Design analysis of bearing units of conveyor rollers

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Abstract: This article discusses various types of bearing seals, including groove, stuffing box, labyrinth and combined, as well as their advantages and disadvantages depending on operating conditions. Various types of rolling bearings are described, such as ball and roller angular contact tapered single row bearings, their features and applications. Special attention is paid to the causes of bearing failure, including fatigue failure and abrasive wear. Methods for calculating the durability of bearings and the influence of dynamic loads on their operation are also considered. The work highlights the importance of an integrated approach to the design and operation of bearing units to improve the reliability and efficiency of conveyor systems.

Keyword: bearing units, conveyor rollers, conveyor belts, bearing seals, abrasive wear, fatigue failure, bearing life, dynamic loads, ball bearings, roller bearings, bearing lubrication

Depending on the operating conditions, belt conveyors of various types and designs have been developed, which are usually divided according to the following characteristics [1,2]:

- as intended;
- by type of cargo;
- by type of drive devices;
- by the number of drives;
- by tape type;
- by unloading method;
- according to the location of the load carrying branch of the belt;
- according to the cross-sectional shape of the load-carrying branch of the belt;
- according to the type of conveyor position;
- by the angle of inclination of the conveyor;
- but the type of conveyor route (straight or curved).

The main design element of belt conveyors is an endless belt that goes around the drive and tension drums. The belt along the entire length of the conveyor is supported by roller supports of load-carrying and empty branches (Fig. 1).

Fig.1- Belt conveyor

The conveyor design also includes a drive, devices for tensioning and cleaning the belt, catchers, special roller supports, elements of automatic control and control of the movement of the belt[3,4,5,6].

A roller support is a metal structure on which conveyor rollers are installed, designed to support the belt, both on the cargo and empty branches of the conveyor. At mining enterprises, belt conveyors with three roller supports are widely used, which consist of rollers of the same length with an angle of inclination of the side rollers of 20, 30, 36, 45 degrees. Depending on the operating conditions, rollers are available in light, medium and heavy versions. In open-pit and underground mines, heavy-duty conveyor rollers are most often used. In open-pit and underground mines, heavy-duty conveyor rollers are most often used. This is due to the fact that such rollers have increased structural reliability that can withstand heavy loads. This is due to the fact that such rollers have increased structural reliability that can withstand heavy loads. The main difference between rollers of different designs is the degree of dust protection using different types of seals of the bearing assembly, as well as the series of bearings used (Fig. 2).

Fig. 2 - Roller support and roller of the conveyor belt

As noted above, in the design of rollers, groove, labyrinth, contact and stuffing box types of seals are used to protect the bearing assembly. A combination of different types of protective devices is also often used. Depending on the operating conditions, each type of seal has a number of advantages and disadvantages, which are presented in Table 1.

Table 1.

Main types of conveyor roller sealing devices

№	Seal Type	Advantages	Flaws
1	2	3	4
1	Groove	They have good sealing ability, provided they are filled with moisture-resistant greases	Doesn't hold moisture well enough
2	Gland	Simplicity of design and installation in the bearing assembly	Doesn't work long enough
3	Labyrinth	Widely used in bearing units; minimal resistance to rotation of the rollers, in the absence of dust in the gaps	The gaps do not retain lubricant well; there is no protection from direct moisture; if the gaps are filled with dust, the roller locks due to the stationary sealing element
4	Frame-cuff	Ease of manufacture; compactness	Increased resistance to roller rotation; If dust gets into the seal, the contact point of the seal and the roller surface are intensively worn.
5	Disk	They have high dust resistance and good gap filling	Does not retain moisture reliably; increased resistance at low operating temperatures

In general, the designs of bearing units and their sealing devices can be divided into contact, non-contact, slotted and combined. All of these types are in turn divided into the following subgroups:

- contact: cuff, stuffing box, ring;
- slotted: grooved. disc, simply slotted, labyrinth;
- combined.

