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THE RESEARCH OF FREIGHT FLOW NON-UNIFORMITY ON THE BELT CONVEYOR

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Abstract:
The purpose of the study. increasing the performance of belt conveyors and reducing transportation costs based on the developed mathematical modeling of transient processes of asynchronous motors of open-pit conveyor transport. The object of the research is the operating modes of asynchronous motors of belt conveyors of mining enterprises. The subject of research is the starting and braking modes of operation of asynchronous motors of belt conveyors of mining enterprises. Research methods are based on the modern theory of electrical machines, methods of linear and nonlinear mathematical programming, mathematical statistics, as well as methods of system analysis. The practical results of the study are as follows: the actual coefficient of resistance to the rotation of the conveyor rollers and the coefficient of resistance to the movement of the belt, leading to a decrease in the tractive effort, were determined; a method was developed for determining the additional power consumption of electric motors of belt conveyors, taking into account the overall volume, weight and speed of transported lumpy cargo; a mathematical model of braking and starting modes of induction motors of belt conveyors of mining enterprises was developed, taking into account the resistance coefficient of the belt and rollers.

Keywords: cyclic-flow technology, dependences of currents, conveyor belt is loaded.

INTRODUCTION

In the global mining industry, it is important to improve the energy efficiency of conveyor belts and save energy. "The use of conveyor belts in quarries around the world is dramatically reducing rock transport distances, reducing shipping costs by 30-40% and doubling labor productivity." In this regard, much attention is paid to the optimization of asynchronous motors of belt conveyor transport, normalization of consumed electricity, the search for combination methods for extracting minerals from the horizons of deep quarries and increasing the reliability of conveyor equipment.

In the world, research is being carried out aimed at increasing the productivity of a quarry, reducing the cost of mining and transporting rocks, developing energy-efficient control algorithms and reducing losses during transient processes of asynchronous motors. In addition, asynchronous motors are considered, including mineral quality metrics to improve energy efficiency, as well as starting and controlling an asynchronous drive, determining the additional torque for the asynchronous motor, belt and roller drag coefficients, and determining energy consumption is important.

In the Republic, to improve the efficiency of conveyor transport at open-pit mining enterprises, extensive measures are being taken, including the introduction of cyclic transport technology, frequency regulation of electric drives, as well as the introduction of energy-saving technologies. The development strategy of the Republic of Uzbekistan for 2017-2021 includes the following tasks: "... reduction of energy and resource capacities of the economy as a priority in the near future, widespread introduction of energy-saving technologies in the expansion of renewable energy sources." To solve this problem, including the determination of the actual drag coefficients of conveyor belts and rollers, a method has been developed for calculating the additional power consumption of belt conveyors, taking into account the overall volume, weight and speed of the transported lumpy cargo, as well as the rational use of an asynchronous motor to save energy and efficiently use it in quarrying ... One of the important tasks is the development of a control system and ensuring an energy-saving mode of conveyor transport.

This dissertation research, to a certain extent, serves to fulfill the tasks stipulated in the Decree of the President of the Republic of Uzbekistan No.UP-4947 dated February 7, 2017 "On the Strategy of Actions for the Further Development of the Republic of Uzbekistan", Resolutions of the President of the Republic of Uzbekistan No. PP-3238 dated August 23, 2017 " On measures for the further introduction of modern and energy efficient technologies "and No. PP-3379 dated November 8, 2017" On measures to ensure the rational use of energy resources "and the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated January 12, 2018" On additional measures to improve the procedure for using electrical energy and natural gas ", Resolution of the President of the Republic of Uzbekistan No. PP-3054 dated June 13, 2017‶ On the Program for Further Development and Modernization of the Coal Industry for 2017–2021 ", as well as in other regulatory documents adopted in this area.

METHODOLOGY

The research methods are based on the modern theory of electrical machines, methods of linear and nonlinear mathematical programming, mathematical statistics, as well as methods of system analysis of conveyors, depending on the length and slope of the conveyor.

LITERATURE REVIEW

Scientific research is aimed at improving the efficiency of belt conveyors using advanced methods for calculating belt conveyors and determining the prospects for their development, are carried out in leading research centers and universities in the world, including Freiberg Mining Academy (Germany), California Institute of Technology (USA), Queen's University Belfast. Great Britain), Turin Polytechnic University, Moscow University of Steel and Alloys (Russian Federation), Tashkent State Technical University, Scientific and Technical Center LLC (Uzbekistan), as well as extensive research is being conducted in other research organizations.

