INNOVATIONS IN TECHNOLOGY AND SCIENCE EDUCATION
ISSN 2181-371X
https://science-research.org.uz/index.php/ITSE

ANALYSIS OF THE ROTATIONAL DYNAMICS OF BELT CONVEYOR DRUMS AND THE VARIATION PATTERNS OF DRIVE LOADING UNDER TECHNOLOGICAL RESISTANCE CONDITIONS

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Abstract: This article analyzes the rotational dynamics of belt conveyor drums and the variation laws of drive loading under conditions of technological resistance. The study establishes the mechanical interrelation between the drum's angular velocity, drive torque, and technological load, while identifying the key factors influencing the dynamic stability of the system. Furthermore, the temporal behavior of torque transmission and drum speed under varying load conditions is examined through mathematical modeling. Based on the analytical results, scientific and technical recommendations are developed for improving the efficiency of belt conveyor drive mechanisms, reducing energy consumption, and ensuring operational stability. These findings hold practical significance for gaining a deeper understanding of the dynamic operating modes of conveyor transport systems and enhancing their mechanical reliability.

Keywords: belt conveyor, drum, rotational dynamics, drive loading, technological resistance, angular velocity, dynamic stability, mechanical analysis, load

Annotatsiya: Mazkur maqolada tasmali konveyer barabanlarining aylanish dinamikasi va yuritma yuklanishining texnologik qarshilik sharoitida o‘zgarish qonuniyatlari tahlil qilinadi. Tadqiqotda konveyer barabanining burchak tezligi, yuritma momenti va texnologik yuklama o‘rtasidagi mexanik bog‘lanish aniqlanadi hamda tizimning dinamik barqarorligini ta’minlashga ta’sir etuvchi asosiy omillar o‘rganiladi. Shuningdek, yuklanish o‘zgarishi natijasida moment uzatish va baraban tezligining vaqt bo‘yicha o‘zgarish xarakteri matematik modellashtirish asosida tahlil etiladi. Tahlil natijalari asosida tasmali konveyer yuritma mexanizmlarining samaradorligini oshirish, energiya sarfini kamaytirish va harakat barqarorligini ta’minlash bo‘yicha ilmiy-texnik tavsiyalar ishlab chiqiladi. Ushbu natijalar konveyer transport tizimlarining dinamik rejimlarda ishlash xususiyatlarini chuqurroq tushunish va ularning mexanik ishonchliligini oshirishda amaliy ahamiyat kasb etadi.

Kalit so‘zlar: tasmali konveyer, baraban, aylanish dinamikasi, yuritma yuklanishi, texnologik qarshilik, burchak tezlik, dinamik barqarorlik, mexanik tahlil, yuklama

Аннотация: В данной статье проводится анализ динамики вращения барабанов ленточного конвейера и закономерностей изменения нагрузки привода в условиях технологического сопротивления. В исследовании устанавливается механическая взаимосвязь между угловой скоростью барабана, приводным моментом и технологической нагрузкой, а также выявляются основные факторы, влияющие на динамическую устойчивость системы. Кроме того, посредством математического моделирования изучается временной характер изменения передаваемого момента и скорости вращения барабана при колебании нагрузки. На основе полученных аналитических результатов разработаны научно-технические рекомендации по повышению эффективности приводных механизмов ленточных конвейеров,

снижению энергозатрат и обеспечению устойчивости движения. Полученные выводы имеют практическое значение для более глубокого понимания работы транспортных конвейерных систем в динамических режимах и повышения их механической

Ключевые слова: ленточный конвейер, барабан, динамика вращения, нагрузка привода, технологическое сопротивление, угловая скорость, динамическая устойчивость, механический анализ, нагрузка

INTRODUCTION

Today, continuous transport systems, in particular belt conveyors, are one of the main mechanical systems that determine the efficiency of production processes in mining enterprises. Such conveyors play an important role in the continuous transportation of goods, ensuring the logistics continuity between processes, and rational use of energy resources. Therefore, the analysis of the drive mechanisms of belt conveyors, the study of the dynamics of rotation of their working drums, and the determination of torque changes under the influence of technological loads are one of the urgent scientific and technical issues.