Combination seals are an assembly of the same or different types of seals. Layouts such as labyrinth-contact, labyrinth-contact with a large-capacity chamber, contact-slot, and labyrinth-groove are widely used. labyrinth-groove with a large-capacity prechamber, radial-axial labyrinths, radial-axial labyrinths with a large-capacity prechamber [3,8,9].

In the design of bearing units of conveyor rollers, various types of rolling bearings are widely used. The use of rolling bearings is due to low friction losses; high efficiency; less friction torque at start-up; compact overall dimensions in the axial direction; ease of maintenance and repair of the unit due to the interchangeability of bearings. Most often, ball and roller angular contact tapered single-row rolling bearings are installed in roller bearing units. [7,12,13]. Information on the use of different types of bearings depending on the series of rollers is given in Table 2.

Table 2.

Series of bearings used in conveyor rollers.

№	Roller diameter, mm	Easy roller series	Middle roller series	Heavy roller series
1	102; 108	180203; 60203; 80203	180203; 180204; 60204; 80204	180304; 80304

2	127; 133	180204; 60204; 80204	180304; 60304; 80304	180305; 180306; 80305; 80306
3	152; 159; 168; 178		180305; 60305; 80305	180306; 180308; 80306
4	194; 219	-	180306; 180308; 80306	180308; 180312; 80308

The operating efficiency of bearings is largely determined by the design, the precision of manufacturing of the surfaces of the parts, the operating load, the type of lubrication, and operating conditions.

One of the main reasons for the failure of bearings installed in the rollers of the linear part of a conveyor train is fatigue failure of the bearing friction surfaces (outer and inner ring, rolling elements), as a result of prolonged constant and variable exposure to the weight of the transported load.

Destruction of bearing units of conveyor rollers at loading points during the movement of rocks can occur due to peak loads exceeding the static strength of their working parts.

In rare cases, bearings may jam due to the penetration of large abrasive particles into them, as well as destruction of the separators [9,14]. These types of wear occur due to the factors listed above, or are caused by improper use of rollers and bearings, which does not take into account the influence of operating conditions.[10,15].

In the latter case, the cause of bearing failure is the radial clearance exceeding its permissible value due to abrasive wear of the rolling surfaces. Due to the fact that the operation of conveyor rollers in mining conditions is characterized by a high radial load, early failure of bearings due to wear by abrasive particles in their pure form is not the cause of their failures. It can be assumed that either fatigue failure of the bearing elements or mixed failure occurs [11,21].

The cyclicity and magnitude of the load of the bearing units installed in the rollers of the linear part of the conveyor train are determined by a number of factors:

Firstly, the operation of the conveyor alternates between periods of continuous receipt and periods of no cargo flow. Therefore, the calculations must take into account the net operating time of the conveyor.

Secondly, during periods of continuous cargo flow, its level fluctuates. The characteristic time of fluctuations in continuous cargo flow, according to experimental data [17, 19], is always significantly higher than 5 s. The implementation of the corresponding random process is usually approximated by a step function [20,21], the values of which obey the normal distribution law, and the time intervals between successive changes in values follow the Poisson law.The Poisson's law parameter is called the counting rate in the process under consideration.

Thirdly, along with the small-piece component of the cargo flow, large pieces of cargo enter the conveyor, causing dynamic loads on the roller supports. The characteristic period of change of these loads does not exceed the time a piece of cargo passes through the interval between the roller supports $\tau = l_p / v_л$, which is a fraction of a second. Actually, the time of exposure of a large piece of transported material to a conveyor roller is much less [9].

