INTRODUCTION

Modern coal mines predominantly use longwall systems composed of powered roof supports, armored face conveyors and drum shearer loaders [1–3]. Drums of shearer loaders cut coal and load it to AFC [4] to be transported along the longwall to a stage loader. Working capacity and specific energy consumption are the key indicators of drum efficiency in coal loading to the conveyor. Regarding the frontal drum, the calculation procedure of coal cutting performance yields data agreeable with the calculated results on the dump output in coal loading [5]. On the other hand, as shearer loader improves its productivity in coal cutting, it consumes much energy, yields more fines and leaves much more coal on the longwall floor [6]. For another thin, maximum output of loading should always exceed maximum output of coal cutting, even at the higher power-to-weight ratio of shearer loader [7–9].

The known formula of the rear drum productivity in coal loading, obtained from the theory of operation of an auger conveyor, disregards such factors as (Fig. 1): persistent clogging of space between the blades of the drum 1 with broken coal and high resistance of coal to transportation by the drum blades 2 to a conveyor. The resistance is governed by the dimensions of the conveyor side wall and the drum drive gear box 3, slope angle of the conveyor and by the distance between the rear drum and face conveyor.

The problem lies in the lack of engineering solutions and efficient procedures to allow design engineers to unambiguously define the structure and parameters of loading facilities of shearsers such that to ensure preset efficiency of coal loading to face conveyor with regard to the above emphasized factors.

COAL LOADING BY SHEARER DRUM

In the course of loading (See Fig. 1), the rear drum 1 displaces broken coal by the blades 2 from the coal cutting zone, through transition zone II, to the conveyor in zone IV. Coal flow crosses the sliding lines a–a and enters zone III under the pressure created by the rotating drum [10, 11]. Some coal remains in the gap between the drum and conveyor (zone I).

When analyzing factors that influence the process of coal loading on conveyor by shearer drums, it should be emphasized that this process is complex and multi-factorial. The major effect on this process is exerted by the slope angle of the conveyor and by the distance between the rear drum and face conveyor.

INFLUENCE OF SEAM DIP ANGLE ON COAL LOADING EFFICIENCY

Amongst the whole set of geological influence on coal loading performance, the highest effect is exerted by the slope angles $\beta$ of the conveyor and shearer loader (Figs. 2a and 2b), for instance, in logwalling down-dip or up-dip. An increase in $\beta$ changes the volume and direction of coal flows from the frontal and rear drums.

According to the studies by Aksanov and Bobrov [12–14], the increase in the slope angle $\beta$ from $-7^\circ$ to $-12^\circ$ drastically impairs conditions of coal loading (Fig. 2). When
β grows from −14° to −18°, the cutting time coefficient rises by 1.4–1.74 times while productivity of shearer drops. The findings of Kuidong Gao and Changlong Du [15, 16] show that the increase in the dip β from −10 to 10° more than doubles efficiency of coal loading on face conveyor. At the negative values of β the volume of coal left in gap II between the conveyor and drum (See Fig. 2a) and on the floor behind the drum builds up. From the performance studies of shearer drums in Kuzbass mines, when dip angle β grows from 7° to 12°, conditions of coal loading worsen at once, which lowers operation and maximum allowable feed speed \( v_f \) of shearer (Fig. 3) [14].

**Influence of transition zone size on coal loading efficiency**

Specific energy consumption in coal loading by cutting machines, in particular, by shearer loaders, is found from the known relation [11]:

\[
H_p = \frac{P_p}{60 - Q_p} + \frac{P_s}{60 - Q_s}, \quad \text{kW} \cdot \text{m}^3 / \text{h},
\]

where \( P_p \) is the drum energy spent for coal loading on face conveyor, kW; \( Q_p \) is the drum productivity in coal loading to face conveyor, m\(^3\)/min; \( P_s \) is the drum energy spent to maintain coal circulation in the flow, kW; \( Q_s \) is the amount of circulating coal in the flow, m\(^3\)/min.

