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RELIABILITY ASSESSMENT AND DETERMINATION OF SERVICE LIFE OF ROLLERS OF BELT CONVEYORS FOR VARIOUS TYPES OF ROLLERS

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Abstract: In this work, the problem of determining the average service life of the rollers of a belt conveyor for various designs of roller bearings is posed and solved. The solution of this problem makes it possible to assess the reliability of the belt conveyor stack.
Key words: belt conveyor, carrying roller, reliability analysis, exponential reliability distribution, loaded redundant units, unloaded redundant units, reliability indices, mean time between failures, Weibull distribution

Beam conveyor with rollers - an important part of the belt conveyor, the technical condition of which depends on the reliability of the conveyor as a whole. The reliability of the stave is determined by the reliability of the rollers of the roller bearings, since the reliability of the supporting metal structures is an order of magnitude higher.

An important indicator for evaluating the reliability of a roller is its service life, which depends on the type, parameters of roller supports and operating conditions.

L. G. Shakhmeister, V. G. Dmitriev, V. F. Monastyrsky, A. I. Dodatko and other researchers were engaged in the task of determining the service life of the rollers of a belt conveyor. In their works, it is stated that the main cause of failure of the rollers is the failure of the bearing unit, the loads on the rollers during the transportation of the rock mass are determined, and on the basis of this, formulas are proposed for calculating their service life. At the same time, the loads on the roller bearings arising from large pieces of cargo are not taken into account accurately enough. In works [2,6], formulas are proposed for calculating the average service life of roller bearings of a conveyor belt. However, when describing the load on the roller bearing, the authors did not take into account the dynamic forces arising from the movement of the load along the conveyor line and due to the bending of the belt. As shown in [7], at belt speeds of more than 2 m/s, these forces are significant.

An analysis of the failures of the conveyor belt showed that the main reasons for the failure of the rollers are the increased radial clearance in the bearing due to abrasive wear and fatigue failure of the bearing elements from the impact of dynamic loads. Therefore, the service life of one roller is determined by the service life of the bearings.

The purpose of this work is to determine the service life of the rollers of belt conveyors for various types of idlers.

The life or 90% life of rolling bearings L_{09}, measured in hours, is determined according to [8]:

$$L_{09} = \left(\frac{C_n}{P_m}\right)^p \cdot \frac{10^6}{60n} k_э, \qquad (1)$$

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where C_n is the dynamic load capacity, N, (the load at which the durability is 1 million revolutions, this value for each specific bearing is selected from the reference book); P_m is the equivalent dynamic load on the roller bearing, N; n- bearing rotation frequency, 1/s; p - power exponent (p = 3 for ball bearings and p = 10/3 for roller bearings); $k_э$ - coefficient taking into account operating conditions. The average bearing life, according to [9], is determined from the ratio

$$t_{cp} = 4.08 \cdot L_{09} \tag{1.1}$$

The rotational speed n is determined by the formula:

$$n = \frac{60 v_l}{2\pi r} \tag{1.2}$$

where v_l *is the speed of the conveyor belt, m/s; r - roller radius, m.*

In our case, the roller bearing assembly is loaded with a load flow that creates a radial and axial load on the bearing. We neglect the axial load on the bearing, because the impact of the load on the bearing is transmitted through a metal cup and the proportion of the axial component is small. Therefore, in the rollers of the conveyors under consideration, radial and angular contact bearings are used. For deep groove ball bearings, angular contact bearings, and angular contact roller bearings, the dynamic radial load is calculated using the formula:

$$P_m = V K_m K_6 F_r \tag{1.3}$$

where F_r- is the radial load on the bearing; V - coefficient of rotation (during the rotation of the outer ring of the bearing in relation to the load $V = 1.2$); K_t - temperature coefficient selected from the tables [9] (in our case, $K_t = 1$); K_b - safety factor selected from the tables [9] (in our case, we assume $K_b = 1$, since we take into account the influence of the nature of the load on the bearing when calculating F_r).