The solution of scientific problems aimed at the development and improvement of systems of electric motors and belt conveyors made a significant contribution by A.O. Spivakovsky, E.E. Sheshko, V.I.Galkin, V.P. Dyachenko, Yu.R. Tarasov, A. Ryzhik. B., Reutov A.A., Aleksandrov M.P., Andreev A.V., Barabanov V.Yu., Zelensky O.V., Belfor V.E., Bilichenko N.Ya., Volotkovsky BC, Vasiliev M V.V., Glukharev E.G., Grudachev A.A., Dzhienkulov S.A., A.V. Ivanov-Smolensky, I.G. Shtokman, prof. L.G. Shaikhmeister, V. G. Dmitriev and others. In the Republic, the following scientists were engaged in the development and implementation of energy-saving technologies based on the use of frequency converters in belt conveyors: Khamudkhanov M.Z., Allaev K.R., Kamalov T.S., Khoshimov O.O., Muminov K., Bobozhanov M.K., Pirmatov N.B., Ishnazarov O.Kh., Toirov O.Z. other.

However, despite significant advances in improving the method for calculating the transient processes of belt conveyors, the determination of the drag coefficients of conveyor belts and rollers, the determination of the overall volume, weight and speed and power consumption of belt conveyors depending on the length and slope of the conveyor have not been studied enough.

FINDINGS AND DISCUSSIONS

In steady-state modes, asynchronous motors of conveyor belts are characterized by a nominal mode [1,2]. Transient processes are much more diverse and more complex than steady-state processes [1,2]. Transient processes in asynchronous motors of a belt conveyor occur when the frequency and voltages at the motor terminals change and when it is disconnected from the braking network, etc. [1,2].

Belt conveyors as the most economical, productive and reliable type of transport of bulk cargo are widely used in our republic and abroad. With the increase in the length of the conveyors and their productivity, the dynamics of the start-up is of particular importance. Therefore, the start-up of the belt conveyors is very important. Dynamic processes in belt conveyors are characterized by the appearance of dynamic tension, which, algebraically summing up with static, significantly increase the resulting tension in the conveyor belt and the forces in the elements of the conveyor. At start-up, these changes can lead to unstable operation of the drive drum, for example, partial or complete slipping [2, 3].

Slipping is unacceptable for many reasons: heating the drum, a sharp decrease in the coefficient of adhesion, which makes it difficult to start the conveyor, etc. All this can cause emergency situations and even cause a fire, which is unacceptable in the Angren Mine because it leads to property damage, in addition, dynamic forces increase the loads in the tensioning device mechanisms, in the gearbox and other elements of the conveyor. Therefore, the analysis of the processes of starting and braking belt conveyors is of great importance.

An analysis of these processes makes it possible to accurately determine the values of dynamic loads, which will help to avoid irrational technical solutions, increase the reliability of the belt conveyor-motor system, and therefore, sharply reduce the likelihood of emergencies and increase the productivity of the belt conveyor [1,2].

The practice of operating belt conveyors in delfts (with deep and open-cast mining) shows that 40-60% of these conveyors are loaded on productivity and only 30-35% are used in time. Such a low degree of using conveyors is explained by a significant non-uniformity of the freight flows coming to the bottom [1-4].

The estimated performance is used while calculating the parameters of conveyor units Q_p, determined by the expression

$$Q_p = \frac{Q_г К_н}{Т_р}, \quad \text{m/h}$$

where the annual volume of traffic is $Q_г$; $K_н$ - coefficient of the freight flow non-uniformity; T_p- the planned net operating time of the equipment per year.

The coefficient of non-uniformity is taken in the range of $K_н$=1.15-1.5, regardless of the number of conveyors in the line. This method of calculation does not take into account quite accurately the emergency downtime of the conveyor line, determined by the reliability of the equipment, and the freight flow non-uniformity coming to the line, which has a significant impact on the choice of the necessary width and strength of the belt, as well as the power of the drive devices of individual plants.

The reliability of the conveyor line can be taken into account with sufficient accuracy by the average availability factor, which is the product of the readiness coefficients of the individual elements of the line in series type connection. Considering the reliability, the required average hourly productivity $Q_ч$ will be determined by the expression [1-4]:

$$Q_{cp} = \frac{Q_г}{TK_г}, \text{ t/h,} \qquad (1)$$

where T is the planned operating time of the equipment in a year, including emergency downtime; $K_г$ - the availability factor of the conveyor system.

