**Study of the energy efficiency of conveyor installations in mining transportation systems**

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**Abstract.** The article energy efficiency of mining and metallurgical enterprises depends on the following factors: mining and geological, climatic and meteorological, production and technological, organizational and managerial. When moving rock mass, energy consumption increases and energy consumption decreases with an increase in the degree of crushing. An increase in the specific resistance to destruction and the coefficient of loosening increases energy consumption. In addition to the above-mentioned factors, the efficiency of mining transport systems is also affected by the design and operating parameters of technological equipment, as well as the specific energy consumption during the transportation of rock mass. Therefore, of the above-mentioned significant factors, the most important is the electricity consumption for the useful work performed by the technological equipment.

**INTRODUCTION**

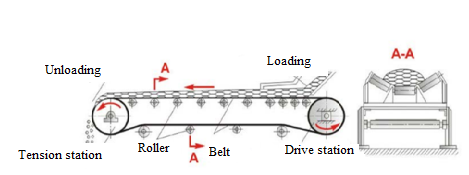
At present, the divisions of the mining and metallurgical sector are among the largest consumers of electricity and are characterized by high energy usage. In mining and metallurgical beneficiation enterprises, energy consumption represents 23–30% of the total [1-3].

The electrical energy consumed by the conveyor system makes up 15% of the enterprise’s total energy consumption, with potential savings reaching up to 57%. Other units of the enterprise have individual shares of 15–25%, while their energy savings range from 10% to 25%. It can be stated that the transportation of ore masses by conveyor exhibits high energy efficiency [4-9, 15].

In most cases, conveyor productivity is overestimated because of the low utilization coefficient. Increasing the utilization coefficient requires adjusting the transportation load to approach its nominal value. [10].

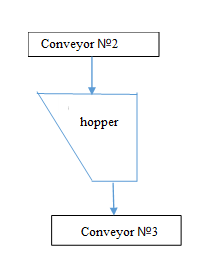
Electricity savings can be achieved by varying the conveyor speed, installing additional bunkers, and improving the electric drive’s efficiency through smooth start-up and higher performance. Belt conveyors (BC) are employed for the transportation of ore masses and are regarded as the most efficient form of conveyor transport in mining and metallurgical complexes [10-19].

Figure 1 illustrates the principal scheme of the conveyor. The conveyor comprises a pulling element — the belt, serving as the load-carrying unit, an electro mechatronic system, a transmission mechanism that drives the rotating components, and the conveyor assembly [20-29].



**FIGURE 1.** Belt conveyor diagram

At present, the electro mechatronic system of a belt conveyor includes the drive drum, electric motor, transmission mechanism, brake system, start-up device, power converter, and control system. Modern conveyor electro mechatronic systems comprise single- and double-drum asynchronous electric drives, functioning continuously under variable load conditions with speed control implemented in 2–3 stages [30-35].



**FIGURE 2:** Conveyor–hopper–conveyor system

**METHODS AND MATERIALS**

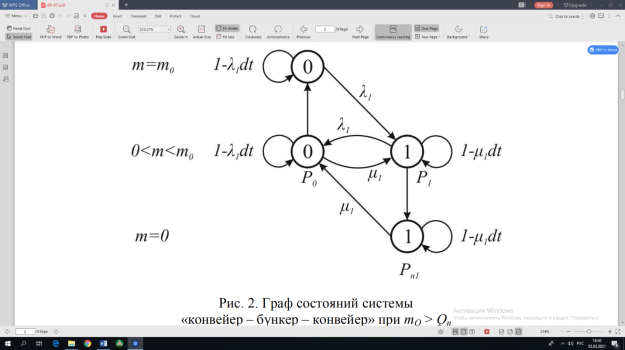
In order to determine the influence of constructions and parameters on the operation of ore transportation, the ‘conveyor–bunker–conveyor’ system was examined from the perspective of energy efficiency, and mathematical models of the system’s operation were developed. Using these models, the system’s throughput was analyzed in relation to the bunker capacity and the ore flow rates entering and leaving the bunker. Figure 3 presents the computational scheme of the ‘conveyor–bunker–conveyor’ system: m Q – throughput of the conveyor above the bunker; Q p – feeder throughput; λ₁, λ₂ – failure (breakdown) parameters of the upper and lower conveyors; μ₁, μ₂ – restoration (repair) parameters of the upper and lower conveyors [36-40].