Based on this, the total dynamic radial load on the roller bearing is:

$$P_m = 1.2 F_r \tag{1.4}$$

The radial bearing load Fr can be represented as the average bearing load:

$$F_r = \frac{1}{2} M[x(t)], \tag{1.5}$$

where $M[x(t)]$ is the mathematical expectation of the load on the central roller of the roller support; $x(t)$ - random function of the load on the roller support.

The work [10] presents a statistical model of the traffic flow, which is considered in the form of a fine fraction and large pieces located in it. According to this work, $M[x(t)]$ is defined by the formula

$$M[x(t)] = 0.5 \sum_i^s g\, k_{d_i} \tau_k Q P_i + q_t l_p \tag{1.6}$$

where P_i - weight fractions of pieces of the i-th fraction in the total mass of the cargo entering the conveyor; Q - productivity of the conveyor, kg/s; k_{d_i}- coefficient of dynamism during the interaction of a piece of cargo of the i-th fraction with a roller support; l_p - distance between roller supports (pitch of roller supports), m; τ_k- interaction time of a large piece of cargo with a roller support, s; q_t - linear load on the bearing assembly, N / m; g - free fall acceleration, m/s^2; s– is the number of fractions.The coefficient of dynamism when interacting with a piece of cargo is determined from the expression

$$k_\partial = \frac{P_к + P_\partial}{P_к}$$

where, $P_к = m_к \cdot g$ – is the force of gravity of a piece of cargo.

P_∂ - dynamic force during the interaction of a piece of cargo with a roller support

$$P_\partial = \frac{2 \cdot m_к \cdot \vartheta_л^2 \cdot \theta_\partial}{l_к}$$

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Where $m_к$is the mass of the piece, kg
θ_∂ - the angle of deflection of the belt with the roller at the moment of overlap of the piece
$l_к$ is the length of the piece, and
Substituting into the formula k_∂, the values $P_к$ and P_∂ we get

$$k_\partial = 1 + \frac{2\vartheta_л^2}{l_к} \cdot \theta_\partial = 1 + \frac{2 \cdot 5^2}{0{,}4} \cdot 0{,}002 = 1{,}25.$$

We determine θ_∂ by the formula

$$\theta_\partial = \frac{P_к}{S_л} = \frac{m_к \cdot g}{S_л} = \frac{50 \cdot 10}{260000} = 0{,}002$$

A large piece interacts with the roller over two spans between the roller supports, so the time$\tau_k$is defined as

$$\tau_k = \frac{2l_p}{v_л} \quad (1.7)$$

The load q_m, taking into account the uneven load on the side and middle rollers, is determined by the formula [8]

$$q_t = 0.7k'_d \cdot (q_r + q_l) + q_p \quad (1.8)$$

where q_r - linear load on the tape from fine fractions (ie, excluding the percentage of coarse fractions, considered separately), N/m; q_l - linear weight of the tape, N/m; q_p is the weight of the rotating parts of the roller, N; k'_d is the coefficient of dynamism in the interaction of a small-sized fraction with a roller support.In formula (1.8), the coefficient 0.7 takes into account the part of the load perceived by the middle roller.Conveyor performance Q, according to [1], is determined by the formula

$$Q = \frac{q_g v_л}{g} \quad (1.9)$$

where q_g is the linear weight of the cargo, including small and large fractions, N/m.

When determining the load on the roller, pieces of those fractions are taken into account for which the average distance between the pieces l_i is greater than the distance between the roller supports l_p $(l_i>l_p)$, that is, it is assumed that at the moment only one large piece interacts with the roller support.It can be seen from formula (1.7) that the average load on the idler roller depends on the dynamic coefficient k_{d_i} when interacting with a piece of each fraction and the particle size distribution of the transported cargo.

Studies have shown that k_{d_i}depends on the design of the roller bearings and the parameters of the conveyor.