The main parameters characterizing the movement of belt conveyor drums are the rotational speed, angular acceleration, torque and resistance forces. These factors directly determine the mechanical stability and energy efficiency of the system. An increase or decrease in the load on the drive shaft as a result of a change in technological resistance has a significant impact on the dynamic characteristics of the conveyor system. Therefore, it is necessary to analyze the changes in the torque transmission process over time and determine their regularities through mathematical modeling.

In recent years, scientific research in the field of optimization of industrial mechanisms has shown the need for a thorough study of the mechanical interaction of conveyor drums and drive elements. In particular, dynamic changes in load and technological resistance, torque distribution, and rotational speed instability have a significant impact on the reliability and long-term efficiency of conveyor systems. Therefore, this study analyzes the dynamics of rotation of belt conveyor drums, the laws of change in drive load, and the mechanisms for their stabilization. As a result, the obtained scientific and technical results serve as a practical basis for designing conveyor transport systems, selecting their mechanical parameters, and increasing energy efficiency.

LITERATURE REVIEW

The mechanical vibration of belt conveyor roller mechanisms is caused by the oscillating motion of the conveyor belt. It is recommended to consider the vibration phenomenon from low frequency to ultrasonic frequency. Eccentricity, imbalance of rotating masses, incorrect adjustment of the working elements of the guide roller mechanism, including incorrect centering of rolling bearings in the installation, cause frequent occurrence of low-frequency vibrations (from 0 to 300 Hz). The occurrence of medium-frequency vibrations (from 200 to 2000 Hz) is observed as a result of the interaction of the rotating and stationary elements of the rolling bearing, as well as due to high vibrations that occur during the transportation of loads.

The main cause of low-frequency vibrations of the roller mechanism, including the vibration of the rolling bearings, is various vibration components. A detailed analysis of the spectrum of low-frequency vibrations of the guide roller mechanism revealed the presence of other components that are distinguished by the quality of assembly of the working elements and the quality of installation of the rolling bearings, as well as the influence of various operating factors on the rolling bearings [1].

As a result of high-quality lubrication of the sliding parts of the mechanism with lubricants, they smooth out their non-symmetrical edges with low radial loads, which leads to a decrease in the medium-frequency vibrations of the bearing. At the same time, in parts that perform the function of a loaded sliding support, medium-frequency vibrations may increase [2].

DISCUSSION

In this study, a comprehensive set of analytical, computational and experimental methods was used to determine the laws of change in the dynamics of rotation of belt conveyor drums and the load

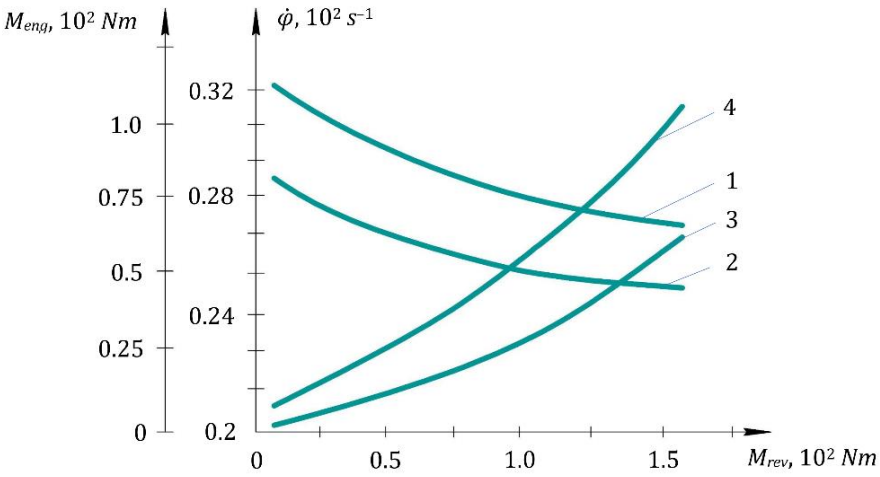
on the drive under technological resistance. The conducted studies allowed for a thorough analysis of the laws of change in the dynamics of rotation of belt conveyor drums and the load on the drive under technological resistance. The results of the study showed that the angular velocity of the conveyor drums and the load on the drive shaft directly depend on the parameters of technological resistance and load.

