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KHAC LINH NGUYEN, *Post-Graduate Student*
V. V. GABOV, *Professor, Doctor of Engineering Sciences*
D. A. ZADKOV, *Associate Professor, Candidate of Engineering Sciences, dzadkov@yandex.ru*

Saint-Petersburg Mining University, St. Petersburg, Russia

IMPROVING EFFICIENCY OF CLEANUP AND COAL FLOW FORMATION ON CONVEYOR BY SHEARER LOADER WITH ACCESSORIAL BLADE

Drums of shearer loaders in longwall systems execute the primary function of coal cutting and secondary function of coal loading to conveyor. Drums feature workability, rational dimension, simple design, reliability and durability. At the same time, drums offer insufficient cleanup quality, which results in lower productivity of shearer loader, increased energy consumption and coal over-crushing when flowing to conveyor.

This article discusses processes of coal loading by shearer loader drum from the cutting zone to the conveyor and formation of coal flow in the transition zone between the rear drum and conveyor. Furthermore, the influence exerted on these processes by the drum—conveyor distance, seam dip, as well as velocities and directions of shearer loader and conveyor chain is considered. The mechanisms of coal loading from the cutting zone by the drum blades and the related productivity of the rear drum in coal loading to conveyor are taken into account. The authors propose to install an accessorial blade in the transition zone between the cowl and conveyor in order to form coal flow to it and present the calculation formulas for the drum productivity and loading energy consumption. The proposed engineering solution—coal with accessorial blade—ensures higher efficiency of coal loading from cutting zone to conveyor, lower circulation of coal and reduced flow resistance, improved cleanup quality, diminished over-crushing and dusting of coal, as well as cut down specific energy consumption.

For the comparative analysis, the processes of coal loading to conveyor are modeled using EDEM 3D for two variants with and without the accessorial blade. The modeling results prove that the proposed design modifications improve productivity drum in coal loading to conveyor and decrease energy consumption the process.

Keywords: *coal longwall, shearer loader, drum, conveyor, loading, productivity.*
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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 shearers 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 β of the conveyor and shearer loader (Figs. 2a and 2b), for instance, in logwalling down-dip or up-dip. An increase in β 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 β from –7° to –12° 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_p 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]:

$$H_W = \frac{P_p}{60 \cdot Q_K} + \frac{P_s}{60 \cdot Q_s}, \text{ kW·h/m}^3, \quad (1)$$

where P_p is the drum energy spent for coal loading on face conveyor, kW; Q_κ 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; Qs is the amount of circulating coal in the flow, m^3/min.

Coal loading productivity Q_κ of 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:

$$Q_\kappa = Q_h - Q_{pl} - Q_p - Q_i, \text{ m}^3\text{/min}, \quad (2)$$

where Q_h is the estimated productivity, m^3/min; Q_{pl} is the rate of flying dust formation, m^3/min; Q_i is the rate of the abandoned coal layer formation, m^3/min; Q_p is the volume of coal under conveyor (loss), m^3/min.

The values of Q_{pl} and Q_p are lower than Q_i in (2). The rate of the abandoned coal layer formation can be found from the expression [17, 18]:

$$Q_i = v_p \cdot L \cdot h, \text{ m}^3\text{/min}, \quad (3)$$

where v_p 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.

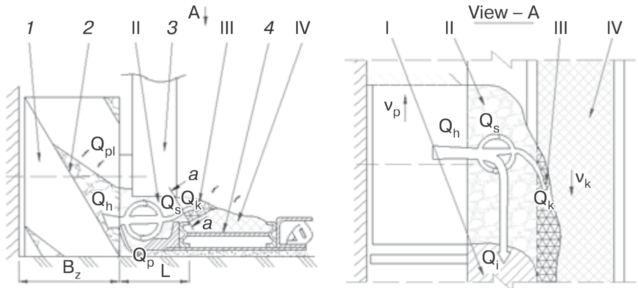

Fig. 1. Schematic formation of coal flow in loading to face conveyor:
I — gap where a layer of unloaded coal forms between the drum and conveyor; II — coal flow between the conveyor and drum; III — coal flow incoming to the conveyor; IV — coal flow on the conveyor; *1* — drum; *2* — blade; *3* — gear box; *4* — conveyor

