DESIGN IMPROVEMENT AND SCIENTIFIC SUBSTANTIATION OF THE PARAMETERS OF COMPOSITE GUIDE ROLLER MECHANISMS FOR BELT CONVEYORS

Akbarjon Jumaev
Almalyk State Technical Institute
Corresponding author: akbarjumayev011@gmail.com
Makhbuba Musayeva
Akhangaran technical school
Dilafruz Xajikulova
Ohangaron District Technical School №1
ORCID: *https://orcid.org/0009-0009-3026-8052*
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Abstract. This study proposes an improved structural configuration and examines the operating principles of a belt conveyor equipped with composite guide rollers incorporating elastic shock-absorbing elements. Through comprehensive theoretical and experimental investigations, the motion characteristics of the system and its operating conditions were established. Experimental studies were conducted to determine the kinematic behavior of the conveyor drums, rotational resistance, vibration characteristics, and loading conditions of the composite guide rollers. Based on full-scale experimental testing, the rational design and operating parameters of the guide rollers were determined.

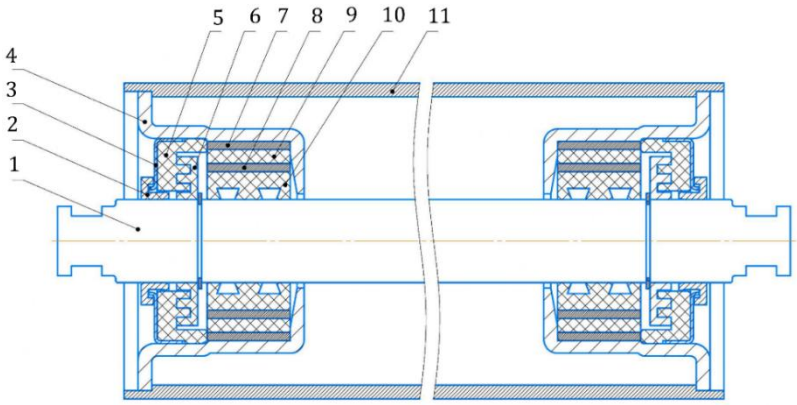
Key words. Belt conveyor, guide roller, composite roller, elastic element, vibration

The advancement of mechanical engineering solutions is an essential factor in strengthening the competitiveness of the mining sector worldwide. Particular attention is being paid to resource-saving technologies and machinery that ensure high operational reliability, extended service life, and increased productivity. Since material transportation constitutes approximately 40–70% of the overall costs of mineral extraction and transportation in open-pit mining operations, the introduction of advanced and efficient belt conveyor designs is of considerable economic importance. Belt conveyor systems enable the continuous transportation of extracted minerals over long distances. In this regard, the development of energy-efficient conveyor equipment with enhanced productivity and improved technological performance remains a priority for the mining industry.

Nevertheless, existing approaches to the design of resource-saving belt conveyors and the assessment of their dynamic behavior have given insufficient consideration to variations in operating parameters and the fundamental principles of lubrication. Specifically, the effect of lubricant characteristics on the operating behavior of composite guide roller mechanisms in mining conveyor systems remains an important research aspect. In this context, composite guide roller mechanisms equipped with elastic components were designed, and their design parameters and operational regimes were scientifically justified through theoretical and experimental studies. The effectiveness of the proposed solutions was subsequently assessed through conveyor performance tests [1].

An investigation into the operational conditions and performance characteristics of mining belt conveyors provided the basis for establishing specific design criteria for their principal components. Following an examination of conventional roller mechanism configurations, a new composite structural arrangement incorporating elastic elements was proposed. Figure 1 presents the recommended configuration of a belt conveyor featuring sliding bearings and an advanced roller mechanism with elastic components. The proposed arrangement takes into account the operational and maintenance requirements of mining conveyor systems, as well as the design limitations of existing solutions [2].

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1-shaft, 2-labyrinth cover, 3-metal cover, 4-hub, 5-labyrinth protective cover[1], 6-labyrinth protective cover[2], 7-ring[1], 8-ring[2],
9-flexible element, 10-sliding bushing base (graphite-caprolon), 11-shell

FIGURE 1. Structural diagram of the proposed belt conveyor with a composite elastic element of the guide roller mechanism

Today, the key to the successful operation of all mining enterprises remains, first and foremost, the need for additional energy resulting from defects and problems in the belt conveyor and its components, and the mutual coordination of all departments to ensure reliable and trouble-free operation of the equipment. All of this has been analyzed in research conducted to develop new, improved designs for maintenance mechanisms, reliability diagnostics, and timely equipment repair.

