PAPER

Substantiation of parameters of coal unloading process onto conveyor using shearer drums

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Substantiation of parameters of coal unloading process onto conveyor using shearer drums

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Abstract. In this article the process of coal unloading from the face's fracture zone to the conveyor using shearer drums is presented. The effect of the form and dimensions of the sectional area of the loading window and the height of the conveyor's edge surface in the working zone of the rear shearer drum on filling with coal of the auger's intervane space and the effect on circulation of the broken-down coal are analyzed. Estimations and directions of further studies of the coal unloading process from the fracture zone to the face conveyor are proposed.

1. Introduction

Shearer drums are characterized by their workability, compactness, simplicity of construction and reliability [1-3]. They are predominantly used in narrow-web cutter loader shearers for the extraction of minerals in the long faces and salt mines. However, the mineral excavating process using shearer drums is characterized by some negative features as follows:

- increased energy costs and intense dust formation, since the destruction of the virgin coal is carried out by compact milling from the surface using crescent-shaped picks[4];
- insufficient loading capacity of rear augers, working on the bed floor, due to the small size of the sectional area of the loading window;
- additional re-grinding of coal when unloading from the fracture zone and when loading onto a conveyor [1, 3, 5].

2. Coal loading process

The process of unloading coal from the working area of the drum is complicated, highly unstable and the least studied among all of the processes related to the work a shearer. There are no clear methods to calculate the instantaneous values of intensity, power and energy characteristics of the loading process and to determine the rational dimensions of the loading window. This process is considered as a complex one and the values of its parameter are formed randomly. Therefore, it is necessary to study these processes, in models, as well as in experimental and working conditions, to ensure obtained substantial results.

Resistance of the coal movement at the exit of the auger leads to an increase in the intensity of its circulation, additional grinding and dust formation. Consequently, leading to significant losses from unrealized benefits. The dust formation intensification results in increasing the costs of carrying out measures to suppress and neutralize explosive dust.

Hence, substantiating the efficient parameters of coal unloading process using shearer drums, which ensure a reduction in the intensity of coal circulation and grinding, is significant.

The loading process and the effect of the dimensions of the loading window in the working zone of the rear shearer drums is analyzed in this paper.

Currently, in concurrence with the movement direction of the picks in the contact zone with the crushed virgin coal and with respect to the direction of the shearer's feed rate, co-rotating and counter rotating rear auger are both used in shearers. The broken-up material is located in the auger's intervane space in a specific way and its position is dependent on the rotation direction of the rear drum [1, 6, 7]. Coal, broken-down by extreme picks, enters the free, not filled, auger's intervane space. Two processes occur simultaneously at the bottom of the face picks: virgin coal break down and coal unloading by the effective area of vanes in an axial direction. At the exit of the vanes, the filling of the interlobar reaches its maximum value.

3. Circulation process

The coal flow in the vanes' effective area can be represented by three zones: I - the loading zone (loading window), II - the area, closed by drum's body and III - the zone, closed by the side of the face conveyor at a distance L from the vanes. The boundaries between zone I (coal flow) and zones II and III (without coal flow) can be determined from the boundaries of the loading window in the direction of the axial velocity vector V_{ak} of the material (Fig. 1).

