:

A) of the working line is determined by the following dependence:

$$S_1 = K_0 \frac{F_t \cdot e^{f \cdot \alpha}}{e^{f \cdot \alpha} - 1}, \quad (2.10)$$

where $K_0 = 1.3$ –for a screw tensioning device we accept:

$e = 2.72;$

$F_t = 2075.4$ H –wheel force;

$f = 0.2 \ldots 0.3$ –coefficient of friction of the rubberized tape against a steel or cast-iron drum; we accept $f = 0.3$;

$\alpha = 3.14$ (180° – girth angle of the drive drum)

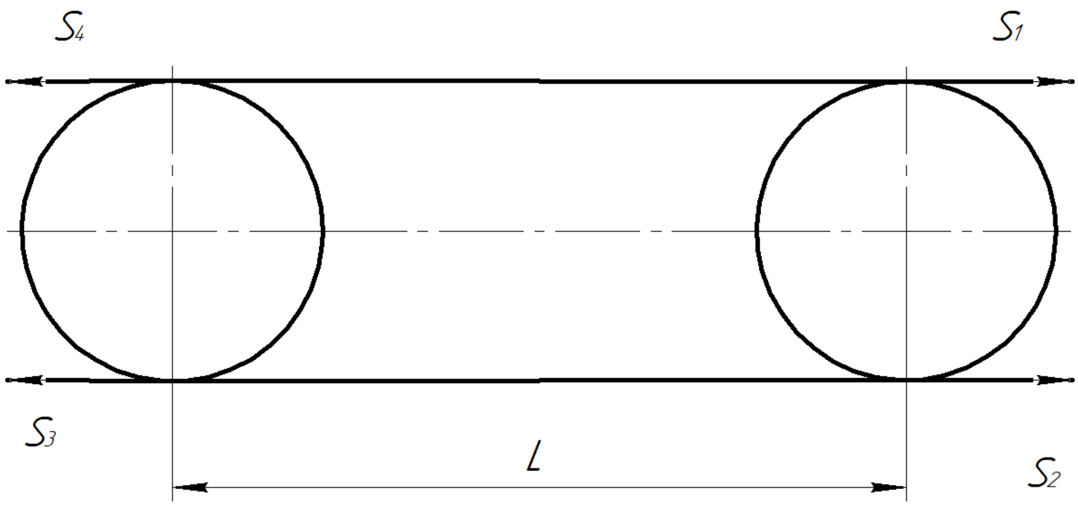

Figure 2.2 - Scheme of the tension forces of the conveyor lines

Then the effort takes the following values:

$$S_1 = 1.3\frac{2075.4 \cdot 2.72^{0.3 \cdot 3.14}}{2.72^{0.3 \cdot 3.14} - 1} = 4420.89H;$$

$$S_4 = S_1 - W_1 - W_2;$$

$$S_4 = 4420.89 - 2.75 - 944.74 = 3473.4H.$$

B) on the non-working line of the belt conveyor takes the following values:

$$S_3 = \frac{S_4}{C_1}; \quad (2.11)$$

$$S_3 = \frac{3473.4}{1.1} = 3157.63H;$$

$$S_2 = S_3 - W_3;$$

$$S_2 = 3157.63 - 939.24 = 2218.39H.$$

We refine the value of the wheel force according to the following dependence:

$$F_t = S_1 - S_2; \quad (2.12)$$

$$F_t = S_1 - S_2 = 4420.89 - 2218.39 = 2202.5H.$$

The conditions for the transmission of this force are determined by the following ratio:

$$e^{f\cdot a} \geq \frac{S_1}{S_2}; \tag{2.13}$$

$$2.72^{0.3\cdot 3.14} = 2.56;$$

$$\frac{S_1}{S_2} = \frac{4420.89}{2202.5} = 2.00.$$

The condition is fulfilled.

Let's check the strength of the tape under the following conditions:

$$K = \frac{S_1}{B\cdot z} \leq K_\text{р}, \tag{2.14}$$

where$S_1 = 4420.89H;\ B = 450\text{мм}; z = 4;$

$$K = \frac{4420.89}{450\cdot 4} = 2.45\frac{H}{\text{мм}};$$

$K_\text{р} = 5.5\frac{H}{\text{мм}}$,that is, the strength of the tape is sufficiently ensured.

We choose a cast iron drum. We accept the diameters of the drive and tension drums as the same, which are equal to: $D_{\text{ПР}} = D_{\text{НТ}} = 115\cdot z = 115\cdot 4 = 460\text{мм}$.We accept in accordance with DSTU $D_{\text{ПР}} = D_{\text{НТ}} = 450\text{мм}$. The length of the drum takes the following value:

$$l_\delta = 0.45\text{м} + 0{,}03\text{м} = 0{,}48\text{м}.$$

Fastening of the drive drum of the drive shaft is carried out using a key connection. The tension drum rests on the rotating axis through rolling bearings.

The tape is tensioned by moving the tensioning drum with the help of a screw tensioning device.

Output data for the kinematic calculation of the conveyor drive:

The power on the drive shaft is determined by the formula

$$P_в = F_t \cdot v \tag{2.15}$$

And takes this meaning

$$P_в = F_t \cdot v = 2202.5 \cdot 1 = 2202.5 \text{ Вт.}$$

The angular speed of the drive shaft is determined by the dependence

$$\omega_в = \frac{6.28 \cdot v}{\pi \cdot D_{пр}} \tag{2.16}$$

And takes the following value

$$\omega_в = \frac{6.28 \cdot v}{\pi \cdot D_{пр}} = \frac{6,28 \cdot 1}{3,14 \cdot 0,450} = 4,44 \frac{рад}{с};$$

2.4. Kinematic calculation of the belt conveyor

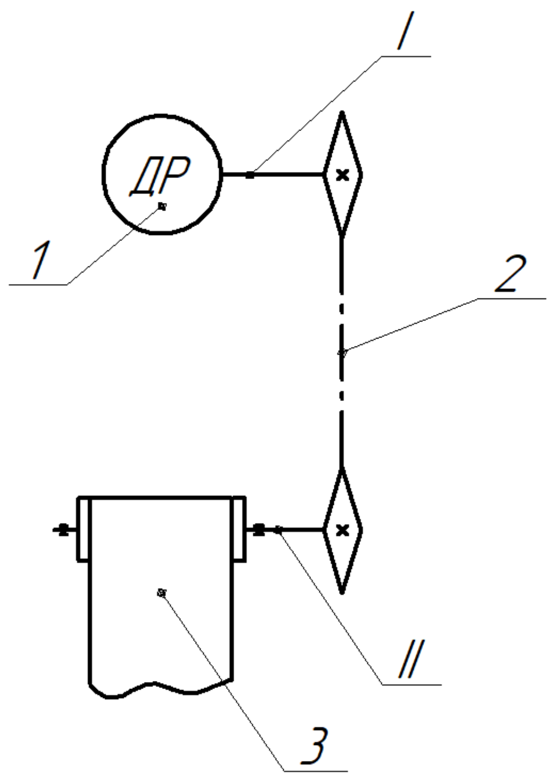

Figure 2.3.- Kinematic scheme of the belt conveyor drive: 1 – gear motor, 2 – chain transmission, 3 – rubberized belt;

The type of electric motor is chosen taking into account the following factors: purpose of the conveyor; availability of one or another source of energy; required capacity; limitations in weight, dimensions, working conditions; mode of operation of the conveyor and provision of its technological parameters.

The purpose of the conveyor determines the main requirements for the electric motor, the specifics of its operation and technical characteristics. At the same time, it is necessary to take into account the mobility of the conveyor, the external environment of its operation, temperature conditions, etc. The presence of sources of electrical energy leads to the choice of an electric drive, as the most simple and reliable in operation.

Depending on the required power, weight limitations and dimensions, an electric motor or an internal combustion engine is chosen for the drive. The selected engine must meet the following conditions:

- provide a moment sufficient to start the mechanism with a given acceleration, and during braking - with a deceleration of the given amount;
- during operation in the operating mode, the engine should not perceive long-term overloads, which leads to overheating of the electric motor and intensive wear of the internal combustion engine.

Determination of the required power of the electric motor of the conveyor is carried out according to the following formula

$$P_{\text{м.р.потр}} = \frac{P_{\text{в}}}{\eta_{\text{заг}}} \cdot K \qquad (2.17)$$

And takes this meaning

$$P_{\text{м.р.потр}} = \frac{2202.5}{0.92} \cdot 1.1 = 2630\text{Вт} = 2{,}63\ \text{кВт},$$

$K = 1.1$ – коефіцієнт, що враховує тимчасове навантаження електродвигуна;

$\eta_{\text{заг}} = \eta_{\text{л}} = 0.92$ – загальний ККД приводу стрічкового конвеєра.

Determination of the angular speed limit of the motor shaft is carried out according to the following formula:

$$\omega_{\text{м.рпотр.}} = \omega_{\text{в}} \cdot u_{\text{л}} \qquad (2.18)$$

And accepts such limits

$$\omega_{\text{м.рпотр.}} = \omega_{\text{в}}(2 \dots 5) = (8.88 \dots 22.2).$$

The torque of the motor-reducer is determined according to the following dependence:

$$T = \frac{P_{\text{м.р.потр.}}}{\omega_{\text{м.р.потр.}}} \cdot 10^3 \qquad (2.19)$$

And accepts such limits

$$T = \frac{2.63}{(8.88 \dots 22.2)} \cdot 10^3 = 118.5 \dots 299.5\ H \cdot \text{м}.$$

The frequency of rotation of the output shaft of the gear motor is determined by the formula:

$$n = \frac{\omega_{\text{м.р.потр.}} \cdot 30}{3.14} \qquad (2.20)$$

And accepts such limits

$$n = \frac{(8.88 \dots 22.2) \cdot 30}{3.14} = 84.84 \dots 212.1\ \text{об/хв}.$$

We accept the MC 2S-80-140 motor-reducer, according to DSTU, which has the following parameters:

$n_{\text{ном}} = 140 \frac{\text{об}}{\text{хв}}$; $P_{\text{дв.тр.}} = 4\text{кВт}$; $\omega_{\text{ном}} = \frac{\pi \cdot n_{\text{ном}}}{30} = \frac{3.14 \cdot 140}{30} = 14.65\text{рад/с}$; $m = 75\text{кг}$;

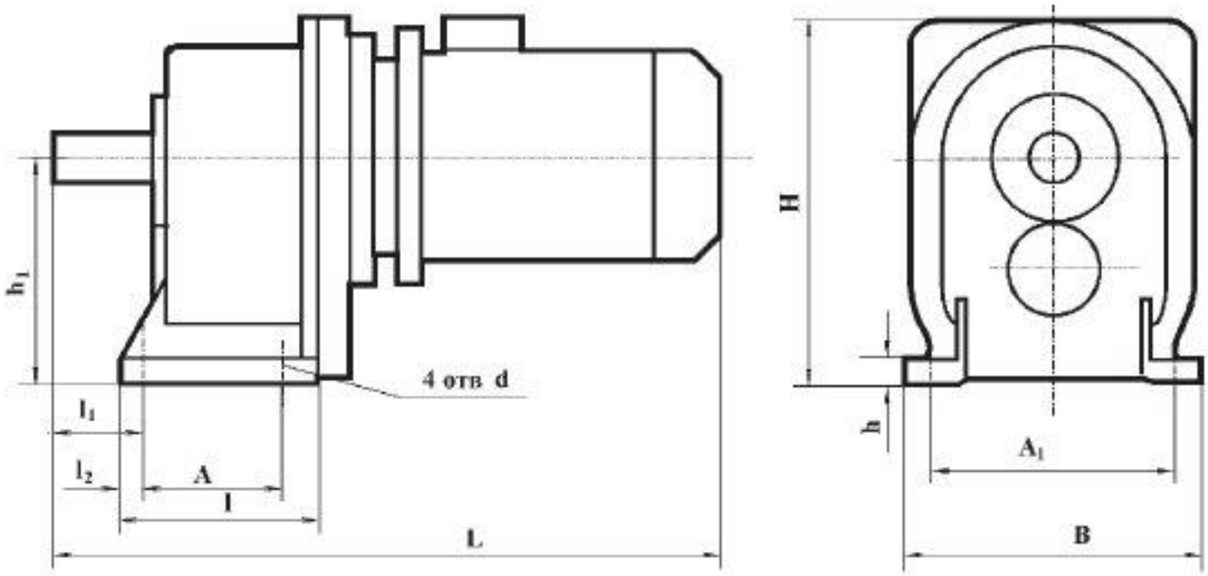

Figure 2.4 - Motor-reducer MC 2S-80-140, GOST 20721-75

Table 2.5.