Изображение выглядит как текст, программное обеспечение, снимок экрана, веб-страница

Контент, сгенерированный ИИ, может содержать ошибки.

**FIGURE** 3: Calculation diagram of the ‘Conveyor–Bunker–Conveyor’ system

Within the ‘conveyor–bunker–conveyor’ system, the failure and recovery flow parameters for the upper and lower conveyors are μ₁, λ₁; μ₁, λ₂; and μ₂, respectively. The productivity of the upper conveyor and the feeder are m Q and Q n, respectively. When m Q exceeds Q n, the sub-bunker (lower) conveyor runs continuously, meaning λ₂ = μ₂ = 0. The state diagram for this system is presented in Figure 4.



**FIGURE** 4. Position of the "conveyor ‒ hopper ‒ conveyor" system when mQ> Qn

Thus, P₀(m, t) and P₁(m, t) represent the probabilities of the system being in states ‘0’ and ‘1’, respectively, given that the ore mass in the bunker is m. P₃₀(t) denotes the probability of the system being in state ‘0’ when the bunker is full, while P₁ₙ(t) denotes the probability of the system being in state ‘1’ when the bunker is empty. In this case, the set of equations characterizing the bunker operation is as follows:

(1)

The following initial conditions should be met in this case:

If t = 0 P0(m,0) = P1(m,0) = P30(0) = 0, Pn1(0) = 1; (2)

‒ Boundary conditions;

**If** m = m0 QnP1(m0,t) = P30(t); (3)

**Agar** m = 0 (mQ – Qn)P0(0,t) = Pn1(t), (4)

‒ Normalization condition

(5)

Where: m is the current ore mass in the bunker (t, tons), and m₀ is the maximum ore mass in the bunker (t, tons). As t approaches infinity (t → ∞), and considering the boundary conditions (2)–(4), the system of equations (1) can be expressed as follows:

(6)

Here, P₀(m) and P₁(m) represent the limiting values of the functions P₀(m, t) and P₁(m, t) as t approaches infinity (t → ∞); P₃₀ and P₁ₙ denote the limiting probabilities P₃₀(t) and P₁ₙ(t) as t → ∞. Under these conditions, the throughput of the ‘conveyor–bunker–conveyor’ system is given by the following expression:

(7)

By solving equations (6) and (7), the throughput capacity of the ‘conveyor–bunker–conveyor’ system is obtained in the following form:

(8)

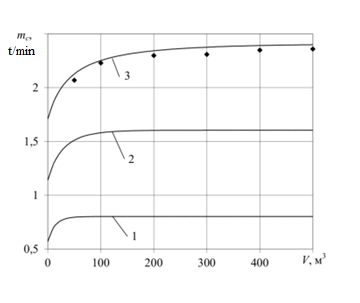
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Where: γ₁ is the failure coefficient of the upper (over-bunker) conveyor, and γ is the specific gravity (density) of the ore mass. When the lower conveyor functions with interruptions (λ₂ ≠ 0, μ₂ ≠ 0), the mean value of Q n is expressed as follows:

(9)

Here, **–** the failure coefficient of the lower (sub-bunker) conveyor.

In Figure 5, the relationship between the average productivity m c of the ‘conveyor–bunker–conveyor’ system and the bunker volume is presented for various values of the incoming (m Q) and outgoing (Q n) load flows



**FIGURE**  5. Dependences of the average productivity mc of the conveyor-hopper-conveyor system on the hopper volume V when m ~~Q~~>Qn

The mean throughput of the incoming load is m Q = 3.7 t/min, with the failure and recovery flow parameters for the upper and lower conveyors set to the following values: The parameters are λ₁ = 0.025 min⁻¹, μ₁ = 0.0614 min⁻¹; λ₂ = 0.017 min⁻¹, μ₂ = 0.069 min⁻¹; with the ore mass specific gravity γ = 1 t/m³. Curves 1, 2, and 3 represent Q n values of 1, 2, and 3 t/min, respectively.