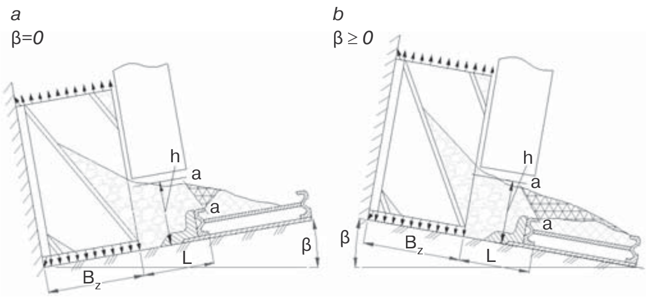

Fig. 2. Influence of dip angle of coal seam on coal loading efficiency

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

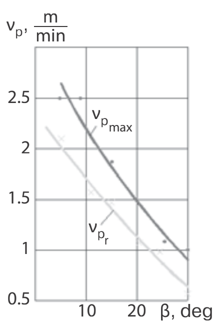

Fig. 3. Experimental curves of feed speed and slope angle

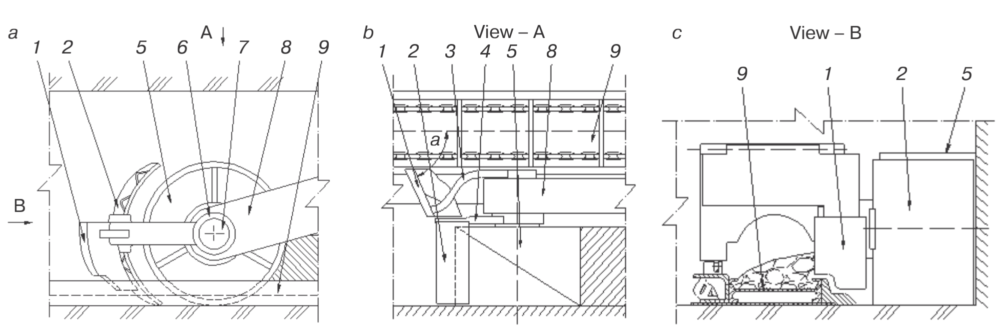

Fig. 4. Coal and bladed of rear drum of shearer loader:
a – general view; *b* – top view; *c* – back view; *1* — blade; *2* — cowl; *3* — bracket; *4* — support bracket; *5* — shearer drum; *6* — hub; *7* — spider; *8* — drive housing; *9* — conveyor

from the transition zone to the conveyor. The device is composed of the drum drive housing *8*, cowl *2* and accessorial 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 accessorial blade.

The modeling included such parameters as: drum diameter of 1800 mm, spider diameter of 600 mm, drum helix rise angle $\alpha=19^{o}$, 3 drum blades, blade thickness of 50 mm, cutting width of 800 mm, drum speed 60 rpm, conveyor wall height h_k = 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 accessorial 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.

References

1. Peng S.S. Longwall mining. U.S.: 2nd edition, October 2006. 621 p.
2. Solod V. I., Getopanov V. N., Rachek V. M. Design and construction of mining machines and systems. Moscow : Nedra, 1982. 350 p.
3. Wang F., Tu S., Bai Q. Practice and prospects of fully mechanized mining technology for thin coal seams in China. *Journal of the South African Institute of Mining and Metallurgy*. 2012. Vol. 112, No 2. pp. 161–170.
4. Zvonarev I. E., Shishlyannikov D. I. Efficiency improvement of loading of potassium ore by means of Ural-20R heading-and-winning machine. *IOP Conf. Series: Earth and Environmental Science*. 2017, 87 022025. DOI :10.1088/1755-1315/87/2/022025.
5. Maleev G. V., Guliyaev V. G., Boiko N. G., Gorbatom P. A. Design and construction of mining machines and systems. Moscow : Nedra, 1988. 368 p.
6. Nguyen Khac Linh, Gabov V. V., Zadkov D. A., Improvement of drum shearer coal loading performance. *Eurasian Mining*. 2018. No. 2. pp. 22–25. DOI: 10.17580/em.2018.02.06
7. Boiko N. G. Coal loading by shearers. Donetsk : DonNTU, 2002. 157 p.
8. Zagrivnyi E. A., Basin G. G. External dynamics formation in mining machines. *Journal of Mining Institute*. 2016. Vol. 217. pp. 140–149.
9. Skryabin R.M., Timofeev N.G. Development of an innovative storage auger for hole drilling in permafrost. *Eurasian Mining*. 2016. No. 1. pp. 33-36. DOI: 10.17580/em.2016.01.05.
10. Kuidong Gao. Particle movement behavior in drum coal loading process by discrete element method. *EJGE*. 2016. Vol. 21. pp. 163-173.
11. Piotr Gospodarczyk. Modeling and simulation of coal loading by cutting drum in flat seams. *Archives of Mining Sciences*. 2016. Vol. 61, No 2. p. 365–379.
12. Bobrov G. N. Operation of mechanisms in the downdip longwall mining of thick gently dipping seams. *Synopsys of Cand. Eng. Sci. Theses*. 1973. 23 p.
13. Verner V. N. Loading capacity of drums equipped with disc roller cutters by production test data. *KuzPI' Inter-University Collection of Papers*. Iss. 1. Mechanization of mining. 1977. pp. 23–26.
14. Verner V. N. Analysis and evaluation of rational parameters for screw loading-and-haulage elements of mining machines. Dr. Eng Sci. Theses. Kemerovo, 1999. 319 p.
15. Kuidong Gao, Changlong Du, Jianghui Dong, Qingliang Zeng. Influence of the drum position parameters and the ranging arm thickness on the coal loading performance. *Minerals*. 2015. Vol. 5. pp. 723–736. DOI:10.3390/min5040520.
16. Kuidong Gao, Liping Wang, Changlong Du, Jiannan Li, Jianghui Dong. Research on the effect of dip angle in mining direction on drum loading performance: A discrete element method. *Int. J. Adv. Manuf. Technol*. 2016. Vol. 89. pp. 2323–2334.
17. Nguyen K. L., Gabov V. V., Zadkov D. A., Le T. B. Justification of process of loading coal onto face conveyors by auger heads of shearer-loader machines. *IOP Conference Series: Materials Science and Engine*ering. Volume 2018. 327 042132. DOI:10.1088/1757-899X/327/4/042132
18. Gabov V. V., Nguyen K. L., Nguyen V. X., Le T. B., Zadkov D. A. The rationale of geometric and modal parameters of cutter drums ensuring the efficiency of coal loading onto a downhole conveyor. *Ugol'*. 2018. No. 2. pp. 36–39. DOI: 10.18796/0041-5790-2018-2-00-00