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Longwall shearer's haulage systems - a historical review. Part 1 – cable haulage systems

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Słowa kluczowe: system ścianowy, kombajn węglowy, kombajn ścianowy, system posuwu kombajnu

Abstract:

The longwall shearer haulage systems are an indispensable component of these machines. The technical solutions of the haulage systems have changed along with the evolving mining technique and the development of mechanization of the entire longwall system. The longwall technology development has also resulted in increasing length of the longwalls and also influenced the technical solutions of the longwall shearer haulage systems. Next reason for shearer's haulage systems changes and improvement were expanding of acceptable conditions for LW use as inclination or geological disturbances. Implementation of mechanized roof supports and bidirectional cutting were next reasons for haulage systems development. This article is the first part of the historical review of solutions of the longwall shearers' chain haulage systems from the creation of the first shearers to the present day.

Streszczenie:

Systemy posuwu ścianowych kombajnów węglowych są niezbędnym zespołem tych maszyn. Rozwiązania techniczne systemów posuwu zmieniały się wraz z ze zmianą techniki urabiania i rozwojem mechanizacji całego systemu ściany. Rozwój technologii ścianowej spowodował także wzrost długości ścian i także wpłynął na techniczne rozwiązania systemów posuwu kombajnów ścianowych. Rosnące długości ścian i wzrastające wymagania wobec produktywności ścian węglowych powodowało zmiany i rozwój systemów posuwu kombajnów ścianowych. Dodatkowym czynnikiem wymuszającym zmiany tych systemów stanowiło rozszerzanie zakresu stosowania systemów ścianowych, w tym zakresu nachyleń. Wprowadzenie zmechanizowanych obudów ścianowych oraz dwukierunkowego urabiania kombajnami także było czynnikiem powodującym zmiany technicznych rozwiązań systemu posuwu kombajnów ścianowych. Artykuł stanowi pierwszą część historycznego przeglądu rozwiązań cięgnowych systemów posuwu kombajnów ścianowych od chwili powstania pierwszych kombajnów do czasów współczesnych.

1. Foreword

The hard coal mining longwall system has been known since the 17th century [1], but practically until the end of the 19th century it was a traditional mining method with manual performance of all the actions and operations in the longwall. The first mechanized action was mining with pneumatic hammers, and the first mechanized operation was probably undercutting of the coal face. At the beginning of the 20th century, the first conveyors (vibratory conveyors and then belt conveyors) were applied in the coal longwalls which resulted in "the conveyor system" term to be used instead of "the longwall system" in the British mines. However, the longwall production rate still depended on the number of miners working there and their individual efficiency in the following operations: mining, coal loading and erecting the roof support [2].

At the end of the 1930s, the first attempts were made to create mining machines that would mechanize longwall operations of coal mining and loading onto the conveyor, based on the renowned coal cutters. Thus, the first coal cutter-loaders appeared in Great Britain and Germany, performing both functions by means of several different actuators (components) driven by a single engine

(initially a pneumatic motor, then an electric engine) [3]. The condition for the good operation of these machines was to enable them to move along the face and to ensure constant pressure on the coal body being mined. This function was provided by the longwall shearer haulage systems. These shearers were created as a development of the former coal cutters and they repeated many of their mechanical solutions, including the haulage systems. The first longwall shearers lay on the floor and moved along the face conveyor (originally a belt conveyor, then an armoured face conveyor), then the shearer mainframe stood on the floor on legs above the conveyor, to finally move along the armoured face conveyor. The requirements for the longwall performance (production rate) enhanced, aimed at increasing the number of working cycles per day, increasing the speed of longwall shearers. The shearers meeting these expectations appeared in the 1950s, including but not limited to the trepanner shearers and the milling drum shearers [4]. The increasing power and weight of these machines forced the development of longwall shearer haulage systems in order to increase the cutting speed. The scope of application of the longwall systems also expanded, including inclined and steep coal seams, which required different solutions of the haulage systems [5, 6]. The first longwall shearers were developed and intended for an exploitation of faces at the height of 1.0 m approximately, where manual operation was difficult and inefficient. When the capabilities of cutting higher faces with shearers increased (nowadays even up to 8.5m [7]), the exploitation of thin faces started to be avoided. However, the extraction of thin coal seams with mechanized shearer longwall systems was not completely abandoned. Due to spatial constraints, these shearers used the solutions of the haulage systems taking into account the aforementioned constraints were applied.

2. Typologies of coal shearer haulage systems

The typologies of longwall shearer haulage systems according to various classification criteria [8, 9, 10, 11], including:

- Haulage drive location,
- Method of the drive relocation.

Fig. 1 shows the typology of longwall shearer haulage systems based on the haulage drive location.