Coal loading productivity \( Q_e \) or the drum, considering formation of coal flows and coal discharge from the blade-to-blade space (See Fig. 1), can be given by the equation of flow balance:

\[
Q_e = Q_a - Q_d - Q_e - Q_f, \quad \text{m}^3 / \text{min},
\]

where \( Q_a \) is the estimated productivity, m\(^3\)/min; \( Q_d \) is the rate of flying dust formation, m\(^3\)/min; \( Q_e \) is the rate of the abandoned coal layer formation, m\(^3\)/min; \( Q_f \) is the volume of coal under conveyor (loss), m\(^3\)/min.

The values of \( Q_a \) and \( Q_d \) are lower than \( Q_e \) in (2). The rate of the abandoned coal layer formation can be found from the expression [17, 18]:

\[
Q_f = v_f \cdot L \cdot h, \quad \text{m}^3 / \text{min},
\]

where \( v_f \) is the feed speed of shearer loader, m/min; \( L \) is the distance between the drum and conveyor, m; \( h \) is the height of coal layer in the gap between the drum and conveyor, m (See Fig. 2).

The drum-to-conveyor distance \( L \) is conditioned by arrangement features of the equipment. The shorter \( L \) for cut coal to travel to the conveyor brings lower resistance of coal flow to the conveyor, smaller volume of the abandoned coal and higher efficiency of loading. However, this distance is considerable in the modern structure of the shearer and conveyor arrangement—300 mm and more.

It is required to find and develop unconventional engineering solutions to enhance efficiency of coal loading to face conveyor by rear drum of shearer loaders.

**Engineering solutions**

The loading device 1 (Fig. 4) is proposed to equip a shearer with two cutting drums 5 arranged symmetrically along the shearer length and adjustable with respect to the coal seam thickness, can promote efficient coal loading.
from the transition zone to the conveyor. The device is composed of the drum drive housing 8, cowl 2 and accessorional blade 1. The cowl 2 and blade 1 are fastened to the drive housing of the drum 5 by brackets 2 and 3, respectively. The shearer loader abuts the conveyor 9 and can perform reciprocating motion. The blade 1 is set between the cowl and conveyor 9 at equal distances to them, at an angle less than 90° relative to the conveyor wall and with a gap relative to the conveyor surface.

When shearer loader reverses direction at the ends of the longwall, positions of the frontal and rear drums change relative to the seam thickness. The frontal drum cuts top coal and loads it to the conveyor. The rear drum 5 (See Fig. 4) cuts bottom coal and loads it to the conveyor with the help of the coal 2 and blade 1. The blade is installed so that there is a clearance between the blade and the side wall of the conveyor and the lower edge of the blade repeats the side wall profile.

Spacing of the rare drum 5 and conveyor 9, as well as the cross-section area of the discharge opening are imposed with size constraints governed by the assembly features of the equipment to be coupled, which creates higher flow resistance of coal when loaded to the conveyor. The coal and blade improve coal loading efficiency, which is reached by elimination of coal circulation in-between the drum blades, reduced amount of coal loss on the longwall floor due to poor loading quality as well as by better removal of coal from the zone between the conveyor side wall and drum.

The processes of coal loading on conveyor were modeled in EDEM 3D for the variants with and without the accessorional blade. The modeling included such parameters as: drum diameter of 1800 mm, spider diameter of 600 mm, drum helix rise angle $\alpha=19^\circ$, 3 drum blades, blade thickness of 50 mm, cutting width of 800 mm, drum speed 60 rpm, conveyor wall height $h_b=350$ mm, conveyor pan width 800 mm, gear box wall height 350 mm, conveyor feed speed 4 m/min.

The modeling yields that owing to the proposed redesign, the drum efficiency in coal loading to the conveyor is improved by 1.64 times while the energy consumption of this process is reduced by 1.2 times.

**Discussion**

The proposed integrated solution ensures formation of a steady-state loading flow of coal without its circulation, which reduces over-crushing, dusting and flow resistance while improves productivity. The outcomes are achieved through the harmonization of sizes and shapes of elements in the structure, which allow local flow resistances and perturbation actions on coal flow to be abated.

**Conclusion**

After the implemented analytical work, the integrated solution on improved efficiency of coal loading to conveyor is proposed. The rear drum equipped with the cowl and accessorional blade ensures:

- directed coal flow from cutting zone to conveyor;
- reduction in coal loss on the longwall floor;
- higher efficiency of coal loading to conveyor;
- lower resistance to coal flow;
- better cleanup quality;
- lower energy consumption in coal loading.

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**References**