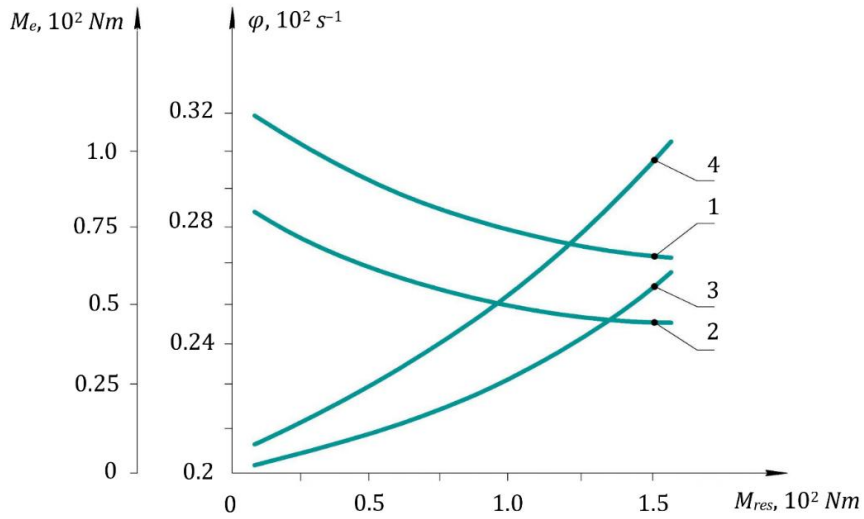
Theoretical studies were mainly based on the study of the law of motion of conveyor drums, determination of the limits of change in angular velocities, dissipative-primary properties of the belt, the influence of changes in process resistances and inertial parameters on the load [3].

According to the analysis of the obtained graphs of the laws of motion and adhesion, with a change in the values of M_{res} from $0.15 \cdot 10^2$ Nm to $1.5 \cdot 10^2$ Nm, the torque on the electric drive shaft increases from $0.17 \cdot 10^2$ Nm to $0.86 \cdot 10^2$ Nm, and the friction torque, it can be seen, reaches from $0.11 \cdot 10^2$ Nm to $0.41 \cdot 10^2$ Nm. It is evident that the difference in the angular velocities of the drums decreases with an increase in process resistance. The main reason for this is that the change intervals are small, the belt deformation values are large under heavy loads (Fig. 2).

It should be noted that the reduction in belt vibration due to the composite roller damper also results in a reduction in the angular velocity of the drums. However, ensuring that the belt vibrates only as much as necessary ensures that the transported ore remains flat. Therefore, it is recommended that process resistance values not exceed $(1.3 \div 1.6)\ 10^2$ Nm [4].

Based on the results of experimental studies, it is recommended that the angular velocity of the lead drum be in the range of $\Delta\dot{\varphi}_2 \leq (0.21 \div 0.25)\ 10\ s^{-1}$ in the presence of process resistance $c_2 \leq (260 \div 0.25)$ Nm/rad of the transported ore to ensure that the magnitude of the vibration coating is in the range of $\Delta\dot{\varphi}_2 \leq (0.21 \div 0.25)\ 10\ s^{-1}$. As noted above, an increase in the rotational rigidity of the belt leads to a decrease in the angular velocities of the drums by $\Delta\dot{\varphi}_1$ and $\Delta\dot{\varphi}_2$, respectively [6].

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$1 - \dot{\varphi}_1 = f(M_{res})$; $2 - \dot{\varphi}_2 = f(M_{res})$; $3, 4 - \dot{\varphi}_1 = f(M_{res})$

FIGURE 2. Graph of the dependence of angular velocities and changes in the drive load of the drive and guide drums with a flexible element containing the recommended support of the belt conveyor on the process resistance

Based on the experiments, it was found that the best indicator for the part and Litol-24 oils made of rubber (7B-54MBC, 7IRP13-46, 7IRP13-48) and plastics (PVC, fluoroplastic, garfitokaprolon) with a load of F_r = 130 N, 190 N, 270 N and a rotational speed of f = 150 *rpm*, 300 *rpm*, 450 *rpm*, which depends on the rotational resistance of the belt conveyor guide roller mechanism, load F_r = 130 N, rotational speed f = 150 *rpm*. Litol-24 indicators of change in temperature coefficient relative to the rotational resistance of the mechanism are determined from the formula $k\ (t) = 1 - 0.16\ (t + 30)$, the upper and lower values of the temperature coefficient were considered in the range from 0.27 to 0.021.

It follows that the belt conveyor roller mechanism is recommended for use at ambient temperatures ranging from – 30 to + 30 °C, provided that the temperature coefficient is $k(t) = 0.16$ and takes the form $t \geq 30$ °C. This value can be concluded to be the best. The friction force between the graphite-caprolon material and the bearing axis was also determined using Litol-24 oil. In this case, the rotating resistance of the composite roller was minimal [7, 8].

During testing, the guide roller mechanism installed on the belt conveyor ensured uniform rotational motion. Analysis was conducted in the plant's quality control department and research laboratory. Test results showed that the operating frequency of the plain bearing, instead of the rolling bearing performing both support and rotational motion, increased by 4.5%, mechanical damage to the roller mechanism decreased by 5.6%, external damage decreased by 4.99%, and productivity increased by up to 15%. Based on an extended cost-benefit calculation, the payback period is 3.6 years; the return on investment is 28%.

The design of mechanisms for composite guide rollers of belt conveyors with an elastic element has been developed, and the parameters and modes of their operation have been substantiated based on the results of comprehensive theoretical and applied research, as well as testing.

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