Impact of selected parameters on the loading process with cutting screw heads

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INTRODUCTION

Many years of experience and a number of research on cutting heads have allowed progress in the design from the first cutting drums to the currently manufactured ones, such as cutting screw heads commonly used in longwall shearers. The construction of these heads has been evolved in the direction of increasing their functionality from only cutting heads (cutting drums) to heads performing two processes at the same time, namely cutting and loading of output.

The loading process is often referred to as an auxiliary process, because in the entire operation of the head the cutting process is considered dominant. The loading of output with cutting screw heads is carried out thanks to the specific construction of the screw heads. This process consists of several phases, namely: taking the output, moving it horizontally and vertically, and pouring it on a scraper conveyor. The output which is not immediately loaded and remains on the floor is loaded (removed out) on the scraper conveyor by forcing its movement with the head panels, the process is pulsating (not continuous), and the frequency of excitations correlates with the number of panels and then rotational speed of the head.

The heads, regardless of the way they are made (welded or cast), are made of a hub2, inside which there is a separable connection (i.e. a sleeve with an internal square or in earlier solutions, a toothed bushing) transmitting the torque from the shaft on which it is seated. On the surface of the hub 2panels4 are arranged, forming a cylindrical contour of the head to which the cutting knife holders are welded 5. The hub is most often provided with a cutting disc 3, which is formed of a plate in the shape of a circle of specified width and diameter (Fig. 1) (Wydro , 2015).

Cutting screw heads can be made in different versions with different shape of the cutting disc (Krauze, 2000). The cutting head, like any other construction, has the right parameters. In the monograph (Krauze, 1994) the author divided

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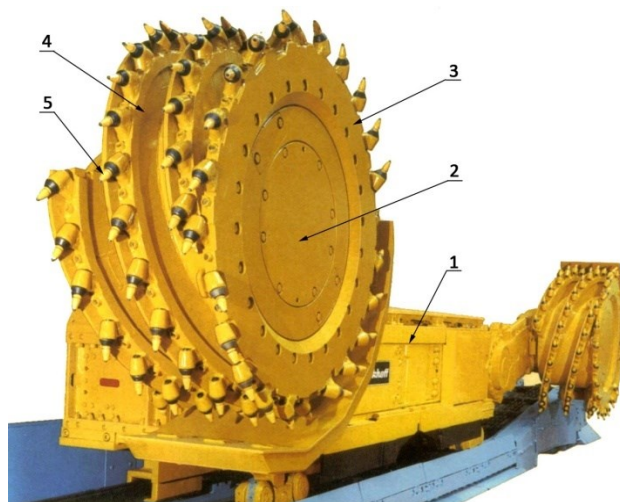head parameters into three groups: geometrical parameters, kinematic parameters and energy parameters.

Fig. 1 Cutting screw heads mounted on a mining longwall shearer
Source: (Krauze, et al. 2009)

The above-mentioned parameters have a significant impact on both the cutting process and the loading process, therefore they must meet certain requirements (criteria). Undoubtedly, such requirements include achieving the assumed productivity, loading efficiency, durability and reliability as well as granulation of output and load variability.

SELECTED PARAMETERS AFFECTING THE LOADING PROCESS
One of the main construction parameters of cutting screw heads affecting the implementation of the loading process is its internal volume. The volume has a significant impact on the amount of output which the body can transport (lead away) to the longwall conveyor, and the condition for proper loading process with the cutting screw head is the requirement that the head internal volume V_o is greater than the volume of output arising during mining V_u (Wydro, 2015). Then, the condition for the proper loading process should be met. Such a condition is its analysis during one rotation of the head, which is expressed with the following relationship:

$$\Delta = k_w V_o - V_u \geq 0 \tag{1}$$

where:
V_o – internal volume of the head, [m³],
V_u – cutting efficiency, [m³/min],
k_w – coefficient of head filing.
Also the shape of the hub (conical or cylindrical) and the amount and shape of the panels affect the internal volume of the head V_o, which for heads with normal panels can be expressed:

$$V_o = 0{,}25\pi\left(D^2 - k_{kp}d^2\right)\left(Z_u - \frac{b}{\cos \alpha_2}\right) \tag{2}$$