Geometric parameters of motor-reducer MC 2S-80-140,

	Номінальна частота обертання валу об/хв	L_{max}	l	l1	l_2	A	A_1	B_{max}	H_{max}	l_1	h	d
МЦ2С 80	28; 31,5; 35,5; 40; 45	625	175	22	75	115	180	250	322	170	20	15
	50; 56; 63; 71; 80; 90; 100 112; 125; 140; 160; 180	670										

Let's determine the transmission ratio of the belt conveyor according to the following dependence:

$$u_л = \frac{\omega_{ном}}{\omega_в} \qquad (2.21)$$

And takes this meaning

$$u_л = \frac{14.65}{4.44} = 3.3.$$

Let's determine the initial data for calculating the transmission of the belt conveyor:

I shaft:

$$P_I = P_{\text{м.р.потр.}} = 2.63 \text{ к}H;$$

$$\omega_I = \omega_{\text{ном}} = 14.65 \frac{\text{рад}}{\text{с}};$$

$$T_I = \frac{P_I}{\omega_I} \cdot 10^3 = \frac{2.63}{14.65} \cdot 10^3 = 179.522 \text{ Н} \cdot \text{м};$$

II shaft:

$$P_{II} = P_I \cdot \eta_{\text{л}} = 2.63 \cdot 0.92 = 2.42 \text{ кН};$$

$$\omega_{II} = \frac{\omega_I}{u_{\text{л}}} = \frac{14.65}{3.3} = 4.44 \text{ рад/с};$$

$$T_{II} = \frac{P_{II}}{\omega_{II}} \cdot 10^3 = \frac{2.42}{4.44} \cdot 10^3 = 545.024 \text{ Н} \cdot \text{м}.$$

Table 2.6

Source data for chain transmission calculation:

The name of the transfer	Power on the drive shaft, kW	Angular velocity on the drive shaft, рад/с	Torque on the drive shaft, Nm	Gear ratio
Chain transmission	2.42	4.44	545.024	3.3

2.5. Calculation of chain transmission of the conveyor drive

advantages compared to other mechanical transmissions :

the possibility of use at significant distances (up to 8 m) between the shafts;

transverse loads on the shafts are smaller than in belt drives;

sufficiently high efficiency (up to 0.98);

the possibility of transmitting rotary motion by one chain to several shafts, including those with the opposite direction of rotation.

The principle of engagement, as well as the higher strength of the chain compared to the drive belt of the belt drive, allows the chain drive, other things being equal, to transmit much greater power. Chain engagement with sprockets eliminates chain slippage, which ensures a constant gear ratio.

Disadvantages of chain transmissions include the following:

- an increase in the length of the chain due to the wear of the hinge joints and the corresponding weakening of the tension;
- uneven chain movement and related dynamic phenomena in transmission and increased noise;
- low kinematic accuracy when reversing;
- the need to use additional devices to adjust the chain tension.

Chain transmissions are used in agricultural and transport machines (motorcycles and bicycles), lifting devices, conveyor drives, technological machines of light industry, etc. The chain transmission allows you to provide rotary motion to the shafts located at a relatively long distance, and its overall dimensions are much smaller than the overall dimensions of the belt transmission.

In addition, there is no slippage in the chain transmission, and greater forces can be transmitted by the drive mechanism.

We determine the step of the chain according to the following formula:

$$t = 280 \times \sqrt[3]{\frac{P_1 \times K_e}{z_1 \times \omega_1 \times [\rho] \times m_p}}, \quad (2.22)$$

$[\rho]$=35 МПа;

$m_p = 1.$

The number of sprocket teeth is determined by the formula

$$z_1 = 29 - 2U \quad (2.23)$$

And takes value

$z_1 = 29 - 2 \times 3.3 = 22.4.$

In order to increase the durability of the chain transmission, we take the number of sprocket teeth to be 23;

The coefficient of chain transmission efficiency is determined by the formula

$$К_е = К_д \times К_{рег} \times К_Н \times К_{см} \times К_{реж} \times К_а, \quad (2.24)$$

where$К_д = 1.0$;

$К_{рег} = 1.15$-;

$К_Н = 1.0$;

$К_{см} = 1.5;$

$К_{реж} = 1.25;$

$К_{а} = 1;$

Then the efficiency coefficient takes the following value

$К_{е} = 1 \times 1.15 \times 1 \times 1.5 \times 1.25 \times 1 = 2.15;$

The number of teeth of the driven sprocket is determined by the formula

$z_2 = z_1 \times u;$

And takes this meaning

$z_2 = 23 \times 3.33 = 77;$

Then the step is

$$t = 280 \times \sqrt[3]{\frac{2.42 \times 2.15}{23 \times 4.44 \times 35 * 2,5}} = 280\sqrt[3]{\frac{5.2}{1531.8}} = 280\sqrt[3]{0.0005} = 280 \times 0.079$$
$$= 22,12\text{мм}.$$

We accept the pitch of the chain t= 25.4 mm;

We perform a check for the required number of chain rows in the drive mechanism of the belt conveyor according to the formula:

$$V = \frac{z_1 \times t \times w_1}{2000 \times \pi} \tag{2.25}$$

$$V = \frac{23 \times 25,4 \times 4.44}{2000 \times 3.14} = \frac{4539.23}{6280} = 0.413\frac{м}{c}$$

$$V_{max} = 7.3\sqrt{\frac{z_1}{t}}; \quad (2.26)$$

$$V_{max} = 7.3\sqrt{\frac{23}{25,4}} = 6.944\frac{м}{с}$$

Because $V < V_{max}$, за ДСТУ приймаємо ланцюг

Drive roller with a step of 25.4 mm, version A, number of rows - 3:

Accessories for this chain:

Connecting chain: 3PR-25.4-171 GOST 13568-97

Connecting link - link - 3PR-25.4-171 GOST 13568-97

Transition link - link 3PR-25.4-171 GOST 13568-97

The main parameters of the circuit

Chain pitch – t=25.4mm;

Destructive load – Q=171.0 kH ;

The diameter of the roller is not less $d_1 = 15.88$ мм;

The diameter of the roller is not less $d_2 = 7.92$ мм;

The distance between the inner plates is not less $b_1 = 15.88$мм;

Mass of one linear meter -$q = 7.50$кг/м;

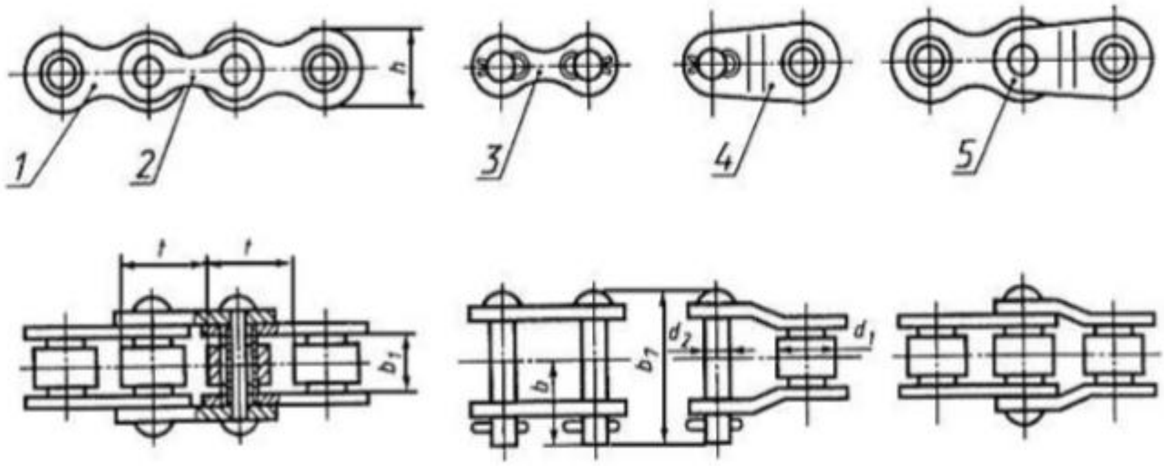

Figure 2.5 - Sketch of a belt conveyor chain

We determine the interaxial distance and length of the chain according to the following formula.

$$a = a_t \cdot t \,, \quad (2.27)$$

wherea_t=25 кроків – попередньо прийнята міжосьова відстань становить

a = 25 ·25.4 = 635 mm.

The required length of the chain in steps is determined by the following relationship

$$L_t = 2 \cdot a_t \frac{z_1+z_2}{2} + \left(\frac{z_2-z_1}{2\Pi}\right)^2 \cdot \frac{1}{a_t} = 2 \cdot a_t + a_1 + \frac{b}{a_t}, \quad (2.28)$$

where$a_1 = \frac{z_1+z_2}{2} = \frac{23+77}{2} = 50$

$$b = \left(\frac{z_2 - z_1}{2\Pi}\right)^2 = \frac{(77-23)^2}{2 \cdot 3.14} = 73{,}863$$

$$L_t = 2 \cdot 25 + 50 + 73{,}863 = 173{,}863 \text{ кроків}$$

We accept the number of chain steps$L_t = 147$ кроків

We specify the interaxial distance of the transmission according to the following dependence

$$a = \frac{t}{4}(L_t - a_1 + \sqrt{(L_1 - a_1)^2 - 8b} \qquad (2.29)$$

$$a = \frac{25{,}4}{4}(174 - 50 + \sqrt{(174 - 50)^2 - 8 \cdot 73{,}863}) = 6{,}35 \cdot 188.32 = 1559.515м$$

To ensure chain sag, reduce the interaxial distance by the following amount

$$(0.002 \ldots 0.004)a = (0.002 \ldots 0.004)1559.515 = (3.119 \ldots 6.238) = 4$$

$$a = 1559.515 - 4 = 1555.515 мм$$

The number of link strokes per 1s is determined by the condition

$$V = \frac{2z_1 + w_1}{П \cdot L_t} \leq [V], \qquad (2.30)$$

where [V]=30c^{-1}.

$$V = \frac{2 \cdot 23 \cdot 4.44}{3.14 \cdot 147} = \frac{202.24}{461.58} = 0.438 < [V].$$

We determine the forces acting in the links of the chain and the pressure forces on the drive shafts of the belt conveyor.

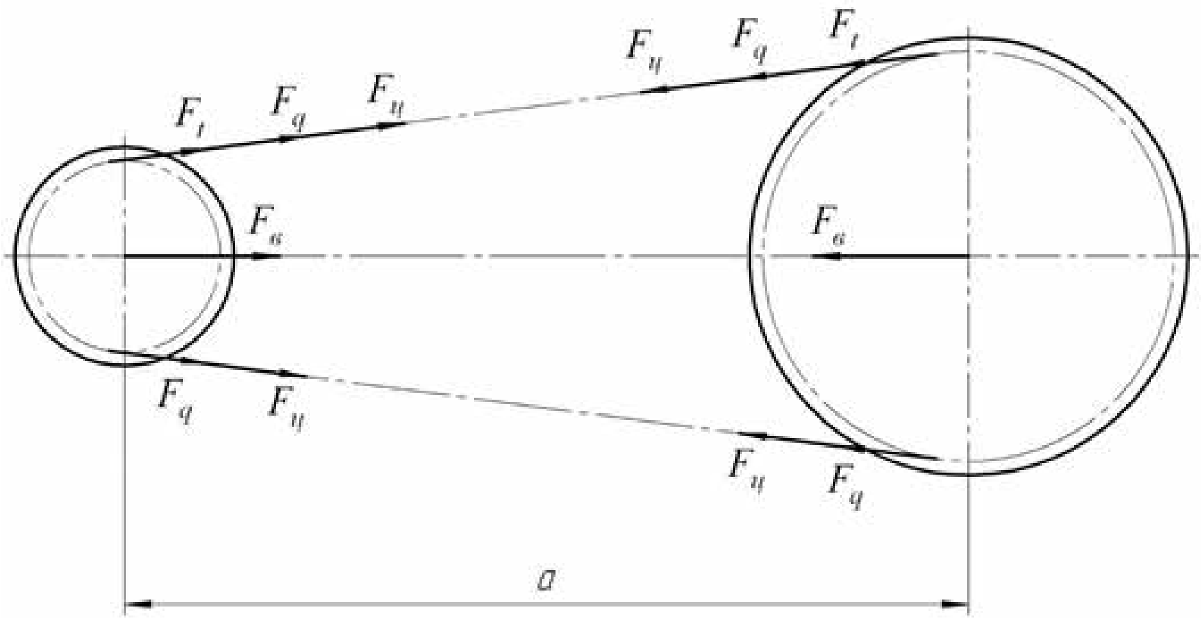

Figure 2.6 - Forces acting in chain transmission

The wheel force is determined by the following formula

$$F_t = \frac{1000 \cdot P_1}{V} \tag{2.31}$$

$$F_t = \frac{1000 \cdot 2.42}{0.438} = 5525.114\,H$$

The tension of the chain from sagging is determined by the formula

$$F_q = k_f \cdot q \cdot a \cdot g; \tag{2.32}$$

$k_f = 2{,}0.$

$q = 7.5$ кг/м

$F_q = 2.0 \cdot 7.5 \cdot 1555.515 \cdot 10^{-3} \cdot 9.8 = 228.66H.$

The tension of the chain from centrifugal forces is determined by the formula

$$F_ц = q \cdot V^2 \quad (2.33)$$

$F_ц = 7.5 \cdot 0.438^2 = 1.438H$

The total effort in the drive link of the chain is determined by the formula:

$$F_{заг_1} = F_t \cdot К_д + F_q + F_ц \quad (2.34)$$

$F_{заг_1} = 5525.114 \cdot 1 + 228.66 + 1.438 = 5755.212$ Н;

The total force in the drive line of the chain takes the following value:

$$F_{заг2} = F_q + F_ц \quad (2.35)$$

$F_{заг2} = F_q + F_ц = 228.66 + 1.438 = 230.098\, H$

The forces acting on the drive and driven sprocket shafts are determined by the following relationship:

$$F_b = F_t \cdot k_д + 2F_q \quad (2.36)$$

$F_b = 5525.114 \cdot 1 + 2 \cdot 228.66 = 5982.434H$

Checking the chain according to the specific pressure in the joints is determined from the following condition:

$$p = \frac{F_t \cdot K_E}{S \cdot m_p} \leq [p], \quad (2.37)$$

where S=539мм^2 – проекція площі опорної поверхні шарніра;

[p]=35MPa – the allowable specific pressure in the joints of the chain is equal to

$$\mathrm{p} = \frac{5525.114 \cdot 2.15}{539 \cdot 2.5} = \frac{2711.7}{105} = 8.93 \le [\mathrm{p}]$$

The margin of strength of the chain is determined from the following condition

$$n = \frac{Q}{F_{заг1}} \ge [n], \tag{2.38}$$

where [n]=7.0 – the permissible safety margin of the chain is;

$$n = \frac{171 \cdot 10^3}{5755.212} = 29.712 \ge [n]$$

Therefore, the transfer is calculated correctly, because all the conditions are fulfilled!