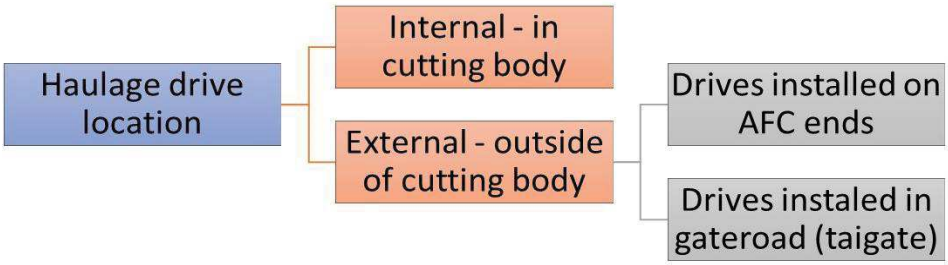

Fig. 1. Coal shearers haulage systems typology based on drive location [author's]

Some sources [2] indicate that the first coal cutter-loaders were relocated by means of winches installed in gateroads, but this information probably relates to the coal cutters moving on rails along the longwall.

The second criterion for a classification of the longwall shearer haulage systems is the method of carrying out the haulage operation with breakdown into the systems with cable and cordless systems (Fig. 2). This typology creates a certain difficulty due to the fact that there are solutions with a flexible cord – chain, but rigid due to being guided.

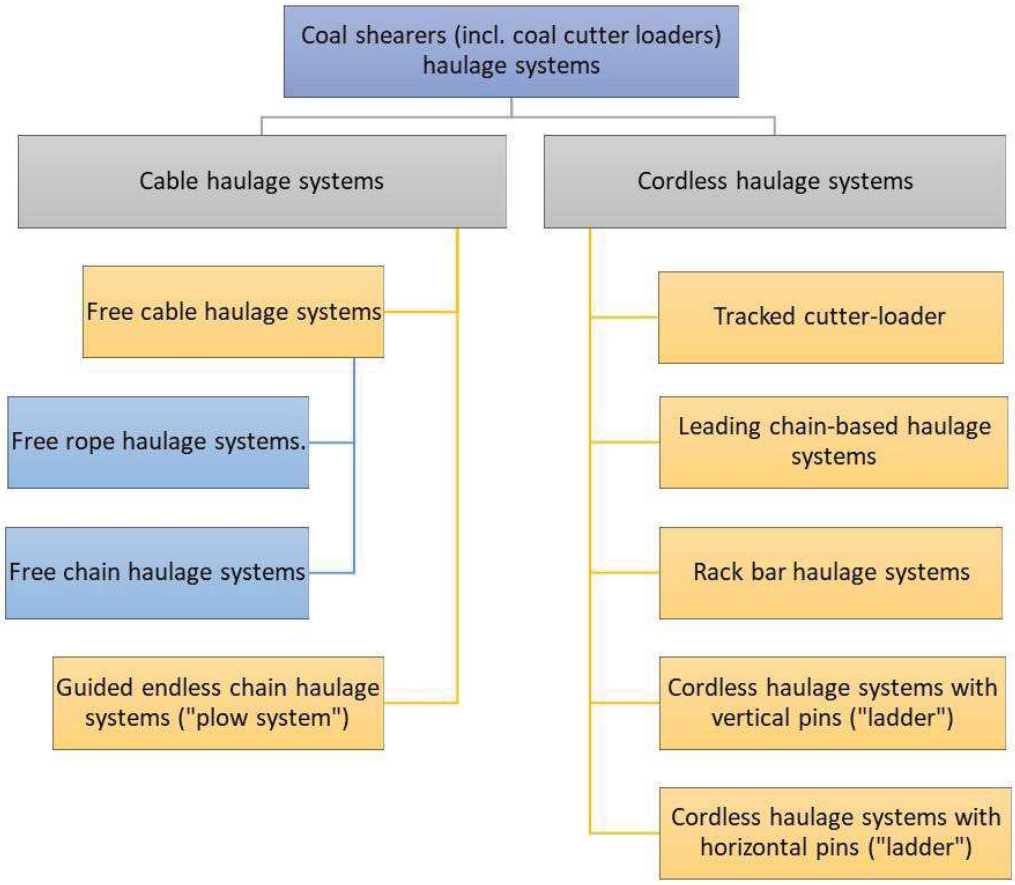

Fig. 2. Coal shearers haulage systems typology based on cable or cordless systems [author's]

In the past, systems with a cable were used to move the longwall shearers, originally in a form of a steel rope and then a chain. Starting from the 1960s, cordless haulage systems were implemented.

3. Cable haulage systems

The longwall shearers' cable haulage systems are used when the haulage drives are located in the frame of the cutting machine or with external haulage drives.