The results of mathematical modeling and experimental measurements showed that the drum rotation speed and driving torque change in accordance with the increase in technological resistance. For example, when the technological resistance increases by 10–15%, the rotational torque on the driving shaft increases by 12–18%, and the drum angular velocity decreases by 7–10%. This situation increases energy losses and mechanical vibrations, which reduces the efficiency of the system. Changes in the technological load in the system have a significant impact on the torque profile over time. An increase in the load leads to an increase in the moment of inertia, which causes an increase in the vibration amplitude during the initial deceleration of the drum rotation speed and subsequent stabilization. This result indicates the relevance of ensuring a stable balance between torque and speed in conveyor drive systems.

During the discussion, it was found that the drum diameter, the number of reduction stages, and the belt transmission material have a significant impact on the dynamic properties of the system. Therefore, it is necessary to optimize these parameters in order to increase mechanical stability and torque transmission efficiency. The imbalance between the friction torque of the drive shaft and the tension in the belt reduces the stability of torque transmission in the system. At the same time, the dynamic change in the drum rotation speed and the drive torque directly affects energy efficiency. Experimental analysis showed that in the optimal operating mode, the torque transmission efficiency is maintained in the range of 0.88–0.92, which ensures the energy stability of the system. The results obtained allow optimizing the operating mode of belt conveyor drive mechanisms, stabilizing torque distribution and minimizing angular velocity changes, thereby increasing energy efficiency, reducing vibration loads, and increasing system reliability. The results will also be of practical importance in innovative design, structural optimization, and technical diagnostics.

RESULTS

Figure 1 shows graphs of dependence of the angular speeds of the leading and driven drums with the belt element of the proposed belt conveyor bearing and the change of the driver load on the technological resistance and the resistance torque of the friction force.



where, 1 – $\dot{\varphi}_1 = f(M_{res})$; 2 – $\dot{\varphi}_2 = f(M_{res})$; 3.4 – $M_{enj} = f(M_{res})$; 3 – M_{fric} = 43 *Nm*; 4 – M_{fric} = 26 *Nm*.

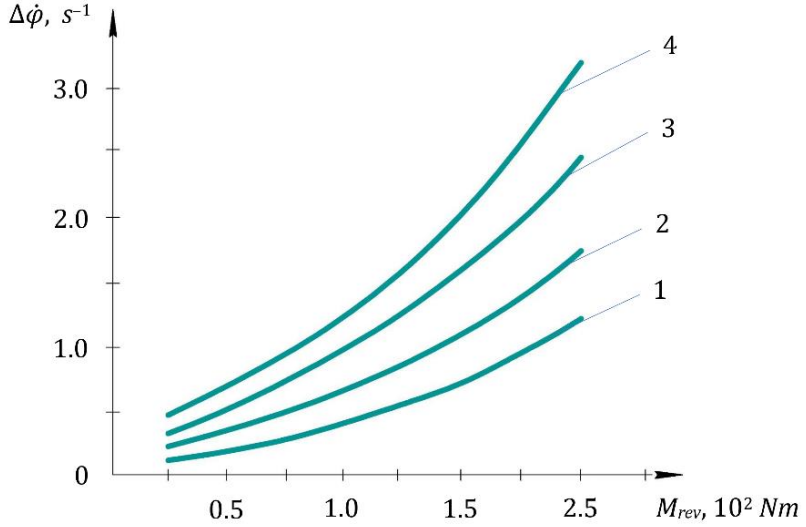
Figure 1. Graphs of angular velocities and conveyor load variations of the leading and driven drums with a belt element of the proposed belt conveyor bearing support and technological resistance dependence graphs