We determine the geometric and design parameters of the sprockets of the chain transmission:

The geometric characteristic of the engagement is determined by the formula

$$\lambda = \frac{t}{D_ц} = \frac{25.4}{15.88} = 1{,}599.$$

We accept the tooth height factor equal to K=0.532.

The diameter of the dividing circle of the driving sprocket is determined by the following formula

$$d_1 = \frac{t}{\sin\frac{180^0}{Z_1}} = d' \cdot t,$$

Whered'=7,344

$$d_1 = 7{,}344 \cdot 25.4 = 186.537 \text{ мм.}$$

The diameter of the pitch circle of the driven sprocket is determined by the following relationship:

$$d_2 = \frac{t}{\sin\frac{180^0}{Z_2}} = d' \cdot t,$$

Whered'=24.517

$$d_2 = 24.517 \cdot 25.4 = 622.731 \text{ мм.}$$

The radius of the depressions is determined as follows

$$r = 0{,}5025 \cdot D_ц = 0{,}5025 \cdot 15.88 = 7.98 \text{ мм.}$$

Since the transmission is non-reversible, we accept the profile of the teeth with displacement of the centers of the arcs of the depressions. For this profile, we determine the largest chord for a drive sprocket with an odd number of teeth$Z_1 = 23$

$$L_x = d_1 \cdot \cos\frac{95^0}{Z_1} - 2 \cdot r = 186.537 \cdot \cos\frac{95^0}{23} - 2 \cdot 7.98 = 170.092 \text{ мм.}$$

The diameter of the circle of the tops of the drive sprocket is determined by the formula:

$$d_{a1} = t \cdot \left(K + ctg\frac{180^0}{Z_1}\right) = 25.4 \cdot \left(0{,}532 + ctg\frac{180^0}{23}\right) = 198.323 \text{ мм.}$$

The diameter of the circle of the vertices of the driven star is determined according to this dependence

$$d_{a2} = t \cdot \left(K + ctg\frac{180^0}{Z_2}\right) = 25.4 \cdot \left(0{,}532 + ctg\frac{180^0}{77}\right) = 635.889 \text{ мм.}$$

The diameter of the circle of the depressions of the driving sprocket is determined according to this dependence

$$d_{f1} = d_1 - 2 \cdot r = 186.537 - 2 \cdot 7.98 = 170.577 \text{ мм.}$$

The diameter of the circle of the depressions of the driven sprocket is determined by the formula:

$$d_{f2} = d_2 - 2 \cdot r = 622.731 - 2 \cdot 7.98 = 606.771 \text{ мм.}$$

The radius of the smallest rounding of the tooth is determined by the formula

$$r_x = 1{,}7 \cdot D_ц = 1{,}7 \cdot 15.88 = 26.996 \text{ мм.}$$

We accept$r_x = 27$ мм.

The distance from the top of the tooth to the line of the centers of the arcs of the rounding is defined as :

$$f = 0{,}8 \cdot D_ц = 0{,}8 \cdot 15.88 = 12.704 \text{ мм.}$$

The value of the rounding radiusr_c для t<35 приймаємо $r_c = 1{,}6$ мм.

The tooth width of a three-row sprocket is determined by the following relationship

$b_{f1} = 0{,}90 \cdot b_1 - 0{,}15 = 0{,}93 \cdot 15.88 - 0{,}15 = 14.61$ мм.

We acceptширину зуба $b_{f1} = 15$ мм.

The rim width of the three-row sprocket is determined as follows:

$c = b_{f1} + 2 \cdot r_c = 15 + 2 \cdot 1{,}6 = 18.2$ мм.

We accept the width of the rim c=19 mm.

The largest diameter of the drive sprocket rim is determined by the formula and takes the value

$$d_{g1} = t \cdot ctg\frac{180^0}{Z_1} - 1{,}3h = 25.4 \cdot ctg\frac{180^0}{23} - 1{,}3 \cdot 24.20 = 167.322 \text{ мм}.$$

We accept діаметр обода рівним $d_{g1} = 168$ мм.

The largest rim diameter of the driven sprocket is determined by the following relationship:

$$d_{g2} = t \cdot ctg\frac{180^0}{Z_2} - 1{,}3h = 25.4 \cdot ctg\frac{180^0}{77} - 1{,}3 \cdot 24.20 = 590.916 \text{ мм}.$$

We take the rim diameter of the driven sprocket$d_{g2} = 591$мм

The thickness of the sprocket rim is:

$b_{об} = D_ц = 15.88$ мм.

The diameter of the drive sprocket rim is determined by the following formula:

$d_{об1} = d_{g1} - 2b_{об} = 168 - 2 \cdot 15.88 = 136.24$ мм.

We accept$d_{об1} = 137$ мм.

The diameter of the rim of the driven sprocket is determined as follows:

$d_{об2} = d_{g2} - 2b_{об} = 591 - 2 \cdot 15.88 = 559.24$ мм.

We accept $d_{об2} = 560$ мм.

The approximate diameters of the shafts under the leading and driven sprocket are determined by the following formula:

$$d_{в1} = 10^3 \cdot \sqrt[3]{\frac{T_1}{0,2 \cdot [\tau]_{кр}}} = 10^3 \cdot \sqrt[3]{\frac{179.522}{0,2 \cdot 20 \cdot 10^6}} = 35.5 мм$$

We accept $d_{в1} = 35$мм

$$d_{в2} = 10^3 \cdot \sqrt[3]{\frac{T_2}{0,2 \cdot [\tau]_{кр}}} = 10^3 \cdot \sqrt[3]{\frac{545.024}{0,2 \cdot 20 \cdot 10^6}} = 51.4 мм.$$

Where $[\tau]_{кр}$=20 МПа- underestimated values of allowable torsional stresses.

Obtained values $d_{в1}$ i $d_{в2}$ round to the nearest value according to current standards: $d_{в1} = 36$ мм, $d_{в2} = 55$ мм.

The diameter of the hub is determined by the following dependencies:

$d_{м1} = (1,8 \dots 2,0)d_{в1} = (1,8 \dots 2,0)36 = 70$ мм;

$d_{м2} = (1,8 \dots 2,0)d_{в2} = (1,8 \dots 2,0)55 = 110$ мм.

The length of hubs is determined from the following conditions:

$l_{м1} = (1,8 \dots 2,2)d_{в1} = (1,8 \dots 2,2)36 = 70$ мм;

$l_{м2} = (1,8 \dots 2,2)d_{в2} = (1,8 \dots 2,2)55 = 110$ мм.

The diameter of the technological holes in the drive sprocket disc is determined from the following conditions:

$$d_{o1} = 0{,}25(d_{об1} - d_{м1}) = 0{,}25(137 - 70) = 16.75 \text{ мм.}$$

Since the valued_{o1} more than 10 mm, it is advisable to make technological holes in the sprockets.

The diameter of the technological holes in the drive sprocket disk is determined by the following expression:

$$d_{o2} = 0{,}25(d_{об2} - d_{м2}) = 0{,}25(560 - 110) = 112.5 \text{ мм.}$$

We acceptd_{o2} =112 мм. We assume the number of technological holes to be 6.

The diameter of the placement of technological holes in the disk of the driven sprocket is determined from the condition:

$$D_{o2} = 0{,}5(d_{об2} + d_{м2}) = 0{,}5(560 + 110) = 335 \text{ мм.}$$

We accept the diameter of the holesD_{o2} = 335 мм.

Since the transmission is non-reversible, we accept the profile of the teeth with the displacement of the centers of the arcs of the cavities and determine the parameters of the tooth profile.

To build the profile of the leading and driven sprockets of the chain transmission, we calculate the following parameters:

The conjugation radius is determined from the condition:

$$r_1 = 1.3025 D_ц + 0.05 = 1.3025 \cdot 15.88 + 0.05 = 20.73 \text{мм;}$$

Half the angle of the depressions:

$$\alpha_1 = 55° - \frac{60°}{Z_1} = 55° - \frac{60°}{23} = 52.39°;$$

$$\alpha_2 = 55° - \frac{60°}{Z_2} = 55° - \frac{60}{77} = 54.22°;$$

Conjugation angle:

$$\beta_1 = 18° - \frac{56°}{Z_1} = 18° - \frac{56°}{23} = 15.56°;$$

$$\beta_2 = 18° - \frac{56°}{Z_2} = 18° - \frac{56°}{77} = 17.27°;$$

Half of the angle of the tooth:

$$\Phi_1 = 17° - \frac{64°}{Z_1} = 17° - \frac{64°}{23} = 14.21°;$$

$$\Phi_2 = 17° - \frac{64°}{Z_2} = 17° - \frac{64°}{77} = 16.16°;$$

The radii of the tooth head is determined by the following dependencies:

$$r_{2,1} = D_ц(1.24cos\Phi_1 + 0.8cos\beta_1 - 1.3025) - 0.05$$
$$= 15.88(1.24 \cdot 0.969 + 0.8 \cdot 0.963 - 1.3025) - 0.05 = 10.58мм;$$

$$r_{2,2} = D_ц(1.24cos\Phi_2 + 0.8cos\beta_2 - 1.3025) - 0.05$$
$$= 15.88(1.24 \cdot 0.960 + 0.8 \cdot 0.954 - 1.3025) - 0.05 = 10.28мм;$$

The straight section of the profile is determined by this dependence

$$FG_1 = D_ц(1.24sin\Phi_1 - 0.8sin\beta_1) = 15.88(1.24 \cdot 0.245 - 0.8 \cdot 0.268) = 1.41мм$$

$$FG_2 = D_ц(1.24sin\Phi_2 - 0.8sin\beta_2) = 15.88(1.24 \cdot 0.278 - 0.8 \cdot 0.296) = 1.71мм$$

The distance from the center of the arc of the cavity to the center of the arc of the head takes the following values:

$$OO_2 = 1.24D_ц = 1.24 \cdot 15.88 = 19.69мм;$$

The displacement of the center of the arcs of depressions takes the following values:

$$e = 0.03 \cdot 25.4 = 0.762мм;$$

Point coordinatesO_1 визнвчаються наступними формулами:

$$X_{1.1} = 0.8D_ц sin\,\alpha_1 = 0.8 \cdot 15.88 \cdot 0.792 = 10.06мм;$$

$$Y_{1.1} = 0.8D_ц cos\,\alpha_1 = 0.8 \cdot 15.88 \cdot 0.610 = 7.75мм;$$

$$X_{1.2} = 0.8D_ц sin\,\alpha_2 = 0.8 \cdot 15.88 \cdot 0.811 = 10.30мм;$$

$$Y_{1.2} = 0.8D_ц cos\,\alpha_2 = 0.8 \cdot 15.88 \cdot 0.584 = 7.41мм;$$

Point coordinates

$$X_{2.1} = 1.24D_ц cos\frac{180}{Z_1} = 1.24 \cdot 15.88 \cdot 0.990 = 19.49мм;$$

$$Y_{2.1} = 1.24D_ц sin\frac{180}{Z_1} = 1.24 \cdot 15.88 \cdot 0.136 = 2.67мм;$$

$$X_{2.2} = 1.24D_ц cos\frac{180}{Z_2} = 1.24 \cdot 15.88 \cdot 0.999 = 19.67мм;$$

$$Y_{2.2} = 1.24D_ц sin\frac{180}{Z_2} = 1.24 \cdot 15.88 \cdot 0.040 = 0.78мм;$$

CHAPTER 3. DYNAMIC ANALYSIS OF A CONVEYOR BELT FOR TRANSPORTING POTATOES

3.1. Modeling the dynamics of the conveyor belt movement

To increase the efficiency of belt conveyors, it is necessary to increase their productivity and reliability. The increase in productivity is associated with an increase in the speed of movement of the traction body and a reduction in the duration of transient processes. At the same time, the workload on the structural elements of the belt conveyor and the drive mechanism increases. Increased loads reduce the reliability of belt conveyors and negatively affect the transported cargo. This is especially dangerous for agricultural goods that are subject to damage, in particular potatoes, because they are not well stored in a damaged form. Therefore, there is a need for increased requirements for methods of designing and calculating belt conveyors. When creating belt conveyors, it is necessary to use dynamic calculation methods that take into account the effect of dynamic loads on structural elements and cargo and at the same time ensure the necessary accuracy of calculations.

To determine the nature of the change and the maximum values of dynamic loads, it is necessary to carry out a dynamic analysis of the movement of the belt conveyor during the transportation of potatoes. There is an uneven movement in the conveyor belt, which is caused by the vibrations of the potatoes during their transportation. The presence of uneven movement of the belt with potatoes leads to the occurrence of additional dynamic loads in the structural elements and the drive of the belt conveyor. Dynamic loads reduce the reliability of the structural elements of the belt conveyor and lead to its premature destruction. At the same time, the energy costs that go into the destruction of the belt conveyor structure also increase. As a result, the efficiency of the belt conveyor decreases and the conditions of potato transportation deteriorate.