3.1. Free rope haulage systems with internal drive

The first coal cutter-loaders were created due to a development of the former coal cutters. Their haulage system was derived directly from the latter. The machines moved on the floor next to the face conveyor (Fig. 3).

The shearer was hauled by means of a winch (installed in the shearer mainframe) winding the steel rope, the end of which was attached to a pull up prop positioned in the longwall. Such a solution enabled correcting the direction of the shearer movement by a transverse displacement of the pull up prop. The limited capacity of the winch drum and the resulting reduced rope length and low traction force did not cause the phenomenon of transverse rope vibrations.

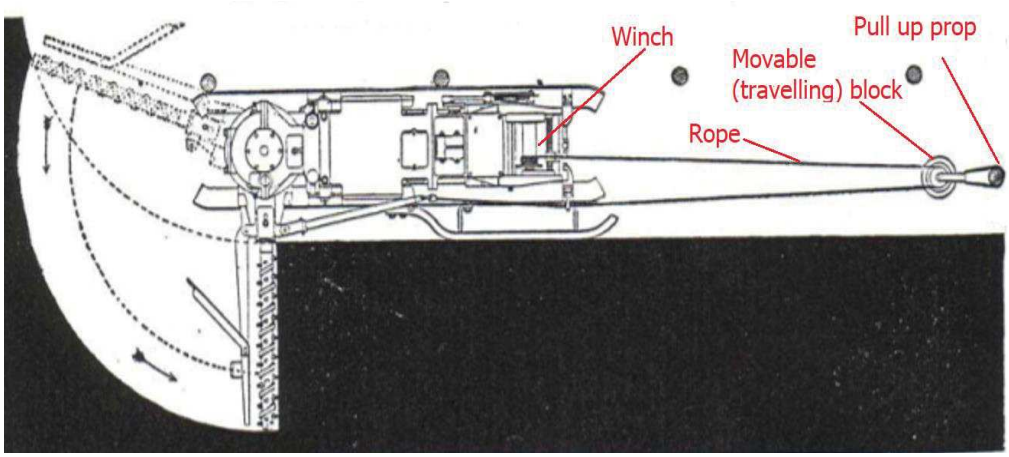

Fig. 3. First free rope haulage system with winch [12]

The first coal cutter-loaders cut the face in one direction only, and the idle return movement required only a different positioning of the pull up prop to start the next cycle. The winch was mechanically driven from the cutting system's drive motor and it ensured a low, constant haulage speed (up to 0.6 m/min). Ratchet or pulse drive and finally hydraulic drives were applied. The operation of displacing the pull up prop, after the entire rope had been wound up on the drum, caused frequent downtimes related to unwinding the rope and displacing the prop. At that time, solutions of longwall shearers with the mainframe above the face conveyor also appeared, and the first shearers, moving over the armoured face conveyor route were applied. Instead of a rope pulling winch, a parabolic drive wheel was used (Fig. 4). This solution enabled an extension of the working rope and a reduction of the number of operations related to the displacement of the pull up props.