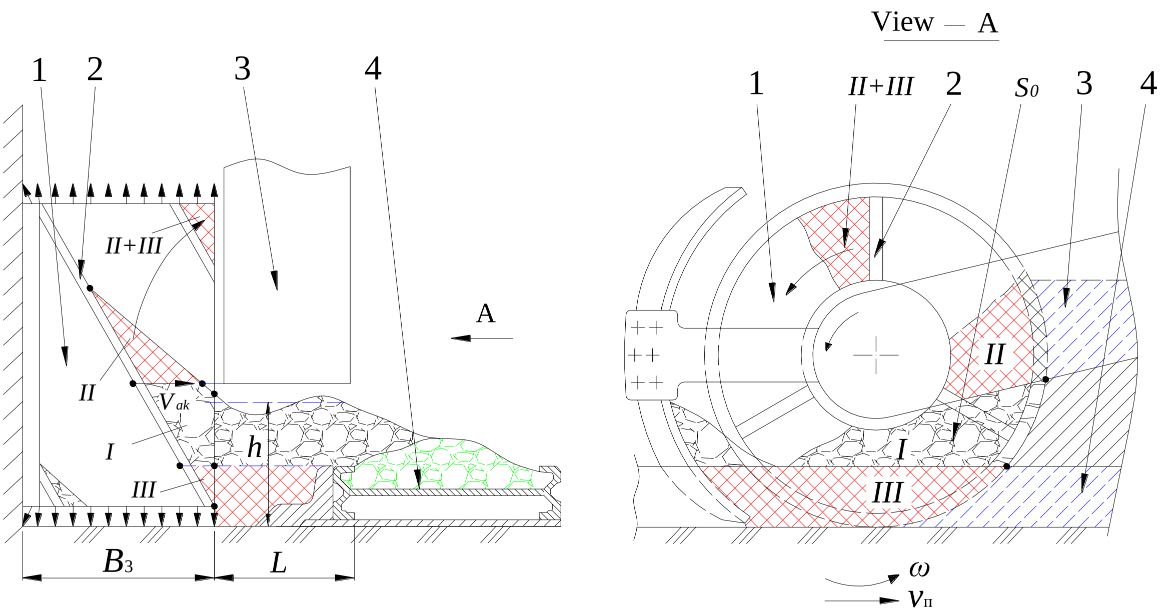

Figure 1. Schematics of vane and coal position in loading window:
where 1 - auger; 2 - auger vane; 3 - reducer; 4 - conveyor; S_o - loading window area.

The axial flow rate of the coal can be determined using the following formula [8]:

$$V_{ak} = \frac{S.n}{60}(\cos\gamma_n.\sin\gamma_n + f.\cos^2\gamma_n), \; m/s, \tag{1}$$

where S - the auger spacing, m; n - auger speed, s^{-1}; γ_n - the angle of inclination of the auger line (blade) and f - the friction coefficient of the material along the vane.

Here, only that part of the coal, bounded by zone I, enters the window, and the remaining parts, from zones II and III, move to the unloading side of the vane and will be unloaded into the window, only at the vane's next approach to the unloading point. Thus, the part of the material, corresponding to the volumes of zones II and III is transferred to the non-working side of the vane. The remaining material, depending on the presence of the retaining flap, is either left behind, not loaded, or will be involved in the circulation process with subsequent (repeated) loading.

Figure 1 shows that the volume of circulating coal can be determined by the expression:

$$V_{t1} = V_2+V_3, \qquad (2)$$

where V_2, V_3 are the volumes of coal in zones II and III, which do not enter the loading window.

Depending on the size of the sectional area in the loading window, the ratio of volumes V_{t1} to the initial volumes of broken-down coal is considered as a quantitative estimate of the volume of circulating coal in the auger.

The coal in the transition zone is set into motion in the effective zone of the vane by the impact from the vanes. This is accompanied by coal compaction, additional grinding and circulation in the effective zone of the vane (see fig. 2). The diagram shows the general case of coal loading at bedding angle β. After the next auger passes through the loading zone, the upper theoretical limit of the broken-down material is determined by the angle ρ - the natural slope, which is formed by gravity, internal friction and the height of filling the transition zone between the auger and the conveyor with coal (h'_k). This boundary passes along the slide line abc. The next vane entering the loading zone picks up the broken-down coal in the region of zone abeand displaces it upwards towards the conveyor.

The circulating volume of coal from the fracture zone under the impact of the vanes will be forced out to the transition zone, and subsequently, the coal in the transition zone moves to the face conveyor. The increase in the distance between the auger and conveyor L (Figures 2 and 3) shows an increase in the width of the buffer zone, which leads to an increase in resistance of coal movement and a decrease in the flow velocity [9-13].