To carry out dynamic calculations of a belt conveyor, it is necessary to move from its real design to a dynamic model. In the dynamic model of the belt conveyor, the characteristics and elements that are not essential for the dynamic calculation are neglected. At the same time, as a rule, discrete dynamic models of the conveyor are used. When building such belt conveyor models, concentrated masses, elasticity of elements, dependence of driving and braking forces of electric motors on shaft rotation frequency, etc. are taken into account. The developed dynamic model of the belt conveyor is the basis for building its mathematical model, which is presented in the form of mathematical equations and allows for dynamic calculations.

3.2. Dynamic model of a belt conveyor

In the process of creating a dynamic model of a belt conveyor, the main controlled movement, which is determined by the drive mechanism, and uncontrolled movements, which are the cause of the elastic properties of individual links, are taken into account. When building a dynamic model, we consider that all elements of the belt conveyor are absolutely solid links, except for the drive elements, which have elastic properties. In this case, the dynamic model of the belt conveyor has two degrees of freedom and can be represented as a two-mass dynamic model. We reduce both masses of the dynamic model of the belt conveyor to the drive drum. Since the drum performs a rotational movement, the combined masses must also be rotational. The obtained masses of the dynamic model are connected by an elastic element, the stiffness coefficient of which depends on the stiffness of the elements of the transmission mechanism of the drive. One of the masses of the dynamic model is acted upon by the driving torque of the drive electric motor reduced to the axis of rotation of the drum, and the other mass is reduced to the axis of the same drum by the moment of the forces of resistance to the movement of the belt with the load (potatoes). The combined moment of the resistance forces depends on the weight of the potatoes on the belt and the combined resistance coefficient between the belt and the support rollers of the conveyor.

The first combined mass of the dynamic model includes the elements of the rotor of the electric motor and the transmission mechanism, and the second mass includes the driving and tensioning drums, the tape and the mass of potatoes on it. For the resulting dynamic model of the belt conveyor, all dynamic parameters are determined, which include: combined moments of inertia of the first and second combined masses; stiffness coefficient of the elastic element of the drive mechanism; the dependence of the driving moment of the electric motor on the frequency of rotation of the rotor, as well as the dependence of the combined moment of the resistance forces of the belt conveyor.

To study the dynamics of the motion of the belt conveyor, a two-mass dynamic model with discrete rotating masses reduced to the axis of the drive drum is shown in Fig. 3.1.

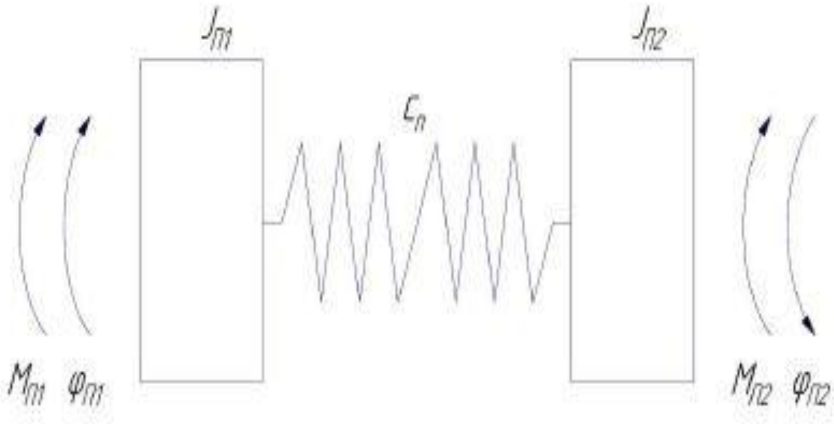

Figure 3.1 Dynamic model of a belt conveyor

In the dynamic model of the belt conveyor, the following notations are adopted: $J_{П1}$, $J_{П2}$ - combined moments of inertia of the first and second masses of the dynamic model of the belt conveyor; C_n - reduced to the axis of the drive drum, the stiffness coefficient of the elastic element, which reflects the elastic elements of the transmission mechanism of the drive; $M_{П1}$, $M_{П2}$ - the driving moment of the drive electric motor of the first mass and the combined moment of the resistance forces of the second mass of the dynamic model of the belt conveyor, respectively reduced to the axis of the drive drum; $\varphi_{П1}$ - angular coordinate of rotation of the first consolidated mass of the dynamic model of the belt conveyor; $\varphi_{П2}$ - the angular coordinate of rotation of the second combined mass of the dynamic model of the belt conveyor.

The first combined mass of the dynamic model of the belt conveyor includes an electric motor and a drive transmission mechanism, and the second - drive and tension drums, a belt with a load (potatoes).

To determine the combined moment of inertia of the first mass of the belt conveyor, $J_{П1}$ we equate the kinetic energy of the first part of the real drive mechanism T_1 to the kinetic energy of the first combined mass of the dynamic model $T_{екв}$,

$$T_I = T_{екв.}. \quad (3.1)$$

To find the moments of inertia $J_{п1}$ та $J_{п2}$ of the combined masses of the dynamic model, we will determine the moments of inertia of individual links of the belt conveyor.

Let's determine the moment of inertia of the drive drum, J_1,which is represented by the dependence

$$J_1 = \frac{1}{2}\frac{m_1 \cdot D_1^2}{4} = \frac{8.5 \cdot 0.591^2}{8} = 0.44 \text{ кг} \cdot \text{м}^2.$$

Let's determine the moment of inertia of the tension drum J_2, which is represented by a dependence and takes the following numerical value

$$J_2 = \frac{1}{2}\frac{m_2 \cdot D_2^2}{4} = \frac{8.5 \cdot 0.591^2}{8} = 0.4\ 4 \text{кг} \cdot \text{м}^2.$$

Let's find the combined moment of inertia of the transported cargo

$$J_3 = m_з \cdot \frac{D_2^2}{4} = 28\frac{0.591^2}{4} = 2.44 \text{ кг} \cdot \text{м}^2.$$

The combined moments of inertia J_4 та $J_5$are determined by the dependence

$$J_4 = J_5 = m_4 \cdot \frac{D_4^2}{4} = 8.5\frac{0.46^2}{4} = 0.44 \text{ кг} \cdot \text{м}^2,$$

Summarized moment of inertia of the working part of the belt conveyorJ_6

$$J_б = (m_в + m_c)\frac{D_4^2}{4} = (110 + 239.2)\frac{0.46^2}{4} = 18.47 \text{ кг.м}^2,$$

where $m_в = 110$кг*is* the weight of the cargo (potatoes) transported by the belt conveyor;

$$m_c = 2 \cdot l_k \cdot \rho = 2 \cdot 20 \cdot 5.98 = 239.2 \text{ кг}.$$

Let's determine the moment of inertia of the rotor of the electric motor and the transmission mechanism of the drive reduced to the axis of the drive drum$J_{п1}$

$$J_{п1} = (J_0 + J_1 + J_2)U^2 = (0.25 + 0.002 + 0.152) \cdot 3.3^2 = 4.6 \text{кг} \cdot \text{м}^2,$$

Let's find the value of the moment of inertia of the belt with the load reduced to the axis of the drive drum of the belt conveyor $J_{п2}$

$$J_{п2} = (J_4 + J_5 + J_6)U^2 = (0.44 + 0.44 + 18.47) \cdot 3.3^2 = 19{,}35 \text{кг} \cdot \text{м}^2.$$

The driving torque on the drive electric motor shaft is determined by

$$M_{дв.} = \frac{2M_{\max} \cdot U \cdot \eta}{\frac{S}{S_{кр.}} + \frac{S_{кр.}}{S}}, \quad (3.2)$$

where S , $S_{кр.}$ - the current and critical slip of the electric motor.

The maximum torque on the electric motor shaft depends on this

$$M_{max} = \lambda \cdot M_н = 2.8 \cdot 273 = 764.4 \text{ Н} * \text{м}.$$

The current value of the slip of the electric motor is determined by the following formula

$$S = 1 - \frac{\vartheta_1 \cdot U}{\omega_н}. \quad (3.3)$$

The critical value of electric motor slippage is determined by the formula

$$S_{кр} = S_{ном} \cdot (\lambda + \sqrt{\lambda^2 - 1}), \quad (3.4)$$

where λ=2.8 **is** the multiple of the maximum torque of the electric motor.

The nominal value of sliding is determined according to this dependence

$$S_н = 1 - \frac{\omega_н}{\omega_0} = 1 - \frac{146{,}5}{157} = 0.06. \qquad (3.5)$$

By substituting the obtained numerical values into dependence (3.4), we will find the critical slip of the electric motor

$$S_{кр} = 0.06\left(2.8 + \sqrt{2.8^2 - 1}\right) = 0.32.$$

The combined moment of the forces of resistance to the movement of the belt conveyor is determined as follows

$$M_{п2} = \frac{(F_{нб} - F_{зб})D^4}{2} = \frac{2202.5 \cdot 0.46^2}{2} = 506.6\, H \cdot м. \qquad (3.6)$$

The coefficient of stiffness of the elastic element of the drive mechanism of the belt conveyor is determined by the formula

$$C = \frac{М_н}{\Delta\varphi}. \qquad (3.7)$$

As a result of substituting the obtained numerical values, we find the permissible deformation of the elastic element of the drive

$$\Delta\varphi = 1°;$$

$$\Delta\varphi = \frac{3.14 \cdot 1}{180} = 0.017 \text{ рад},$$

where $\Delta\varphi$ is the permissible deformation of the elastic element of the drive

By substituting the obtained numerical values into dependence (3.7), we will obtain the stiffness factor of the drive

$$C_п = \frac{273}{0{,}017} = 16060.8 \frac{Н \cdot м}{рад},$$

where $C_П$ is the stiffness coefficient of the elastic element of the belt conveyor drive.

3.3. Mathematical model of a belt conveyor

The mathematical model of the belt conveyor is a system of differential equations that can be obtained on the basis of the constructed dynamic model. To do this, we will use the principle of dynamic equilibrium, according to which the mechanical system of the belt conveyor is presented in the form of a model that is in a state of dynamic equilibrium. In the used principle of Dalembert, the dynamic equilibrium of each of the masses of the dynamic model with all the forces applied to them is considered. Therefore, we divide the combined masses of the dynamic model of the belt conveyor into two separate masses with the action of all active forces, inertial forces of the combined masses and reaction forces of the connection between the combined masses (Fig. 3.2).

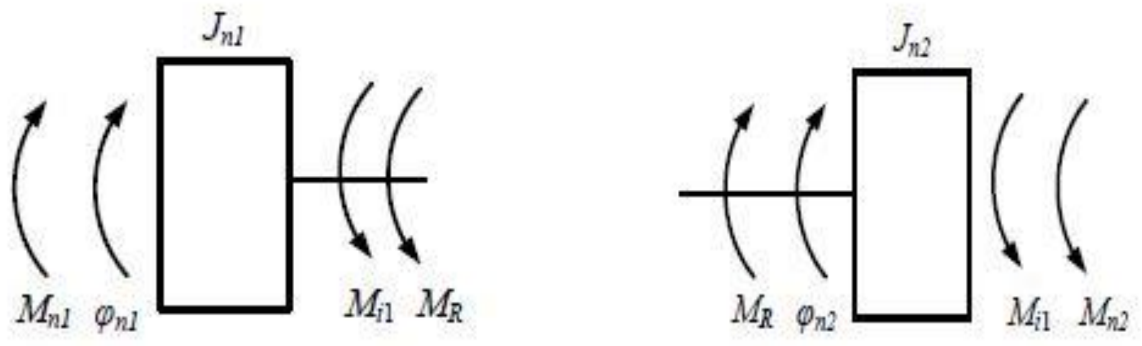

Figure 3.2 - Disaggregated composite masses of a dynamic model of a belt conveyor

In accordance with the principle of dynamic equilibrium of each of the combined masses of the belt conveyor with acting combined forces, we obtain a system of two differential equations, which represent a mathematical model of the dynamics of the belt conveyor:

$$J_{n1}\ddot{\varphi}_1 = M_{n1} - c(\varphi_1 - \varphi_2);$$

$$J_{n2}\ddot{\varphi}_2 = c(\varphi_1 - \varphi_2) - M_{n2}, \qquad (3.8)$$

The obtained system of equations (3.8) is a system of two nonlinear differential equations of the second order, which describes the dynamic processes of the motion of the belt conveyor. The nonlinearity of the system of differential equations is related to the nonlinearity of the drive torque of the belt conveyor.

Since the mechanical characteristic of the belt conveyor drive is non-linear, the system of differential equations (3.8) cannot be solved analytically, therefore the numerical method in the Wolfram software environment was used Mathematica .

3.4. Results of the dynamic analysis of the belt conveyor

In the master's work, sufficient calculations of the belt conveyor were carried out, which made it possible to develop the elements of the structure, the traction body and the drive. For such a belt conveyor, the parameters and characteristics necessary to perform a dynamic analysis during the transportation of potatoes are selected.

As a result of the numerical integration of the system of differential equations of motion of the belt conveyor (3.8) with the help of a computer program, the kinematic, power and energy characteristics of the developed belt conveyor were determined.

Graphical dependences of kinematic (Fig. 3.3,..., Fig. 3.6), power (Fig. 3.7-3.8) and energy (Fig. 3.9) characteristics of the belt conveyor are constructed.