The freight flow non-uniformity coming to the conveyor line, as before, can be taken into account by the coefficient of non-uniformity, that, however, should be taken different in calculating the width of the belt, the strength of the belt and the power of the drive devices motors. The width of the conveyor belt must be determined by the coefficient of cyclic variation in the minimum time interval, because it is necessary to take into account the peak value of the freight flow, i.e., almost prompt. The strength of the belt and the power of the drive motors should be with a glance to the non-uniformity measured over a period equal to the time of movement of the load along the length of the conveyor.

To assess the quantitative indicators of the coefficients of non-uniformity, we present the results of the work in which the freight flow supplied to the conveyor line of the Inguletsky GOK (Ukraine) was investigated [5].

These studies have established a significant non-uniformity of daily, shift and hourly productivity. The non-uniformity coefficient of daily and shift productivity during the observation of the InGOK conveyor line reached appropriately 1.7-2.0 and 1.4-1.5. The non-uniformity of hourly productivity is also great [5].

Significant non-uniformity of daily, shift and hourly freight flows is mainly caused by irregular work in the mine in different periods of the day and emergency stops of the conveyor line.

The change in the coefficient of non-uniformity of the conveyor line freight flow $K_н$ depending on the degree of loading, determined by the ratio of the possible productivity of the mining and loading machine $Q_в$ to its technical (given in the technical characteristics) productivity Q_p is shown in Fig. 1 [5].

Figure 1 also shows (curves with a dash) the dependence of the non-uniformity coefficient on the degree of loading of the Angrensky conveyor line.

The curve reflecting relationship between the coefficient of cyclic variation and the ratio $\frac{Q_в}{Q_p}$ is described with sufficient accuracy by the equation

$$K_н = 1{,}08 + \frac{0{,}32}{\frac{Q_в}{Q_p} - 0{,}2} \qquad (2)$$

As can be seen from Fig. 1, the coefficient of cyclic variation with a machine performance equal to technical has a value of about 1.4.

Based on the foregoing, we can recommend the values of the coefficients of the freight flow non-uniformity, which must be taken into account in calculating the parameters of conveyor systems.

The general coefficient of non-uniformity for calculating the width of the tape varies between 1.4-1.7, the average value is 1.56. To calculate the strength of the conveyor belt, the coefficient of cyclic variation, determined by the ratio $K_н = \frac{Q_в}{Q_p}$, the value of which can be taken equal to 1.2-1.3, is taken into account. The same coefficient with a certain margin can also be taken to calculate the required power of the drive stations.

The instantaneous productivity of the freight flow coming from the mining machine to the conveyor is continuously changing over a wide range. According to existing methods of calculation, the width of the conveyor belt is determined by the maximum value of the incoming freight flow (according to the estimated productivity). The required belt width is overestimated, and the conveyor is respectively powerful and expensive. If we take into account the freight flow non-uniformity, it turns out that powerful and expensive conveyors work most of the time with significant underloading. This leads to an unjustified increase in the cost of transporting rock mass by conveyors.

