Study of the influence of structure and parameters of loading and transporting devices of a cleaning combine on the efficiency of coal loading

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Abstract. The article analyzes the factors that influence the process of unloading coal from the zone of its separation by cutters from the massif and loading the destroyed rock mass to the face conveyor by screw executive bodies of shearsers. The modeling of the process of loading coal with a shearer to the face conveyor was carried out in order to improve the quality of loading. When modeling, the program EDEM 3D was used. As indicators of the effectiveness of the process adopted: productivity and specific energy consumption. Simulation of the process of loading coal with a shearer was carried out for the following options: the cross-sectional area of the loading window of the auger varied from 0.55 to 1.00 m²; the gap between the screw and conveyor is from 250 to 450 mm; combine feed speed – from 2 to 6 m/min; the angles of winding the blades were taken from 16° to 24°. The purpose of research is to find a comprehensive technical solution that provides resistance to the movement of coal flow, coal circulation in the stream, achieving the completeness of cleaning the soil and loading coal on the conveyor, the formation of a rational section of the coal flow on the conveyor.

1. Introduction
Currently, in underground coal mining from shallow formations of medium power, narrow-capture shearsers with screw actuators are prevailing, which are distinguished by the combination of mass destruction operations, coal unloading from the destruction zone and its loading onto the conveyor [1–4], simplicity of design and reliability functioning.

The theory of the function of screw executive organs is based on the main principles of the theory of screw conveyors. Methodological and normative materials for determining the geometric and structural parameters of screw executive organs on shearsers and their operating modes are based on the results of experimental studies of the irreal samples, models and on the results of their wide testing in production conditions.

Many experts note that with an increase in the intensity of the mining process, the disadvantages of screw executive organs of shearsers manifests itself more significantly: soil cleaning by a lagging screw worsens, circulation and concomitant grinding of coal in the stream increase, the formation of fine dust, including volatile, hazardous by sanitary standards, is intensified and explosion, and increases specific energy consumption. Therefore, improving the process of unloading coal lagging screw executive organs, from the destruction zone and loading it onto the downhole conveyor is an urgent task.
The main features of the process under consideration as an object and subject of research are determined by external and internal factors, their influence on the loading process (Fig. 1). External factors include mining and geological conditions, strength parameters of the developed formation and technological parameters of the treatment works.

2. Materials and Method

A significant influence on the process under study is exerted by internal factors, which include (Fig. 1) the geometric parameters of screw executive organs, the parameters and operating modes of shearsers and shearer mechanized complexes in general. The geometrical parameters include [1, 2, 5–9]: reduced diameter of the actuator – \(D_{sh}\), diameter of the screw hub – \(d_{sh}\), pitch of the blades winding – \(S\), thickness of the screw blades – \(\delta_{s}\), number of visits of the screw blades – \(N_{s}\), interlobe filling factor augers’ paces – \(K_{z}\), parameters of the arrangement of incisors, sectional area of the loading window – \(S_{o}\), distance between the screw and the conveyor – \(L\), the shape and dimensions of the loading space, the height of the conveyor – \(H_{K}\), etc. The operational parameters of shearsers and treatment mechanized complexes include: feed rate – \(v_{p}\) and cutting – \(v_{r}\), convey or chain speed – \(v_{k}\). The values of these parameters depend, as a rule, on the external conditions, the organization of work in the complex mechanized face, the established operating modes of the shearer and canvary, in certain ranges: for example, during designer operation.

The values of some parameters characterizing these factors change deterministically with the mining of the extraction column and can be represented by the average (expected) values, others have a random nature of their formation, and can be represented by dispersion, standard deviation, coefficient of variation and spectrum.

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**Figure 1.** Factors affecting the loading process of screw executive organs
The components of the loading process as a whole in its different series-conjugated zones (Fig. 2): separation of coal from the array –1, unloading of the destroyed mass by the auger blades from the destruction zone – 2, passive movement of the destroyed mass in the spatial zone between the auger and the conveyor side – 3 and the formation of the cargo flow on the conveyor – 4 are different in their mechanical essence, the number of factors influencing them and the nature of their influence on these processes. Therefore, these processes should be attributed to complex, multifactorial and analyze them in order to identify features and areas of improvement should be separately in each of the four spatial zones in which the processes under consideration.