Substituting (1.3) into (1) taking into account (1.4)-(1.9), and then substituting the resulting resource expression L_{09} into (1.1), we finally determine the average bearing service life.

Using this method, we determine the above parameters for conveyor 3.1 installed in the Argren mine face: rollers with a diameter of 159 mm (r = 0.0765 m) are installed, bearings No. 307 are used in these rollers. In this case, the conveyor parameters were taken as follows: belt tension S_l = 20000 N, load linear weight q_g = 1760 N/m, roller support pitch L = 1.2 m.

Dynamic load capacity C_p for bearing No. 307 was selected from the tables [9]. For this bearing C_n = 33200 N. The weight fractions of pieces of the i-th fraction P_i were taken from the table [9]. Also, from this table, the values of the average distance between the middles of the pieces of the i-th fraction l_i were selected. By setting a number of values for the size of the pieces (ak, hk, lk), performance (Q), belt tension force (S_l), belt speed (v_l), distance between roller supports (l_p), we find the corresponding average bearing life (t_cp). The calculation results are shown in table-1.

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Table 1.
The results of the calculation to determine the average life of the bearing of conveyor rollers

The name of indicators	Designations	Unit rev.	Experience №1	Experience №2	Experience №3	Experience №4	Experienceт №5	Experience №6
Linear weight of cargo	q_g	N/m	1727	1727	1727	1727	1727	1727
Performance	Q	t/s	616	704	792	880	968	1056
Linear load on the bearing assembly	q_m	N/m	3290	3712	4191	4725	5316	5963
Linear weight of the tape	q_l	N/m	326	326	326	326	326	326
Weight of the rotating parts of roller bearings	q_p	N/m	475	475	475	475	475	475
rock density	γ	t/m^3	1,65	1,65	1,65	1,65	1,65	1,65
Dynamic load rating	C_n	H	33200	33200	33200	33200	33200	33200
Weight fractions of pieces of the i-th fraction in the total mass of the cargo	P_i	%	0,22	0,22	0,22	0,22	0,22	0,22
Gravity of a piece of cargo	P_k	H	583	583	583	583	583	583
Dynamic forces during the interaction of a piece of cargo with a roller support	$P_д$	H	57,0	74,4	94,2	116,3	140,7	167,5
Tape tension	S_l	H	49600	49600	49600	49600	49600	49600
Distance between idlers	l_p	m	1,2	1,2	1,2	1,2	1,2	1,2
Distance between idlers	n	Rp/m	421	481	541	601	661	721
Conveyor belt speed	V_l	m/s	3,5	4	4,5	5	5,5	6
roller radius	r	m	0,0795	0,0795	0,0795	0,0795	0,0795	0,0795
Durability or 90% service life of rolling bearings	L_{09}	hour	46797	28205	17264	10748	6812,4	4396,64
Equivalent dynamic load on roller bearing	P_m	H	2916	3302	3739	4227	4767,5	5359,0
Radial bearing load	F_r	H	2430	2751	3116	3523	3972,9	4465,8
Mathematical expectation of the load	M	H	4860	5503	6231	7046	7945,8	8931,7
Coefficient of dynamism in the interaction of a piece of cargo of the i-th fraction with a roller support	k_d		1,96	2,25	2,59	2,96	3,3692	3,8196

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The time of interaction of a large piece of cargo with a roller support	τ_k	sec	0,6857	0,6	0,533 3	0,48	0,436 4	0,4
Piece Width	a_k	m	0,4	0,4	0,4	0,4	0,4	0,4
Piece height	h_k	m	0,3	0,3	0,3	0,3	0,3	0,3
Piece length	l_k	m	*0,3*	*0,3*	*0,3*	*0,3*	*0,3*	*0,3*
The angle of deflection of the tape with the roller at the time of the piece running	θ	glad	0,012	0,012	0,012	0,012	0,011 75	0,011 75
Piece weight	m_k	kg	59,4	59,4	59,4	59,4	59,4	59,4
Average bearing life	t_{sr}	hour	**19093 3**	**11507 8**	**70437**	**43853**	**2779 4**	**17938**

The analysis showed that the service life of the conveyor rollers depends on the linear load, the parameters of the conveyor, the particle size distribution of the type of transported cargo and the parameters of the roller bearings.