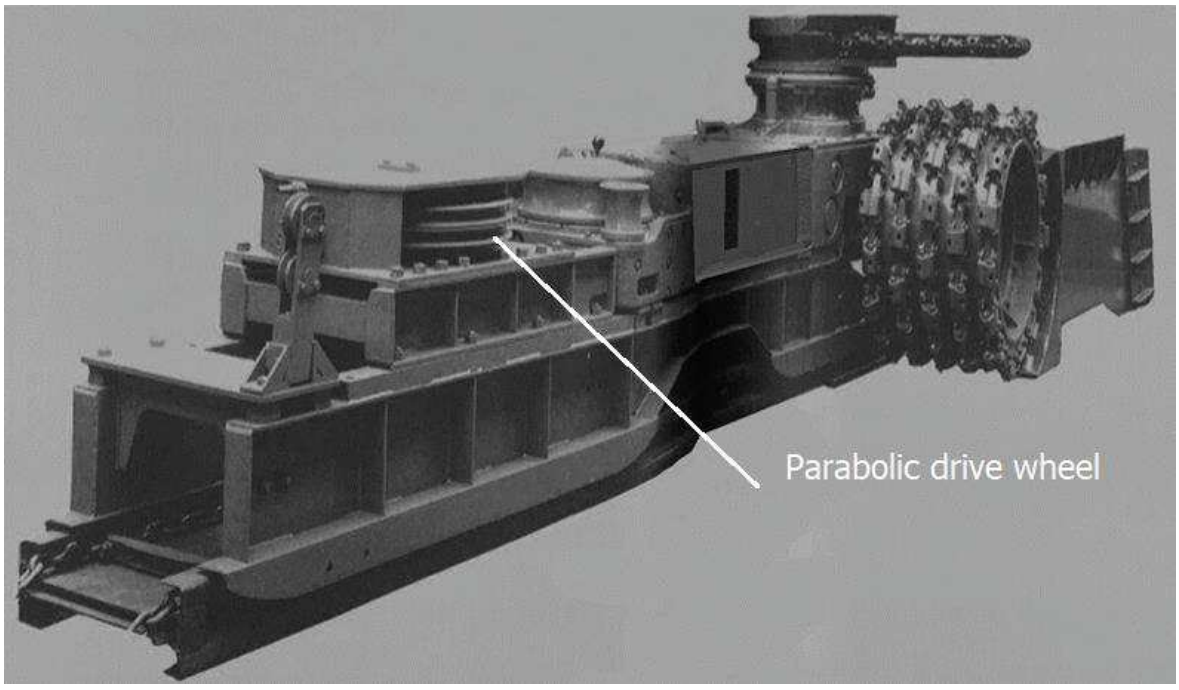

Fig. 4. Free rope haulage system equipped with parabolic drive wheel with vertical axis in the first Eickhoff's W-SE III drum cutter-loader (shearer) [13]

The use of parabolic drive wheels in shearers moving over the armoured face conveyor enabled attaching the rope ends the conveyor drives located at the longwall ends. This made it necessary to protect these drives against the force transmitted from the drive wheel through the rope. In the first mining machines with a parabolic drive wheel, the haulage power was taken from the cutting unit motors by means of a mechanical gearbox (force ratio). The inability to adjust the haulage with the simultaneously expected increase in the machine haulage speed resulted in a hydraulic haulage drive with a smooth haulage speed control to be applied for the cutting machine.

The first Polish mass-produced drum coal shearers (KWB-2) had a rope haulage system (Fig. 4). The shearer adapted for one-direction mining was equipped with a plow type loader. The shearer movement over the face conveyor was not forced yet.

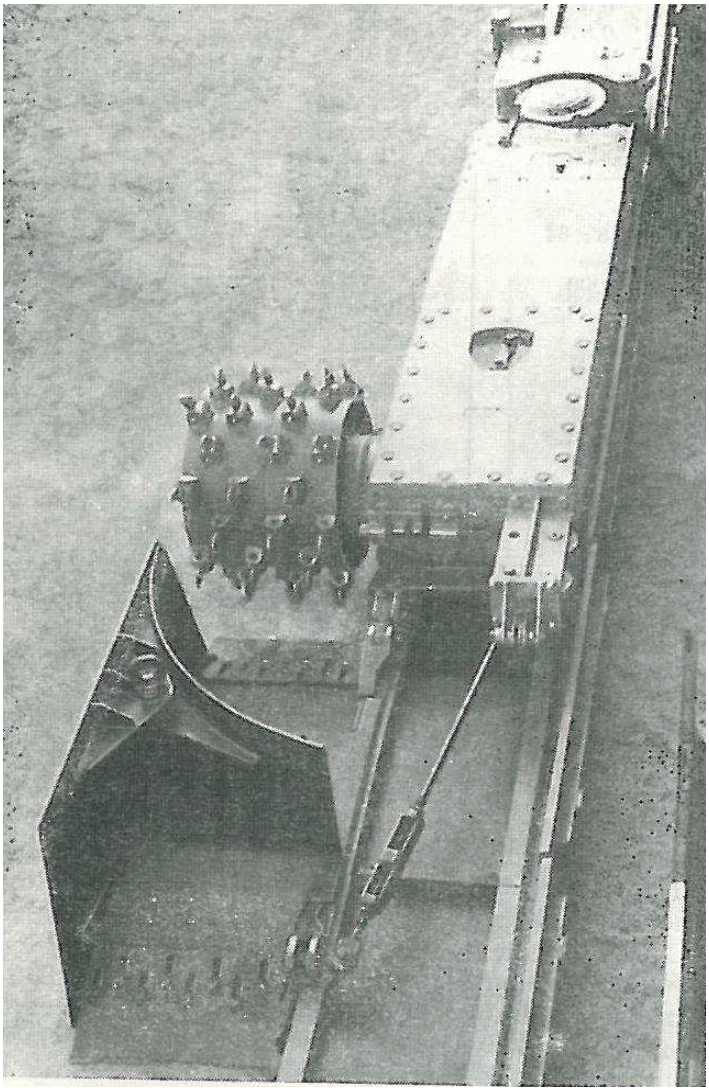

Fig. 5. First Polish single drum shearer with rope haulage system with parabolic drive wheel. [14]

An increasing productivity was expected from the longwall shearers, which was associated with an increase in the cutting speed of the shearer. For this reason, it became necessary to increase the haulage speed, and at the same time, the trepanner shearers and drum machines were implemented more widely [15]. The steel ropes used in the shearer haulage systems were of insufficient strength in relation to the expected increase in the pulling force, and due to multiple winding on the parabolic wheel, they were also subject to fast wear. Therefore, a new type of cord in a form of steel chains was applied.