However, for heads with overlapping panels, this relationship has the following form:

$$V_o = 0{,}25 Z_u \left(D^2 - k_{kp} d^2\right) \left(\pi - \frac{ib}{D \sin \alpha_2}\right) \tag{3}$$

where:

Z_u –head webwithout a cutting disk, [m]

D – diameter of the head drum, [m]

d – diameter of the head hub, [m]

b – thickness of the panel, [m]

i – number of panels,

$α_2$ – panel's inclination angle,

k_{kp} – coefficient taking into account the shape of the head hub other than cylindrical.

It should be emphasized that even if the head's parameters are correctly selected due to the quality of loading, failure to comply with the fact that the internal volume of the head should be greater than the amount of output produced during mining V_u can reduce the efficiency of loading, even up to blocking the head.

An equally important parameter affecting the loading process is the height of the longwall. This parameter has a big influence on the machine's construction, and especially on the shape of the arm on which the cutting head is mounted. The design (shape and size) of the arm is very important when it comes to the size of the so-called loading port. In case of low longwalls below 1.5 m, possibility of setting height of the arm with the cutting head is particularly important, since it provides adequate space for smooth flow of detached output to the longwall conveyor.

The so-called loading port (Fig. 2) must allow a free flow of the stream of material escaping from the head onto the conveyor (Wydro, 2015, Krauze, 2000).
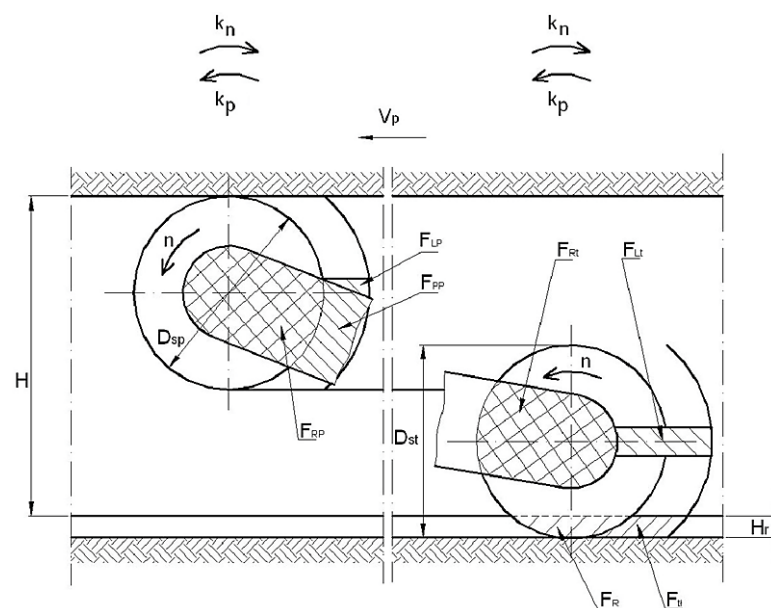

Fig. 2 Scheme of the arms system to determine the loading port of the front and rear head
Source: (Bołoz, 2018)

Failure to meet the above assumptions is associated with a reduction in the efficiency of loading.

The diagram below illustrates the positions of the cutting machine arms during operation, allowing the determination of free space called a loading port of the front and rear heads through which the output can be moved to the conveyor. The analysis of the operation of heads without or with loaders in different directions of rotation has been carried out. The formulas that allow to determine the value of the loading port have the following form (Krauze, 1994):

- front head without loader

$$F_p = 0{,}25\pi k_{wp}\left(D_{sp}^2 - d_p^2\right) - F_{RP} \tag{4}$$

- rear head without loader

$$F_t = 0{,}25\pi k_{wt}(D_{st}^2 - d_t^2) - (F_{Rt} + F_R) \tag{5}$$

- front head withloader

$$F_t = 0{,}25\pi k_{wp}\left(D_{sp}^2 - d_p^2\right) - \left(F_{Rp} + F_{pp} + F_{Lp}\right) \tag{6}$$