**Figure 2.** Structural diagram of the processes of loading coal onto a conveyor with a screw

| Zone | Coal loading efficiency indicator |
|------|----------------------------------|
| I    | \( Q_v = v \cdot B \cdot H \cdot \dot{\lambda} \) (1) |
|      | \( W_{d1} = 100 \left[ 1 - \exp \left( -\frac{k}{m^0} d_{m}^{*} \right) \right] \) (2) |
|      | \( H_{w1} = \frac{P}{60 \cdot B \cdot H \cdot v_{f}} \) (3) |
| II   | \( H_{w2} = 17.6 \cdot 10^{-6} \frac{M}{(S - S_1) v_{m}^0 n_{d0}} \) (4) |
|      | \( Q_{III} = \frac{\pi}{4} \left( \frac{D_{III}^2 - d_{III}^2}{2} \right) \frac{\delta_{w} S \cdot n_{d0} \cdot K_{1} \cdot \cos \alpha_{w}}{2 \sin \alpha_{w}} \) (5) |
| III  | The process is not formalized |
| IV   | The process is not formalized |

3. Results and Discussion

The most important parameters affecting the efficiency of coal loading include the geometric, structural, and operational parameters of the auger and handling devices. It is these parameters that can change with the improvement of the process of loading coal onto the conveyor. The most effective method for studying such complex and multifactorial processes is modeling.
Modeling is carried out in order to assess the efficiency of the process of loading coal onto the conveyor with a shearer with changing parameters: the dimensions of the cross-sectional area of the loading window, the gap between the screw and conveyor, the feed speed of the shearer and the angles of winding the blades. In the simulation, the EDEM 3D program was used [10–12]. The following indicators were taken as indicators of process efficiency: productivity \( (Q_k) \), specific energy consumption \( (H_w) \) and particle size distribution \( (W_d) \) for evaluating the secondary grinding of rock mass during loading.

![Figure 3. Loading window of the shearer](image)

During the simulation, the following values of design parameters were adopted [2, 4, 14]: screw diameter – 1800 mm; hub diameter – 600 mm; the angles of winding the auger blades \( \alpha = 20^\circ \); the number of blades – 3; blade thickness – 50 mm; working width – 800 mm; conveyor bead \( h_k = 350 \) mm; screw rotation speed – 50 rpm; and values of parameters characterizing the dispersed mass of coal: average particle diameter – 30 mm; coefficient of friction of particles in the dispersed mass – 0.8; the coefficient of friction of particles on the metal is 0.6, the angle of repose of the material in the bulk \( \rho = 350 \).

The performance of loading coal on to the conveyor or with a lagging screw executive body during modeling was determined by the formula:

\[
Q_k = \frac{M}{t} \text{ kg/s, or } Q_k = 3.6 \cdot \frac{M}{t} \text{ t/h,}
\]

where \( M \) is the mass of coal loaded on to the conveyor, kg and \( t \) is the time, s.
The simulation results of the process of loading coal onto the conveyor are shown in Figures 4–8.

**Figure 4.** Dependence of loading performance on the cross-sectional area of the loading window

**Figure 5.** Dependence of loading performance on the length of the loading window

**Figure 6.** Dependence of loading performance on feed rate

**Figure 7.** the relationship of the volume of coal loading onto the conveyor over time

**Figure 8.** Dependence of loading performance from the angle of winding of the auger blades

The discussion of the results:

An increase in the cross-sectional area of the So loading window leads to a significant increase in the intensity (productivity) of the coal loading process (Figure 4).

The greater the distance (L) from the screw actuator to the conveyor, which is due to the layout features of the units of the mating equipment, the greater the resistance to the movement of the coal.

Mathematical models:

\[ y = 102.96 \cdot S_0 - 2.1299 \]

\[ R^2 = 0.9519 \]

\[ y = -0.3838 \cdot L + 237.32 \]

\[ R^2 = 0.9906 \]

\[ y = 5.214 \cdot v_n + 38.436 \]

\[ R^2 = 0.652 \]

\[ y = -91 v_n + 903.6 \]

\[ R^2 = 0.9851 \]

\[ y = -0.6571 \alpha^2 + 25.306 \alpha - 137.44 \]

\[ R^2 = 0.8399 \]
Stream during its loading onto the conveyor. From figure 3 it follows that the shorter the path of movement (L) of the destroyed mass to the conveyor, the higher the efficiency of the loading process. However, in modern designs of shears and conveyors, this distance (L) is 300 mm or more. Reducing this gap between the screw and the conveyor is difficult due to the design features of their layout.