3.2. Free rope haulage systems with external drive

As the intended use of the longwall system expanded, this system was implemented into the seams with increasing inclination gradients (steep slopes). Since the end of the 1950s the longwall shearers have been also implemented in the longwalls with slopes of up to 90°. On slopes up to approx. 35°, classic solutions of the shearers moving over the AFC with a hydraulic cable haulage system were used [15]. As the cable could be broken when the inclination gradient was exceeding 12°, it was necessary to secure the shearer with a special safety hoist installed in the tailgate [16, 17].

For greater inclinations, where the mined coal rolled itself down, a longwall system without a conveyor with a shearer moving longwall floor was applied. The shearer's movement along the longwall was carried out by means of a system of two hoists installed in the tailgate and a system of two ropes (work rope and back-up rope) (Fig. 6).

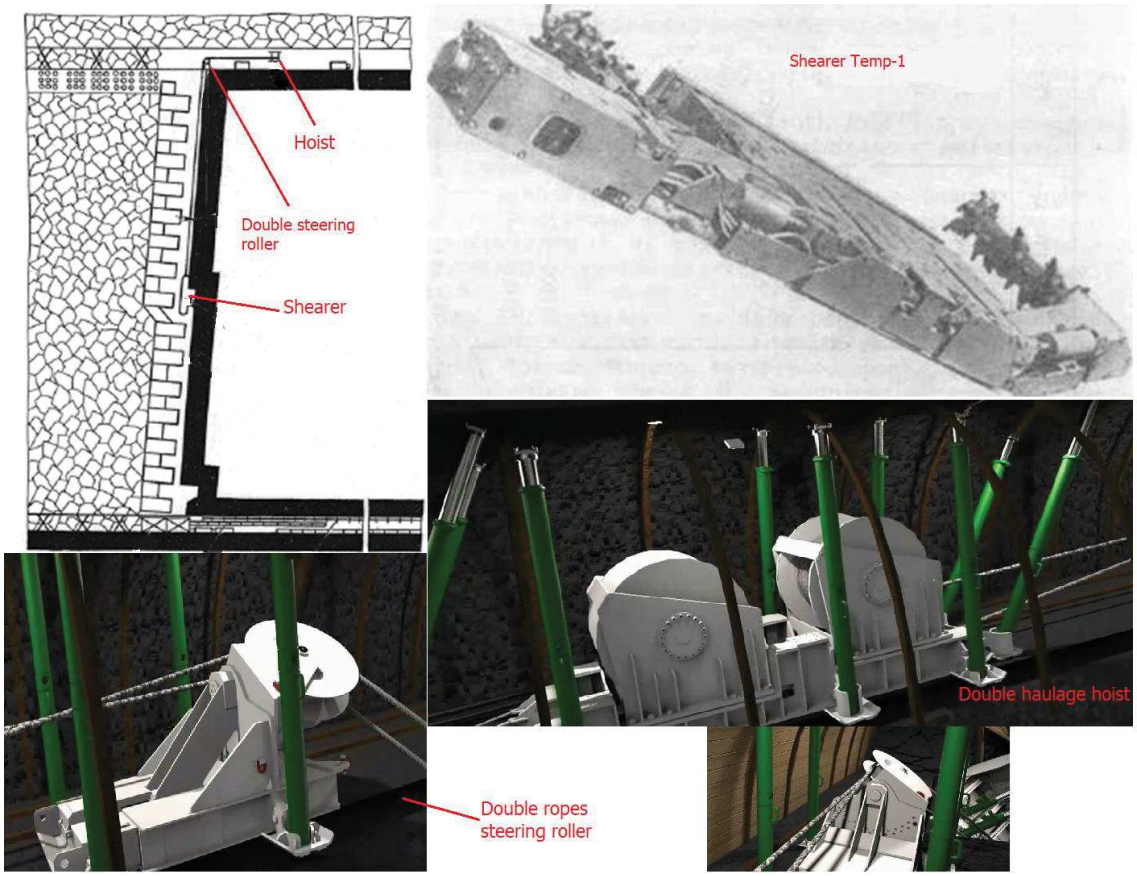

Fig. 6. Solution for steep seams – coal shearer with free ropes haulage system with external drives [author's]

The shearer in this system cut the coal mechanically, but the loading and transport of the excavated material were carried out under gravity.