Figures 1. and 1.1 show the dependencies of the average roller life tcp on the belt speed v_l for two types of idlers: on a rigid line (rigid idlers) (Fig. 1.) and suspended on a rope line (suspended idlers) (Fig. 1.1).

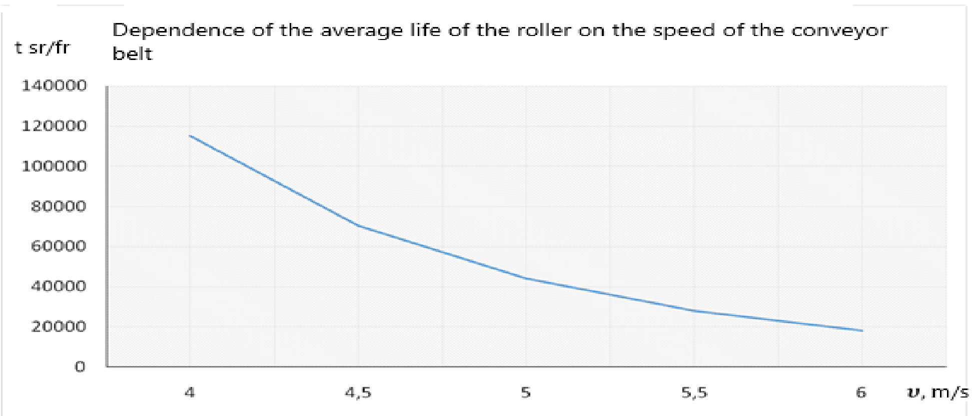

Figure 1- Graph of the dependence of the average life of the roller on the speed of the conveyor belt for rigid idlers

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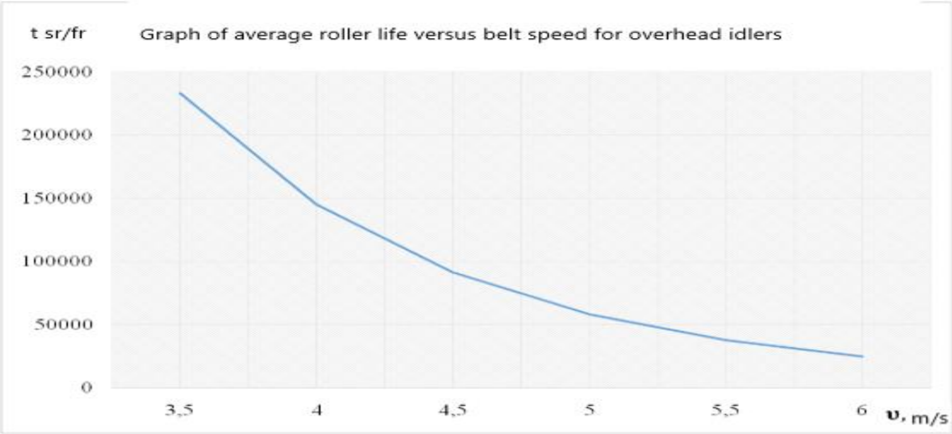

Figure 1.1 - Graph of the dependence of the average life of the roller on the speed of the conveyor belt for overhead idlers on a cable train

From figures 1. and 1.1 it can be seen that with an increase in the speed of the conveyor belt for rigid and overhead idlers, the average life of the rollers decreases. At the same time, the value of the average service life of the rollers in the range of conveyor speed change 0 <vl< 5 m/s for suspended rollers is somewhat higher than the service life of rollers for rigid rollers.

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