From the analysis and comparison and analysis of the simulation results (Fig. 6), it follows that with an increase in the feed rate of the shearer, the intensity of the loading process (productivity) increases, and at the same time, the amount of coal (Fig. 7) remaining on the soil increases. Therefore, when choosing a harvester operating mode (feed rate), it is necessary to consider the values of the process indicators: coal breaking capacity, loading capacity, torque and specific energy consumption.

The process of loading coal onto a conveyor can be represented by a parabolic dependence of the loading intensity on the angle of winding of the auger blades in the range of their actual values of 16°–24° (Fig. 7). In this case, the maximum performance corresponds to an angle of 19.2°.

4. Conclusion

Based on the foregoing, we can draw the following conclusions:

• the process in each local spatial zone differs from others in physical and mechanical nature, relates to complex and multifactorial;
• increasing the efficiency of the loading process can only be achieved by a comprehensive technical solution that provides a reduction in resistance to the movement of the coal stream, a decrease in the circulation of coal in the stream, an increase in the completeness of the soil cleaning and the formation of a rational section of the coal stream on the conveyor;
• an increase in the cross-sectional area of the loading window from 0.55 to 1.00 m² leads to an increase in loading performance by 1.73 times, an increase in the gap between the screw and conveyor from 250 to 450 mm reduces the loading performance by 2.28 times due to intermittent resistance in the passive zone; a three-fold increase in feed rate (from 2 to 6 m / min) increases loading performance by only 1.45 times;
• the maximum productivity of loading coal on the conveyor corresponds to the angle of winding of the screw blades of 19.2°.

References

[1] Pozin E Z, Melemac V Z, Ton V V 1984 Coal destruction with excavation machinery (Moscow: Nedra)
[2] Peng S S 2006 Longwall Mining
[3] Gorbatov P A, Ptsrushkin G V 2006 Mining machines for excavation (Donetsk: DonTU).
[4] L V Fedorova, Yu S Ivanova, M V Voronina 2017 Improvement of Threaded Joint Reliability by Means of Electromechanical Processing Journal of Mining Institute 226 456-461.
[5] Khakimova R I, Malkova R I 1984 Backwall configuration's influence on strain distribution and deformation on the bed selvedge Sovershenstvovanie tehnologii gornykh rabot 227 90-94.
[6] Eiderman B A 1984 Theory of the traffic organization on drag-type conveyor (Moscow: Nauka).
[7] Kuidong Gao Kuidong 2016 Particle movement behavior in drum coal loading process by discrete element method EJGE 21 163-173
[8] Zagrivniy E A, Basin G G 2016 External dynamics of the mining machinery Bulletin of Mining university 217 140-149.
[9] Gabov V V, Zadkov D A, Nguyen Khac Linh 2019 Features of elementary burst formation during cutting coals and isotropic materials with reference cutting tool of mining machines Journal of Mining Institute 236 153.
[10] Nguyen Khac Linh, Gabov V V и Zadkov D A 2018 Improvement of drum shearer coal loading performance EURASIAN MINING 2 22-25.
[11] Nguyen K L, Gabov V V, Zadkov D A, Le T B 2018 Justification of process of loading coal onto face conveyors by auger heads of shearer-loader machines IOP Conference Series:
Materials Science and Engineering. DOI: 327 042132 doi:10.1088/1757-899X/327/4/042132.

[13] Gospodarczyk P 2016 Modeling and simulation of coal loading by cutting drum in flat seams Archives of Mining Sciences 61 365-379.

[14] Ayhan M, Eyyuboglu E M 2006 Comparison of globoid and cylindrical shearer drums’ loading performance The Journal of The South African Institute of Mining and Metallurgy 106 51-56.

[15] Grundke K et al 2015 Advances in Colloid and Interface Science 222 350–76