The shearers with free rope haulage system with external drive were developed in the former Soviet Union and were also used in the coal mining industries of Poland, former Czechoslovakia, Spain, Iran and Turkey. As early as in the 21st century, a mechanized longwall system (shearer + powered longwall support) was delivered (Ostroj) [18] to the Turkish ATi Amasra mine. The shearer systems of this type were also produced in Ukraine, Spain and the Czech Republic.

3.3. Free chain haulage systems with internal drive

The implementation of link chains as a cord in the coal shearer haulage systems allowed to increase the pulling force of the shearer and increase the cutting force. The KWB-2 shearer with a hydraulic haulage system with a steel rope had a haulage speed of up to 2.5 m/min, and the KWB-3 shearer (also with a hydraulic haulage system, but with a chain) achieved the cutting speed of up to 5.0 m/min. - it ensured a twofold increase in cutting efficiency (mining production). There was also a problem of increasing traction forces transmitted to the shearer chain and the phenomenon of transverse chain vibration (chain whipping), which was a great threat to the miners working in the longwall. Initially, this threat in unidirectional cutting, mainly concerned the part of the chain in the cutting direction of the machine (Fig. 7). The shearers were constructed in such a way that the working part of the shearer chain was guided along the coal face side, which only partially solved the problem because the amplitude of the transverse vibrations of the chain could exceed 1.5m [19], even when the chain was partially gripped.

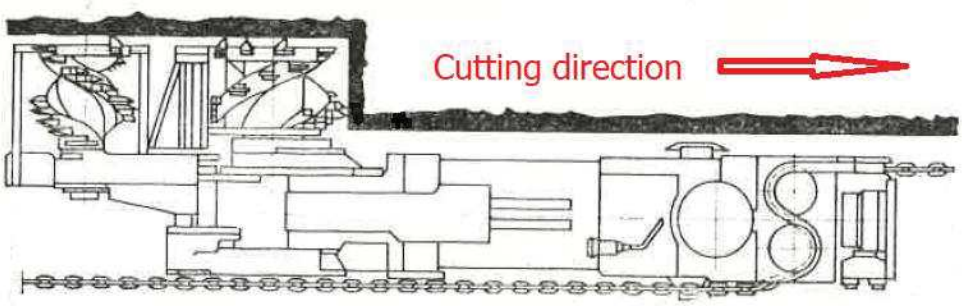

Fig. 7. Soviet 2K-52 shearer with working chain guided close to the wall – drive wheel with vertical axis [6]

The appearance of shearers enabling two-directional face cutting, especially shearers with ranging arms and having cutting heads at both ends of the machine, meant that the threat of chain transverse vibrations occurred along the entire length of the longwall - the chain had to be located along the working compartment. Therefore, attempts were made to reduce the threat by multi-point gripping of the chain with special grips attached to the structure of the armoured face conveyor (Fig. 8).

Fig. 8. Simply, hand operated anti-whip grips in longwall face [author's]

Such a solution required modifications in the AFC design and only partially eliminated the problem [19]. Solutions at various levels of technical complexity were applied - from fully manual ones, through hydraulic, to automatic devices to prevent transverse vibrations of the chain – anti-whip systems (Fig. 9).