- rear head with loader

$$F_t = 0{,}25\pi k_{wt}(D_{st}^2 - d_t^2) - (F_{Rt} + F_{Lt} + F_R + F_{tt}) \tag{7}$$

where:

k_{wp}, k_{wt} – coefficients taking into account that in the loading process, depending on the direction of rotation, part of the surface resulting from the cross-section of the head is involved

The use of longwall shearers equipped with cutting screw heads at low longwalls is a problem precisely due to the loading process on the longwall conveyor. Not enough space (loading port) under the arm of the machine results in leaving it on the so-called shearer path. Leaving the output on the shearer track may be the cause of the so-called raising of the conveyor, which consists in lifting it on the remaining output. This can cause difficulties in keeping the machine working at the height assumed for a given wall. In addition, it can lead to a reduction in the durability of cutting knives (due to the fact that cutting heads cut into the roof rocks), increase work dynamics and increase dustiness (Szlęzak and Szlęzak 2013).

Therefore, a significant problem for shearers carried on a conveyor as well as those extended beyond a conveyor, is covering of the head parts both by the arm and the conveyor.

One of the companies specializing in the production of ultra-thin longwall shearers below 1 m is Mackina-Westfalia S.A. Therefore, it is worth recalling one of the machines of this company, the HMG100-TP shearer (Fig. 3).

Fig. 3 The HMG100-TP longwall shearer by Mackina-Westfalia S.A. for ultra-thin deposits

It is a longwall shearer, with a single arm and chainless haulage system, where the range of used heads is 0.44÷0.90 (Bołoz, 2018). The diameter of the cutting heads used may give rise to a question of how the output is discharged onto a longwall conveyor, where the height of the panels is not large, and thus the volume of the head.

Hence the construction of the shearer is so interesting that an integral part of the shearer is a short scraper conveyor that works perpendicular to the direction of the shearer traction, which significantly improves the extraction of output from the shearer path.

One of the elements of a longwall shearer, which allows to improve efficiency of the loading process, i.e. the percentage share of output loaded in the whole of the output moved by the head, is a shielded loader (Fig. 4).
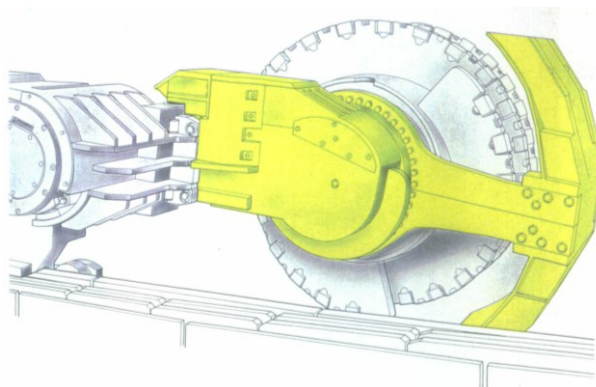

Fig. 4 Scheme of a shielded loader
Source: (advertising materials of the company Eickhoff)

The shielded loader strengthens the loading effects, preventing the output from remaining on the floor. However, it should be remembered that in extreme cases, it may lead to blocking the head as a result of an excessive amount of accumulated output. At the same time, in this situation there is an increased degradation of coal and an increase in power consumption, as the head starts to work like a compactor or crusher (Wydro, 2015, Krauze et al, 2010).

Another obstacle to loading output on the conveyor, which is often neglected in the analysis of loading of output by the screw heads are the mining and geological conditions. Each longwall work is characterized by individual hazards and difficulties in coal mining. However, each longwall working is characterized by individual hazards and difficulties in coal mining. Such threats include the so-called co-existing hazards: fire, rock burst, temperature and methane (Wydro, 2015). In mining practice, in the case of inclined seams, the excavation is oriented in such a way that the transverse inclination angle of the wall is as small as possible, permitting higher values of longitudinal inclination, even 45°.