Quite a lot of experimental and theoretical work has been devoted to the calculation of dynamic loads on the rollers of belt conveyors transporting large-sized cargo at mining enterprises [9, 11, 22, 23], as a result of which two approaches to considering the causes of dynamic loads have been formed. In the first approach, the main mechanism for the impact of large pieces of cargo on the rollers is considered to be an impact due to the mismatch in the direction of the velocity vector of the piece and the tangent to the surface of the roller at the point where the tape impinges on the roller.A number of works [23,24] show that at sufficiently high values of belt tension (from approximately 110 N per 1 mm of spacer width), the force of interaction between pieces of cargo and rollers ceases to depend on the value of belt tension. This means that another interaction mechanism—pulse—becomes the main one. Within the framework of this approach, the interaction of the transverse compression zones of the conveyor belt, which arise under the contact spots of a piece of cargo with the roller, is considered. When these zones approach each other, starting from a certain distance between the centers of the contact spots (approximately equal to 1-2 times the thickness of the tape), a sharp hardening of the contacts occurs, which manifests itself externally as a shock pulse.

Along with contact-fatigue destruction of rolling elements and tracks, abrasive and friction-fatigue types of wear are typical for conveyor roller bearings [9, 24]. These types of wear predominate for the upper bearing units of the rollers of the working branch [11]. It is these types of wear that determine the technical life of bearings. The cause of this phenomenon is considered to be poor quality manufacturing of the roller bearing seal elements. However, conveyor rollers are such a mass product that, apparently, the savings on the cost of seals are justified, so we have to consider a type of wear that is not specific to rolling bearings.

There are many works on the study of bearing wear. For example, in work [21], based on experimental studies in a dust chamber with different dust levels of quartz particles in the air, indirect empirical regression dependences of the change in the radial clearance in rolling bearings of conveyor rollers with different types of seals on the test time, which was 350 - 600 hours, were constructed. Roller rotation speed - 700 rpm.

The dependencies given in [21] are called indirect, since the change in the radial clearance is given as a function not of time or the number of revolutions of the bearing, but of the amount of abrasive dust accumulated in the bearing lubricant. The dust content of a lubricant is expressed by the weight fraction of dust particles in the lubricant. In addition, the regression dependence of lubricant dust content on test time is given:

$$m = pt^{u} M^{K}, \% \quad (1)$$

where: t- time, h;

M- air dust content, kg/m^3;

p and *K*- empirical constants depending on the design of the bearing assembly.

The radial clearance in the bearing is determined by the formula:

$$\Delta = \delta_0 + 12.23 \cdot 10^{-6}, m \quad (2)$$

where: δ_0 - initial working radial clearance, for tested bearings having an internal diameter d=30 mm, $\delta_0 \approx 10$ μm under a load of 100 N.

In this case, abrasive wear of the raceways (scratches) was often observed.

Having written formulas (1) and (2) into one and taking into account the roller rotation speed n, which differs from the experimental one, we obtain:

$$\Delta = \delta_0 + \frac{12.23 \cdot 10^{-6}\left(1 + \frac{d}{8}\right)}{700^{u} \cdot 4.75} pt^{u} M^{k} n^{u} \quad (3)$$

It is taken into account that the experimental studies were carried out at roller rotation speeds of the same order as the actual ones used in production conditions, and the amount of contamination penetrating through the seal is strictly related to the roller rotation speed [9].

In conclusion, the considered designs of bearing units for conveyor rollers demonstrate a variety of approaches to ensuring reliability and durability under operating conditions. The use of different types of seals, such as groove, stuffing box, labyrinth and combination seals, optimizes the protection of bearings against contamination and moisture, which is critical for the mining industry. Due to their high efficiency and low friction losses, the use of ball and roller bearings also plays a key role in maintaining the performance of conveyor systems.

The need to accurately calculate durability and take into account dynamic loads emphasizes the importance of an integrated approach to the design and operation of bearing units.Fatigue failure, abrasive wear and the effects of dynamic loads remain the main challenges that require constant monitoring and improvement of structures.

Research and development in the field of conveyor roller bearings continues to evolve, offering new solutions to improve the reliability and efficiency of conveyor systems.Considering the importance of these units in the overall system of mining enterprises, further innovations and improvements will help increase their operational life and reduce maintenance costs.

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