**RESEARCH RESULTS**

From the dependence of the average throughput m c of the ‘conveyor–bunker–conveyor’ system on the bunker volume, it can be seen that for any values of m Q and Q n, as the bunker volume increases, the throughput of the system initially rises. However, even if the ore volume V continues to increase further, m c remains unchanged and reaches a constant value.If m Q > Q n, as the output flow Q n increases, the throughput m c of the ‘conveyor–bunker–conveyor’ system also increases. However, if m Q ≤ Q n, m c remains nearly unchanged even when Q n increases.

Analysis of the ‘conveyor–bunker–conveyor’ system indicates that with an increasing ore volume in the bunker, the system’s throughput first increases and subsequently stabilizes at a constant value [41-70].

Furthermore, if the throughput of the upper conveyor is greater than that of the lower conveyor

(m Q > Q n), then an increase in Q n leads to an increase in the throughput m c of the ‘conveyor–bunker–conveyor’ system. However, if m Q ≤ Q n, m c remains nearly unchanged even as Q n increases.

The operational efficiency of mining transport systems is influenced by the design and operational parameters of technological equipment, as well as the specific energy expenditures involved in transporting the ore mass.

Among the important factors mentioned above, the most significant is the electrical energy consumed to perform useful work by the technological equipment in the mining transport system. The energy efficiency of the conveyor performing useful work in transporting ore over a distance is measured by the specific electricity consumption, calculated in kWh per ton-kilometer (kWh/(t· km))..

The dependence of the average throughput m c of the ‘conveyor–bunker–conveyor’ system on the bunker volume V illustrates the relationship between the specific energy consumption E for ore transportation and the average incoming load m Q to the upper (above-bunker) conveyor. The dependency was examined for an uncontrolled bunker under two scenarios: first, with a constant upper conveyor belt speed (curve 1); second, with the upper conveyor belt speed regulated according to different nominal throughputs – Q\_m1 = 5, 6, 7 t/min (curves 2, 3, and 4, respectively).

Furthermore, in the case of a controlled upper conveyor belt speed, the linear load q\_Γ1 attains its maximum value, calculated using the following equation:

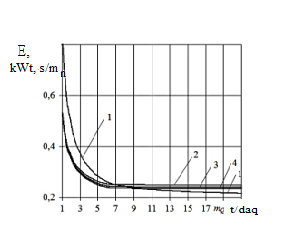
(9)

In this case, the speed of the upper (above-bunker) conveyor belt depends on the incoming load

m Q and is given by the following expression;

(10)

Here, v\_{dm1} – the permissible maximum speed of the upper (above-bunker) conveyor belt, m/s.

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**FIGURE 6.** Graphs of the dependence of the specific energy consumption E of the conveyor-hopper-conveyor system on the average value of the cargo flow m Q

**CONCLUSIONS**

From the graph showing the dependence of the specific energy consumption E of the ‘conveyor–bunker–conveyor’ system on the average load m Q, it can be seen that when m Q < 6.8 t/min, the specific energy consumption E of the system is 23% lower in the case of a controlled belt speed compared to the case of an uncontrolled belt speed. If the load flow to the upper bunker conveyor is m Q ≥ 6.8 t/min, then the specific energy consumption E of the ‘conveyor–bunker–conveyor’ system, whether the upper conveyor belt speed is controlled or uncontrolled, reaches a constant value, independent of both the incoming load m Q and the nominal throughput Q\_m1 of the upper conveyor. Thus, when adjusting the conveyor belt speed, with the maximum linear load on the belt kept constant, if the incoming load to the conveyor is halved, regulating the belt speed reduces electricity losses by 30% [14].

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