This is mainly due to the operational capabilities of machines and devices working in the wall (Krauze et al, 2010). An example of longwall shearers working at a large longitudinal inclination are Beijing HOT Mining Tech shearers (Fig. 5) (Krauze et al, 2010, Szlęzak and Szlęzak 2013)

**Fig. 5 Classic longwall shearer for strongly inclined seams
at the testing grounds of Beijing HOT Mining Tech**
Source: (Bołoz and Castañeda, 2018)

As can be seen from the literature, the range of permissible slopes for mechanized longwall systems is: longitudinally up to 45˚, and transversely up to +/- 20˚. It should be noted that the best results are obtained by mechanized walls in horizontal or slightly inclined seams, and as the inclination increases, the efficiency of the walls decreases significantly (Szlęzak and Szlęzak 2013)

This inconvenience results in a more difficult discharge of output on the conveyor and a reduction in the loading efficiency. In such walls, loading the output with the screw heads can be improved by tilting the head panels towards the head outlet, or by applying the conical shape of the head's hub shell (Wydro, 2015, Krauze et al, 2010)

Also an important problem of the process of output loading is the fact that in this process the literature quite often omits the aspect of loading also with the rear head. The front head is mainly analysed, which cuts rock on the whole of its diameter, while the rear head cuts on incomplete diameter and is often obscured (Fig. 6).

The author (Jaszczuk, 1999) in his book presented the development of a new theoretical model of the process of output loading with a longwall shearer, including loading with the front and rear heads.
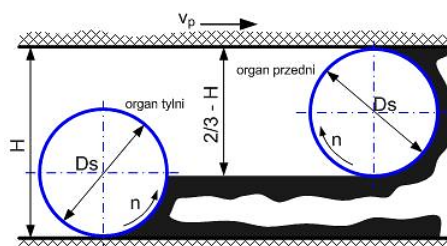

**Fig. 6 The mining scheme with a two-armed, two-head shearer
H – wall height, Ds – head diameter, n – heat rotation, Vp – direction of feed of the shearer**

The proposed new model of the loading process is based on a different approach to determining the amount of output loaded with a given head as well as determining the volume of the free space of the cutting head. An important

role played by the rear head that works at the bottom is that it must load the output not only the one that it produces, but also the one left (not loaded) by the front head. The proposed by the author (Jaszczuk, 1999) new theoretical model of the process of output loading allows taking into account important factors affecting the course of this process as well as obtain a favourable state of external load of the longwall shearer. The detailed analysis of the loading process with the front and rear heads allowed the author to formulate conclusions and propose guidelines for the design of cutting heads, which are widely presented in the literature (Jaszczuk, 1999)

SUMMARY

Cutting screw heads are commonly used in longwall shearers that cut unmined coal rock. Their unquestionable advantage is the implementation of two processes at the same time, namely the process of cutting and loading. In the literature, references to analysis and research regarding the loading process can be found more often. In connection with the above, the article presents selected parameters that influence the loading process with cutting screw heads.

It should be said that in addition to construction and kinematic parameters of cutting heads, also mining and geological conditions have a great influence, especially the transverse and longitudinal slope of the wall. Therefore, it is important that the selection of cutting heads for each wall is treated individually. Such an approach to design will later allow avoiding possible downtime of the mining machine, increase unpredicted dynamics and variability of the load caused by their operation (Wydro, 2015, Krauze, 1994, Bołoz & Castañeda, 2018, Bołoz Ł., Midor K. 2018).

Compliance with specific rules and proper selection will also allow the user to achieve the assumed parameters of grain size distribution and associated dustiness during operation of the head. Then it is important to meet the conditions set out in the article regarding the loading process, which directly affects the kinematics of the shearer's operation and, consequently, daily output.

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Abstract.

The article presents the influence of selected constructional and kinematic parameters of cutting screw heads on the loading process. The loading process is often referred to as an auxiliary process, because in the entire operation of the head the cutting process is considered dominant. Proper determination of the relationship between the cutting process and the loading process allows to understand how individual constructional and kinematic parameters of cutting heads and the cutting machine on which they are installed have an impact on each other. This knowledge gives potential users an opportunity to determine a reason for the lack of effective loading in the working conditions of a given wall. Besides construction and kinematic parameters, shielded loaders also have an impact on the loading process. The use of a shielded loader allows for improving the efficiency of the loading process, i.e. increasing the percentage of output loaded in the whole of the output transferred by the head.

Keywords: longwall shearer, loading of output, cutting screw head