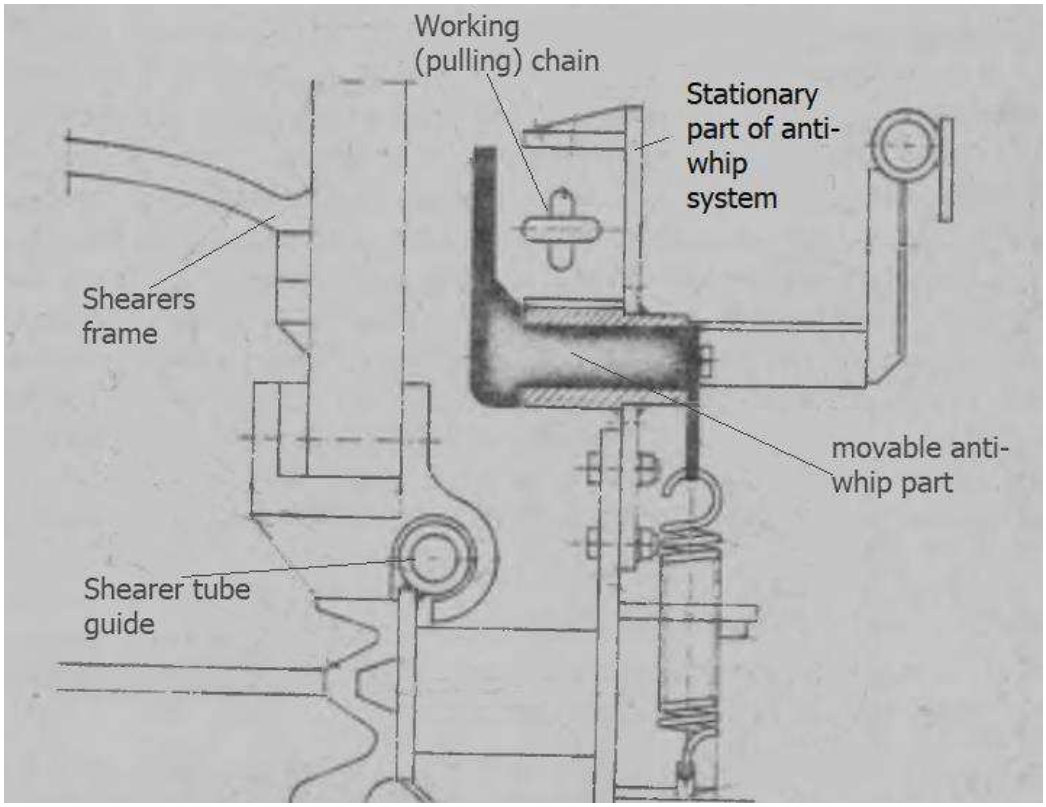

Fig. 9. Example of working chain anti-whip grip system [19]

The increasing requirements concerning the performance (production rate) of the longwall shearers, and therefore the cutting speed and the shearer traction force related to it, made the chain haulage systems extremely dangerous. Due to the increasing lengths of longwalls, the shearer chain made the excavated material ejected out of the armoured face conveyor route, and it was subject to premature wear by contact with the face conveyor chains. All these unfavorable phenomena were identified very quickly and since the 1960s, attempts have been made to eliminate the free shearer chains, but in the 1990s the cable haulage systems were used in the coal mining industry worldwide. A hydraulic haulage drive was mainly applied with a drive wheel having a vertical or, less frequently, a horizontal axis of rotation. The chain required special systems fixing/aligning its position at the entrance to the drive wheel and eliminating its twisting.

3.4. Guided endless chain haulage system with external drives (“plow type”)

First coal shearers were intended for mining low longwalls of the heights slightly exceeding 1 meter. This was due to the need of replacing human labor in walls, where it was difficult to obtain high human labor efficiency, and the effectiveness of mining with coal body undercutting was constrained. An implementation of coal drum shearers for low longwalls caused another systemic conflict to arise between the expected capability to transport raw coal on the armoured face conveyor under the shearer (coal clearance) and the need to contain the shearer’s haulage system (originally hydraulic, then electric one) in the shearer mainframe. A solution renowned from plow systems was applied, i.e. haulage of the longwall shearer by means of a chain driven by driving wheels installed on the AFC drives. The drive chain was guided inside specially profiled guideways in the AFC adapters, thus eliminating the possibility of its transverse vibrations (whipping). A smooth adjustment (control) of the haulage speed was achieved by changing the frequency of the current powering the haulage

drives by an inverter installed into one of the gateroads. In the Polish coal mining industry plow type hauled KGS-150 shearer was implemented as first. As an improvement next the KGS-200 shearer with this haulage system operated in several longwalls (Fig. 10).

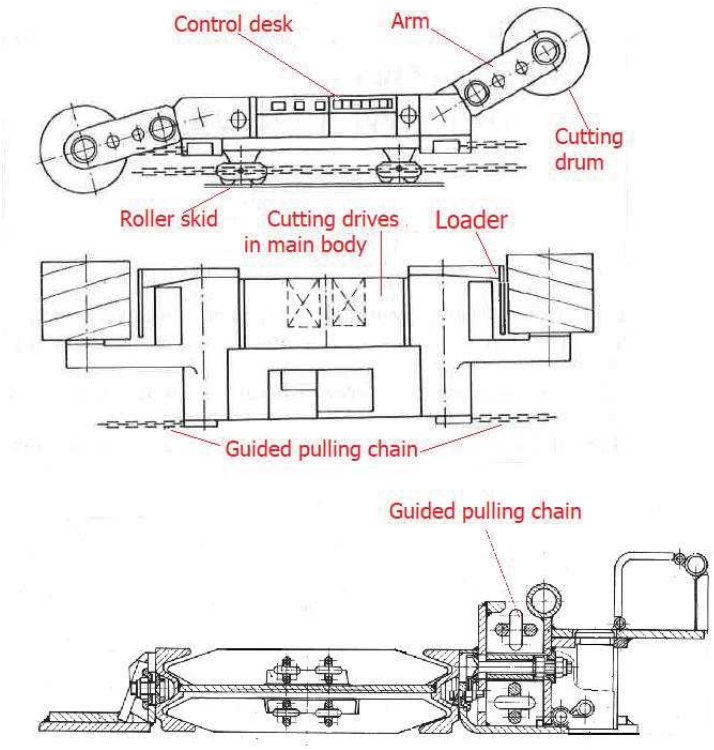

Fig. 10. Guided chain haulage system with external drives – Polish KGS-200 shearer on Rybnik-175/642/TP Armoured Face Conveyor [author's]

The shearer was adapted [18] for cutting coal seams in longwalls of the 0.9-1.5 m height and 200 m lenght with the haulage speed of up to 4.0 m/min [20].
Since 2010, the Mikrus GUŁ-500 shearer with guided chain haulage system with external drives has been developed in Poland as a part of the longwall system for thin seams (Fig. 11). The first version was tested in one of the Polish mines, where further modifications were introduced based on the experience gained.