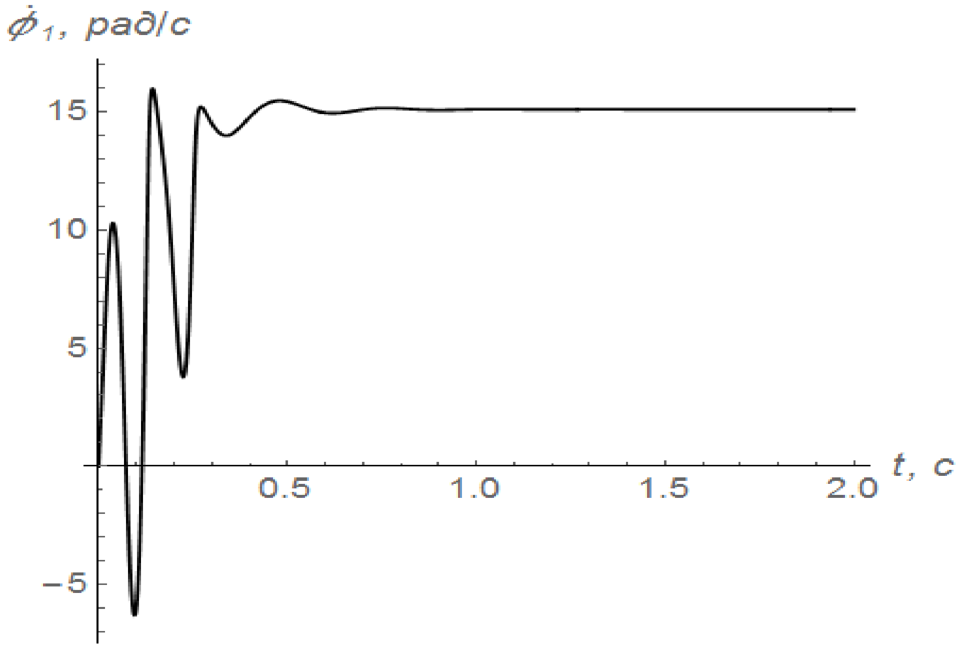

Figure 3.3 - Velocity graph of the first combined mass of the dynamic model of the conveyor

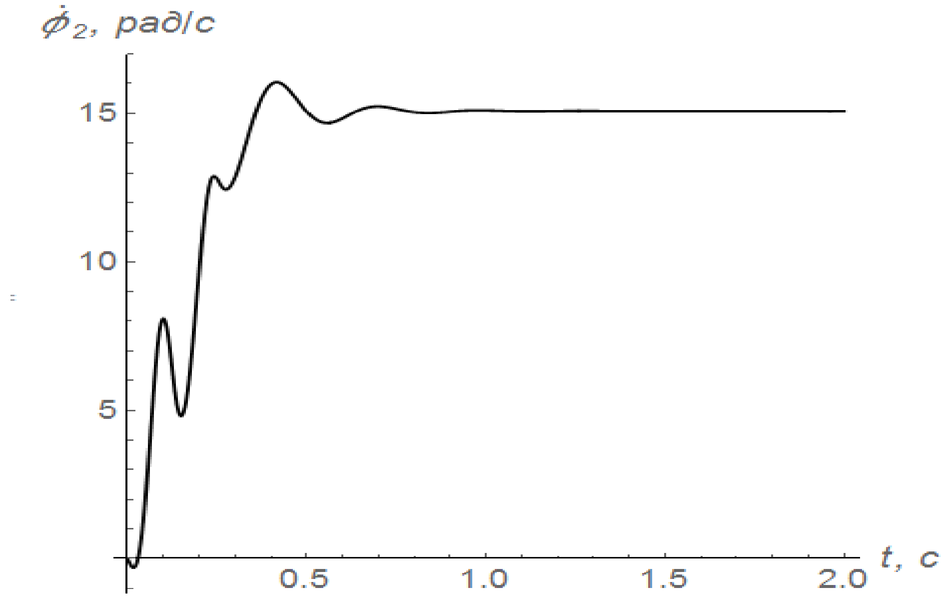

Figure 3.4 - Velocity graph of the second consolidated mass of the dynamic model of the conveyor

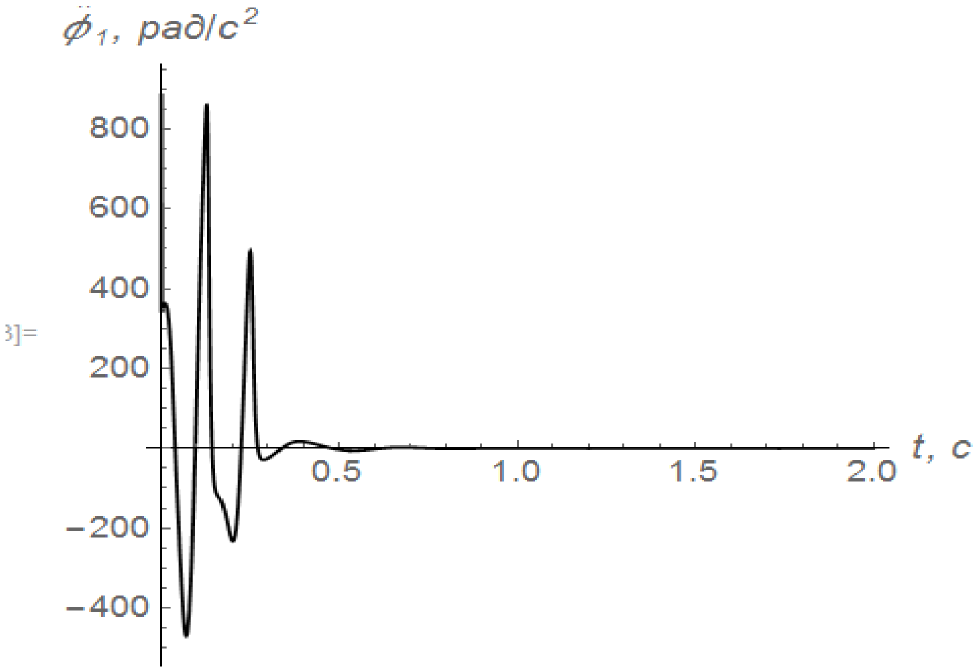

Figure 3.5 - Graph of the acceleration of the first combined mass of the dynamic model of the conveyor

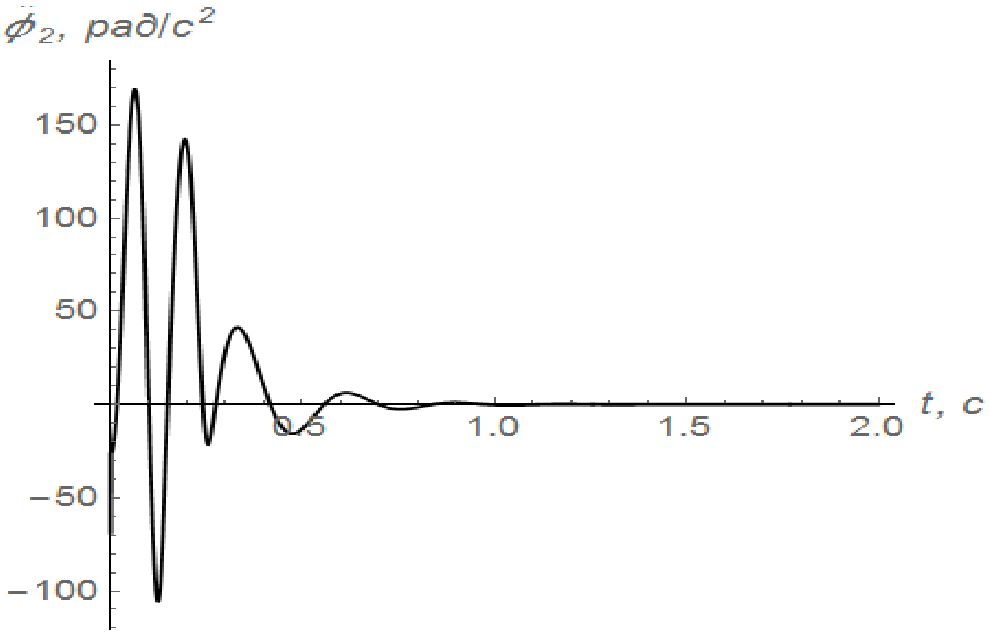

Figure 3.7 - Acceleration graph of the second combined mass of the dynamic model of the conveyor

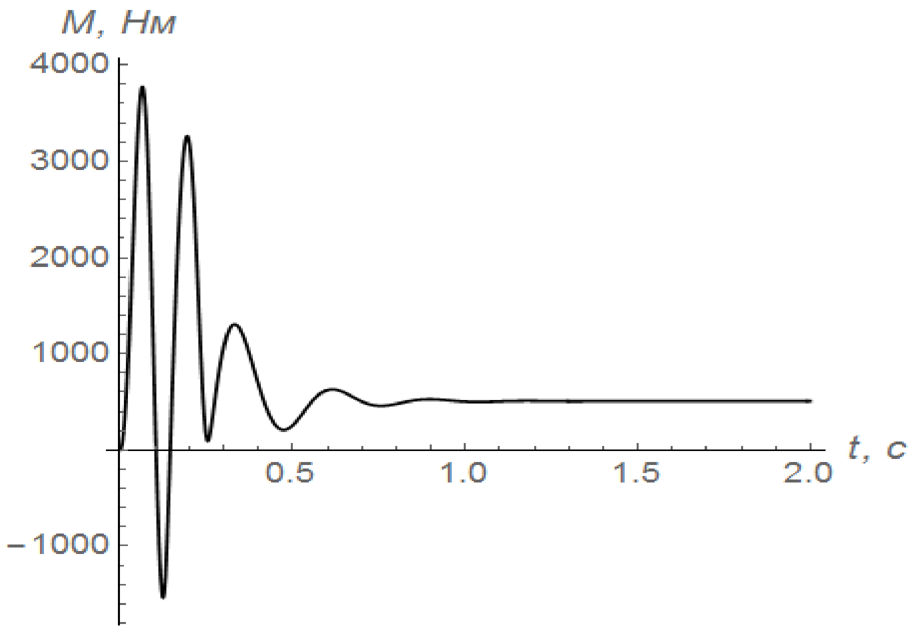

Figure 3.7 - The schedule of changes in the elastic moment of the conveyor drive

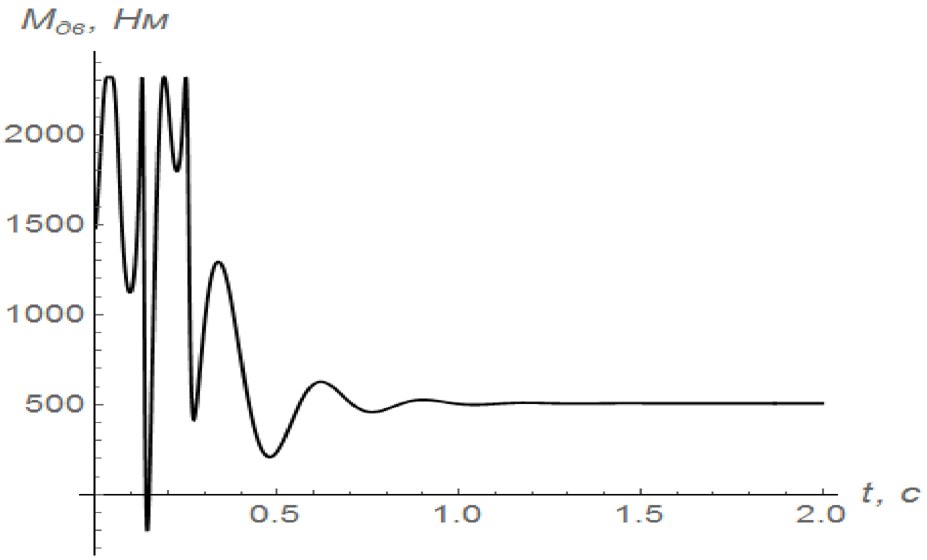

Figure 3.8 - The graph of the change in the driving torque of the conveyor drive

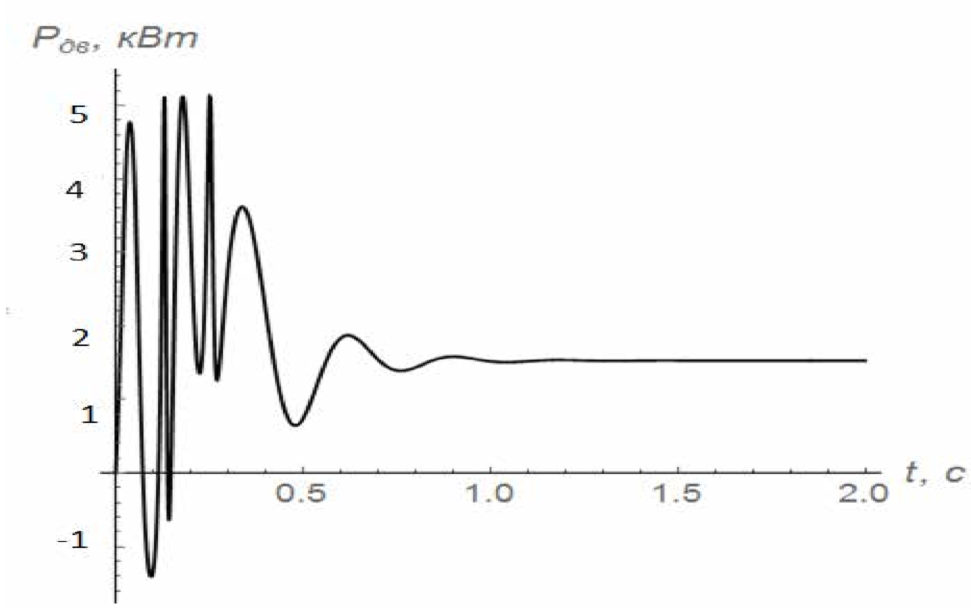

Figure 3.9 - The graph of the power change of the conveyor drive

The analysis of the obtained dependencies of the kinematic, power and energy characteristics of the belt conveyor shows that when all these characteristics change, oscillatory processes are observed in the starting area. At the same time, the maximum value of the elastic moment is almost 8 times higher than the established value (Fig. 3.7). The maximum value of the driving torque exceeds the established value by almost five times, and the power by

2.7 times. Such a significant excess of the maximum values over the established values indicates the presence of significant dynamic loads during the start-up process of the belt conveyor. According to the simulation results, it can be seen that the value of the average power of the electric motor does not exceed the nominal value, but the maximum value exceeds the nominal value by 2.69 times. In order to significantly reduce dynamic loads during the start-up process, there is a need to optimize the traffic mode in this area.