Based on the graphical connections, when the values of M_{res} change from $0.15 \cdot 10^2$ *Nm* to $1.5 \cdot 10^2$ *Nm*, the torque on the drive shaft increases from $0.17 \cdot 10^2$ *Nm* to $0.86 \cdot 10^2$ *Nm*, while the torque of the friction forces increases from $0.11 \cdot 10^2$ *Nm* It can be seen that it reaches $0.41 \cdot 10^2$ *Nm*. It can be seen that the difference between the angular velocities of the drums decreases as the technological resistance increases. The main reason for this is that even if the deformation values of the belt are large under a large load, the change intervals are small. In particular, it can be seen from the equation that when the values of M_{res} increase from $0.2 \cdot 10^2$ *Nm* to $1.5 \cdot 10^2$ *Nm*, the values decrease linearly from $0.305 \cdot 102$ s^{-1} to $0.274 \cdot 102$ s^{-1}, and the angular velocity of the leading drum decreases from $0.283 \cdot 102$ s^{-1} to $0.256 \cdot 102$ s^{-1} can be determined.

The difference between the angular velocities, as we noted above, occurs due to the rotation of the conveyor belt, due to the change in friction, due to a sufficient level of sliding. It should be noted that the reduction of belt vibrations at the expense of the composite roller shock absorber also leads to a reduction of the angular speed fluctuations of the drums. However, by ensuring that the belt vibrates at the required level, it causes the transported ore to be level. Therefore, it is recommended to achieve the values of technological resistance $(1.3 \div 1.6)\ 10^2$ *Nm* from, and the torque of friction force does not exceed $(35 \div 40)$ *Nm*.

Figure 2 shows graphs of dependence of belt conveyor drums angular velocities, vibration range, technological resistance and friction moment. In this case, when the technological resistance and M_{res} incoming resistance increase from $0.25 \cdot 10^2$ *Nm* to $1.98 \cdot 10^2$ *Nm*, the angular velocity of the driving drum increases in a non-linear pattern from 0.46 s^{-1} to 2.95 s^{-1} when the vibration range is c_2 = 260 *Nm*/*rad*. can be achieved (Fig. 2, graph 4).

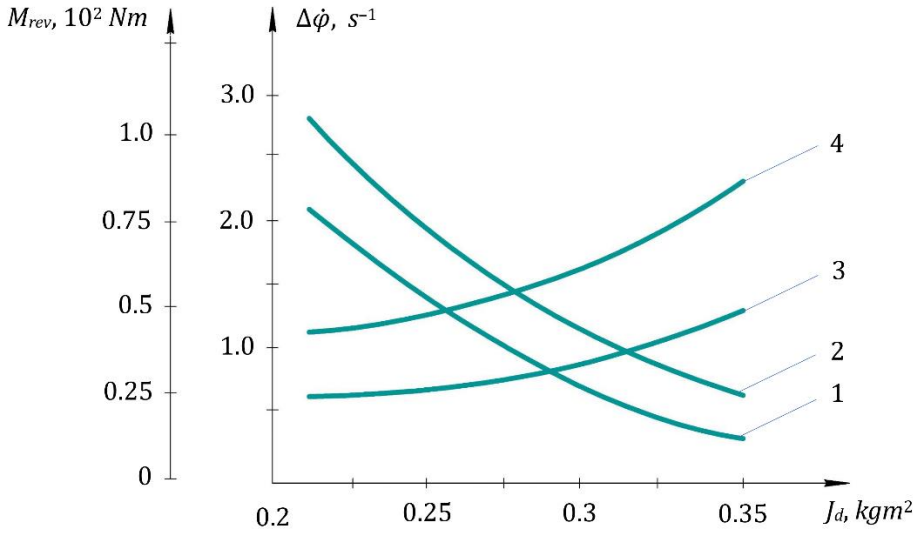
Correspondingly, when the rotational speed coefficient of the conveyor belt increases to 320 *Nm*/*rad*, the range of oscillation of the angular velocity of the driving drum increases from 0.42 s^{-1} to 2.19 s^{-1}, and the values of $\Delta\dot{\varphi}_1$ only increase to 1.11 s^{-1}. In this case, the maximum difference between $\Delta\dot{\varphi}_1$ and $\Delta\dot{\varphi}_2$ reaches $(1.0 \div 1.25)$ s^{-1} when $M_{res} + M_{fric} = 2.0 \cdot 10^2$ *Nm* (Fig. 2, graphs 2, 4). According to the results of experimental studies, to ensure that the angular velocity of the driving drum is within the range of $\Delta\dot{\varphi}_2 \leq (0.21 \div 0.25)$ 10 s^{-1}, $c_2 \leq (260 \div 300)$ *Nm*/*rad* coming from the transported ore and it is recommended that the torque of the friction force should be in the range of technological resistance $M_{res} + M_{fric} = (1.3 \div 1.6)$ *Nm*. As mentioned above, increasing the speed of belt rotation causes the angular velocities of the drums to converge and decrease $\Delta\dot{\varphi}_1$ and $\Delta\dot{\varphi}_2$.