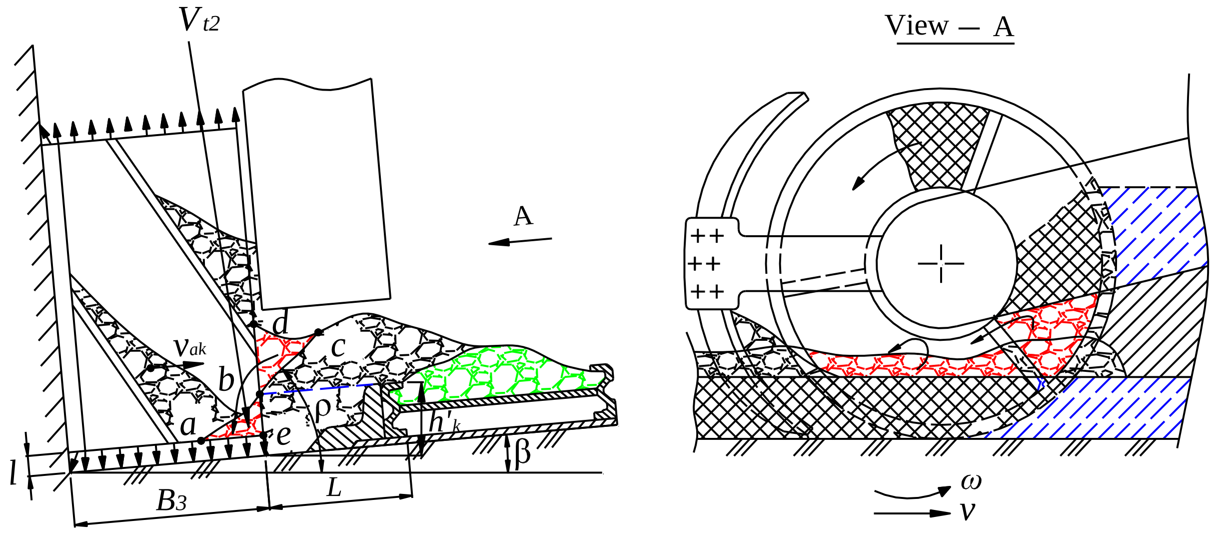

Figure 2. Circuit of coal circulation in the transition zone

Reducing the height of the transition zone by reducing the height of the face conveyor's board significantly reduces the circulating volume of coal. If there is no inflow of coal into the auger from the fracture zone, then the circulation of the volume considered, which is equivalent to that of the shaded area, can last indefinitely. However, due to the manifestation of the propelling power of the vanes at a low material height in the transition zone, a gradual decrease in the circulating volume occurs.

The quantitatively described process can be represented by a circulation coefficient, which is equal to the ratio of the circulating volume to the volume of coal entering the auger from the fracture zone and has the following form:

$$k_{tk} = \frac{NV_B}{V_P}, \tag{3}$$

where N is the number of blades of the auger; V_B - volume of coal circulating after passage of each blade: $V_B = V_{t1} + V_{t2}$; V_p - the volume of newly arrived material from the fracture zone during one auger revolution.

If $k_{tk} = 1$, then the volume of the freshly broken-down material will be equal to the volume of material returned to the auger.

4. Conclusions

The cyclical nature of unloading the broken-down material from the auger's struck volume can be formalized and described mathematically using the basis of kinematic models that incorporates the dimensions of the unloading window, the loaded material at the output section of the vane, the web width and the number of loading attempts. The ratio of these parameters determines the loading mode (with or without circulation) and the clogging conditions.

With a web width less than a certain critical value, an increase in the loading capacity can be achieved by replenishing the working volume of the auger with broken-down coal from the fracture zone. If the web width exceeds the critical value, the output section of the auger is supplemented with a circulating mass, which leads to a limitation of the permissible productivity of the tool, used for the breaking-down process.

The output section of the drum is partially filled with a constant recoiling flow of broken-down coal due to its return from the transition zone with a frequency proportional to the product of the number of vanes per auger speed.

With a change in the web width and the feed rate, there is a definite volume of the circulating mass of the broken-down coal, which ensures a flow balance at the inlet and outlet of the auger. This volume, determined by the dimensions of the extraction window and the axial flow rate of the coal in the loading zone, makes it possible to establish an analytical relationship between the feed rate and the web width using the loading capacity factor.

Analysis of the flow balance in the effective zone of the rear shearer cutting drum, implies that installation of the cowl on the front auger ensures an increase in the productivity of the combine for loading, and on when installed on the rear auger can lead to a limitation in the feed rate. An increase in the web width yields an increase in the positive effect of the cowl.

The following conclusions can be made based on the analysis of the coal unloading process:

- According to the physical and mechanical nature of the auger blade, the coal unloading process at its output section is complex, and by the number of influencing factors - multifactorial;
- Increase in the coal movement resistance at the exit of the auger leads to an increase in the intensity of its circulation, additional grinding and dust formation;

- the larger the sectional area of the loading window and the lower the height of the face side of the conveyor, the lesser will be the intensity of its circulation, crushing and dust formation;
- the effect of the size of the sectional area of the loading window on the coal unloading process from the interaction zone of the auger executive body with the broken-down virgin coal, including modeling and experimental studies in production conditions needs further studies.

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