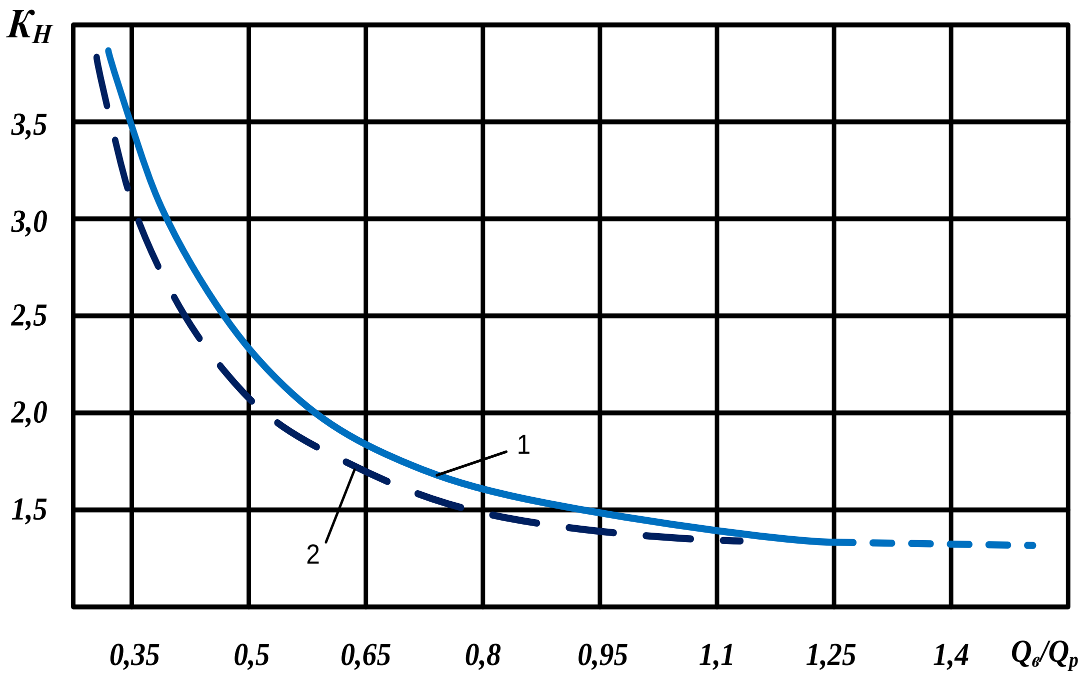

Fig. 1. The dependence of the coefficient of non-uniformity on the degree of the conveyor line loading [6]

Reducing the cost of the conveyor by reducing the width of the belt, the cost of transporting the rock mass can be reduced, but at the same time, the nameplate productivity of the conveyor is also reduced. Therefore, at times when the capacity of the freight flow will exceed the nameplate productivity of the conveyor, spills of transported rocks appear. This leads to added cost for their cleaning. In addition, due to spillage, the average productivity of both the excavator and the conveyor is reduced. All this increases the cost of transporting the rock mass. Thus, reducing the width of the tape leads to a decrease in some costs (capital) and an increase in others (operational). Therefore, there is an optimal width of the tape, providing the minimum cost of excavation and transportation of rock mass.

The optimal belt width was expressed in terms of the average productivity of the freight flow (Qav.gr. m3/h), its coefficient of variation (V), conveyor productivity coefficient (K), belt speed (ϑ , m/s) and rock loosening coefficient (k_p). As a result, the following expressions were obtained for calculating the optimal tape width and the coefficient of the incoming freight flow non-uniformity:

$$B_{опт} = \sqrt{Q_{ср.гр} \frac{1+1{,}5V}{K\vartheta} k_p} \text{ , m;} \qquad (3)$$

$$k_н = 1 + 1{,}5V \text{ .}$$

By this technique in the conditions of Grushevsky quarry [7], Nikopol basin [8] and other mines determined the optimal width of the belt for six overburden complex conveyors of mining continuous operation transport equipment, having an actual belt width from 1200 mm to 2800 mm.

The numerical values of the quantities included in formulas (2) and (3), established on the basis of their technical characteristics or their operation data, are given in Table 1, the calculation results $B_{опт}$ and $k_н$, as well as the recommended value of the tape width for the complexes studied are given in Table 2 [7, 8].

When choosing the width of the tape according to the given method, its optimal (calculated) value rarely coincides or does not coincide with the standard value (Table 2). The nearest larger or smaller typical value should be taken for installation.

It appears from the tables 1 and 2 that for conveyors of complexes of the same type No. 1,2,3 operating in various conditions of Grushevsky quarry, the value of the optimal width does not exceed 0.815 m, while its actual width for these complexes is 1.2 m [7, 8].

Table 1
Numerical values of quantities included in formulas (2) and (3) [6]

Designations of dimension	Complex numbers					
	1	**2**	**3**	**4**	**5**	**6**
	Grushevsky quarry			Angren coal mine		
Qav.gr. m3/hour	818	549	405	1850	3375	10000
V	0,262	0,59	0,386	0,333	0,333	0,333
ϑ, m/s	5,2	3,56	4,26	4,0	4,5	5,4
K	525	525	525	525	525	525
k_p	1,15	1,20	1,25	1,25	1,25	1,25
The length of the conveyor stand on the overburden ledge, m	1725	1795	1530	1450	1000	1800

According to table 2, No. 4,5 and 6 for conveyors of complexes, the value of the optimal belt width is almost two sizes smaller than the actual size for these complexes [7, 8].

Table 2.
Computational results and recommendations [6]

№	Parameter Names	**Complex numbers**					
		1	**2**	**3**	**4**	**5**	**6**
1.	The coefficient of freight flow non-uniformity, $k_н$	1,2	1,2	1,2	1,6	2,0	2,8
2.	The actual value of the belt width, *B*, m	0,686	0,815	0,358	1,285	1,640	2,51
3	Optimal (estimated) belt width, $B_{опт}$, m	1,00	1,00	1,00	1,4	1,6	2,50
4.	Recommended (standard) belt width, $B_{рек}$, m	1,393	1,88	1,581	1,5	1,5	1,5

Thus, the presented results showed that the conveyors of continuous stripping complexes can be operated either with a belt one or two sizes smaller than the existing ones, or they can be operated in combination with excavators of higher productivity.

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