where, 1, 2 – $\Delta\dot{\varphi}_2 = f(M_{res})$; 3, 4 – $\Delta\dot{\varphi}_2 = f(M_{res})$; 1, 3 – c_2 = 380 *Nm*/*rad*; 2, 4 – c_2 = 260 *Nm*/*rad*

Figure 2. Graphs of dependence of angular speeds of belt conveyor drums on technological resistance

Figure 3 shows graphs of the dependence of the angular speed of the belt conveyor drums on the vibration range and the load on the conveyor on the changes in the moments of inertia of the drums.



1 – $\Delta\dot{\varphi}_1 = f(J_{d1})$; 1 – $\Delta\dot{\varphi}_1 = f(J_{d2})$; 3, 4 – $M_{ener} = f(J_{d1})$;
3 – $M_{res}+M_{fric} = 0.75\cdot10^2$ Nm; 4 – $M_{res}+M_{fric} = 1.25\cdot10^2$ Nm

Figure 3. Graphs of the dependence of the angular speed of the belt conveyor drums, the vibration range and the load change on the conveyor on the change of the moments of inertia of the drums

It is known that with the increase of moments of inertia in rotating joints, the motion becomes smooth. Therefore, in order to obtain the angular velocity unevenness coefficient within the desired limit, the moment of inertia values are chosen accordingly. It can be seen that when the moment of inertia values of belt conveyor drums are increased from 0.32 kgm^2 to 0.45 kgm^2, the values of $\Delta\dot{\varphi}_1$ decrease nonlinearly from 2.12 s^{-1} to 0.36 s^{-1}, and the angular velocity of the driving drum decreases from 2.9 s^{-1} to 0.82 s^{-1} can be seen (Fig. 3, graphs 1, 2). In order to keep $\Delta\dot{\varphi}_2$ in the desired range, it is recommended that $J_{b1} = (0.45 \div 0.52)$ kgm^2 and $J_{b2} = (0.42 \div 0.45)$ kgm^2. It should be noted that as the moment of inertia of the drums increases, the load on the electric conductor also increases. For example, when $J_{b1} = J_{b2} = 0.45$ kgm^2 increases to $M_{res} = 1.25\cdot102$ Nm, it can be seen that M_{ener} values increase from $0.46\cdot10^2$ Nm to $0.83\cdot10^2$ Nm, i.e. up to two times. Therefore, the moment of inertia of drums is limited.

CONCLUSION

The results of the research made it possible to deeply analyze the dynamics of the rotation of belt conveyor drums and the laws of change in the driving load under technological resistance conditions. The main scientific and technical conclusions of the research included the following. Namely, the angular velocity and driving torque of the conveyor drums are directly dependent on the technological resistance and load parameters. Under optimal conditions, the torque transmission efficiency is maintained in the range of 0.88–0.92, which ensures stable operation of the system. An increase in the load leads to an increase in the moment of inertia, which causes an increase in the amplitude of oscillations during the initial deceleration of the drum rotation speed and subsequent stabilization.

This phenomenon determines the energy efficiency and mechanical stability of the system. The diameter of the drum, the number of reducer stages and the belt transmission material have a significant impact on the dynamic properties of the system. Therefore, it is necessary to optimize these parameters to increase mechanical stability and torque transmission efficiency. The imbalance of belt tension and friction torque reduces the stability of torque transmission and negatively affects the energy efficiency of the system. The results of the research allow optimizing the operating mode of belt conveyor

systems, stabilizing torque distribution and minimizing angular velocity changes, thereby reducing energy consumption, reducing vibration loads and increasing system reliability.

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