Fig. 11. Polish GUŁ-500 shearer with guided chain haulage system with external drives [20]

Having gathered relevant experience, a development version of the machine was elaborated, which was used in the Chinese Shygetai mine in the Ordos Basin.

For several years, a Chinese shearer for thin seams has been presented at exhibitions and mining fairs in China, also with guided chain haulage system with external drives (Fig. 12).

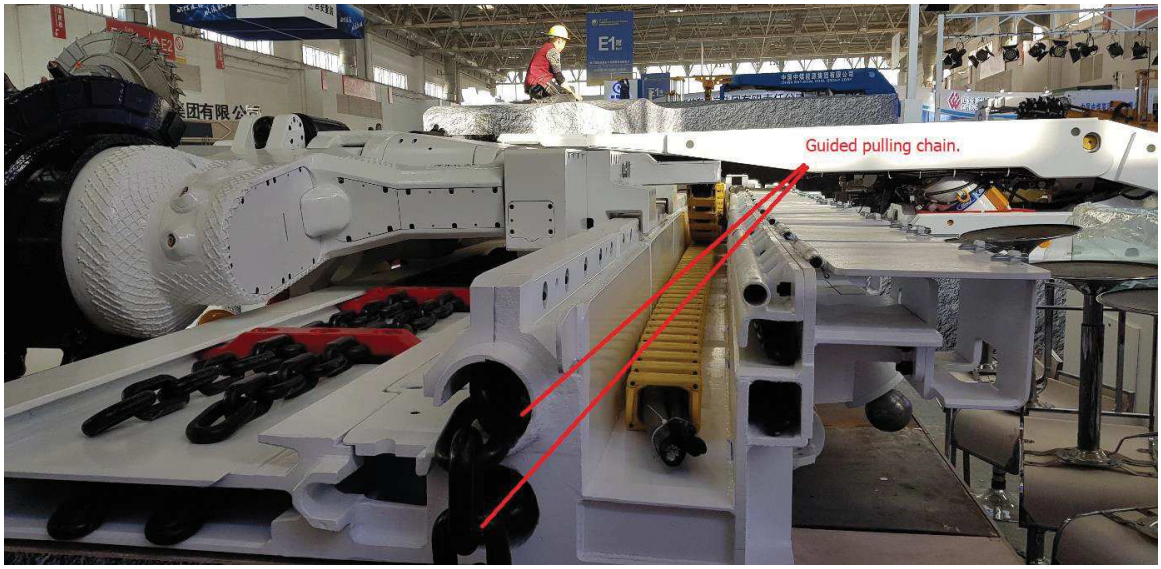

Fig. 12. Chinese shearer with endless guided chain haulage system with external drives [author's]

Two modern solutions (Polish and Chinese ones) have very similar guided chain haulage systems with external drives. There are differences in the design solutions of the cutting and loading systems.

4. Cable haulage systems – summary

From one cycle per day in semi-mechanized longwall systems to multicycles solutions with mechanized roof supports and next fully mechanized longwall systems with shearers was crossed long way and part of this road was with cable (rope or chain) haulage systems.

Cable (rope or chain) cutter-loader and shearers haulage system were developed from longwall cutters. Longwall technological progress and capacity expectations forced shearers haulage systems improvement but showed disadvantages and constraints of them also. Cable haulage systems with hydraulic drives allowed to get both: higher cutting speed and smooth speed control than with mechanical drives.

Increasing longwall length, expected capacity as a result forced haulage power increasing new disadvantages and threats for longwall crew as chain whipping. It was reason of many accidents.

In time of chain haulage systems with hydraulic drives improvement in connection with growing production showed another constrains as hydraulic oil cooling and possible oil volume - it was main reason for searching for new drive solution.

After a long period of development, the cable haulage systems of longwall shearers began to decline and disappear as a result of their identified defects and technical limitations. In most cases, they were replaced by chainless haulage systems, which have been developing since the 1960s. Currently, the haulage systems with external drives and a chain intended for low longwalls are still being developed but today main group of shearers haulage system are chainless with electric drives with frequency converter in shearer body.

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