CONCLUSION

The dynamic analysis of the belt conveyor was carried out in order to determine the maximum loads acting on the links and the nature of their change during the transition process of start-up. According to the results of the work carried out, the graphs clearly show oscillating processes, which negatively affect the reliability of the conveyor design and drive, as well as damage to potatoes during movement. Thus, the values of torques and forces in the links exceed the level several times during steady operation of the conveyor. This must be taken into account, and if necessary, re-choose nodes for the belt conveyor. The transmission mechanism of the conveyor drive is also subject to significant fluctuations.

This calculation shows the need to reduce these loads and can serve as a basis for the introduction of drive soft start systems that will dampen oscillations in the most heavily loaded nodes.

CHAPTER 4. OPTIMIZATION OF BELT CONVEYOR START-UP MODE

4.1. Selection of criteria for optimization of the belt conveyor start-up mode

From the dynamic analysis of the mode of movement of the belt conveyor during the transportation of potatoes, it was established that significant fluctuations in kinematic, power and energy characteristics occur in the drive mechanism and traction body (belt). The amplitude of these oscillations is quite significant. Here, the maximum values of dynamic and energy characteristics are several times higher than the established values. Considering the above, there is a need for a significant reduction of dynamic and energy loads in the drive mechanism and traction body of the belt conveyor. These loads lead to the premature destruction of the elements of the drive mechanism and the traction body of the belt conveyor during the transportation of potatoes.

It is possible to achieve a reduction of dynamic loads in the elements of the belt conveyor by choosing the appropriate mode of movement of the drive mechanism. To reduce dynamic loads and eliminate oscillations in the drive elements and traction body of the belt conveyor, it is proposed to optimize the start-up mode of the drive mechanism, since the largest dynamic loads and oscillations occur precisely on this section of traffic . The presence of oscillations leads to the occurrence of significant dynamic loads in the structural elements and drive of the belt conveyor. Such dynamic loads significantly affect the fatigue failure of the drive elements and traction body of the belt conveyor, which reduces the reliability of its operation.

To optimize the start-up mode of the drive mechanism of the belt conveyor, we will choose an optimization criterion. Since there are significant dynamic loads in the structural elements of the belt conveyor at the start-up area , the criterion should reflect exactly these loads. Dynamic loads must be taken into account during the entire conveyor startup process . Therefore , we will choose the action of the elastic moment in the drive mechanism during the entire start-up section as the criterion for optimizing the start-up mode of the belt conveyor . Since the optimization involves comparing traffic modes, the criterion must be expressed as a specific number. In addition , it must be expressed in the form of an integral over time during the entire section of the start-up process.

Taking into account the above, as a criterion for optimizing the start-up mode of the belt conveyor, we will take the root-mean-square value of the elastic moment in the drive of the belt conveyor , which acts during the start-up process and is expressed by the following functional

$$M_{pc} = \left(\frac{1}{t_1}\int_0^{t_1} M_p^2\, dt\right)^{\frac{1}{2}}, \qquad (4.1)$$

where t , t_1 – time coordinate and duration of the conveyor start-up process ;

M_r is the moment of force in the elastic element of the belt conveyor drive.

Since the criterion reflects dynamic loads that are undesirable for the belt conveyor, it should be the smallest in the process of optimizing the start-up mode.

4.2. Methodology for optimizing the belt conveyor start-up mode

To optimize the conveyor startup mode, we can develop an optimization criterion that must be minimized during the conveyor startup. The expression of this criterion must include the moment of force in the elastic element of the belt conveyor drive, so let's find it. For this, we will use the following dependency

$$M_p = c(\varphi_1 - \varphi_2), \qquad (4.2)$$

Where c is the stiffness coefficient of the elastic element of the belt conveyor drive; φ_1, φ_2 − angular coordinates of the first and second combined masses of the dynamic model of the belt conveyor.

From the second equation of the system of equations (3.8) we get mo

$$M_p = c(\varphi_1 - \varphi_2) = J_{p2}\ddot{\varphi}_2 + M_{p2}, \qquad (4.3)$$

where J_{p2} is the moment of inertia of the second combined mass of the dynamic model of the conveyor belt when transporting potatoes;

present the integral expression of the criterion (4.1) taking into account the dependence (4.3), after which we will have

$$f = (J_{p2}\ddot{\varphi}_2 + M_{p2})^2. \qquad (4.4)$$

The minimum condition of the criterion (4.1) taking into account the expression (4.4) is the Poisson equation

∂f∂ φ 2-ddt·∂f∂ φ 2+d2dt2·∂f∂ φ 2+d3dt3·∂f∂ φ 2+d4dt4·∂f∂ φ 2IV= 0 .

As a result of substituting the expression (4.4) into the Poisson equation, we obtain the minimum condition of the criterion (4.1). This condition looks like this

$$2J_{p2}^2\dddot{\varphi}_2 = 0. \qquad (4.5)$$

Condition (4.5) is valid only when, $\dddot{\varphi}_2 = 0$,since the other components cannot be equal to zero. As a result of successive integration of equation (4.5), we obtain the dependences of the coordinates of the second combined mass of the dynamic model and its time derivatives:

$$\dddot{\varphi}_2 = C_1;$$

$$\ddot{\varphi}_2 = C_1 t + C_2;$$

$$\dot{\varphi}_2 = \frac{C_1 t^2}{2} + C_2 t + C_3; \qquad (4.6)$$

$$\varphi_2 = \frac{C_1 t^3}{6} + \frac{C_2 t^2}{2} + C_3 t + C_4.$$

Here are C_1, C_2, C_3, C_4constant integrations , which are determined from the boundary conditions of the conveyor movement:

$$t = 0: \varphi_2 = 0;\ \dot{\varphi}_2 = 0;\ \ t = t_1:\ \ \dot{\varphi}_2 = \omega;\ \ddot{\varphi}_2 = 0. \qquad (4.7)$$

Under conditions (4.7), ω −the angular velocity of the drive drum of the belt conveyor is fixed.

From the boundary conditions (4.7) for expressions (4.6), we find constant integrations that take the following values :

$$C_1 = -\frac{2\omega}{t_1^2};\ C_2 = \frac{2\omega}{t_1};\ C_3 = 0; \qquad C_4 = 0. \tag{4.8}$$

As a result of substituting expressions (4.8) into equation (4.6), we find the characteristics of the optimal dynamic mode of starting the belt conveyor, which ensure the minimization of the elastic moment in the drive of the belt conveyor. In the obtained start-up mode, there are no oscillations and increased dynamic loads in the drive and traction body of the belt conveyor.

From the second equation of the system (3.8), we express the coordinate of the first combined mass of the dynamic model of the belt conveyor, which reflects the drive mechanism

$$\varphi_1 = \varphi_2 + \frac{J_2}{c}\ddot{\varphi}_2 + \frac{M_{p2}}{c}. \tag{4.9}$$

Differentiating the expression (4.9) in time, we find the speed and acceleration of rotation of the first combined mass of the dynamic model of the belt conveyor:

$$\dot{\varphi}_1 = \dot{\varphi}_2 + \frac{J_{p2}}{c}\dddot{\varphi}_2 + \frac{M_{p2}}{c}; \tag{4.10}$$

$$\ddot{\varphi}_1 = \ddot{\varphi}_2 + \frac{J_{p2}}{c}. \tag{4.11}$$

Now determine the elastic moment in the drive mechanism and the driving moment of the belt conveyor drive, which are represented by the following dependencies :

$$M_p = J_{p2}\ddot{\varphi}_2 + M_{p2}; \tag{4.12}$$

$$M_d = J_{p1}\ddot{\varphi}_1 + J_{p2}\ddot{\varphi}_2 + M_{p2}, \tag{4.13}$$

Here are J_{p1}, J_{p2} – зведені the moments of inertia of the first and second masses of the dynamic model of the belt conveyor, which represent the drive and traction body with the potato of the belt conveyor.

Let's express the power on the drive drum of the belt conveyor

$$P_d = M_d\dot{\varphi}_1.$$

4.3. Results of optimization of the belt conveyor start-up mode

As a result of the calculations of the mathematical model of the belt conveyor at the optimal mode of movement, graphical dependences of the kinematic, power and energy characteristics of the start-up process were constructed, which are displayed in fig. 4.1,..., fig. 4.8.

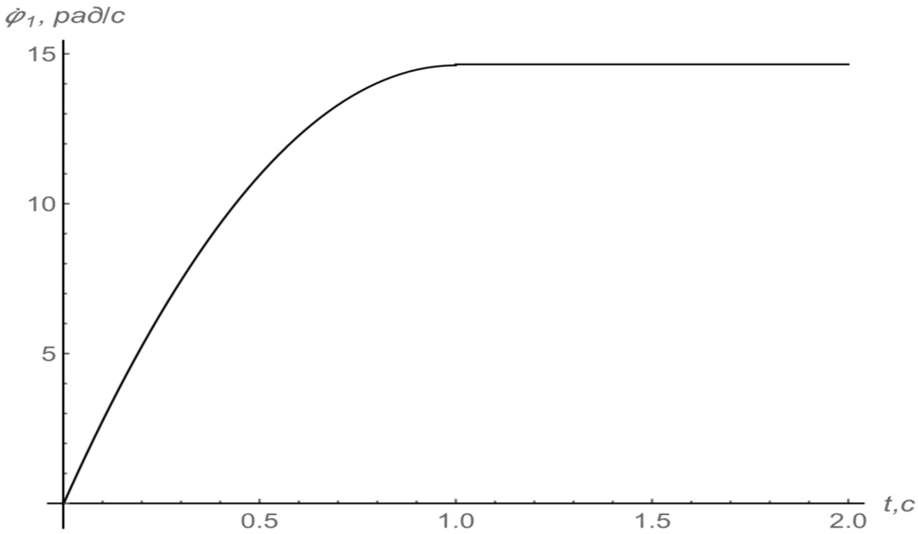

Figure 4.1 - Graph of the angular velocity of the first combined mass of the dynamic model of the conveyor in the optimal mode of movement

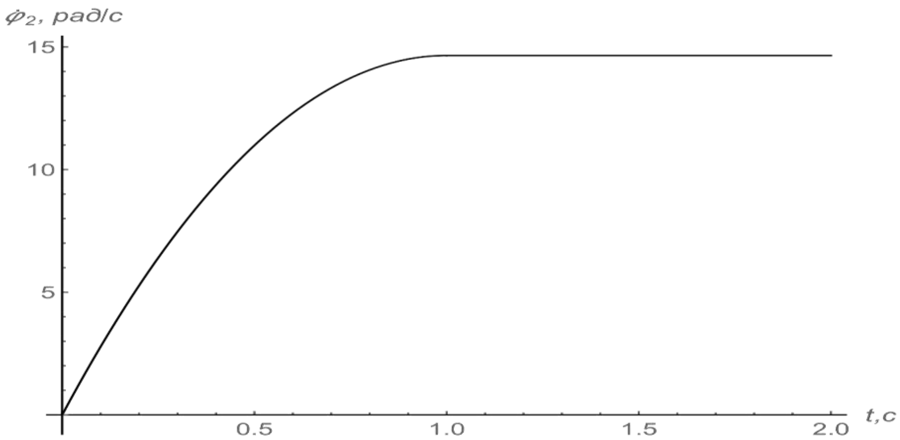

Figure 4.2 - Graph of the angular velocity of the second combined mass of the dynamic model of the conveyor in the optimal mode of movement

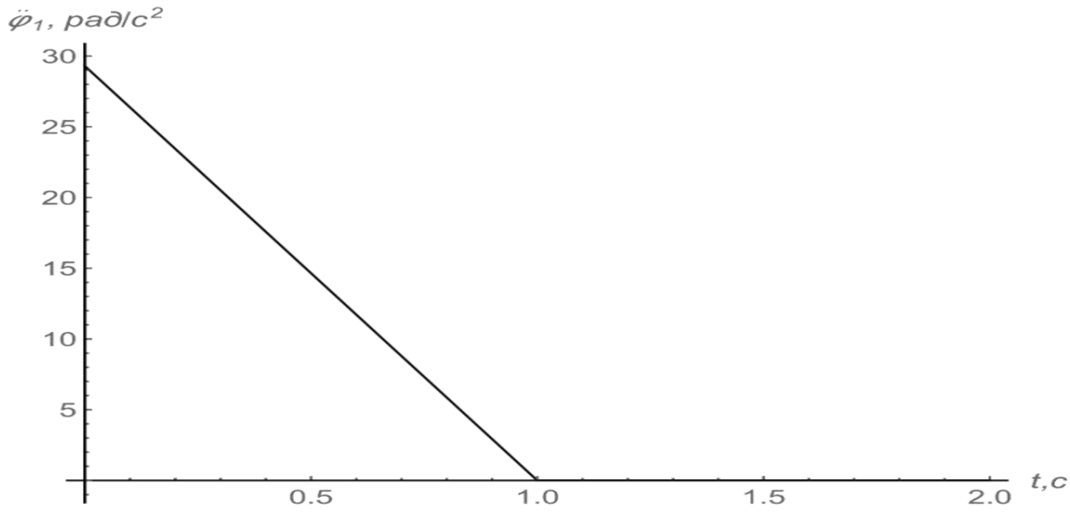

Figure 4.3 - Graph of the acceleration of the first combined mass of the dynamic model of the conveyor in the optimal mode of movement

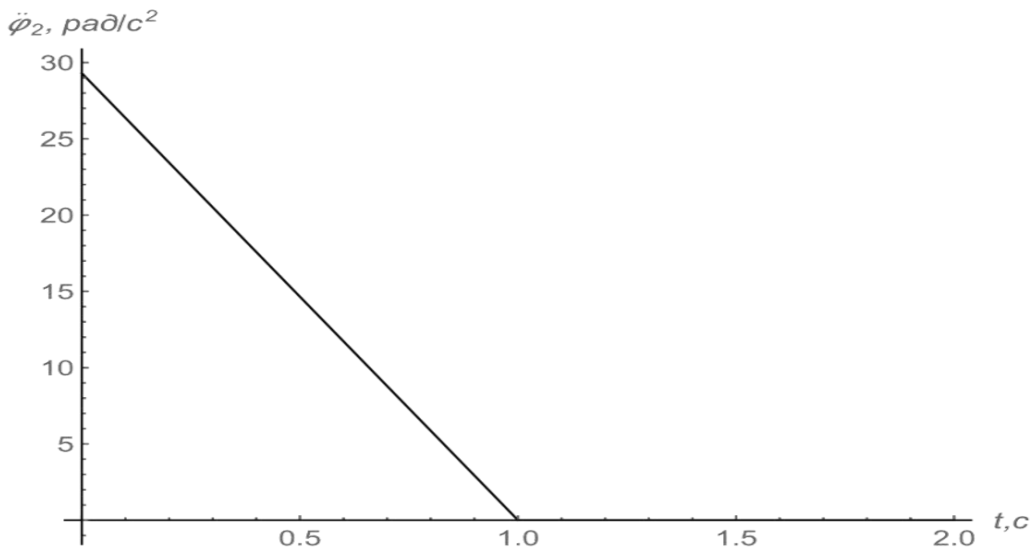

Figure 4.4 - Graph of acceleration of the second combined mass of the dynamic model of the conveyor in the optimal mode of movement

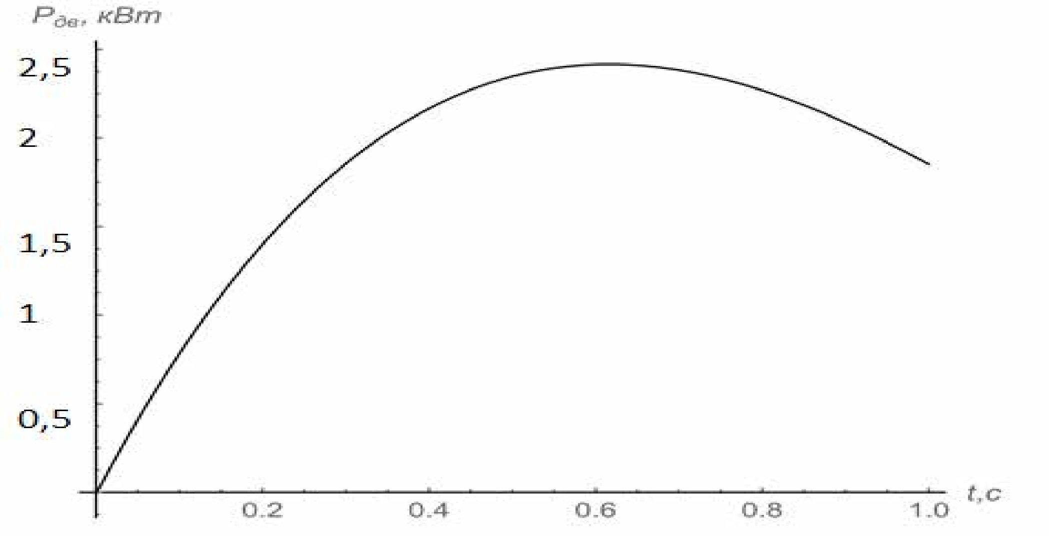

Figure 4.5 - The graph of the change in the power of the conveyor drive in the optimal driving mode

From the graphical dependences of the kinematic, power and energy characteristics of the optimal dynamic start-up mode, it can be seen that in this mode there are no oscillations of the belt conveyor links. This leads to the minimization of dynamic loads of belt conveyor elements and reduction of energy costs .

CHAPTER 5. LABOR PROTECTION

Safety requirements for structures and operation of lifting and transport equipment

Lifting and transport equipment is widely used in production, accordingly, there are a large number of types and types of machines for its implementation. In general, such machines can be divided into two groups: transporting and lifting.

Transport machines are designed to move bulk cargo in a non-stop manner. These include means of horizontal transportation: belt and chain conveyors (conveyors), screw conveyors (screws), pneumatic transport devices for moving mainly dusty materials. In addition, pipeline transport is widely used at oil refining and construction enterprises. Horizontal movement of materials is also possible by periodically operating means of transport with the help of suspended roads, railed and non-railed transport (railway tanks, wagons, cars, coaches, etc.). However, compared to non-stop transport, these methods of moving goods require significant manual maintenance, are more dangerous and less hygienic.

An example of means of horizontal transport is belt and chain conveyors, which are widely used in industry. Injury analysis shows that 90% of accidents on these conveyors occur as a result of parts of the body or clothing being caught by parts of the equipment that are moving or run over while troubleshooting the conveyor. Therefore, on a working conveyor, it is forbidden to correct the shift (flow) of the belt and eliminate its slippage, pick up spilled material, sweep under the conveyor, remove stuck materials.

It is important to be able to correctly apply devices that eliminate or reduce the need for manual labor, in particular, the use of scrapers and brushes for mechanical cleaning of tapes from adhering materials.

Drive and tension drums are fenced off; two limit switches are installed on them, which stop the system in the event of overloading of traction devices or in the event of a tape break. A safety finger is installed on the clutch connecting the electric motor of the drive with the drive drum, which works on the cut when the traction force is increased by 25% compared to the normal one.

of the State Supervision and Protection of Labor participate, are allowed to drive and service forklift trucks . Periodically (at least once a year) knowledge of the rules of construction and dangerous operation of lifting cranes is checked.

Occupational health and safety instructions for belt conveyor drivers

1. General provisions

1.1. Persons who have professional skills in working on a conveyor and have passed a medical examination are allowed to work independently on a conveyor.

1.2. A belt conveyor driver (transporter) who is hired must undergo an introductory briefing on occupational health and safety, industrial sanitation, fire safety, methods and methods of providing first aid to victims and be familiar with the working conditions, rules and benefits for working in hazardous and dangerous working conditions, about the rules of behavior in the event of accidents.

1.3. Before starting work directly at the workplace, the operator of the belt conveyor (transporter) must undergo an initial briefing on safe methods of work performance.

Regarding the conduct of introductory briefings and briefings at the workplace, relevant entries are made in the Journal of registration of introductory briefings on labor protection issues and the Journal of registration of briefings on labor protection issues. At the same time, the signatures of both the person who was instructed and the one who instructed are mandatory.

1.4. After the initial training at the workplace, the belt conveyor driver (transporter) must undergo an internship under the guidance of an experienced, qualified belt conveyor driver (transporter) who is appointed by an order (order) for the enterprise within 2-15 shifts (depending on length of service, experience and nature of work).

1.5. A belt conveyor operator (transporter) must undergo repeated instruction on the rules and techniques of safe work and occupational health:

- periodically, at least once a quarter;

– in case of unsatisfactory knowledge of labor protection no later than one month;

– in connection with an incident of injury or violation of labor protection requirements that did not lead to an injury.

1.6. The operator of the belt conveyor (transporter) must work in overalls and shoes, as well as personal protective equipment provided by the Standard Industry Standards: a cotton dustproof suit, leather boots, combined gloves, protective glasses (against mechanical damage), a helmet, in addition, for outdoor work and in the unheated galleries in winter additionally – jackets and trousers cotton on the insulation pad.

Overalls, special shoes and personal protective equipment must be in good condition and correspond to height and size.

1.7. A belt conveyor operator must use only a serviceable tool.

1.8. It is forbidden to allow persons who do not have the right to do maintenance and repair.

1.9. The driver of the belt conveyor is prohibited from leaving the working conveyor unattended.

1.10. Electrical wires within the belt conveyor and from the conveyor to the breaker must be enclosed in a rubber hose and protected from mechanical damage. The conveyor frame must be grounded.

1.11. Conveyors, under which people can be or pass, must be equipped with sides, and a metal grid is installed over the passage.

1.12. It is forbidden to walk along the conveyor belts in both longitudinal and transverse directions.

1.13. The upper end of the belt conveyor must overlap the loading platform for a length of at least 0.5 m.

1.14. When feeding dusty materials (cement, lime, alabaster, etc.), the conveyors must be closed to prevent scattering of materials.

1.15. When transporting man-made materials, the conveyor must be equipped with sides with a height of at least half of the maximum dimensions, and its drum on the unloading side must go no less than 0.5 m deep into the receiving platform.

1.16. A special receiving device must be installed in the transporter to accept artificial loads. It is forbidden to take artificial loads by hand directly from the conveyor belt.

2. Safety requirements before starting work

2.1. Before starting work, the operator of the belt conveyor must:

- carefully examine the parts of the belt conveyor mechanisms;

– whether the pads of the tape fit tightly to the surface of the drum and whether there is no damage to the tape;

– whether the protective means of the moving parts of the mechanism are sufficient, or whether their fastening is strong;

– during the trial run of the conveyor, check the ease of rotation of the drums and rollers, the movement of the belt, whether its tension is sufficient, as well as the condition of the protective means of the counterweight of the tensioning device;

- put on overalls, special shoes, and if necessary, personal protective equipment;

- inspect the condition of the starting electrical equipment, the corresponding fuses, as well as the grounding of the electric motors;

– after inspecting the conveyor mechanisms and troubleshooting, the driver must lubricate all friction parts of the unit.

3. Safety requirements during work

3.1. Before starting the conveyor, you should make sure that there are no remains of materials, tools and other foreign objects on it, and also warn the workers who service the mechanism with a sound signal about its start. The presence of outsiders near the mechanism is prohibited when it is put into operation.

3.2. Make a trial run of the conveyor without loading. If this does not reveal any malfunctions, it should be loaded gradually.

3.3. During the test run, it is necessary to check the correct operation of all parts of the machine.

3.4. To ensure the normal operation of belt conveyors, it is necessary to observe the following rules:

- systematically monitor the operation of roller supports ;
- constantly monitor the operation of tensioning devices;
- regularly inspect loading funnels, unloading and cleaning devices.

3.5. The transporter driver is prohibited from:

– stop belt conveyors in a loaded state (except in emergency cases);

– clean and repair while driving;

– avert the overlap of the tape to the side with the help of a stop, eliminate slipping of the tape on the drive drum by sprinkling rosin, sand and other materials.

3.6. During conveyor operation, it is forbidden to eliminate the sliding of the conveyor belt by sprinkling sand, clay, slag, rosin, tar, etc. between the tape and the drum, tension, strengthen , correct the tape, rearrange the rollers supporting the tape, as well as clean the tensioning and drive stations (drums), sprockets manually.

These operations are allowed to be carried out with the electric motor turned off, when the fuses and disconnecting plugs have been removed by the electrician.

3.7. When operating a belt conveyor in conditions where the entire track is not visible, a two-way sound alarm must be installed at the starting points. Direct signaling with control from the starting point of the conveyor is allowed to be used personally only in cases where the conveyor is fully visible along its entire length.

4. Safety requirements after the end of work

4.1. At the end of the work, the driver of the belt conveyor must:

- inform the workers about stopping the loading of the belt conveyor with materials;

– stop the mechanism and turn off the circuit breaker; lock the box in which it is installed.

4.2. Inspect and clean the parts of the mechanism from dirt, material and dust. Safety glasses must be used when cleaning mechanisms.

4.3. After the end of the shift and before starting work, it is necessary to periodically lubricate bearings, rollers that do not rotate and replace defective ones.

4.4. At the end of the work, the operator of the belt conveyor must remove the overalls, clean them of dust and other dirt and take them to the place designated for storage. Then wash your face and hands with warm soapy water or take a shower.

4.5. The driver must inform the mechanic or shifter about all malfunctions discovered during the inspection or operation of the conveyor.

5. Safety requirements in emergency situations

5.1. If metal tears, sharp bends and weld defects are detected on the conveyor belt, work should be stopped immediately. It is necessary to review the tape before starting each shift.

5.2. It is forbidden to put out burning wires or electric cables without turning off the voltage.

5.3. In the event of a fire, it is necessary to immediately move people to a safe distance, notify the fire department and take measures to extinguish it.

5.4. In the event of a sudden interruption of the current supply, the operator of the belt conveyor must turn off the circuit breaker and brake the mechanism.

5.5. Immediately turn off the current in the following circumstances:

– in the event of a breakdown of any part of the mechanism;

– in case of an accident that happened near the mechanism to someone from the service personnel;

- in the event of a fire in the work area.

5.6. In case of accidents, the driver of the belt conveyor must provide first aid to the victim, and in urgent cases, call an ambulance and immediately inform the administration about the accident.

Projected measures to improve working conditions

General list of planned activities. Production is saturated with machines , mechanisms, electrical installations. It is connected with the necessity of strict observance of technical and fire safety rules.

The following main technological measures for the factory are foreseen.

The appearance of outsiders at the factory is prohibited.

Workers should be allowed to work places after passing a briefing on labor safety.

Mechanisms with rotating nodes must have guards.

All electrical installations must be grounded and have an emergency shutdown.

When repairing electrical installations and wiring, it is necessary to disconnect everything completely and hang signs that will inform about the repair.

To reduce noise and vibration, separate the premises with partitions.

After detection of labor safety violations, re-instruction should be conducted.

Workers must be provided and work in overalls.

All cases of injury should be considered in accordance with the requirements and in a timely manner.

The following basic fire prevention measures are proposed:

Each room must be equipped with various fire extinguishing means and fire shields.

Keep the premises and territory clean.

In order to ensure the fire safety of electrical installations, it is necessary to correctly choose their grounding.

Choose the types of lamps depending on the fire resistance of the lamps. Heating devices must be provided with sound signaling and emergency shutdown.

CHAPTER 6. ECONOMIC JUSTIFICATION OF THE PROJECT

Determination of injection costs on a belt conveyor

Estimated cost of the basic design of the belt conveyor:

$$С_{баз} = Ц_{оп}К_{б}, \tag{6.1}$$

where: C $_{op}$ – wholesale price of the conveyor, C $_{op}$ = UAH 300,000.

K $_{b}$ = 1.12 – the coefficient of transition from the wholesale cost to the average cost.

$С_{баз} = Ц_{оп}К_{б} = 300000 * 1{,}12 = 336000$ грн.

The average cost of a belt conveyor after improvement:

$$С_{б_{мод}} = С_{баз} + С_{мод}, \tag{6.2}$$

where:

S $_{b\,.\,mod}$ - the cost of improvement, C $_{b\,.\,mod}$ = UAH 15,000.

$С_{б_{мод}} = С_{баз} + С_{мод} = 336000 + 15000 = 351000$ грн.

Determination of annual operational productivity

The operational performance of the belt conveyor is determined on the basis of technical performance under the same operating conditions.

Hourly operational productivity:

$$П_{Г}^{Е} = П_{Г}^{Т}К_{Т}, \tag{6.3}$$

where:

$П_{Г}^{Т}$– hourly technical productivity, for the basic design of the belt conveyor: $П_{Г}^{Т}$=20 t/h.

For an improved belt conveyor design:

$П_{Г}^{Т}$= 25t/h, Kt is the transition coefficient.

Productivity:

$П_{Г_{баз}}^{Е} = П_{Г}^{Т}К_{Т} = 20 * 0{,}8 = 16\ \frac{т}{год};$

$$П^{Е}_{Г_{мод}} = П^{Т}_{Г} К_{Т} = 25 * 0{,}8 = 20\ \frac{т}{год}.$$

Annual operational productivity of the belt conveyor:

$$П^{Е}_{р} = П^{Е}_{Г} Т_{річне} К_{в}, \quad (6.4)$$

where:

Kv = 0.82 – the coefficient of use of shift time,

T_{annual} – the annual effective working time fund of the belt conveyor,

T_{annual} = 90 days = 2160 hours ;

For the basic design of the belt conveyor

$$П^{Е}_{р} = П^{Е}_{Г} Т_{річне} К_{в} = 16 * 2160 * 0{,}82 = 21254.4\ \frac{т}{год},$$

For an improved belt conveyor design:

$$П^{Е}_{р} = П^{Е}_{Г} Т_{річне} К_{в} = 20 * 0{,}82 * 2160 = 35424\ \frac{т}{год}.$$

Determination of annual costs

Current annual expenses:

$$С_{річне} = С_{машин.-зм} - Н_{зм} \quad (6.5)$$

where:

$$С_{машин.-зм} = С_{ам} + С_{обсл} + С_{ен} + С_{то} \quad (6.6)$$

Nzm - the number of changes in a year, Nzm = 270 changes.

$С_{ам}$ – variable costs of depreciation deductions,

$С_{обсл}$ – variable costs for service personnel,

$С_{ен}$ – variable energy costs,

$С_{то}$ – variable maintenance and repair costs.

Variable costs of amortization deductions:

$$С_{ам} = \frac{А}{Н_{см}}, \quad (6.7)$$

A - depreciation deductions for complete restoration and overhaul of the loader, hryvnias.

$$А = \frac{С_б * а}{100}, \quad (6.8)$$

$С_б$– the average cost of a belt conveyor,

$С_{баз} = 336000$ грн,

$С_{б.мод} = 351000$ грн.

and - 12% rate of depreciation deductions.

$$А = \frac{С_б * а}{100} = \frac{336000 * 12}{100} = 40320 \text{ грн},$$

$$А^I = \frac{С_б * а}{100} = \frac{351000 * 12}{100} = 42120 \text{ грн}.$$

$$С_{ам} = \frac{А}{Н_{см}} = \frac{40320}{270} = 149.3 \frac{\text{грн}}{\text{маш} - \text{зм}},$$

$$С_{ам} = \frac{А}{Н_{см}} = \frac{42120}{270} = 156 \frac{\text{грн}}{\text{маш} - \text{зм}}.$$

Variable personnel costs:

$$С_{обсл} = N * З_{зм} * 1{,}25; \quad (6.9)$$

where:

N- the number of service personnel,

$З_{зм}$- employee's salary per shift (UAH).

$$З_{зм} = Т_{ст.4} * t_{см}, \quad (6.10)$$

where:

$Т_{ст.4}$– h single rate of the operator$Т_{ст.4} = 35 \frac{\text{грн}}{\text{год}}$.

$t_{см}$= 8 hours - shift duration.

$$З_{зм} = Т_{ст.4} * t_{см} = 35 * 8 = 280 \frac{грн}{маш - зм},$$

$$С_{обсл} = С_{обсл}{}^{/} = N * З_{зм} * 1{,}25 = 1 * 280 * \frac{1}{10} = 28 \frac{грн}{маш - зм}.$$

Variable energy consumption:

$$С_{ЕН} = W_{ЕН} * S_i, \tag{6.11}$$

where:

$W_{ЕН}$– energy consumption by the conveyor drive

S_i- the cost of one kilowatt of energy. S_i= UAH 1.67

$$W_{ен} = \frac{N_{ном} * t_з * К_{см} * К_в * К_{дм} * К_п}{\epsilon} \tag{6.12}$$

where:

$N_{ном}$– nominal power of the drive (4 kW),

$К_в$= 0.86 – engine utilization factor,

$К_{дм}$= 0.4 – coefficient of engine power utilization,

$К_п$= 1.05 – coefficient that takes into account energy consumption,

ϵ= 0.8 – the efficiency of the bend during loading.

$$W_{ен} = \frac{N_{ном} * t_з * К_{см} * К_в * К_{дм} * К_п}{\epsilon} = \frac{4 * 8 * 3 * 0{,}86 * 0{,}4 * 1{,}05}{0{,}8} = 43.344 \frac{грн}{маш - зм},$$

$$С_{ЕН} = W_{ЕН} * S_i = 43.344 * 1{,}67 = 72.384 \frac{грн}{маш - зм},$$

$$С_{ЕН}{}^{/} = W_{ЕН} * S_i = 43.5 * 1{,}67 = 72.645 \frac{грн}{маш - зм}.$$

Variable maintenance costs can be taken as 13% of the average cost of the conveyor:

$$C_{то} = \frac{C_б * 0,13}{H_{см}}; \quad (6.13)$$

$$C_{то} = \frac{C_б * 0,13}{H_{см}} = \frac{336000 * 0,13}{270} = 161.7 \frac{грн}{маш - зм};$$

$$C_{то}{}^{/} = \frac{C_б * 0,13}{H_{см}} = \frac{351000 * 0,13}{270} = 169 \frac{грн}{маш - зм};$$

$$C_{маш.зм} = 149.3 + 8 + 72.384 + 161.7 = 391.384 \frac{грн}{маш - зм};$$

$$C_{маш.зм}{}^{/} = 156 + 8 + 72.645 + 169 = 405,645 \frac{грн}{маш - зм};$$

$$C_{рік} = 391.384 * 3 = 1174.152 \text{ грн};$$

$$C_{рік}{}^{/} = 405,645 * 3 = 1216.935 \text{ грн}.$$

Determination of the main indicators of economy and capital investment

The specific capital investment per 1,000 tons of transported cargo is determined by taking into account the estimated cost of the machine and its annual productivity.

$$K_y = \frac{1000 * C_б}{П^E_{річн}}; \quad (6.14)$$

$$K_y = \frac{1000 * C_б}{П^E_{річн}} = \frac{1000 * 336000}{21254.4} = 15808.49 \frac{грн}{1000 \text{ т}};$$

$$K_y{}^{/} = \frac{1000 * C_б}{П^E_{річн}} = \frac{1000 * 351000}{35424} = 9908.53 \frac{грн}{1000 \text{ т}}.$$

Specific current costs for transportation of 1,000 tons of basic and advanced design cargo:

$$S_y = \frac{1000 * C_{річне}}{C^E_{річне}}; \quad (6.15)$$

$$S_у = \frac{1000 * С_{річне}}{С^{Е}_{річне}} = \frac{1000 * 1174.152}{21254.4} = 55.24 \frac{грн}{1000\ т};$$

$$S_у{}^{/} = \frac{1000 * С_{річне}}{С^{Е}_{річне}} = \frac{1000 * 1216.935}{35424} = 34.35\ \frac{грн}{1000\ т}.$$

Specific costs per 1,000 tons of loaded cargo:

$$З_{пр} = S_y + Е_н + К_у{}^{/}; \qquad (6.16)$$

$Е_н$=0.15 – normal coefficient of economic efficiency:

$$З_{пр} = 55.24 + 0,15 + 15808.49 = 15863.88\ \frac{грн}{1000\ т};$$

$$З_{пр} = 34.35 + 0,15 + 9908.53 = 9943.03\ \frac{грн}{1000\ т}.$$

Annual economic effect on one conveyor:

$$Е_р = \left(З_{пр} - З_{пр}{}^{/}\right) * \frac{П^{Е}_{річне}}{1000}; \qquad (6.17)$$

$$Е_р = (15863.88 - 9943.03) * \frac{35424}{1000} = 209740.19\ \frac{грн}{рік}.$$

Payback period of additional investments:

$$Т_{ок} = \frac{К_у - К_у}{S_у - S_у}; \qquad (6.18)$$

$$Т_{ок} = \frac{К_у - К_у}{S_у - S_у} = \frac{15808.49 - 9908.53}{55.24 - 34.35} = \frac{5899.96}{20.89} = 282 днів = 0,79\ року.$$

The results of the calculations are entered in the table. 4.1

Table 6.1

Technical and economic indicators.

Indicators	Units of measurement	Machinery	
		Basic	Improved
The average cost of the conveyor	UAH	336000	351000
Operating performance of the machine: An hour	 t/ h	 20	 25
Annual economic effect	UAH/year		209740.19
Specific capital investments	UAH/1000t	15808.49	9908.53
Payback period of additional investments	Year		0.79

CONCLUSION

In the process of performing the qualifying master's thesis, the technological calculation of the belt conveyor for transporting potatoes was performed. The technological scheme of transporting potatoes was considered, according to which the initial data for the development of the belt conveyor design were established.

On the basis of the analysis of the existing designs of belt conveyors, morphological tables of the designs of the belt conveyor and its drive mechanism were developed. Based on the developed morphological tables, the design of the belt conveyor and its drive mechanism is proposed. The belt conveyor drive consists of a motor-reducer and a chain transmission. Calculations were made on the strength of the elements of the belt conveyor.

A dynamic analysis of the movement of the belt conveyor was carried out. Dynamic and mathematical models of the belt conveyor were developed for the analysis. The calculation of the mathematical model made it possible to determine the kinematic, dynamic and energy characteristics that change with significant fluctuations, which leads to an increase in dynamic loads. In order to eliminate oscillations and reduce dynamic loads, the starting mode of the drive mechanism was optimized. The results of the optimization of the conveyor movement mode showed that during the start-up process, fluctuations in the links of the belt conveyor are eliminated and dynamic loads are minimized.

Labor protection measures during belt conveyor operation have been developed.

As a result of the development of a new design of the belt conveyor, an annual economic effect in the amount of UAH was obtained 209740, which confirmed the expediency of the development of the new design.

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APPENDICES